Large-scale Renewable Energy?

A transdisciplinary view on conflicts and trade-offs in the implementation of renewable energy

PhD Thesis

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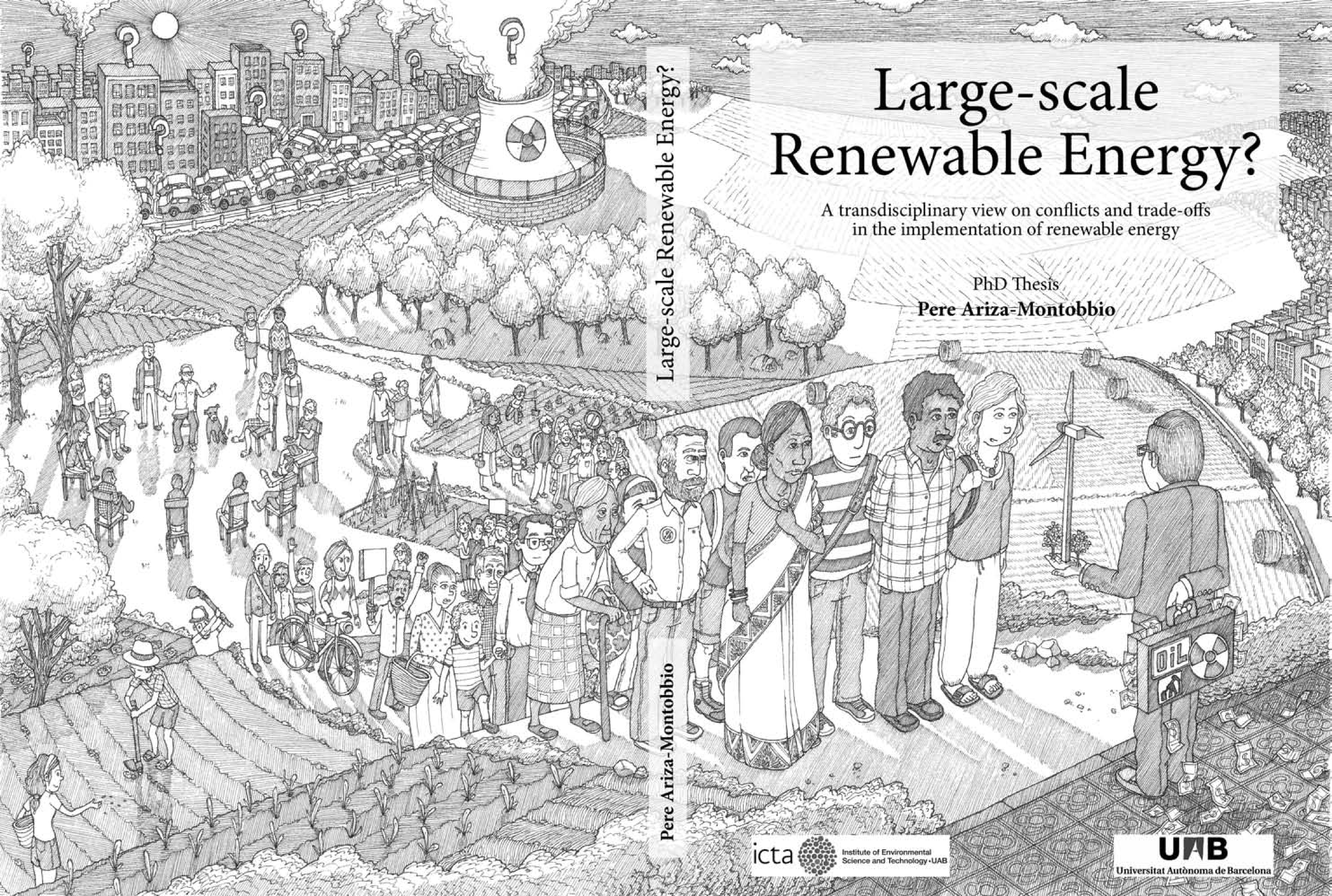

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"May all beings be happy"

Siddharta Gautama, Buda

Abstract

Industrial capitalism is nowadays facing a multi-dimensional crisis, confronting serious environmental, social, cultural, economic and political challenges. Cheap fossil fuels made possible the industrial revolution. They have sustained the growth of industrial society. Now fossil fuels are getting scarce while generating global warming. Responding to climate change and 'peak oil', governments, corporations, citizens and social movements are promoting renewable energy. The lower power densities and the dispersed character of renewable energies increase the demand for land both quantitatively and qualitatively. This requires attention to spatial changes and land use planning for their implementation. Moreover, there are different possible pathways to follow toward an energy system based on renewables. A 'hard' path would promote large-scale power plants and biomass plantations connected to centralized grids and infrastructures for 'bulk power' and fuels transport. A 'soft' path would emphasize distributed energy generation through small-scale facilities matching to end uses. Given these two possible scenarios with different losers and winners, the implementation of renewable energy is likely to be shaped by social conflict.

This thesis is an interdisciplinary study of current conflicts and trade-offs in the implementation of renewable energy, with a special interest on energy and land use relationships. The thesis follows a case study research strategy and assesses the implementation of renewable energies in two different world regions, India and Europe. It analyses agrofuels, biodiesel plantations in Tamil Nadu in South India and wind energy in Catalonia, Spain, as two of the most mature and booming renewable technologies. A third case study assesses the potential and constraints for distributed generation of renewable energy in Catalonia, with a special focus on demand management.

The research is framed within the broader theoretical framework of societal metabolism. It has the methodological objective of integrating discourse analysis with biophysical accounting. The thesis pays particular attention to three elements: (a) how land demands for generating renewable energy relate to the rural-urban dichotomy and land use planning. (b) How conflicts and ideological struggles between varieties of environmentalism influence planning and implementing renewable energies. How hegemonic paradigms such as neoliberalism and ecological modernization interact with grassroots contestations and local populations hosting renewable energy. (c) How in the interaction between science and politics, certain representations of metabolism become authoritative while others are dismissed.

Throughout the case studies this thesis found that conflicts and trade-offs in renewable energy implementation, rather than acknowledged and negotiated, were suppressed by the imposition of reductionist perspectives. The superiority of a "weak" over a "strong" sustainability approach is revealed in the inability of renewable energy policies to tackle *technical* (trade-offs between different dimensions) and *social inconmensurability* (the existence of multiple legitimate perspectives in conflict). Moreover, we found that the neglect of *social and technical inconmensurability* is part and parcel of a process of privileging technical and fact-based argumentation over political and value-based argumentation. This process privileges political positions whose arguments are more compatible with the *status quo* rather than views which claim for societal transformation.

Renewable energy is promoted, in our cases, as commercially oriented and as an industrial sector rather than as a strategic part of broader multi-functional reconfiguration of land use planning. Drawing on Georgescu-Roegen’s distinction between “funds” and “flows”, land use planning and socio-demographic transformations (fund centered) are secondary, in front of boosting energy and revenue flows, which are the priority. This approach seems to be beneficial to the consolidation of a 'hard' path to renewable energies rather than a 'soft' path.

Resumen

El capitalismo industrial se encuentra ante una crisis multidimensional con serios retos ambientales, sociales, culturales, económicos y políticos. Los combustibles fósiles baratos hicieron posible la revolución industrial y han sostenido el crecimiento de la sociedad industrial. Ahora los combustibles fósiles están empezando a escasear y están generando el calentamiento global. En respuesta al cambio climático y al 'pico del petróleo' gobiernos, corporaciones, ciudadanos y movimientos sociales promueven las energías renovables. La menor densidad energética y el carácter disperso de las energías renovables aumentan la demanda de territorio tanto cuantitativamente como cualitativamente. Ello requiere atención a los cambios espaciales y a la planificación del territorio para su implementación. Además, hay diferentes posibles caminos hacia un sistema energético basado en renovables. Un camino 'duro' promovería centrales eléctricas y plantaciones de biomasa a gran escala conectadas a redes e infraestructuras centralizadas para la masiva generación y transporte de electricidad y combustible. Un camino 'suave' enfatizaría la generación distribuida de energía a través de infraestructuras a pequeña escala ajustadas a los usos finales. Dada la existencia de diferentes posibles escenarios, la implantación de las energías renovables probablemente se verá moldeada por conflictos sociales.

Esta tesis es un estudio interdisciplinar de conflictos tanto entre grupos sociales como entre varias dimensiones en la implantación de energías renovables, con especial interés en las relaciones entre energía y territorio. La tesis sigue una estrategia de investigación basada en casos de estudio. Evalúa la implementación de energías renovables en dos distintas regiones del mundo, en la India y en Europa. Analiza los agrocombustibles, plantaciones de biodiesel en el Sur de la India y la energía eólica en Cataluña, España como ejemplos de las tecnologías renovables más maduras y en mayor desarrollo. Un tercer caso evalúa el potencial y las restricciones a una generación distribuida de energía renovable en Cataluña con un especial foco en la demanda.

Esta investigación se enmarca en el estudio del metabolismo social y tiene el objetivo metodológico de integrar el análisis de discurso con la contabilidad biofísica. La tesis da particular importancia a tres elementos: (a) como la demanda de tierra para generar energía renovable está relacionada con la dicotomía rural-urbana y la planificación del territorio. (b) como los conflictos y disputas ideológicas entre ambientalismos influencian la planificación e implementación de las renovables. Paradigmas hegemónicos como el neoliberalismo o la modernización ecológica interactúan y chocan con la contestación popular y las poblaciones locales dónde se implantan proyectos renovables. (c) como en la relación entre ciencia y política ciertas representaciones del metabolismo son consideradas y otras descartadas.

A lo largo de los casos de estudio encontramos que los conflictos entre distintas dimensiones y grupos sociales en lugar de ser reconocidos y negociados son reprimidos por la imposición de perspectivas reduccionistas. La superioridad de un enfoque de sostenibilidad 'débil' frente a un enfoque de sostenibilidad 'fuerte' se revela en la incapacidad de las políticas de energía renovable de lidiar con la *inconmensurabilidad técnica* (la existencia de conflictos entre diferentes dimensiones) y la *inconmensurabilidad social* (la existencia de múltiples perspectivas legítimas en conflicto). Además, encontramos que esta negación de la *inconmensurabilidad social y técnica* es parte de un proceso de toma de decisiones que privilegia la argumentación técnica basada en los hechos sobre la argumentación política o basada en los valores. Ello privilegia posiciones políticas que son más compatibles con el *status quo* más que visiones que reclaman la transformación social.

La energía renovable es orientada en nuestros casos de estudio al desarrollo de un sector industrial y comercial en lugar de como parte de una reconfiguración multifuncional de la planificación del territorio. Usando la distinción de Nicholas Georgescu-Roegen entre “fondos” y “flujos”, la planificación del territorio y las transformaciones socio-demográficas (centradas en los fondos) son secundarias frente al fomento de flujos de energía e ingreso monetario que es la prioridad. Este enfoque parece ser beneficioso a la consolidación de un camino 'duro' hacia las renovables, en lugar de uno 'blando'.

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Main acronyms and abbreviations

AEE	Asociación Empresarial Eólica
AEEC	Assamblea d'Entitats Ecologistes de Catalunya
BMR	Barcelona Metropolitan Region
BOE	Boletín Oficial del Estado
CDA	Critical Discourse Analysis
CHP	Combined Heat and Power
CWDP	Comprehensive Wasteland Development Programme
DA	Discourse Analysis
DEC	Domestic Energy Consumption
ECNMGC	European Cross Networking Meeting on the Global Crises
EDC	Ecological Distribution Conflicts
EFA	Energy Flow Analysis
EIA	Environmental Impact Assessment
EMR	Exosomatic Metabolic Rate
EROI	Energy Return On (Energy) Investment
GENCAT	Generalitat de Catalunya
GEPEC	Grup d'Estudi i Protecció dels Ecosistemes del Camp
GWEC	Global Wind Energy Council
HANPP	Human Appropriation of Net Primary Production
HCA	Hierarchical Cluster Analysis
HEP	Human Exceptionalism Paradigm
ICAEN	Institut Català de la Energia
ICC	Institut Cartogràfic de Catalunya
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDAE	Instituto para la Diversificación y Ahorro de la Energía
IDESCAT	Institut d'Estadística de Catalunya
IEA	International Energy Agency
INE	Instituto Nacional de Estadística
IPCC	International Panel on Climate Change
MEFA	Material and Energy Flow Accounting
MFA	Material Flow Analysis (or Accounting)
MuSIASEM	Multi-Scale Integrated Analysis of Societal and Ecological Metabolism
NWDPRA	National Watershed Development Program for Rainfed Areas
PCA	Principal Component Analysis
PHN	Plan Hidrológico Nacional
QCA	Qualitative Content Analysis
REDD+	Reducing Emissions from Deforestation and Degradation (+ Conservation))
REE	Red Eléctrica de España
RES	Renewable Energy Sources
SA	Societal Average
SC	Scheduled Castes
SJCA	Sala del Juzgado Contencioso Administrativo
SMCE	Social Multi Criteria Evaluation
TEC	Total Electricity Consumption
TEG	Total Electricity Generation
TNAU	Tamil Nadu Agricultural University
TPES	Total Primary Energy Sources
TSJC	Tribunal Superior de Justícia de Catalunya
UNDESA	United Nations Department of Economic and Social Affairs.
UNEP	United Nations Environmental Programme
UPE	Urban Political Ecology
VAO	Village Administrative Officer
ZDP	Zones de Desenvolupament Prioritari (Priority Development Zones)

Preface

"Letting-go is losing the roots temporarily. Not letting-go is to lose them forever"

Søren Kierkegaärd

Any kind of sincere and worthwhile research or inquiring activity has its roots on deep beliefs and motivations. The journey of writing the present thesis started with an inquiry on the environment and ended up being a discovery of my inner intellectual and political commitment. However, when looking back and rethinking how I got here, I see a common thread in my motivations.

All thoughts of this thesis started from the assumption that the project of individual and collective autonomy is feasible and desirable. I could say that it is perhaps the only way to escape from the totalitarianism that advanced industrial capitalism has managed to spread to the whole planet Earth. As Castoriadis (1992 [2010]) wrote, the project of individual and collective autonomy "is a project of a society in which all citizens have an equal, effective possibility of participating in legislating, governing, and judging, and in the last analysis, in instituting society. That state of affairs is predicated on radical changes in the present institutions. That's what we may call the revolutionary project [...]".

I address here a concrete research topic: *conflicts and trade-offs associated to land use planning for implementing renewable energy*. I do so by considering that democracy, as a manifestation of individual and collective autonomy, is a requirement to achieve just and sustainable socio-ecological systems governed by free and equal individuals and collectives. I understand democracy as the actual direct government by citizens of all kinds of societal activities.

I start by referring to such a fundamental question because, as I will clarify along the thesis, I deal with the conflictive character of sustainability and the energy transition. Although not very much prevalent in science, any meaningful research on these topics needs to honestly and transparently present the leading normative assumptions and values behind it.

The reasons for that are central to the argument of this thesis and are three-fold: (1) the growing conflation of facts and values empirically observed in sustainability science and its consequences; (2) the non-sense of separating the representation of reality from the material manifestation of such a reality; (3) sustainability is about purposive action. It is about "What do we want to sustain?"

Democracy is, in my view, part and parcel of any political project towards sustainability. I went to India inspired by the Gandhian bottom-up perspective of starting any social project from the potential of rural villages. I went the first time to India to study traditional irrigation systems, the water tanks ecosystems, looking for the role that those *commons* had at the village level. Aware that effective decentralization is far away from being what is going on nowadays in India, I discovered how the caste society, the process of industrialization and neoliberal agrarian reforms structure the use of common property resources in India. This study was the concluding work of my bachelor degree on Environmental Studies that I did at the Universitat Autònoma de Barcelona (UAB) (Reyes-García et al., 2011). Knowing a bit more about South India, I went back to do the first study of this thesis. I was curious to know the extent to which powerful elites politically manipulated the discourses on biodiesel for decentralized rural energy provisioning. Although my initial interest was to analyze the impacts of Jatropha plantations on common lands, I discovered that in Tamil Nadu, Jatropha was planted in private lands with important consequences to be studied. This research ended up published in two research papers co-authored with Sharachchandra Lele, Joan Martínez-Alier and Giorgos Kallis (Ariza-Montobbio and Lele, 2010; Ariza-Montobbio et al., 2010) and the chapter 2 of this thesis.

During the study of this case, I became familiar with the debate and claims around agro-biofuel plantations in the South. After that, I decided to inquire about the contradictions of renewable energy in the North. Apart from the reasons described below, I thought that a meaningful change in the existing North-South relationships had to come from a change in the energy provisioning of countries in the North. Thus, the controversies around renewable energy in Europe deserved closer attention. Furthermore, wind energy had been, historically, one of the emblems of energy autonomy together with decentralized photovoltaics. The motivation to know about how the energy system could be democratized brought me to look at how wind energy siting had divided environmentalists. Feeling sympathetic with a variety of arguments from different discourses, I became aware of the complexity of the debate. I decided to focus my inquiry in the case of Catalonia, which is the society I come from. My knowledge about the culture and the language facilitated my use of qualitative research methods and the understanding of the historical roots of the conflict, at least in comparison to Tamil Nadu. This research was published in a peer-reviewed article co-authored with Katharine Nora Farrell (Ariza-Montobbio and Farrell, 2012) and the chapter 3 of this thesis.

After the research on wind farm siting in Catalonia, and after a year of a hard process of data collection I conducted the analysis that constitutes the chapter 4 of this thesis in co-authorship with Jesús Ramos-Martín, Gonzalo Gamboa and Katharine Nora Farrell. We have submitted this chapter to Environment, Development and Sustainability. My interest was to investigate about the biophysical base of the wind farm siting conflict presented in chapter 3.

Chapters 2, 3 and 4 of this thesis are based on articles published or submitted to academic journals, with coauthors. I am the principal author of all articles. My co-authors are not using such articles as part of a doctoral thesis. Finally, in chapters 1, 5 and 6 I developed the overall framework that pulls together this whole thesis.

During the years of this PhD, I have attended several international conferences where I have presented my work. I gave some lectures substituting Joan Martínez-Alier, wrote some article for the alternative press, participated in social movements, gave several public talks in the fields of Ecological Debt and Agrofuels impacts on the South, and collaborated with some other researchers in their theses and in research articles (Zorondo-Rodríguez et al., 2012).

The following chapters of this thesis are the product of a reflexive journey throughout all this activities and case studies mentioned above. The motivation of understanding the potential of renewable energy implementation for enhancing or precluding individual and collective autonomy runs throughout the thesis.

1. Introduction

This thesis is an interdisciplinary study of current conflicts and trade-offs in the implementation of renewable energy with a special interest on the energy and land use relationships. This research inquires about threats and opportunities regarding the reproduction or transformation of current unequal power relations during a transition to renewable energy. To what extent is the current way of implementing renewables (and the degree of 'successful' implementation) challenging or reproducing industrial capitalist institutions? What can communities and individuals learn from current experiences to ensure sustainable and democratic control and management of the energy transition towards renewables? This introductory chapter presents the overarching framework, which guides the research and pulls together three case-study chapters on this topic. The thesis analyses two case studies on the conception and implementation of policies on renewable energy: biodiesel (*chapter 2*) in Tamil Nadu, India and wind energy in Catalonia, Spain (*chapter 3*). *Chapter 4* explores present obstacles, constraints and potentialities for future distributed energy generation in Catalonia.

Section 1.1 presents one narrative about the problem, highlighting three interrelated societal challenges when doing a transition to renewable energy: (a) there are important biophysical constraints and trade-offs associated to redesigning the energy system towards renewables. (b) These biophysical challenges relate to future changes in land use and prospects of urbanization. (c) Social relations, institutions, and conflicts shape the reconfiguration of energy and land use and their relationships.

Environmental conflicts about the use, purpose and property of land and energy influence and are influenced by divergent discursive representations. This thesis pays attention to how ideological struggles between environmentalisms shape renewables implementation. The neoliberal hegemony and the discourse of ecological modernization clash with grassroots contestations from a variety of radical environmentalisms: environmental justice, degrowth, food sovereignty, Sumak Kawsay, etc. Moreover, science and technology play a special role in shaping which dominant representation of the problems becomes hegemonic in environmental conflicts. In this thesis, technology as ideology (Marcuse, 2007[1964]) is argued to be of high relevance in framing energy policies, by giving preponderance to technological optimism over structural social transformations for 'sustainability'.

Section 1.2 explains the metabolism of societies as a framework for studying the relations between human and non-human nature. This thesis contributes to a transdisciplinary approach to energy metabolism, integrating natural science and humanistic perspectives. This section summarizes the main strands of this research field and identifies areas for transdisciplinary synergies. It contextualizes the use or contribution to different perspectives on metabolism, in the following chapters.

Section 1.3 wraps up the rationale and broader research design that relates the three case-study chapters. After presenting the overarching research questions and aims of the thesis, I[1]

[1] A note on the expression: The introduction and conclusion of the thesis are written in first person. Chapters being co-authored papers are written in second person.

explain why I followed a case-study research strategy and how I have chosen the case studies and related them to the challenges reported in section 1.1 and the theoretical framework depicted in section 1.2. The end of section 1.3 presents the methods used for data collection and analysis. Finally, section 1.4 offers a short roadmap throughout the contents and purpose of each of the chapters of the thesis.

1.1 Challenges of the transition to renewable energy.

The socio-metabolic transition of western industrialization signified a partial substitution of land-based biomass resources by fossil fuels which generated more energy per hectare than biomass (Fischer-Kowalski and Haberl, 2007; Haberl et al., 2011; Krausmann et al., 2008; Krausmann and Haberl, 2002a; Mayumi, 1991; Sieferle, 2001). As a result biomass lost its predominance as primary energy source in favor of fossil fuels. The growth in energy consumption allowed western society to organize in greater complexity progressively separating production and consumption processes (Erb et al., 2009). Urban areas progressively grew, becoming industrial centers that increasingly relied on distant peripheries for the extraction of the demanded natural resources (Folke, 1996; Hornborg, 1998). The coupled processes of industrialization and urbanization configured a social and spatial organization of human activities, which have grown in fossil fuel dependency. Currently, 80% of world energy demand is covered by fossil fuels, a large part of which is conventional oil (IEA, 2012c).

However, fossil fuel dependency of contemporary globalization faces two important biophysical and environmental limitations: Peak Oil and Climate Change.

As early shown by (Hubbert, 1956) and later extensively investigated from different perspectives (for a review see (Kerschner, 2012)), "Peak oil" is the critical point where the non-renewable oil resource reaches its maximum or peak extraction. Since then, extraction declines at a rate unable to meet growing energy demand (Aleklett and Campbell, 2003; Campbell, 1998).

There has been much debate about the date of "Peak oil" between those who think that it is near or has already passed (Aleklett et al., 2010; Kerr, 2011; Murray and King, 2012; Sorrell et al., 2012) and those who think that there is still abundant conventional and unconventional oil reserves (Maugeri, 2012; Monbiot, 2012; Yergin, 2011). Despite the debate about the time frames of Peak Oil, the non-renewable character of fossil fuels, make them exhaustible sooner or later. Some researchers have alerted how relying on coal (Heinberg and Fridley, 2010) or conventional natural gas or shale gas can delay the transition to a system based on renewables. Coal and natural gas, and other non-renewable resources (uranium and other several minerals that are key raw materials) will reach in due course their global extraction peaks (Heinberg, 2007).

Apart from its immediate scarcity, the extraction and consumption of fossil fuels have serious environmental and social impacts both in the Global South, where are extracted (Orta, 2007), and at the global level. The CO_2 emissions of fossil fuel burning are causing global warming. Global temperature increase will (and is starting to) generate climate change with multiple, some uncertain and unpredictable, consequences, such as the increased occurrence of extreme weather conditions and a rise in sea level (IPCC, 2007). Most of these consequences will be unevenly distributed, affecting more seriously populations and ecosystems of the Global South (O'Brien and Leichenko, 2000; Thomas and Twyman, 2005).

Preventing the most dramatic consequences of climate change would require stabilizing atmospheric CO_2 concentrations at between 445 and 490 ppm, and keeping the average global temperature increase lower than 2°C above the preindustrial mean (IPCC, 2007). Transforming the energy system away from fossil-fuels and towards renewable energy is one of the most direct and urgent actions widely considered for reducing CO_2 emissions (Moomaw et al., 2011).

The finitude of cheap fossil fuels and the impact of climate change open up a scene for political struggles around the reconfiguration and sustainability of future energy systems (Abramsky, 2010). Faced with such a difficult situation there are optimistic and pessimistic views about the feasibility of the needed transformations. The most well-known pessimistic perspective foresees a collapse of industrial civilization (Duncan, 2007) or considers very difficult to organize a plan for the transition (Sorman and Giampietro, 2013). However, being aware of the great difficulties of the energy transition does not imply to consider any action to be futile nor expecting the end of human civilization after the fossil fuel era (Odum, 2001; Smil, 2006).

Discussions around "sustainable degrowth" (Cattaneo et al., 2012; Kallis, 2011; Kallis et al., 2012; Latouche, 2006; Martínez-Alier et al., 2010; Schneider et al., 2010; Sekulova et al., 2013) usually emphasize the importance of distinguishing between an unplanned and forced reduction of energy consumption and the active and organized response to an unavoidable down-scaling of energy consumption (Kallis, 2013).

Thus, optimistic and pessimistic perspectives can be confronted when analysing the governance and social organization of current actions for an energy transition. Optimistic perspectives consider possible to achieve the transition without substantially altering existing institutions, following the mainstream paradigm of ecological modernization. Critical perspectives of such a position base their optimistic views on the emerging changes occurring both *within* social movements and *within* science. Therefore, there are two kinds of optimism regarding the energy transition, one based on ecological modernization and the other based on radical social changes. The author is inclined to the optimism of the second kind.

This introductory chapter contextualizes the relevance of an interdisciplinary analysis of current implementation of renewable energy. It starts with a brief summary of present and future energy scenarios and later presents (i) biophysical constraints, (ii) land use changes and (iii) conflicts and ideological struggles that are key challenges for a transition to renewable energy.

Present and future energy scenarios

The most recent estimates of the International Energy Agency (IEA) depict a scenario where fossil fuels remain the dominant primary energy source from now to 2035. "Global energy demand grows by more than one-third over the period to 2035 with China, India and the Middle East accounting for 60% of the increase. Energy demand remains stable in OECD countries, although there is a pronounced shift away from oil, coal (and, in some countries, nuclear) towards natural gas (with the global spread of unconventional (shale) gas production) and renewables"(IEA, 2012d).

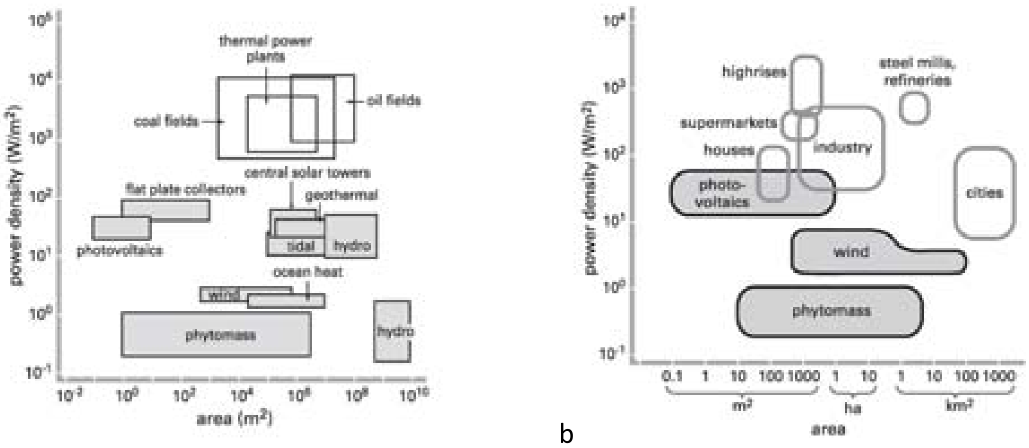
The use of renewable energy, including traditional biomass, accounted for 13% of global primary energy demand in 2010. Since 2000, this share has remained constant but with changes in the contributions of different renewable sources. Traditional biomass has fallen from being 50% of all renewable sources in 2000 to 45% in 2010. Meanwhile the share of the demand for transportation fuel covered by agrofuels has been growing. The role of renewables in electricity generation has been lead by hydropower, the largest source of renewables-based electricity, which has remained stable in relative terms. However, growth in renewable electricity generation has been concentrated on wind, which grew by 27% and on solar photovoltaics (PV), which grew, on average, by 42% per year from 2000 to 2010. Despite the negative impact of the global economic crisis on renewables growth in some parts of Europe and United States, this has been compensated at a global scale by the growth in some other areas, especially in Asia (IEA, 2012a).

Lowering power densities and EROI increases land demand

Undertaking a transition to a renewable-based energy system entails a qualitative and quantitative reconfiguration of land use. The quantity and quality of the required land as well as the spatial dimensions of energy generation and consumption regain importance due to the biophysical characteristics of renewables when compared to fossil energy. The most discussed biophysical challenges of a renewable based system pivot around spatial dimensions.

The power density of an energy source is the rate of flow of energy (Watts (J/s)) it can generate per unit of land (square meter, m^2) (Smil, 2010). As shown in Figure 1a, the power density yields of current fossil energy stock sources (including thermal power plants, oil and coal fields) are two orders of magnitude greater than possible substitutes such as hydro or solar sources, and three orders of magnitude greater than biomass and wind sources (Scheidel and Sorman, 2012; Smil, 2008, 2010). Converting renewable energy flows into energy carriers (fuels, heat or electricity) available for the society requires significantly higher amounts of area as compared to fossil energy. As shown in Figure 1b, the typical power densities of some renewable energy conversions mismatch with the power density of energy consumption of societal activities. While photovoltaics could match the density of consumption in houses and some industrial uses, wind energy is one order of magnitude bellow typical power densities of cities, and phytomass (plant biomass), two orders bellow. Highrises, supermarkets, steel mills and refineries are socio-economic uses of energy with a power density two orders of magnitude above renewable energy sources. Matching it, would likely require large-scale storage and grid interconnection whose sustainability and implications is part of what needs to be assessed for doing a transition to renewable energy. In this thesis, however, we concentrate only on the consequences of the land demand by some renewable technologies.

Figure 1. a. Power densities of fossil fuel extraction compared to power densities of renewable energy conversions. **b.** Mismatch of typical power densities of renewable energy conversions and common energy uses in modern societies. **Source:** (Smil, 2008)



a b

Such a quantitative requirement of land is also a consequence of the quality of energy resources, usually measured through the Energy Return On (Energy) Investment (EROI) (Cleveland et al., 1984; Hall et al., 2009; Hall et al., 1986; Murphy and Hall, 2010). The accumulated stocks of fossil fuels, contain a high energy density that when consumed, compensate in excess for the energy invested in its extraction. Such a high energy return on energy investment (EROI) of fossil fuels has been reduced over time from 100:1 in 1930 (Cleveland, 1992) to around 20:1 over the last century (Cleveland, 2005). Recent research has even found lower EROI figures around 10:1 (Hall, 2008). The EROI of some renewable energy sources (RES) is lower than 20:1, such as agrofuels (in sometimes even lower than 1:1 (Pimentel, 2003; Pimentel et al., 2007)) and photovoltaics (lower than 10:1 (Hall, 2008)). Other renewable sources have higher EROI figures, such as hydropower (around 40:1) and wind power (from 15:1 to 20:1) (Hall, 2008). Despite this figure varies, in general, to obtain the same amount of energy as it is nowadays extracted from fossil fuels a greater amount of energy would need to be invested and consequently higher amounts of land and resources would be used. Moreover, the spatial configuration of generation and consumption of energy will likely affect the EROI of energy sources. In other words, the structure of grids and infrastructures and the spatial distribution of consumption it is likely to affect the energy consumed by the energy sector in generating energy for the rest of society.

Besides the demand on land in terms of quantity, some biophysical characteristics of renewables require attention as regards the qualitative aspects of the spatial organization of the energy system. The intermittent, and to a significant degree unpredictable nature of most renewable energy flows and their uneven and dispersed distribution require an emphasis on spatial planning. Organizing storage and distribution of biofuels and biomass resources and long-distance interconnections in the case of electricity generation are of importance for long-term sustainability of renewable energy supply. Contemporary fossil-fuel based systems are dominated by global diffusion of concentrated energies (with high power densities) extracted from a relatively limited number of nodes (e.g. oil fields, coal mines, thermal (fossil and nuclear) power plants). Basing the energy supply on renewables, with the exemption of large-hydro[2], would mean to change from such a concentrated system to a system that would collect fuels of low energy density at low power densities over extensive areas (Smil, 2010). Renewable resources, also with the exemption of large-hydro, are dispersed, and often they are unevenly distributed over low densely populated rural areas, far from highly consuming urban centers. Industrial society, especially in its contemporary form of globalization, has managed to sustain with fossil fuels a society based on urban consuming centers and rural peripheries where to extract resources.

The transition to renewable energy sources (RES) does open questions about the extent to which it is possible and desirable to sustain with RES current prospects of urbanization. What would be the implications of trying to do so? Society, thus, could either choose to concentrate renewable flows towards the growing urban consumption centers, maintaining the modern rural-urban dichotomy, or purposively undertake a transition towards a new spatial configuration of societal activities. Thus, debates around decentralization and distributed energy generation (Ackermann et al., 2001; Alanne and Saari, 2006; Pepermans et al., 2005) versus centralized grids and infrastructures are intimately connected to discussions on the future of human settlement patterns and land use changes.

The following section presents the current status and prospects on the land use scenario. It derives what would be the features faced in the interaction between the implementation of a renewable energy system with the contemporary and expected land use changes.

Urbanization and rural-urban relationships in a non-fossil fuel future

In 2008, for first time in world history, more than 50% of the world's population lived in cities (UNDESA, 2010). The rapid process of urbanization that took place first in the West especially during the twentieth century (in 1920 less than 30% of the population was urban while in 1950 it was more than a half (UNDESA, 2012)) is now taking place in the Global South. While nowadays Europe, North America and South America and the Caribbean have rates of urbanization around 70-80%, a substantial part of Asia and Africa has an urban population bellow 40%. Asia and Africa are expected to be the world regions were urban growth will concentrate. The expectation for the next 20-30 years is that they will cross a historic threshold, joining the rest of the world in having a majority of urban residents (Montgomery, 2008).

This worldwide urbanization process has important consequences both in terms of energy consumption and the future organizing of renewable energy supplies. The physical and demographic growth of urban areas generate serious environmental and social impacts both

[2] Depending on the scale of hydro-power stations and their associated impacts they are more or less distributed being closer to either a 'soft' or a 'hard' approach to energy technologies, as explained throughout the thesis. Hydro-power has not been studied in this thesis due to time and resources limitations. However, the scale and role of hydro-power and its impacts (Biswas, 2012, Mc Cully, P., 2001) is of utmost importance in the overall assessment of the sustainability of renewable systems. An assessment of a sustainable and just use of hydro-power could start by assessing the scale (if there is any) at which is feasible and desirable to balance between their impacts and benefits. Impacts to consider would be among others, changes on hydro-geological dynamics, land use and on local communities' livelihoods. Benefits, among others, are their capacity to operate as energy storage devices when coordinated with other intermittent renewable sources (Bueno and Carta, 2006, Dell and Rand, 2001).

regionally and globally. The growth of cities as world-system centers would not be possible without resource extraction from distant peripheries (Hornborg, 1998; Martínez-Alier, 2003). The resource extraction frontier of most non-renewable resources is advancing and reaching the last corners of the planet (Martinez-Alier, 2009; Moore, 2000). While sustaining current cities economic activity is increasingly dependent on finite resources from a rural "global hinterland", the physical growth of urban areas poses many threats to the ability of adjacent rural areas to produce food and renewable energy (Atkinson, 2008, 2012).

Traditional rural and urban boundaries are blurring worldwide, though due to different processes in North and South. The growing conurbations of the South generate vast peri-urban areas where rural and urban traditional characteristics merge (Tacoli, 1998, 2003). In the already vastly urbanized North "urban sprawl" and a growing tertiarization of rural landscapes diffuse urban styles to the rural areas (Marsden, 1999).

Responses to climate change and peak oil such as changes in the organization of transportation and agricultural systems are likely to alter rural-urban relationships. Some old differences between rural and urban areas would be reinforced and some would be challenged and rebalanced (Andersson, 2009). The impacts of energy technologies in the extraction or generation sites in the countryside are an important component of such changes. Progressively abandoning fossil fuels and nuclear energy can substantially reduce the impact of oil fields, coal and uranium mining and power plants which use such primary energy sources. However, impacts and 'land grabbing' arising from large scale dams (Biswas, 2012; Mc Cully, 2001), agrofuels (Borras and Franco, 2012; Rosset, 2011) and wind energy (Brown, 2011; Brown, 2012; Oceransky, 2010) can reproduce former uneven development. The growing importance of land as an strategic asset (Scheidel and Sorman, 2012) and the growing threats of a "green grabbing" coming from REDD+ (Fairhead et al., 2012) makes the redefinition of land use and rural-urban relationships an important challenge in a transition towards renewable energy. As raised above, the transition towards renewable energy can either reinforce uneven development or imply an integral transformation beyond the classical rural-urban divide. Conflicts and ideological struggles between varieties of environmentalisms will shape the direction taken, the topic of the next subsection.

The ideological struggle between varieties of environmentalisms

As raised by Barca (2011) the mainstream narrative on the industrial revolution emphasizes mineral technology (the use of fossil fuels) and private property as the key elements boosting modern economic growth, the main driver of rising energy consumption. However, this narrative does not account for the role of social power in the shaping of how energy is used and to what ends. Neither does it consider the socio-ecological costs associated with the increase of energy consumption.

Power relations and social conflicts have influenced energy transitions along human history. The way and the end to which major technological shifts have occurred, are related to changes in social organization. Thus, the current energy transition is likely to occur under social conflict and ideological struggles.

Since the Limits to Growth (Meadows, 1972) and the environmental movement of the 1970s, the environment has gained more importance in political debates. Nowadays the main institutions of modern society have internalized the management of environmental crisis. Different social groups and institutions have embraced the rise of the environment as a topic of public concern, bringing about 'varieties of environmentalism' (Guha and Martínez-Alier, 1997; Martinez-Alier, 2002). Radical or eco-anarchist environmentalism, environmental justice (or the environmentalism of the poor), degrowth, ecological modernization (or the gospel of eco-efficiency) or the cult of wilderness (or deep ecology) have different perspectives about sustainability. Hopwood et al. (2005) illustratively map different views on 'sustainable development' depending on their emphasis on equity and on their world-view, from techno-centred to eco-centered.

Renewable energy is relevant because is part of the discourse of almost all currents of environmentalism. Different currents of environmentalism easily find common grounds for collaboration to fight against mining, waste disposal, nuclear energy and recently, shale gas exploitation, among many other infrastructures. In these cases, there seems to be union about a common enemy, while in renewable energy, different perceptions about priorities and strategy divide environmentalism. Disagreements on implementation, such as in wind farm siting in the 'Global North' (that is why it is the focus of *chapter 3*), become much more controversial than other topics.

These struggles between currents of environmentalism, do not take place in an equal stance, as some ideologies are dominant. Ecological modernization is nowadays the main paradigm influencing environmental policy (Hajer, 1995). Some of its main characteristics (summarized below) are compatible with, and therefore potentially beneficial to the broader neo-liberal hegemony and to what (Mouffe, 2005) calls the post-political *Zeitgeist*[3]. It is not the purpose of this thesis to contribute to the elaboration of theory about the relationships between them. Instead, here we present these three elements as pertaining to the relevant political context that generally influences environmental policy of which renewables are part. Some of our broad and concrete research questions outlined, either in this chapter or in each of the case studies, require such a broad contextualization.

Ecological modernization discourse "recognizes the structural character of the environmental *problematique* but none the less assumes that existing political, economic, and social institutions can internalize the care for the environment" (Hajer 1995: 25). This is possible because: (1) costs and benefits of environmental degradation can be taken into account through quantiative calculation that combine monetary units and concepts from the natural sciences; (2) environmental protection is a 'positive sum-game' and (3) economic growth and the resolution of ecological problems can, in principle, be reconciled.

Ecological modernization, thus, stands from the idea that pollution prevention pays. Legal and regulatory efforts can reform markets in a way that reduction of ecological harm becomes economically beneficial. Innovators, entrepreneurs and other economic agents can promote ecological restructuring towards energy efficiency and dematerialization. The internalization of externalities into the price system is, together with science and technology, central to the abatement of environmental pollution (Mol, 1997). The state adopts more a 'steering' role

[3] Spirit of the age or spirit of the time, it is the intellectual fashion or dominant school of thought that typifies and influences the culture of a particular period in time.

than the former command and control of the 1970s and 80s. Social movements change from criticizing technological developments to actively participating on them.

As highlighted by Coffey and Marston, (2013) and noted by Castree (2008) researchers have rarely explored the relationships between ecological modernization and neoliberalism. However, several elements that make them compatible can explain why the broader neoliberal hegemony can facilitate their coexistence.

Neoliberalism "can not be understood as a *singular* set of ideas and policy prescriptions emanating from one source (Kjær and Pedersen, 2001; quoted in Plehwe et al., 2006)". Usually, neoliberalism is understood as an ideology whose foundations are "the superiority of market-driven competition as the best mechanism of economic allocation, or in the privileging of property rights (above, say, democratic rights) as a foundational condition of liberty" (Plehwe et al., 2006: 2). Neoliberalism, although seen as 'anti-statist', has actually been "about the capture and reuse of the state, in the interests of shaping a pro-corporate, freer-trading ‘market order’’ (Coffey and Marston, 2013; Peck, 2010). It is seen from their critics as 'new' (neo) because it succeeds and recapitulates the 'classical liberalism' of the early twentieth century, their preoccupations are *narrower* than its predecessor, much more focused in economic rather than civic and political freedom and it is a more global project affecting beyond the 'first world' (Castree, 2010).

Neoliberalism is relevant to environmental policies because it entails "the colonisation of non-market spheres of activity by the logic of commodity exchange" (Castree, 2010: 1728). It entails, among others, the privatisation, commodification and marketization of nature, as some of several characteristics of neoliberalism. Market mechanisms to mitigate climate change include emission trading schemes and REDD+ (Reducing Emissions from Deforestation and Degradation (+ conservation)). They have already been contested globally, and particularly in the South. Grassroots and NGOs have denounced current and potential social impacts (land grabbing and communities disposession) and ecological impacts (doubtful effectiveness and even worse, increasing environmental degradation).

The ideology of neoliberalism and its effects take uneven forms in different places and some authors distinguish between neoliberalism as an ideology and 'actually existing neoliberalism' (Brenner and Theodore, 2002) or *neoliberalisation* (Castree, 2010). However, the common denominators of the plural expressions of neoliberalism have consolidated this ideology as hegemonic. It is hegemonic, from a Gramscian perspective, in the sense that hegemony requires the active consent and participation of the ruled; hence it requires mechanisms to ensure the acceptance of the neo-liberal principles by society at large.

This is important here because hegemonies are always contested by other political projects. To keep in power, hegemonies search how to overcome or supress opposition. One way of doing it could be to try to convince the public that we all have the same objective (that is actually the one of the ruler), that a *rational* consensus is possible. (Mouffe, 2005) in his book '*On the political*' analyses the consolidation of the post-political *Zeitgeist* in western societies. According to her, the liberal conception of the political, the one dominant today, negates the antagonic nature of societies. Liberalism, as rationalistic and individualistic does not recognize the nature of collective identities. Thus, a form of a 'post-political' view has aroused that sees free individuals as able to achieve *rational* consensus without conflict and without the bounds of collective identities. Greater detail about Mouffe's theoretical position would distract the text from its focus and structure. The important point here is to clarify the thread of explanation: the elimination of conflict, the 'positive-sum game', is a common element of ecological modernization, neoliberalism and the postpolitical view.

The future of political treatment of conflict and difference especially in environmental issues is likely to have a prominent role in shaping the direction that a new 'green economy' will take. "UNEP defines a green economy as one that results in *improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities*... the concept of a “green economy” does not replace sustainable development, but there is now a growing recognition that achieving sustainability rests almost entirely on getting the economy right" (UNEP, 2011: 2) . Central to this notion of 'green economy' is the promotion of renewable energy sources (van Dril, 2011).

As raised above, grassroots movements and NGOs worldwide are denouncing the threats arising from a growing 'financialization of nature' (ECNMGC, 2011) that the 'green economy' could entail. Such risk includes among other issues, the privatization of life through bio-technological patents applied among others to the agrofuel production (the topic of *chapter 2*). A growing movement on 'climate justice' claims for the centrality of equity in climate change mitigation and adaptation, as part of a broader project for environmental justice (Building Bridges Collective, 2010). In Western societies a growing movement for 'degrowth' has arisen, first in France and Italy and later disseminated throughout Europe and other western industrialized countries. Sustainable degrowth can be defined as "a collective and deliberative process aimed at the equitable downscaling of the overall capacity to produce and consume and of the role of markets and commercial exchanges as a central organising principle of human lives (Schneider et al., 2010; Sekulova et al., 2013).

All these social movements are responses to established paradigms of environmental management. They put at the center of their claims the acknowledgement of conflict, equity and democracy as priorities for socio-environmental transformations.

It is important to notice however, that social movements especially the environmental justice perspective challenges ecological modernization not because it is neoliberal and not even because it is capitalistic, but because economic growth destroys the environment as well as the livelihoods of poor people. The struggle for resources is due to the growth of social metabolism and therefore "neoliberalism" has a limited explanatory power. As argued by (Latorre and Farrell, 2013) in order to understand ecological distribution conflicts, the relevant category is "social metabolism" more than "neoliberalism". Thus, in Ecuador, the government is not neoliberal but conflicts are flourishing. Neoliberalism at a global level is losing power as main explanatory category as we notice the increasing world role of Chinese State Capitalism (that easily get into agreements with South American "nac-pop" governments to further resource extraction).

The need for renewable energy as the need for caring about the environment is a matter of 'consensus' in contemporary societies, especially among "varieties of environmentalism". Both the partisans of ecological modernization and the partisans of environmental justice are against fossil fuels. The question lies however in the principles that would guide the energy transition. The renewable energy transition, as part of a 'green economy', could be made through 'green growth' following the principles of neoliberalism and ecological modernization. Alternatively, it can be done under the principles of environmental justice, degrowth, food sovereignty or Sumak Kawsay.

There are different possible pathways to a 100% renewable energy system. We could trace back the origins of advocacy of renewable energy to the 'appropiate technology' movement of the 1970s. Within the debates of that time, Amory Lovins (1977), distinguished between a 'hard' and a 'soft' path to energy supply. The 'hard' "relies on rapid expansion of centralized high technologies to increase supplies of energy, especially in the form of electricity. The second [soft] path combines a prompt and serious commitment to efficient use of energy, rapid development of renewable energy sources matched in scale and in energy quality to end use needs, and special transitional fossil fuel technologies" (Lovins, 1977: 24 quoted in Szarka 2007). Thus, large thermal power plants, especially nuclear ones, represented the 'hard' path. Accesssible, flexible and diverse renewable technologies matched to end uses represented the 'soft' path. Lovins considered also the societal development paths associated to technology choice. The 'hard' would be based on bureaucratic central control and the concetration of power on oligopolistic companies, undermining market mechanisms and democracy and leading to an 'industrial-military complex' (Szarka, 2007).

Szarka, (2007) inspired by Lovins, extends the distinction between 'hard' and 'soft' paths in energy technology choice, to paths *within* the renewable sector. He notes that the domination of energy supply by major oligopolistic corporations is now extending from fossil fuel and nuclear to renewable sources. This makes possible that renewables follow the 'soft technologies' path represented by the emblematic small-scale and locally owned Danish wind farms or the 'hard' path represented by the integration of wind energy (and the rest of renewables) in the mainstream model of electricity provision. This model relies on centralized grids, providing 'bulk power' for mass industrialization. The 'soft' and the 'hard' paths also differ on their priorities. The 'soft' prioritise social and environmental issues. The 'hard' model is more inclined to economic (*chrematistic*) interests.

This brief summary of the ideological scenario framing and affecting public policies of renewable energy is useful to our purpose of evaluating the discourses and practices prevalent in the implementation of renewable energy.

The positive, desired and consensual character of the renewable energy transition makes it particularly vulnerable to ideologies that negate social inconmensurability (plurality of views and collectives) and technical inconmensurability (the impossibility to reduce multi-dimensional and multi-scalar complex systems to a single measure). The imposition of these reductionist ideologies as leaders of renewable energy implementation could hamper the revolutionary and democratic character of a 'soft' approach to renewable energy. The articulation and consolidation of grassroots alternatives arising from an alliance between environmental justice, degrowth, Sumak Kawsay ('buen vivir') and food sovereignty movements can potentially ensure the democratic priorities of the 'soft' path.

1.2 A transdisciplinary view on energy metabolism: analysing bio-physical and political power

The metabolism of a society refers to the set of conversions of energy, material and water flows occurring within a society, which are necessary for its continued existence (Giampietro et al., 2009). For a review see (Fischer-Kowalski, 1997; Fischer-Kowalski and Hüttler, 1998; Haberl, 2001a, 2001b; Martinez-Alier, 1987; Martinez-Alier, 2009)). Society extracts flows of energy and materials from the environment using them to sustain and reproduce social and economic processes, while returning waste and heat to the environment.

The metabolism of societies has been studied from the biophysical perspective analyzing the material base of socio-economic systems. It has also been studied from the social sciences by looking at institutions and social relations that shape the extraction and use of resources and their disposal as waste. Particular attention has been given to the ecological debt (Bárcena, 1998; Goeminne and Paredis, 2010; Paredis, 2008; Srinivasan et al., 2008), ecological unequal exchange (Giljum and Eisenmenger, 2004; Hornborg, 1998, 2009), urbanization (Heynen et al., 2006; Swyngedouw, 2004) and ecological distribution conflicts arising both at the "extraction frontiers" of natural resources and at the waste disposal sites (Martinez-Alier and O'Connor, 1996; Martinez-Alier, 2009; Martinez-Alier et al., 2010).

In this thesis we intend to adopt a transdisciplinary perspective on societal metabolism drawing from different disciplines throughout the natural and social sciences. We stand from the perspective that "... it is in fact deluding to separate scientific discourses on the "reality" of environmental problems from humanistic discourses on the representations of such realities, simply because the representations (including all our discourse) tend to be active ingredients *in* reality" (Hornborg, 2001: 4).

Here, in a short review of societal metabolism research I attempt to outline this transdisciplinary perspective in relation to the research topic. I proceed by: (1) summarizing the broader strands of thought in this fruitful field; (2) presenting potential and existing ways of integrating them to improve our understanding of socio-ecological systems; (3) relating research strands, their integration, and energy and land use relationships to my empirical work in this thesis.

The biophysical base of societies as part of ecosystems

Energy is of vital importance to sustain the metabolism of a living organism. Seeing ecosystems and socio-economic systems as living organisms, thus, provides fresh insights to the societal goal of sustainability (Ho and Ulanowicz, 2005). Multiple interdisciplinary fields such as systems ecology, far from equilibrium thermodynamics, ecological economics, bio-economics and industrial ecology among others have viewed societies as part of wider ecosystems and therefore as living organisms.

The long tradition of studying the use of energy and material flows by human societies traces back to the inception of agricultural energetics (Martinez-Alier, 1987; Pimentel et al., 1973). From 1800s to the present, the land use change entailed by the socio-metabolic transition from biomass resources to fossil fuels since the industrial revolution has been widely studied (Fischer-Kowalski and Haberl, 2007; Pimentel et al., 2005; Pimentel et al., 1973; Smil, 2010). Comparing traditional or organic agriculture to industrial agriculture this research field has highlighted the loss of energy efficiency of agriculture and its causes and consequences. The historical loss of energy efficiency of agriculture is expressed by the progressive reduction of the Energy Return On (Energy) Investment (EROI) (Hall et al., 2009; Hall et al., 1986) from mid-19th century to present. The introduction of fossil fuel inputs and the functional disconnection of forest, pasture and agricultural lands previously managed integrally are the foremost causes of agriculture's loss of energy efficiency (Cussó et al., 2006; Erb et al., 2008; Krausmann, 2001; Krausmann and Haberl, 2002b; Krausmann et al., 2004; Krausmann et al., 2003; Marull, 2007; Marull et al., 2010).

Fossil fuels were introduced to confront declining returns. By increasing land and labor productivity, agriculture changed from being a producer of energy to a consumer of energy (Pimentel et al., 1973). The raise of energy input demanded by society brought about by industrialization has increased by several orders of magnitude. This has increased the human appropiation of net primary production (HANPP) from being less than 5% of global terrestrial Net Primary Production (NPP) to 30-40% (Vitousek et al., 1986) nowadays and likely to surpass 50% in about 2050 (Haberl, 2006a). Such an increase in HANPP has come from both the increase in land use occupation to extract resources to feed and sustain the expanding population and from the growing built-up and paved area through urbanization. HANPP increase has environmental consequences such as the reduction of energy available to ecosystem processes (Haberl, 2006a), the impact on biodiversity loss (Haberl et al., 2005; Haberl et al., 2004b) and the reduction of "landscape efficiency". "Landscape efficiency" can be understood as the ability of the landscape to satisfy human needs while maintaining the healthiest ecological patterns and processes, such as ecological connectivity (Marull et al., 2010).

In an attempt to grasp the magnitude of socio-ecological impacts of a growing societal metabolism, a variety of concepts, indicators and methodologies have been developed both for material flow and energy analysis.

The Material and Energy Flow Accounting (MEFA) framework is a supporting toolbox to account for socio-economic metabolism and colonization of natural processes; above all, land use. MEFA intends to provide a comprehensive framework for studying and relating energy and material metabolism as well as land use and land cover change (Haberl et al., 2004a). This approach researches the links between land-use policy and energy policy, which although often overlooked, are of prime importance for sustainability (Haberl, 2001a). MEFA uses a set of indicators from Material Flow Analysis (or Accounting) (MFA), Energy Flow Analysis (EFA) and land use change indicators such as the Human Appropriation of Net Primary Production (HANPP). While MFA and EFA provide information about the total amount of energy and materials ‘metabolized’ by society, HANPP provides information of what that implies in terms of ‘‘colonization of terrestrial ecosystems’’(Fischer-Kowalski and Haberl, 1998; Haberl, 2001a; Haberl et al., 2004a; Krausmann et al., 2003).

EFA accounts for the total amount of energy required by an economy and in contrast to conventional energy balances, which only include technically and commercially used energy, EFA also accounts for socioeconomic inputs of biomass (food, feed, wood and other materials of biological origin) (Haberl, 2006b; Haberl et al., 2004a; Haberl et al., 2006). Their developers highlight that this makes EFA useful to compare across different modes of subsistence and analyze transitions from agrarian to industrial society on different spatial and temporal scales (Haberl, 2001a; Haberl, 2006b). Indicators derived from EFA, such as Domestic Energy Consumption (DEC), including biomass not commercially used and therefore not included in conventional total primary energy sources (TPES) also grasp more comprehensively environmental pressure, because they do not neglect environmental impacts resulting from biomass use (Haberl et al., 2004a).

HANPP is used for assessing the impact of human energy use in ecosystems functioning. Land-use fundamentally alters the production ecology of terrestrial ecosystems, reducing or increasing the net primary production (NPP) of ecosystems (Haberl et al., 2004b). The human appropriation of NPP is calculated by subtracting the NPP remaining in the ecosystem after harvest (NPPt, NPPt= NPPact (actual NPP)-NPPh (harvest)) to the potential NPP (NPP_0) if there would not be human activity.

The Ecological footprint (Rees and Wackernagel, 1996; Rees, 1992) is another indicator of human appropriation of land to fulfill society's needs. This indicator aggregates the ecological flows associated with consumption and translates them into appropriated land area. This includes the land used for producing the diet and natural resources needed for a given population, the land appropriated through urbanization and the virtually needed land to absorb the CO_2 generated through fossil fuel (or alternatively the land required to cultivate ethanol or biodiesel to substitute these fossil fuels).

MEFA framework (including HANPP) and Ecological footprint are examples of biophysical accounting methods. Energetics as the science studying the evolution of energy use in nature and society have developed other methods, among them, emergy[4] and exergy[5] analysis.

Both emergy and exergy analyses aim at assessing the energy sustainability of economic processes. Some research has studied the relationship and differences among both (Bastianoni et al., 2007; Brown and Herendeen, 1996; Sciubba and Ulgiati, 2005). The main differences are the goals and the chosen system's boundaries for the analysis. "Emergy evaluation intends to ‘‘trace back’’ the solar energy embodied in a product, while exergy assesses the amount of primary resources of any kind that went into that product. [...] In emergy, the system encompasses the entire biosphere, whose external surface is crossed by the basic input, i.e. solar energy; in exergy analysis, the system boundaries are defined by the analyst, according to the aim of the study" (Bastianoni et al., 2007).

Ecological footprint and the MEFA framework among other methods of energy analysis and land use sustainability appraisal, have been criticized as compressing energies (and land uses) of different qualities being used for different purposes into an energy or land use equivalent (Giampietro and Mayumi, 2004, Giampietro, 2006; Giampietro et al., 2006a). By highlighting the impossibility of defining in substantive terms (i.e. uncontested when used in different contexts and within nonequivalent narratives) the accounting of the overall energy flows, such critiques defend the need for multi-dimensional and multi-scale analysis of energy and land use (among other issues) for sustainability. They propose to use tools expressively designed to

[4] Emergy is the available energy of single kind (solar energy) previously used directly and indirectly to make a product (Odum, 1996).

[5] Exergy is the maximum amount of physical work that can be extracted from a given flow of energy, the available energy or low-entropic energy, the one useful for economic activities (Ayres, 1998).

confront (1) the different qualities of different energy forms, (2) the self-organizing (or autopoietic) characteristic of living systems (socioeconomic systems among them) that reproduce themselves through autocatalytic loops, (3) the need of using at least two different scales to describe emergent complex systems (Giampietro et al., 2013).

The Multi-Scale Integrated Analysis of Societal and Ecological Metabolism (MuSIASEM) is a methodology designed to analyze the feasibility and desirability of metabolic patterns of societies, precisely confronting those challenges. It characterizes at different levels and scales the interference that the metabolization of energy and material flows by human societies induces on the expected patterns of energy and material metabolism of ecosystems (Giampietro et al., 2009). The theoretical foundations of this methodological approach come from the integration between concepts coming from non-equilibrium thermodynamics applied to ecological analysis (Odum, 1983, 1996; Ulanowicz, 1986), complexity theory (Kauffman, 1993; Morowitz, 1979; Rosen, 1958) and bio-economics (Georgescu-Roegen, 1971). MuSIASEM has been at the core of one of the chapters of the thesis. Some of the insights of MuSIASEM's methodological and theoretical foundations run throughout our methodological discussion in *chapter 5*. Further details about this method are in section 1.3 and *chapter 4.*

The variety of tools described above has been applied to study the sustainability of entire nation-states as a whole, to agricultural or rural systems and to urban areas. Perhaps the discussion around the sustainability of cities through the use of the urban metabolism concept has been one of the most fertile fields where transdisciplinary views have and could keep emerging. This is a pivotal topic because as raised by Castán-Broto et al. (2012) based on Hornborg (1998) and Wallerstein (1974), "cities are world-system centers of capital accumulation, and dissipative structures (Prigogine, 1984) which have an ever increasing demand for resources from the periphery, contributing to structural inequality between the core and the periphery in the world system" (Castán-Broto et al., 2012). From this perspective urban metabolism is a key driver of rural-urban relationships as rural areas from regional and global hinterlands, are increasingly supeditated to it.

From this perspective, studying the relationship and conflicts over energy metabolism and land use changes, requires a focus on relating rural and urban metabolism both at lower regional scales (within small regions or countries) and higher global scales (between North and South). Studying ecologically unequal exchange and ecological debt means to study globalized rural-urban relationships between a urbanized Global North (cities, both in North and South, as word-system centers) and a peripheral rural Global South (which includes natural resource extraction sites or waste disposal sites (as in REDD+) in the South, but also those in the North).

Often the study of urban metabolism fails to account for the related metabolism of rural or agrarian systems, neighboring or remote. Nevertheless, urban metabolism research has increasingly being focused on studying functional urban regions (Antrop, 2000, 2004, 2005) and broader territories as urban systems (Marull, 2007; Marull et al., 2010). This approach has considered both the growing built-up land and the rural, agrarian and ecological, interstices of the land matrix.

Research on ecological distribution conflicts (EDC) originated by a growing metabolism (Martinez-Alier, 2009) is not necessarily being specifically framed within the debate about urban metabolism or about ecological urban and land use planning. However, the (un) sustainability of cities generates conflicts both in cities where urban environmental justices arise and in rural areas where the environmentalism of the poor and peasant and eco-agrarianist movements arise (Martínez-Alier, 2003). Together with regional urban metabolism research, the study of EDC can be considered as two complementary approaches to study the rural-urban metabolism at different scales. It is precisely in these two approaches were the politics, conflicts and social relations shaping energy and material flows have been more consistently studied.

The conflictive nature of urban metabolism it is of great relevance when considering conflicting views on urban and land use planning. The *chapter 4* of this thesis uncovers the electricity generation and consumption patterns associated to functional urban specialization of urban systems in Catalonia. Such a biophysical description evidences the dominance of Corbuserian functional specialization at urban and regional levels. However, other views of urban planning would promote a different profile of urban metabolism. "Organic" town and country planning developed around 1900-1930 and was inspired by Patrick Geddes (who was well-known in India and also in Catalonia) (Guha and Martinez-Alier, 1997; Martinez-Alier, 1996). A renaissance of an "organic" perspective would likely promote different patterns of electricity consumption and generation, probably close to the paradigm of distributed energy generation. Thus, understanding societal metabolism requires an accounting of social conflicts between different groups and ideologies. The next subsection is dedicated to presenting the views on societal metabolism stressing how it is shaped by political power.

The politics of metabolism and ecological distribution conflicts

The bio-physical perspective has been criticized by certain political economic, environmental sociology and human geography perspectives as failing to theorize and account for political struggles, social conflicts and socio-ecological processes that historically produce urban areas (Gandy, 2004; Huber, 2009; Swyngedouw, 2006). Such critiques have called for the need for a dialectical analysis where "dynamic processes of social and political contestation take precedence over teleological conceptions of urban form" (Gandy, 2004). This point is of much importance because it warns of the peril of bio-economics accounting to fall into technological optimism. This could depoliticize socio-ecological transformations, "naturalizing" them and make them appear as mere technological problems instead of social processes shaped by political contestation or struggle (Gandy, 2006).

Such a view on metabolism, coming from Marxist Urban Political Ecology (UPE), studies both 'the materiality of socio-ecological metabolic and circulatory processes' and how 'discursive and symbolic power [...] shapes the "nature" of the urban imaginary and urban socio-environmental politics' (Heynen, 2006: 13). The city is seen as a socionatural 'hybrid' where nature is metabolized through the mutual interaction between social and physical processes. This perspective criticizes other perspectives on social metabolism that consider cities as opposed to nature. UPE points at urban infrastructures as mediators of the processes transforming nature into city. The contemporary 'invisibility' of infrastructure networks sustaining the modern city, their 'hidden flows and their technological framing render occult the social relations and power mechanisms that are scripted in and enacted through these flows' (Kaika and Swyngedouw, 2000). By reclaiming the interplay between structure and agency, UPE highlights how, by uncovering power relationships on the creation of social metabolism, it is possible to find ways to subvert contemporary neoliberal urbanization (Castán-Broto et al., 2012).

UPE however, is one of the approaches that have attempted to focus on political power and conflicts when studying social metabolism. Growing research on Social Metabolism and Ecological Distribution Conflicts, has addressed the study of conflict in natural resource extraction in the "commodity frontiers" (Ariza-Montobbio and Lele, 2010; Avci et al., 2010; García-López and Arizpe, 2010; Orta-Martínez, 2010; Takeda and Ropke, 2010; Urkidi, 2010; Veuthey and Gerber, 2010) or waste disposal sites (D'Alisa et al., 2010; De Maria, 2010) originated because of the growing social metabolism. This strand of research sees the growing social metabolism as the main cause of Ecological Distribution Conflicts (EDC). EDC are analyzed through different methodologies and approaches. Some studies focus on understanding the nature and evolution of the conflict through qualitative and quantitative methodologies not necessarily using biophysical accounting tools. Other EDCs studies combine their study with the use of bio-physical accounting tools such as Material Flow Analysis (MFA) (Vallejo, 2010) or HANPP (Temper, 2012). Such studies show in practice the biophysical accounting (tons and joules), an essential ingredient of Political Ecology. *Chapter 2* is a study of a latent Ecological Distribution Conflict arising as a result of the growing energy demand that drives the promotion of Jatropha plantations for biodiesel in Tamil Nadu, India.

The critiques on "the bio-physical perspective" from Urban Political Ecology scholars or from Marxist agrarian political economy, are rooted in discussions an arguments between Marxian political economists and energy analysts since the nineteen century exchange between Marx, Engels, Podolinsky among others (for a review of this issue see (Martinez-Alier, 1987; Martinez-Alier, 2009, 2012). A detailed explanation of such discussions would take much longer than needed for our purpose here. Perhaps we could argue that this division between a "political" and a "biophysical" view on social metabolism has been overcame (Martinez-Alier, 2012) However, it is useful to emphasize that this discussion is much at the core of current debates around social metabolism research and has affected the development of a more fruitful interdisciplinary social metabolism research.

The epistemic rift between social and natural sciences took place despite Marx's concept of 'metabolic rift', the rupture of nutrient cycling between town and country that Liebig had signaled in 1840 (Schneider and McMichael, 2010). The 'metabolic rift' has been considered as one of the central concepts for Environmental Sociology (Foster, 1999), but as raised by Clement (2010) the lack of theorization on the impact of urbanization on the environment in Environmental Sociology has been related to the prevalence of the Human Exceptionalism Paradigm (HEP) (Catton and Dunlap, 1978) in sociology. HEP tended to focus only in the social part of human and non-human nature interactions.

It is important to consider that, while research on bio-physical accounting methods of social metabolism lacks so far an account of social conflicts and discourse analysis, the Urban Political Ecology approach can also be criticized for refusing to use the quantitative approaches of ecology. An important question here is to what extent the risk of being too much functionalist (and not considering agency) when doing only "accounting exercises" and the risk of being too focused on discourse without considering bio-physical limits cannot be overcame through an interdisciplinary integration. The role of science and technology in shaping social metabolism is of help in reflecting about this integrative task. This is the topic of the next subsection.

The role of science and technology in shaping the representation of societal metabolism

Contemporary sustainability problems of risk and environmental management, such as renewable energy implementation and the problems it intends to solve (peak oil and climate change), are related to the increasing complexity of societal metabolism. Such problems usually involve a situation where facts are uncertain, values are in dispute, stakes are high and decisions are urgent. Under these circumstances, the traditional puzzle-solving of 'normal' science, can no longer ensure the required quality of science. Traditional management of uncertainties is no longer enough and it needs to be located from the periphery of science to become the central task. In doing so, a new logic of science, a Post-Normal Science, is proposed (Funtowicz, 1990; Funtowicz and Ravetz, 1993, 1994a, 1994b) to include the values and stakes in dispute and to confront the urgency of decision through an 'extended peer community'. People other than the technically qualified researchers; indeed, all the stakeholders in an issue should participate on the 'extended peer-review community' (Funtowicz and Ravetz, 1994a). Democratizing science and expertise on one hand contributes to fairer procedures for decision-making. However, on the other hand by including multiple legitimate perspectives on the issue at hand, extended peer-review communities ensure or at least improve the quality of scientific descriptions of complex systems (Farrell, 2010; Funtowicz and Ravetz, 1994a; Funtowicz, 1990). Thus, a Post-Normal science approach, overcoming reductionism, highlights the impossibility of defining in substantive terms a unique truth or a unique common good, due to epistemological limits in approaching complex systems (Cilliers, 2005; Funtowicz and Ravetz, 1994a). The observer influences the system she/he is observing and, not being able to separate from it, she/he is only capable of having a non-equivalent description. Such a description depends on her/his position on the observed system and the focal parts of the reality and the system of representation that chooses to approach it from (Rosen, 2000).

Thus, acknowledging the limits we face in our understanding of complex systems, we should embrace a position, which recognizes that our *choice* of a framework of representation is contextual and contingent. As complex systems thinking (both in natural and social sciences) and a deconstruction perspective share, normative, ethical and political positions shape representations of reality, which in itself transform and are influenced by such a reality (Cilliers, 2005).

Depending on what problems are given relevance and under which perspectives they are seen (and which scales are considered), decisions on energy policies would be different. Scientific representations, thus, influence how policy problems are framed, defined and 'solved' and therefore, the way in which flows of energy are being metabolized. In this thesis, we consider of great relevance the role science and technology play on shaping societal metabolism. This is of particular importance in *chapters 2* and *3*. Failing to include all values at stake and giving predominance to 'hard' facts can have important policy implications both in the quality of decisions taken and the sustainability of such decisions. The tendency of 'normal' science to present itself as value neutral and therefore only concerned with 'objective' facts can be considered as an expression of the 'one-dimensional thinking' of technology as ideology (Marcuse, 2007[1964]). 'One-dimensional thinking' is a mode of thinking which erases the possibility of critical dialectical thought by subsuming the question of “what should be” under the question of “what is”. "What is" is the 'actual dimension' of pre-existing norms and structures, while "what should be" is the 'potential dimension' of possibilities that transcend current society's organization. The erosion of dialectical thought can be observed through the emergence of "*one-dimensional thought and behavior* in which ideas, aspirations, and objectives that, by their content, transcend the established universe of discourse and action are either repelled or reduced to terms of this universe. They are redefined by the rationality of the given system and of its quantitative extension (Marcuse, 2007[1964]: 14). In *chapter 3* we use the concept of 'one-dimensional thinking' together with insights from (Hajer, 1995) and build analytical categories to understand the evolution of planning phases on wind farm siting in Catalonia. 'One-dimensional thinking' can be considered as a manifestation of the contemporary quality problems science is facing (Farrell, 2008, 2011a, 2011b) and that a Post-Normal Science approach attempts to address. Considering and acknowledging the 'post-normal' conditions influencing relationships between science and politics, it is a good starting point for building transdisciplinary perspectives on societal metabolism.

Areas for transdisciplinary synergies: beyond distribution

Martinez-Alier (2009b) provides a good entry point to discussions about the transdisciplinarity of research on societal metabolism:

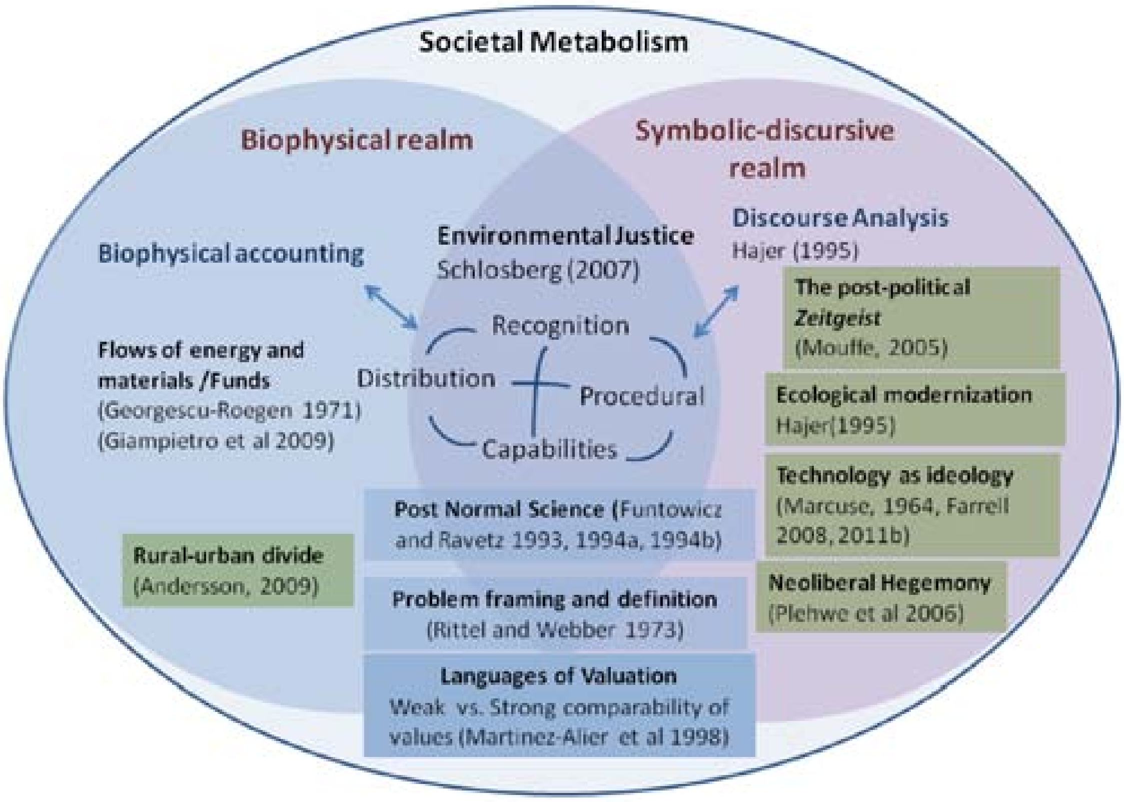
> *There is a common ground between social history, economic history and environmental history, between ecological economics and political ecology, between sustainability science and environmental sociology. It lies in the three tier relation between the increasing social metabolism of human economies pushed by population and economic growth, the resulting ecological distribution conflicts among human groups, and then the different languages of valuation deployed historically and currently by such groups when they reaffirm their rights to use the environmental services and products in dispute (Martinez-Alier, 2009: 6)*.

As stated by Castán-Broto et al. (2012) there is a promising field of inquiry about the integration between the bio-physical, material and symbolic-discursive dimensions of social metabolism. Bio-economics or ecological economics accounting tools provide an understanding of the bio-physical base of socio-economic processes. Institutional and discourse analysis can help to understand how the imposition of some language of valuation over others and the evolution and structure of ecological distribution conflicts is related to conflicting meanings and representations that different actors have about the socio-metabolic process.

A growing research field on just sustainabilities (Agyeman et al., 2003) relating environmental justice and sustainable development has emerged during the last decades, as a result of the activities of critical NGOs, academics and local community organizations world-wide (Agyeman et al., 2002). Environmental Justice arose first as a movement in the United States (UCCCRJ, 1987) and later became more structured into academic discourse (Bullard, 1990; Schlosberg, 2007).

Schlosberg (2007) following Young (1990) and Fraser (1997) proposes to extend the conception of justice beyond distribution, including the procedural, recognition and capabilities dimensions in Environmental Justice. The procedural dimension considers how multiple legitimate perspectives are given (or not) voice in the procedures followed in decision-making. The recognition dimension points about how distributive injustice comes out of social structures, cultural beliefs and institutional contexts that lack recognition of group difference (Young, 1990). Capabilities are about person's opportunities to do and to be what they choose in the context of a given society (Nussbaum and Sen, 1992; Schlosberg, 2007; Sen, 1999). A multi-dimensional view on justice provides a common ground to develop a transdisciplinary view on social metabolism for just sustainability. Bio-economics' tools can help to reveal distributive (in) justice. The analysis of conflicts over the use of languages of valuation and discourse hegemony can be useful for understanding the procedural, recognition and capabilities dimensions. Revealing the imposition of certain representations of reality would be useful to see how it influences the distribution and the organization of infrastructures and production processes that drive metabolic flows. Figure 2, provides a summary scheme of the theoretical framework I have presented here.

Figure 2 A framework for transdisciplinary synergies around societal metabolism. **Source:** own elaboration. Blue boxes are elements central in the narratives which influence actions transforming metabolism. Those actions and the discourse are influenced by elements in green boxes. Within each element present in this figure, I have quoted the authors using the particular approach I have adopted.



As would be reported in the next subsection devoted to the research design this thesis attempts to contribute on the integration of the bio-physical and symbolic-discursive dimensions of societal metabolism. Although not always explicitly using some of the concepts reported in this theoretical section, the three case study chapters approach the distributive, procedural and recognition dimensions of environmental justice. Both discourse analysis (*chapters 2 and 3*) and quantitative assessments of the distribution of energy consumption or/and generation (*chapter 4*) or its consequences (*chapter 2*) are combined. In the concluding chapter, we will return to this issue to gather and discuss the main findings. We will reflect on how deconstructing distinct problem framings can help to understand how struggling actors in ecological distribution conflicts conceive metabolism differently. Competing views on the purpose and function of energy flows have an impact on the final patterns and distribution of energy flows and their socio-ecological impacts.

1.3 Research design and strategy

This section presents the research design followed to approach the aims and research questions. Explanations are given of how and why we followed a case study research strategy as well as why we selected the concrete case studies. When presenting the case studies we explain their relationship with the challenges of renewable energy implementation presented above. In addition, we locate each of the case studies within the different perspectives of societal metabolism, the theoretical framework.

Overarching aims and research questions

The broader aim of this research is to contribute to an interdisciplinary understanding of current conflicts and trade-offs in the implementation of renewable energy with a special focus on the energy and land use relationships. Aiming to be consistent with the framing of the problem at stake and the theoretical approach presented above, we inquire about the multi-dimensional consequences of currently implemented or proposed policies on renewable energy. Thus, the broader research questions are the following:

- Which conflicts and trade-offs in energy and land use relationships is renewable implementation generating? How? Why?
- How such conflicts and trade-offs are being negotiated, managed or disputed? Why?
- Are these conflicts, trade-offs and the way they are faced, the result of a prevailing large-scale mode of implementation?
- To what extent the implementation of renewable energies challenges or reinforces the rural-urban dichotomy, ecological modernization and neoliberalism? How? Why?
- What societal transformations would a renewable energy transition require?
- How can the discursive-symbolic and the bio-physical perspectives on social metabolism be integrated when studying renewable energy policies?

In order to address such questions we focus our inquiry on certain dimensions and perspectives through a case study research strategy. Next, we elucidate the reason behind this strategy, the case study selection and in what particular dimension the cases help to fulfill the research questions and aims.

Case study research strategy: rationale and selection criteria

Issue-driven or problem-driven interdisciplinarity (Robinson, 2008) has been the inspiring approach of this thesis. Particularly, in the first steps of this research, I was guided by an inductive approach. Confronting case studies and using and combining methodologies, I searched explanations to the overall socio-environmental problem I was studying.

The case study research strategy is appropriate when dealing with complex socio-environmental problems like renewable energy implementation. Case studies are adequate to investigate a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not evident. They are useful when "how" or "why" questions are being posed and when the investigator has little or no control over events. Thus, by using case studies the researcher relies on a converging triangulation of multiple sources of evidence which help her/him to find out emergent results which are more than the sum of all data collected. This process is particularly useful for the main goal of a case study research which is to expand and generalize theories, instead of looking for statistical generalization (Yin, 2003). A case study research strategy responds better to the interpretative endeavor of interdisciplinarity as opposed to a positivist approach of mainstream neo-classical economics or compartmentalized natural sciences (LeLe and Norgaard, 2005).

In this thesis we selected three case studies: (*chapter 2)* the implementation of biodiesel plantations in Tamil Nadu, India, (*chapter 3)* the wind farm siting in Catalonia, Spain and (*chapter 4*) the potentials and constraints for renewable distributed electricity generation in Catalonia, Spain. Instead of adopting a comparative approach to similar cases in search of distinctive features, we adopted a strategy based on selecting cases that would be theoretically representative in illustrating relevant points of the general research questions.

The selection and purpose of the three case studies, and their relationship with the overarching research aims, respond to four different logics: (a) the relevance of the technology implemented, also in relation to different world regions. (b) The integration between the bio-physical and the discursive part of societal metabolism. (c) The particular dimension of societal metabolism literature or the feature of the topic at hand addressed. (d) The side of the energy system analyzed the demand or the supply side.

Following the first logic, in *chapters 2* and *3* we evaluate the implementation of two of the most advanced renewable technologies, which have been gaining momentum in the last decade. In *chapter 2*, we approach the broader discussion on biofuels for transport, by concretely focusing on biodiesel plantations in Tamil Nadu, India. In *chapter 3* we address wind energy implementation as one of the most mature renewable technologies for generating electricity, by concretely studying wind farm siting in Catalonia, Spain. In *chapter 4* we further explore the discussion on renewable electricity generation by evaluating existing potential and constraints for implementing distributed energy generation in Catalonia, Spain.

When selecting biofuels, wind energy and distributed energy generation we study them in those world regions where there is more experience of it or where they are booming, either as discursive discussions or in actual implementation. Large-scale biofuel plantations are targeted to highly productive tropical regions of the Global South with the aim of exporting the biodiesel either to regional conurbations or to world-systems centers of the Global North. Studying biofuel plantations in an emergent economy such as India, which is currently undergoing an accelerated process of industrialization, is thus appropriate for the broader aims and research questions of the thesis. Although China and India have taken more and more importance in global wind markets, becoming respectively, the first and the sixth world power in wind installed capacity in 2012 (GWEC, 2013), industrial wind energy was born in Denmark (Szarka, 2007). Europe, especially Germany and Spain, the third and fourth world powers in wind energy, but also Denmark, has been where much of the initial development of wind energy took place. Thus, wind farm siting in Catalonia is a suitable case study to understand causes and consequences of the conflictive implementation of wind energy. Although wind energy is starting to generate conflicts in the Global South (Brown, 2011; Brown, 2012; Oceransky, 2010; Pasqualetti, 2011), the longer period of wind farm siting planning in a European case study was more appropriate for the analysis of the evolution of discourses over time which was conducted in *chapter 3*. *Chapter 4* focuses on renewable distributed electricity generation in Catalonia as a representative industrialized country almost entirely dependent on imported fossil energy. In the advent of a drastic relocalization of production and consumption because of decreasing EROI and exhaustion of fossil fuels, industrialized nations would face an even greater difficulty in reorganizing energy supply. Analysing the implementation of renewable energy in the contrasting circumstances of an industrialized society and an emerging economy under the process of industrialization enriches the scope of the research.

Following the second logic (the integration of the biophysical and the discursive), in both case studies in Tamil Nadu and Catalonia, the research concentrates on the societal metabolism that drives the promotion of agrofuels, wind energy or distributed generation policies and also on the arguments deployed. In *chapter 2* we deconstruct the premises of the dominant “win-win-win” discourse of Jatropha as a ‘pro-poor’, ‘pro-wasteland regeneration’ and “pro- energy security” crop (section 2.4). Drawing on empirical results from a field study of Jatropha plantations in Tamil Nadu, we assess the plausibility of this “win-win-win” discourse by evaluating the agronomic and economic viability (section 2.6) and livelihood impacts of Jatropha plantations on private farms (section 2.7). We consider as well, in our discussion (section 2.8), open and latent conflicts around water and land uses and the marginalization of small farmers resulting from the politics of Jatropha promotion. The two chapters dedicated to Catalonia are complementary approaches to the metabolism of electricity. In *Chapter 3* I analyze the struggle for the hegemonic problem definition that takes place in the conflicting interaction between discourse coalitions and the overall wind farm siting discourse of Catalonia. *Chapter 4*, although standing alone in its reasoning, evaluates the potential of distributed energy generation in light of current constraints. Such an analysis addresses the material and biophysical implications of important controversies found in the discourse analysis of *Chapter 3*.

The third logic refers to the approaches of societal metabolism covered and the concrete dimension of renewable implementation analyzed. The analysis of the viability, livelihood impacts and latent conflicts generated by Jatropha plantations in *chapter 2* focuses on the social, economic and ecological consequences of the growing energy metabolism of India. Thus, this chapter grasps how energy demand in urban regions can affect the metabolism of rural areas in generating livelihood trade-offs and conflicts. This analysis thus inquires about the consequences of "changing the fuel but not the systems powered by it". In *chapter 2*, we also address the underlying "weak sustainability" assumptions of "win-win" discourses very common under the ecological modernization paradigm. Analyzing livelihood trade-offs resulting from monoculture plantations reveals the consequences of substituting monocultures aimed at increasing revenues for multi-functional agro-ecosystems. In *chapter 3* we continue the analysis of features of ecological modernization and address the politics shaping metabolic configurations of networked energy infrastructures. We analyze the evolution of the renewable energy policy discourses and their treatment of uneven development, biodiversity conservation, climate change and energy sector development. The risks of reproducing the 'one-dimensional thinking' of technology as ideology in wind farm siting policies is analyzed. We assess the extent to which fact-based arguments of technological optimism are given preponderance over value-based of structural transformations. Finally, in *Chapter 4*, by formally adopting the approach of Multi-Scale Analysis of Societal and Ecological Metabolism (MuSIASEM) we evaluate the potential and constraints of distributed energy generation. Such an approach could be further developed to integrate different approaches to societal metabolism as it will be addressed in the discussion and conclusions of this thesis. Regarding the concrete features of the energy and land use dilemmas associated to a transition to renewable energies, *chapter 4* approaches the rural-urban dichotomy as one of the categories which is at stake facing the current multi-dimensional crisis of industrial society.

The fourth and last logic (supply or demand side) responds to a research strategy that seeks to enrich an integral view to the implementation of renewable energies. *Chapters 2* and *3* cover technological solutions to the supply of renewable energy: biodiesel plantations and wind farms. *Chapter 4* relates the spatial distribution of socio-demographic and land use characteristics to current electricity generation and consumption patterns with the aim to identify structural changes required for distributed generation of renewable energy.

Techniques and methods of data collection

Depending on the focal questions or aims covered in each case study, we combined different techniques or methods of data collection, both qualitative and quantitative. Except *chapter 4, which* relies on secondary sources from census and official surveys conducted by the regional government of Catalonia, *chapters 2* and *3* combine techniques for primary data collection.

Interviews, participant observation and document collection were the main qualitative sources used to collect the required data for conducting discourse analysis in the two cases. In both, Tamil Nadu and Catalonia, we conducted informal and semi-structured interviews. The degree of *structure* and *flexibility* are among the most relevant features distinguishing between different types of interviews (Guillham, 2000). We chose first to use informal interviews in search of exploratory broad understanding either on the context or on the current status of wind farm siting or Jatropha plantations. Using just a few key open questions we were flexible to the interviewee responses without expecting a concrete set of possible answers.

Once the context and topic was more familiar to me thanks to informal interviews and participant information, we conducted semi-structured interviews. We followed a semi-structured questionnaire of topics to be covered and asked both closed and open questions. However, the interview was still very open in its style, giving space to the interviewee to relax in the explanations. This was also useful for me to let emerge new unexpected topics and relations between them.

The aim of the interviews was similar in both cases, although the time-span covered was very different. In both case studies my interest was to identify different discourses arising from the interviewees' perceptions and evaluation of the policy from its inception to the present situation and their expectations of the future. While in Jatropha plantations in Tamil Nadu, the emphasis was more on the present status, in the wind farm siting of Catalonia the interest was on understanding the history of the policy from the 1980s to the present circumstances. The selection of interviewees was based on the snowball sampling methodology (Biernacki and Waldorf, 1981; Browne, 2005) which yields a study sample through referrals made among people who know each other or recommend each other as knowledgeable about the topic of investigation.

The number of interviews was decided following the principle of saturation which consists of including actors and groups which enrich the category or topic investigated until no additional data is found whereby to develop properties or characteristics of the theme. When similar instances appear over and over again the researcher can be empirically confident that the category is saturated (Glaser and Strauss, 2012). Inspired by such a principle, we stopped interviewing new people when we felt we had a nuanced picture of the perspectives relevant for the research questions we were addressing. When including actors with diverse perspectives we considered the different scales and arenas where they were participating following an approach inspired by the public policy analysis framework of Dente et al (1998).

The qualitative data from interviews was triangulated with the review of documents collected and participant observation throughout the research. Long periods of field work (iterative rounds of weeks or months during half a year in *chapter 2* and an entire year in *chapter 3*) were essential for the completion of data collection. Concrete details of each case, in terms of questionnaire structure and content are given in *chapters 2* and *3* and in the annexes II and III.

Regarding quantitative research methods, the survey was the ideal technique to conduct the assessment of Jatropha plantations agro-economic viability and livelihood trade-offs. Details about the questionnaire and the sample are given in *chapter 2* and in the annex I.

The results of qualitative and quantitative methodologies were integrated in the analytical stages of the research. Interviews, participant observation and the reviewed documents were useful to interpret the results of surveys and other quantitative analyses of *chapter 2* and *4*. Reciprocally, quantitative analyses were useful to support and confirm results obtained through qualitative research. In the following section we describe through which methodologies we approached for this analytical integration of the collected data.

Analytical tools

The main analytical tools used throughout the thesis can be grouped into three wide groups: (a) discourse analysis; (b) Multi-Scale Integrated Analysis of Societal and Ecological Metabolism (MuSIASEM); (c) Database management, methods for statistical analysis and Geographic Information System (GIS) tools.

Discourse analysis

There are certainly many approaches to discourse analysis (DA). DA is a method used to understand how language is used in talking and writing, or other forms of discourse, which accomplishes representations or versions of reality (Bryman, 2008). The approach we used in this thesis is a particular form of Critical Discourse Analysis (CDA) (Weiss and Wodak 2003). CDA views language as a form of social practice and focuses on the ways social and political domination are reproduced in text and talk. CDA takes a particular interest in the ways in which language mediates ideology in a variety of social institutions. 'Describing discourse as social practice implies a dialectical relationship between a particular discursive event and the situation(s), institution(s) and social structure(s) which frame it: the discursive event is shaped by them, but it also shapes them. That is, discourse is socially constitutive as well as socially conditioned [...]. It is constitutive both in the sense that it helps to sustain and reproduce the social status quo, and in the sense that it contributes to transforming it' (Fairclough and Wodak, 1997: 258). Discourse thus, has major ideological effects, reproducing unequal power relations between social groups through the ways in which they represent things and position people (Fairclough and Wodak, 1997).

We used CDA in *chapter 2*, together with my coauthors, when analyzing how the government of India has managed to introduce the concept of biodiesel and expand the discourse in favor of cultivating agro-fuels. First, we looked at particular meanings of the concept of "wasteland" according to different disciplines or dimensions (economic-fiscal, social or agro-ecological). This allowed us to inquire about the way ‘wasteland’ rehabilitation was discursively used to build legitimacy around Jatropha, irrespective of the use, cover and ownership of the land where it was finally planted. Second, we looked at how the particular characteristics of the new crop were deployed as being particularly favorable to the rural poor. Finally we explored the discursive strategies, such as the use of malleable and fuzzy concepts, common to both the "pro-wasteland regeneration" and "pro-poor" discourses to promote and convince farmers and social institutions to plant and promote Jatropha.

In *chapter 3*¸ we used, together with my coauthor Katharine N. Farrell, a particular approach to CDA, inspired by (Hajer, 1995) as a way to analyze the policy process. Hajer's work on the politics of environmental discourse is in turn located within a wider tradition of discourse analysis mainly the approaches developed by Michel Foucault and the social psychologists Michael Billig and Rom Harré. These approaches share in common that both hold a relational ontology, focus on social practices and use a constitutive view of language (Hajer, 1995). Thus, the combination of both perspectives, as used by Hajer, focus on understanding argumentation in social interaction, more than describing *a priori* individual actor positioning (of an individualist ontology). The aim of this kind of discourse analysis is:

> *“…to understand why a particular understanding of the environmental problem at some point gains dominance and is seen as authoritative, while other understandings are discredited… taken on to analyzing the ways in which certain problems are represented, differences are played out, and social [discourse] coalitions on specific meanings somehow emerge” (Hajer, 1995: 44).*

As the detail given in *chapter 3* helps to understand, we derived a set of four *types of argumentation* with help of both Hajer's work and (Marcuse, 2007[1964]) theory. Such four analytical categories helped to classify interventions made by discourse coalitions and how their interaction gave rise to a dominant policy discourse. In a Hajer's inspired discourse analysis, discourse coalitions are of fundamental importance. Discourse-coalitions are defined as the ensemble of (1) a set of story-lines; (2) the actors who utter these story-lines; and (3) the practices in which this discursive activity is based (Hajer, 1995:65). Story-lines are “narratives on social reality through which elements from many different domains are combined and that provide actors with a set of symbolic references that suggest a common understanding”. “Story-lines are essential political devices that allow the overcoming of fragmentation and the achievement of discursive closure” (Hajer, 1995: 62). They are "the discursive cement that keeps a discourse coalition together” (Hajer, 1995: 65). By relating the evolution of the *types of argumentation* used by the story-lines of different discourse coalitions to the hegemonic problem definition of planning phases, in *chapter 3* we analyzed how arguments based on "facts" were progressively seen as more authoritative than "value-based" propositions.

Finally, it is worth noting that qualitative content analysis (QCA) was used in both *chapters 2* and *3* as a first step to conduct discourse analysis. QCA is about organizing the substantive content of qualitative data, either from interviews, field notes or documents (Guillham, 2000). By extracting the content that is of substance, QCA searches out the underlying themes in the materials analyzed (Bryman, 2008). After identifying those key, substantive points they are put into categories (Guillham, 2000). When applying this method to the two cases at hand, we looked for relevant topics highlighted by the policy actors and how did they perceived the relations between them. Concrete details are given in each chapter or in the case of wind energy (*Chapter 3)* annexes IV to VII give details about how content and discourse analysis were conducted.

Multi-Scale Integrated Analysis of Societal and Ecological Metabolism (MuSIASEM)

Chapter 4 can be considered as pertaining to the overall attempt at developing meaningful tools for quantitative analysis of societal metabolism. This research is an application of a pre-established methodology, MuSIASEM, in an innovative way, to the spatial analysis of energy flows within urban regions. Here we explain why we choose to use Multi-Scale Integrated Analysis of Societal and Ecological Metabolism (MuSIASEM) as a particular approach to societal metabolism among other possible methodologies. The details of the particular application are given in *chapter 4*. Here we explain broadly what this method does (and does not) and why it was useful for us in *chapter 4*.

There are three theoretical concepts that are fundamental in MuSIASEM.

First, MuSIASEM deals with the representation of metabolism by using the Flow-Fund scheme of (Georgescu-Roegen, 1971). The strength of the Flow-Fund scheme is that it acknowledges the arbitrariness of system boundaries in a representation of an evolving system. It defines different categories of analysis, flows or funds, regarding the duration of the economic process represented. Flows are elements qualitatively changed over the duration of the representation. Input flows, such as raw materials and primary energy enter but do not exit the process because they exit as output flows such as new products or waste. Funds are elements remaining "the same" over the duration of the representation. The most common funds are human time, manufactured capital and Ricardian land. Important characteristics of funds are: (i) they can only transform flows at specific rate and (ii) they require a periodic renovation through an overhead for their own maintenance and reproduction. Funds transform input flows into output flows during the time of the representation, defining the conversion process. Thus, they represent "what the system is" while the flows represent "what the system does", what the system "consumes" or "generates" or "absorbs from" or "delivers to" the environment (Giampietro, 2003; Giampietro and Mayumi, 2000; Giampietro et al., 2009).

Second, MuSIASEM, building on the Flow/Fund scheme, develops multi-level matrixes through which can assess the congruence over values taken by intensive (flow/fund or fund/fund) and extensive variables (flows; funds) across contiguous levels. Multi-level matrixes distinguish between different scales at different levels. For example the fund human activity (HA) at the level of whole society (*n*) it is divided at level *n-1* between the market (paid work) sector and the household sector and at the level *n-2* between household types and economic sectors. These matrixes make possible to assess the constraints that the distribution of flows and funds to different compartments pose at the pace of metabolism at a lower level (*n-1*). For example, the fraction of the total energy (flow), total human activity (fund) and total available land (fund) (level *n*) allocated to household sector or market (paid work) sector (level *n-1*) poses a constraint on the energy flows dissipated per hour of activity or per hectare of land use at those lower levels. This provides a *mosaic* or *Sudoku effect* verifying the congruence between different levels and dimensions using an expected set of relations over the characteristics of the part (the paid work sector or the household sector) and the whole (the society). This nested hierarchy makes that any change in any variable (or parameter) belonging to a particular level can/must be associated with (is affecting/is affected by) changes in other variables (or parameters) belonging to other levels (Giampietro et al., 2009).

Third, MuSIASEM addresses the impredicative loops characteristic of complex living systems. Impredicativity is the characteristic of an element, which participates in its own definition. In complex systems evolving or "becoming" simultaneously at different levels and scales, the part and the whole participate mutually in their own definitions. Living systems need to sustain themselves through autocatalytic loops. As an example, applied to the society, the energy sector needs to consume energy and employ human time and land to be able to generate available energy to the rest of a society, whose demand should be congruent with the rate of flow that the energy sector is capable of providing. MuSIASEM addresses this challenge by developing "multi-purpose grammars" which are semantically open to changes of narratives (perceptions). These grammars are meta-systems of accounting with flexible relationships between *semantic categories* (relevant attributes for sustainability, such as energy consumption), *formal categories* (names or indicators) generated by production rules applied to data (*tokens)*. This flexibility allows generating different indicators from the same dataset depending on what is relevant for the purpose of the analysis (Giampietro et al., 2013). Thus, the analyst can assess the desirability and feasibility of metabolic patterns by doing an Impredicative Loop Analysis of the congruence of the metabolic patterns of different levels. This means to assess to what extent some part of the society (e.g. the energy sector) is able to provide or resist (depending where you look from) the demand posited by the whole.

The use of the MuSIASEM framework in *chapter 4* provided the possibility to relate electricity consumption and generation (flows) to the land and time use (funds) in different municipalities in Catalonia. Moreover, by operating through different scales it allowed the uncovering of how similar absolute electricity consumption or similar density of it at the level of municipality was explained by different sectors and different rates of consumption per hour of activity. The intensive flow/fund variables obtained by relating flows (in this case electricity) to funds (in this case land and time use) were also of help to allow me to compare among municipalities with different population size and land uses. Details about the application of the MuSIASEM methodology and its combination with statistical analysis and GIS tools are in the next section, *chapter 4*, and the methodological annex.

There were other important reasons for selecting MuSIASEM as appropriate research method. It was useful to confront my methodological question of integration between discourse analysis and quantitative accounting of societal metabolism. This method was useful to provide an alternative representation to the dominant discourse in *chapter 3,* which considered electricity as a matter of supply more than a matter of matching supply to end uses (demand). As a semantically open "multi-purpose grammar", MuSIASEM was also an appropriate framework to reflect on how multiple legitimate (but conflicting) perspectives could represent differently the same reality. This could be precisely the root of struggles towards an energy system based on renewable energy.

Database management, statistical analysis and Geographic Information Systems (GIS) tools

Primary data collected through surveys and secondary data, such as census and government surveys, required a systematic treatment for meaningful analysis. Databases, statistical analysis and GIS tools were used for this purpose.

First, databases were created with the combined help of software such as Excel and Access. The use of a relational database management system, such as Access, was especially needed in *chapter 4* where we created a relational database of multiple dimensions at the scale of municipality, storing information for the 946 municipalities of Catalonia. A relational database stores data in related tables. Through a main table, which contains the unique and identificative information of the main unit of analysis, (a municipality in *chapter 4* or a household in *chapter 2*), relates all the rest of information to such a table through a primary key. We used a relational database to store and relate all the data collected. It allowed us to address our specific research questions in each case study.

Second, we used methods for statistical analysis to evaluate significant differences on the performance or livelihood impacts of Jatropha plantations in *chapter 2*, or to generate a typology of municipalities and characterize the association between their metabolic profiles and socio-demographic characteristics in *chapter 4*. Statistical methods included tests to assess parametric or non-parametric distribution, such as Shapiro-Wilk test or techniques to compare means or medians between two groups, (either parametric (F-tests) or non-parametric tests (Mann-Whitney U-test)) or more than two groups (Kruskall-Wallis one-way analysis of variance by ranks test). Also Logistic regression (or logit regression) was used to measure the relationship between categorical dependent variables (such as farmers' affection or not by specific livelihood trade-offs) with other variables (in these case also categorical) independent variables (such as caste or landholding). For deriving municipality typologies in *chapter 4* we used multivariate statistical analysis methods. Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used to group municipalities according to significant patterns of similarities. Further details about the clustering procedure are given in *chapter 4* and can also be found in other applications (Köbrich et al., 2003; Mingorría, 2010; Siciliano, 2012; Usai et al., 2006).

Third, the use of cartographic information was essential both for fieldwork and qualitative analysis of the case studies at hand. The elaboration of maps and the use of quantitative GIS tools were especially needed in the study of wind energy and distributed renewable electricity generation in Catalonia. In *chapter 3,* we used GIS more from a qualitative perspective through which we represented together different layers from multiple dimensions, see Figure VI.1 and Figure VI.2 in Annex VI of *chapter 3*. In *chapter 4* we calculated indicators and variables using quantitative GIS tools. Distances of population centers to other centers of more than 5000 inhabitants were calculated to obtain a useful "rural characteristics" indicator. The land use map of la Generalitat (GENCAT, 2002a) and the municipalities map were combined through an overlay analysis to calculate the area and obtain the polygons of each land use belonging to each municipality. It helped to calculate relative percentages of land use in each municipality and both the density of population in respect to the actually urbanized area of the municipality or in respect of the total available land. That was also useful for later calculating and representing variables of electricity consumption using the area and polygon corresponding to the land use dedicated to each socio-economic sector. When representing variables with a heavy-tailed distribution, we used a particular methodology for deriving intervals of representation, as explained by (Jiang, 2012). Maps are presented in the coordinate system UTM 31 Northern Hemisphere, Datum ETRS 89, except situation maps that are presented in Latitude-Longitude coordinate system and Datum WGS 84.

1.4 A roadmap to the thesis contents

This introductory chapter presented the topics addressed and located the research within a theoretical framework. It described the research design and explained the rationale of the case studies used to approach the research questions. The following three chapters cover the case study results of the thesis, *Chapter 5* discusses and *Chapter 6* synthesizes their contribution to knowledge in light of the overall contextualization done in this introduction.

The content of the next three chapters corresponds to a reordered collection of three articles published in international peer-reviewed journals and one recently submitted. *Chapter 2* gathers two articles dealing with Jatropha plantations in Tamil Nadu, India. An article published in *Ecological Economics* dealt with the results of the agro-economic assessment of plantations and the latent conflict originated both by the agro-economic failure and the unequal distribution of the impact of these plantations on farmers' livelihood. An article published in *The Journal of Peasant Studies*, dealt with the explanatory causes and consequences of Jatropha failure by both analysing the "win-win-win" discourse and the politics followed throughout plantations implementation. In *chapter 2* we collect both papers together by removing and reshaping the contextualizing and introductory parts of both articles to reduce repetition and avoid excessive length.

Chapter 3 reproduces integrally the content of a paper published in the journal *Sustainability*. *Chapter 3* is a standalone case study, that as explained above covers the discursive aspects shaping wind farm siting in Catalonia. This case is of fundamental importance for understanding the political disputes that would likely shape the process of implementing a distributed energy generation system in Catalonia, the contents of *chapter 4*.

Chapter 4 reproduces integrally an article submitted to the journal *Environment, Development and Sustainability*. This chapter covers the energy demand side of the research design rationale and situates the research on debating future actions instead of currently or past implemented policies, as done in *chapters 2 and 3*. *Chapter 4*, actually, by evaluating potentials and constraints for implementing distributed energy generation, links land use and energy planning discussions, outlined in the discourses analyzed in the preceding *chapter 3*. Such an interrelation is covered in *Chapter 5*. *Chapter 5* summarizes and discusses the concrete and overall results of the thesis. It relates the thesis findings to their relevance for current and future challenges in renewables implementation and to the research agenda for a transdisciplinary view of societal metabolism. *Chapter 6* summarizes the findings and their discussions, and provides the conclusions of the thesis.

2. A Political Ecology of “Waste lands” for Jatropha biodiesel plantations in Tamil Nadu, India: viability, livelihood trade-offs and latent conflict[6]

Abstract

Researchers, policy makers and civil society organizations have been discussing the potential of biofuels as partial substitutes for fossil fuels and thereby as a simultaneous solution for climate change, energy security and rural poverty. Research has highlighted the ambiguity of these claims across various dimensions and scales, focusing on ethanol-producing or oilseed crops in agricultural lands or Jatropha-type crops on common lands. *Jatropha cruces* is promoted internationally for its presumed agronomic viability in marginal lands, economic returns for small farmers, and lack of competition with food crops. We use an interdisciplinary framework based on political ecology approach to analyze both the discourse promoting Jatropha cultivation and its material consequences in Tamil Nadu, India. First, we deconstruct the shaky premises of the dominant “win-win-win” discourse of Jatropha as a ‘pro-poor’, ‘pro-wasteland regeneration’ and “pro- energy security” crop. Second, drawing from empirical results from a study of Jatropha plantations in Tamil Nadu, we assess the success of this “win-win-win” discourse by evaluating the agronomic and economic viability and livelihood impacts of Jatropha plantations on private farms. We found that Jatropha yields are much lower than expected and its cultivation is currently unviable, and even its potential viability is strongly determined by water access. On the whole, the crop cultivation favors resource-rich farmers, while possibly reinforcing existing processes of marginalization of small and marginal farmers. Jatropha cultivation therefore not only fails to alleviate poverty, but its aggressive and misguided promotion will generate conflict between the state and the farmers, between different socio-economic classes and within households. The water demands of the crop can potentially exacerbate the conflicts and competition over water access in Tamil Nadu villages.

Keywords: *Biofuel, Biodiesel, Rural livelihoods, Jatropha cruces, Latent resource conflicts, political ecology, marginalization, India.*

2.1 Introduction

The demand of energy for maintaining the societal metabolism of developed and emerging economies like India[7] has lead many governments to promote agrofuels[8]. The Indian National

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[6] The content of this chapter was published in the form of the following peer-reviewed articles in indexed Journals:

Ariza-Montobbio P. and Lele S., 2010. Jatropha plantations for biodiesel in Tamil Nadu, India: Viability, livelihood trade-offs, and latent conflict. Ecological Economics, 70:189-195.
http://dx.doi.org/10.1016/j.ecolecon.2010.05.011

Ariza-Montobbio, Pere , Lele, Sharachchandra , Kallis, Giorgos and Martinez-Alier, Joan (2010) 'The political ecology of Jatropha plantations for biodiesel in Tamil Nadu, India', Journal of Peasant Studies, 37: 4, 875 — 897
http://dx.doi.org/10.1080/03066150.2010.512462

This chapter integrates the two articles by restructuring the content of both papers, removing and reshaping the contextualizing and introductory parts of both articles to reduce repetition and avoid excessive lenght. That is why the title of the article is the combination of both titles.

[7] India’s fast growing economy is increasing demand for petroleum, which has been growing at the average rate of 5 % per year since 1991 (IEA, 2007). India meets 70% of its oil needs through imports, and 50% of the oil consumption is in the transport sector (Government of India, 2006).

Biofuel Policy (2009) aims at blending 20% bioethanol and biodiesel with gasoline and diesel respectively by 2017 (Government of India, 2009a). Although agrofuels are currently contributing less than 2% of transportation fuels globally, their production is growing rapidly, having tripled from 2000 to 2007 (Howarth et al., 2009). Understanding the socioeconomic and environmental consequences of biofuel production is therefore critically important.

A growing number of studies have been questioning the ecological-economic sustainability of biofuel energy (Pimentel et al., 2007; Pimentel and Patzek, 2005). Integrated assessments of large-scale biofuel production (Giampietro and Mayumi, 2009; Giampietro et al., 2006b; Giampietro et al., 1997; Russi, 2008) show that its low Energy Return on (Energy) Investment (EROI) (Hall et al., 1986; Odum, 1971) compared to fossil fuels imposes a heavy demand on land, water and labor per net GJ delivered. If biofuels are to replace fossil fuels in a major way in the current economy, the associated land use changes will be significant and will entail trade-offs across multiple dimensions (Russi, 2008). Biofuels will probably increase the Human Appropriation of Net Primary Production (HANPP) (Vitousek et al., 1986) to the detriment of the biomass available for other species (Haberl et al., 2004b). The competition for water with other crops and economic activities will also increase due to their high water footprint (DeFraiture and Berndes, 2009; Gerbens-Leenes et al., 2009a; Gerbens-Leenes et al., 2009b).The claimed positive Greenhouse Gases (GHG) emissions balance will be compromised by the "biofuel carbon debt" of converting forest or shrub ecosystems to energy crops (Fargione et al., 2008). The dramatic rise of prices for basic food staples in 2008 was arguably related in part to farmers switching from food crops to biofuels (Ewing and Msangi, 2009; Mitchell, 2008).

The above studies indicate negative consequences of biofuels globally. Nevertheless, some studies at a global scale, argue in favor of using marginal or "abandoned" crop lands to avoid competing with food crops (Fargione et al., 2008; Field et al., 2008; Tilman et al., 2009). Others argue in favor of small-scale production in the South, creating employment and income opportunities for local populations through contract farming, mainly using a new crop: *Jatropha cruces* (Clancy, 2008; ICRISAT, 2007; UNDESA, 2007). *Jatropha cruces* (hereinafter Jatropha) is claimed to be a hardy drought-tolerant shrub that reclaims the land, prevents erosion, and responds better to organic manure than chemical fertilizers (Francis et al., 2005; Openshaw, 2000).

Under the promoter perspective, these properties make this plant suitable to be cultivated both in marginal lands and in small farmers' plots producing economically reliable yields. However, information on the region-specific field performance of Jatropha is limited. Some studies from Kenya have questioned the viability of Jatropha for smallholders (Moraa et al., 2009; Tomomatsu and Swallow, 2007) but they are based on estimated projections from experimental data. Others have focused on impacts of transferring public lands to Jatropha cultivation (GRAIN, 2008; Rajagopal, 2008). But governments are also promoting its cultivation on private lands, using both state-supported and corporate-supported contract farming approaches. These interventions in regions of poverty, agrarian distress and water scarcity have the potential to spark unanticipated conflicts and aggravate the already existing latent conflicts. The implications of Jatropha cultivation in the tropics need closer examination.

[8] The EU has set a target of biofuels 10% substitution for transportation fossil fuels by 2020 and the USA has set a target of 36 billion gallons of ethanol a year by 2022.

With about 300,000 ha, India is a leader in Jatropha plantations and also its research and development (IARI, 2007). The official rationale is that the crop best fits the diverse agro-climatic conditions of the country and has a shorter gestation period than other oil-bearing trees. Jatropha is promoted both as a potential solution to the energy demand-supply deficit that the growing economy of India is facing (Government of India 2006) and as a suitable crop for marginal land reclamation and rural development (Government of India, 2003). The National Biofuel Policy launched in December 2009, building upon the National Biodiesel Mission of 2003, aims at blending bioethanol and biodiesel with gasoline and diesel, respectively, at a proportion of 20% by 2017. The biodiesel target is planned to be met through the cultivation of 13.4 millions of hectares of 'wastelands' with Jatropha (Government of India, 2003). The South Indian state of Tamil Nadu is one of the leaders in biodiesel promotion, with a goal of reaching 100,000 ha of Jatropha between 2007 and 2012 (Government of Tamil Nadu, 2007b, 2009).

This thesis chapter investigates the political, technical, and social construction of Jatropha as a solution to India's energy, agriculture, and poverty problems at the national and the Tamil Nadu state political levels, and contrasts it to the actual ecological, economic, and social failure of the crop at the farm level. We highlight the contrast or mismatch between the results in the field and the discourse behind the continued promotion of Jatropha by regional and national policy makers and researchers in India. We uncover the impact that the crop has in farmers' everyday life. Rather than being "pro-poor", "pro-wasteland regeneration" and "pro- energy security", we found that Jatropha yields are much lower than expected and its cultivation is currently unviable, and even its potential viability is strongly determined by water access. The pattern of cultivation of Jatropha is generating upward redistribution, favoring resource-rich farmers, while possibly reinforcing existing processes of marginalization of small and marginal farmers. Our analysis concludes that an aggressive and misguided promotion of Jatropha cultivation will generate conflict between the state and the farmers, between different socio-economic classes and within households. The water demands of the crop can potentially exacerbate the conflicts and competition over water access in Tamil Nadu villages.

To report our analysis here, we first explain our conceptual framework in Section 2.2 and the research design and methodologies in Section 2.3. Section 2.4 presents the Jatropha policy discourse deconstruction at the national and state levels. Section 2.5 then, presents and contextualize the concrete field case-study area and key results from the agronomic and economic assessment and the livelihood impacts are presented in sections 2.5 and 2.6. We then seek to link these 'outcomes' to latent conflicts at various levels in the region and to the broader politics of Jatropha promotion in our discussion in section 2.8. Conclusions are given in section 2.9.

2.2 A Political Ecology of Jatropha Plantations

Political ecology 'combines the concerns of ecology and a broadly defined political economy' (Blaikie and Brookfield, 1987). Nature-society relationships are examined through an analysis of social forms of access and control over resources (Watts et al., 2004) and the unavoidable conflicts in the temporal and spatial distribution of the goods and bads of socio-environmental change (Heynen et al., 2006; Martinez-Alier, 2002). Socio-environmental change comes from increased social metabolism (Heynen et al., 2006; Martinez-Alier, 2002;

Martinez-Alier, 2009), meaning larger flows of energy and materials, and is unevenly distributed, i.e. 'one person's profit is another's toxic dump', as Watts and Peet (2004, 9) put it. The consequences and the modalities of environmental change depend on the distribution of power in society, which is unevenly distributed along lines of class, race, or gender (Swyngedouw, 2004).

Political ecology traces causation of environmental degradation to broader systems rather than blaming only proximate and local forces. Causes of environmental degradation or impoverishment are searched through 'chains of explanation' at multiple scales (Blaikie and Brookfield, 1987). 'External structures', such as state institutions, global markets, 'peak oil', and the price of energy, frame the incentive structures that pressure national and local actors to act the way they do and serve to explain why for example, new policies, such as those promoting a new 'eco-friendly' crop, fail. Political ecology offers both an understanding of socio-environmental change as well as a conceptual toolkit, consisting of a number of (hypo) theses (patterns of explanation) that have emerged through accumulated empirical studies (Robbins, 2003). Two theses/insights from political ecology are relevant to our analysis here.

The first thesis concerns knowledge, values, and power. Control of knowledge and of the forms of representing reality (scientific or discursive) is an important source of power. Power is not only exerted materially through control of the means of production or the control of political institutions. It is also exerted at the realm of ideas and discourses. Powerful 'valuation languages', often the techno-economic discourses privileged by elites in power, suppress alternative forms of values, expressed often by local communities and indigenous groups in environmental conflicts (Martinez-Alier, 2002).

Political ecologists have contrasted the technocratic simplifying systems and models of ecological knowledge promoted by scientific experts and 'decision-makers' at macro-political levels with the often detailed and spatially or culturally contextualized knowledge of local actors, those who work the land (St. Martin, 2001), and critical interdisciplinary studies. Macro discourses implicitly assume a priority for economic values and the need to have new 'clean' energy supplies for national economic growth, whereas local discourses place a value on household or community reproduction and employ a diverse and more plural set of values.

The second thesis concerns 'marginalization', referring to social and environmental degradation due to production at the margin in economic terms from socially marginalized groups, producing and living in marginal ecosystems (Blaikie and Brookfield, 1987). Ecology, economics, and politics interact when new economic activities such as cash crops change the local agro-ecology, often reducing landscape and productive diversity. Changes in social relations caused by commoditization of exchange and redistribution and increasing dependence on cash can result in processes of further marginalization and proletarianization (or semi-proletarianization) of the already marginalized rural poor (Kay, 2006). However, some studies (Grossman, 1993; Moreno-Peñaranda and Kallis, 2010) urge for caution in assuming a priori that export-oriented or commercial crops have negative social effects, and argue for careful, local-based analyses of how new economic activities fit in and are appropriated/adapted in the livelihood systems of local populations, with due attention to consequences and their distribution.

We find both these theses relevant to the Jatropha experience in Tamil Nadu. National and state policy discourses about Jatropha simplify a complex local agro-ecological reality in a set of techno-economic indicators and accompanying maps, which render certain lands as 'wastelands' amenable to biofuel plantations. The introduction of new technologies is done, in other cases, by constructing local practices as 'inefficient' or 'backward'. Jatropha, a new agrofuel commercial crop, is introduced in the name of expanding energy needs, and the development of wasteland and the rural poor, with the aim to produce fuel, mainly for national urban areas. Local ecological-economic and political-ecology studies are necessary to shed light on the precise socio-ecological changes that take place at the local level and link the micro to the macro level, and the two to the changing political economy of India.

2.3 Research Design and Methods

The two-fold aim of this study required an interdisciplinary approach integrating quantitative and qualitative methodologies. To gather the needed empirical material, we designed our research in a two level data collection process.

First, we used qualitative research methodologies to collect material necessary to accomplish our aim of deconstructing the Jatropha policy discourse. Researchers (6), NGOs representatives (2), government officials (9), private companies' managers and field staff (6) were interviewed through a combination of in-depth and informal interviews [9] Policy documents were reviewed and research institutes and experimental stations were visited from March to July 2008.

Second, we conducted a field-level assessment of the performance of Jatropha plantations on private agricultural lands. Following the above referred preliminary desk work, meetings with knowledgeable persons and officials, and field visits, we chose to work in Tamil Nadu state because it had a significant area under Jatropha cultivation and the first initiatives began in 2005[10]. We further focused on Coimbatore (C) and Thiruvannamalai (T) districts because Coimbatore is a centre of Jatropha research, and has several plantations by 'progressive farmers' who follow the recommendations of the Tamil Nadu Agricultural University (TNAU) and Thiruvannamalai is the leading district in terms of area under Jatropha (3,876 ha in 2007) (Government of Tamil Nadu, 2007b).

We assessed impact focusing on the dimensions of productivity, economic viability, distribution, livelihoods and latent conflict. Our field study was based on a nested approach to data collection in the two districts of Tamil Nadu. We surveyed 79 plantations (21 in C and 58 in T) and in each we collected data on the main agro-economic characteristics of the farm and socio-economic features of the farm-owning or managing households. Out of the surveyed plantations we selected 49 plots (9 in C and 40 in T, 33 rainfed and 16 irrigated) owned by 45

[9] Interviews were conducted in Tamil Nadu Agricultural University (TNAU), Forest College Research Institute (FCRI), Bannari Amman Group factory main plantation site and R&D Branch plantations, D1 Mohan Bio Oils Ltd. R&D Branch plantations, District Collectorate, District Watershed Development Agency, and District Forest Office, among other government agencies. Some interviews were conducted in the field itself as we accompanied company field staff and government officials to the field to understand and observe their work.

[10] Interview with YB Ramakrishna, director of Samagra Vikas, NGO in Karnataka.

households (6 in C and 39 in T[11]) for conducting in-depth interviews about Jatropha adoption (see Table 1).

First, at the farm level, we asked whether Jatropha cultivation was indeed a productive and remunerative activity for the farmer from an agronomic (physical productivity) and economic sense. Second, at the household level, we asked what the livelihood trade-offs and changes in livelihood strategies were due to Jatropha cultivation, changes that would be relevant even if Jatropha was (or were to become) an economically remunerative activity. Third, at both levels, we sought to look for differences across socio-economic classes in adoption and in benefits or impacts, and the extent to which these differences may exacerbate rural inequities and therefore increase latent conflicts.

Finally, an agronomic assessment was carried out to estimate actual productivity in the field. Since Jatropha requires at least 3 years to start giving consistent economic yields (Paramathma et al., 2007), we attempted to identify plots where the plants were at least 3 years old. However, in spite of an intense search, we could not identify enough plots that met this criterion, and we ended up with 14 plantations (9 in C and 5 in T) older than 2.5 years (see Table 1). We therefore modified the agronomic survey to include some variables that may be proxies for eventual yield: number of branches (primary, secondary and terminal), nuts per plant, nuts per terminal branch, height and canopy diameter[12]. These were compared with yield data based on oral recall from the questionnaire survey.

We begin the presentation of results, analysing the discourse on Jatropha promotion in India and Tamil Nadu. After an overview of the field context we describe the Jatropha plantations in Coimbatore and Thiruvannamalai and give details about the findings of the field impact assessment. Finally through our discussion, we look at the causes and consequences of Jatropha failure and their distributive impacts to elucidate whether Jatropha cultivation is really ‘pro-poor’ or if it can, on the contrary, increase social differentiation.

Table 1. Distribution of sample farms surveyed by questionnaire and subset used in agronomic assessment, broken up by district and type of irrigation (with yielding farms given in brackets)

Type of irrigation	Sample size	Coimbatore	Thiruvannamalai
Irrigated	N in household survey	3 (3)	13 (6)
	N agronomic assessment	3	2
Rainfed	N in household survey	6 (3)	27 (3)
	N in agronomic assessment	6	3
Total	N in household survey	9 (6)	40 (9)
	N in agronomic assessment	9	5

[11] The reason for the lop-sided sample for in-depth interviews is that the plantations were clustered in T, while in C, plantations were scattered, limiting the extent of data collection.

[12] These variables were chosen according to expert advice from Dr. Paramathma from Center for Excellence on Biofuels in TNAU.

2.4 'Pro-wastelands' and 'Pro-poor' Crops: A Political Ecology Reading of the Social Construction of Jatropha in India and Tamil Nadu.

The Indian economy is immersed in a rapid structural transformation with an associated socio-ecological (socio-metabolic) transition (Fischer-Kowalski and Haberl, 2007; Krausmann et al., 2008; Schandl et al., 2009), and energy demand is growing. The process of liberalization-globalization in the last two decades has witnessed the interlinked phenomena of industrialization and rapid economic growth for the country as a whole, a slowdown of agriculture, and an intensification of social conflicts (Walker, 2008). The availability of land has been shrinking on account of population growth and the competing demands from various sectors (Government of India, 2009b). The pressure is both on agricultural lands and non-agricultural lands (forests, grazing lands, etc). Simultaneously, within agriculture, the shift from food crops to non-food crops is a matter of concern. India has recently started to lose self-sufficiency in food produce (Jasani and Sen, 2008) and is facing a shortage of edible oils (Government of India, 2003). Food prices have been rising rapidly in the past few years (Rahman, 2008). In this context, any proposal to divert land for producing energy for vehicles is bound to be met with skepticism. How has the government managed to introduce the concept and expand the discourse in favor of cultivating agro-fuels?

The government seems to have used a three-pronged approach. First, there is the constant refrain of 'energy security', the need to become less dependent on foreign petroleum (Government of India, 2006).[13] Second, there is a reference to the opportunity to rehabilitate degraded or dry lands,[14] the so called 'wastelands', without competing with food production. Third, there is an added concern that agrofuels 'could become in itself a major poverty alleviation programme for rural poor'.[15] While the energy security discourse is applicable to all energy policy, and has come in for criticism elsewhere (Pimentel et al., 2007; Pimentel and Patzek, 2005), we focus on the other two elements that are specific to the promotion of agrofuels in general and Jatropha in particular.[16]

The National Policy on Biofuels states:

> *"Plantations of trees bearing non-edible oilseeds will be taken up on Government/community wasteland, degraded or fallow land in forest and non-forest areas. Contract farming on private wasteland could also be taken up through the Minimum Support Price (MSP) mechanism proposed in the Policy. Plantations on agricultural lands will be discouraged". (Government of India, 2009a: 7)*

[13] India is meeting 70% of its increasing oil needs by imports and is the fourth major oil importer after the USA, Japan, and China (IEA, 2009). Petrol and diesel use in transportation are growing rapidly with high economic growth since 1991, and the transport sector accounts for 50% of oil consumption (Government of India, 2006).

[14] K.C. Pant, Deputy Chairman of The Planning Commission of India, Foreword of the Report on the Committee on Development of Biofuel (Government of India, 2003).

[15] D.N. Tewari, Member of the Planning Commission of India, Preface of the Report on the Committee on Development of Biofuel Ibid.

[16] We leave other elements aside, such as the optimistic views on scarce water requirements, the very positive energy return on energy invested (EROI), and the avoided carbon dioxide emissions, that accompany pro-Jatropha discourse not only in India but across the world. They are used complementarily with the 'pro-poor' and 'pro-wasteland' discourses as supporting features.

An assessment by The Energy and Resources Institute (TERI), however, contradicts the above, pointing out that:

> *"The present strategy of the Central Government is to utilize wastelands for biodiesel plantations so as not to affect the food security of the country. However, several private industries and state governments are exploring the possibility of utilizing agricultural land as well for biodiesel production". (TERI 2005: 28)*

Where is Jatropha being planted? Is 'wasteland' rehabilitation discursively used to build legitimacy around Jatropha, irrespective of the use and cover of the land where it is finally planted? To start with, it is useful to explore the concept of 'wasteland'.

The term 'wasteland' has very different connotations depending upon whether one is thinking in fiscal, social, or agro-ecological terms. The economic connotation originated during the colonial period, when the term was applied to all land that did not generate revenue for the British government (Gidwani, 1992). Thus, even dense forests and productive grasslands were classified as 'revenue wastelands' or 'assessed or unassessed wastelands'. In terms of ownership, these lands were under either state ownership or local commons; although a much smaller portion of revenue wasteland was private land that could not be cultivated. Thus, socially speaking, most of these 'revenue wastelands' were crucial components of the livelihood system, and a large portion were agro-ecologically important.

The 1980s saw the re-emergence of the 'wasteland' discourse, this time in a technical sense of 'degraded land that can be brought under vegetative cover with reasonable effort and which is currently underutilized land and land which is deteriorating due to lack of appropriate water and soil management or on account of natural causes' (Chopra, 2001; Government of India, 1989). A National Wasteland Development Board was set up in 1985, and it estimated the total area of wastelands in the country to be 123 million hectares, a staggering 37% of the country's land area![17] The National Remote Sensing Agency was then charged with producing a Wasteland Atlas. The estimate was eventually revised downwards to around 55.3 million ha, according the last edition (National Remote Sensing Agency 2005), which is still 17% of the land area. The mapping also used 28 categories, including permanent snow cover and permanent desert, which are not really lands degraded by human agency. Nevertheless, three categories account for more than 50% of the total available wastelands: degraded forest-scrub dominated land, land with scrub, and land without scrub. Of course, the remote sensing approach is not able to indicate the property rights situation or de facto use of these lands, which, when assessed from local in-depth studies, gets highly more complex (Lele et al., 1998).

The technical approach thus sidestepped the fundamental point that the notion of 'degradedness' is necessarily value-laden and subjective, and methodologies of mapping are further biased in particular ways (Sarin, 2003). Grazing lands which are productive during the rainy season but 'barren' looking during the dry season routinely get classified as wasteland, while their socioeconomic value to local communities, particularly the poor, is actually high (Government of India, 2009b; Jodha, 1990). Attempts to 'regenerate' such common wastelands by planting commercially valuable species such as eucalyptus date back to the Social Forestry programmes of the 1980s; several analyses showed that this 'commercialization' of the commons benefited the paper and pulp industry while depriving

[17] Table 12.1 in Yadav (1989)

local communities of subsistence uses (e.g. firewood and grazing) (Shiva et al., 1985). Thus, degraded 'how' is related to degraded 'for whom', and regenerate 'how' is related to regenerate 'for whom'. But the simplistic discourse on wastelands glosses over these multiplicities, and thereby creates the space for interventions that are one-sided, driven by a technical (productivity-oriented) or techno-economic (return-oriented) rationality, rather than a balance between these and social needs and ecological function.[18]

The idea of wasteland is powerful because it renders debate almost impossible: how can anyone disagree with the propositions that 'wasteland' should be regenerated, that producing agrofuel out of unproductive wasteland is a good thing? Having mooted this, techno-economic missions then take liberties with even the technical definitions to suit their goals. Thus, the Biodiesel National Mission (Government of India, 2003), when estimating the extent of land suitable for Jatropha, it includes categories that go beyond the above three most abundant wasteland categories. It includes understocked forests lands (3 million hectares (mha)), protective hedge around agricultural fields (3 mha), farmlands under agroforestry (2 mha), fallow lands (2.4 mha), wastelands previously covered under various watershed projects (2 mha), and tracks of public lands along railways, roads, and canals (1 mha). That farmlands under agro-forestry are considered wastelands or suitable for Jatropha shows the extreme malleability of the concept! Malleability makes it difficult to estimate what kind of land use and land cover types are really being converted to agrofuels, under which property rights they exist, and to whom they are being given. Such unaccountability allows the government and corporations to legitimize the promotion of agrofuels in favor of their interests. Thus, in practice, Jatropha plantations are promoted through three different models.

The first approach consists of leasing out government lands to private companies and is being practiced extensively in the state of Rajasthan. The state government has set up a 'Rajasthan Land Revenue (Allotment of wasteland for biofuel plantation and biofuel based industrial and processing unit) Rules 2007'. These rules permit wasteland to be leased out to private companies and government enterprises for up to 20 years. Both the rule on the maximum size of a plot that can be held by an individual or a company and the ban on the sale of tribal lands have been abolished. It is now possible for a special government committee to approve up to 1,000 hectares of land to be given to private companies for Jatropha plantations (GRAIN, 2008). Most of Orans (village commons) and Gauchars (grazing lands) legally fall under the 'cultivable wasteland' category and could be snatched away from pastoralist communities (National Consultation on Biofuels, 2007; Navdanya, 2007). Tamil Nadu has also included a leasing component in its Comprehensive Wasteland Development Programme (CWDP), launched in 2003. It targets two million hectares of government wasteland and involves 30 year leases to the corporate houses, for which a 'normative' ceiling of 400 hectares has been fixed. Wasteland would be developed for orchards, medicinal and aromatic plants, horticulture, and other types of commercial agriculture (Government of India, 2009b). However, there has been no clear definition of the kind of wastelands to be developed. Grazing lands, excluded at the beginning, were finally included.

The distribution of wasteland to the rural poor constitutes the second model of Jatropha promotion. The National Watershed Development Program for Rainfed Areas (NWDPRA) aims

[18] Depending on their actual land cover and land use, the so called 'wastelands' provide diverse environmental services, such as carbon sequestration and biodiversity and water conservation.

at increasing productivity of wastelands in rainfed areas. In doing so, the program, as part of other activities, brings government wasteland under cultivation through distribution of land to small farmers for cultivation of 'pro-poor' crops such as Jatropha. However beneficiaries of NWDPRA are being convinced to plant Jatropha on their own private lands, as monocrop instead on leased or transferred public wasteland. State governments, in their above mentioned schemes, add to the target area allotted to companies a share to be allotted to cooperative societies of the rural poor. For instance Tamil Nadu CWDP distributes two acres of government wastelands to landless households. However, among the southern states, Tamil Nadu remains at the bottom in the matter of wasteland transfer.[19] Wasteland transfer, although being discursively 'pro-poor', finally prioritizes agri-business entrepreneurship.

Finally, the cultivation of Jatropha on private lands is the third model of Jatropha promotion. It uses the 'pro-poor' discourse to 'sweeten' the actual contract farming between Jatropha farmers and private companies. This discourse is in favor of small farms, due to the social efficiency of resource use and the improvement of social equity through employment creation and more equal income distribution (UNDP, 1996). The 'pro-poor' discourse goes along with 'the equity-growth-efficiency argument' that is already present in the debates about land reforms (Srivastava, 2006).

The 'pro-poor' discourse is articulated among three main arguments: the short maturation period of Jatropha, its 'low-input crop' characteristics, and the associated promotion of 'small-scale decentralized energy production'. The lack of clear experiences on the maturation period (Achten et al., 2008) and the lack of farmers' knowledge about this new crop have allowed private companies and the government to announce shorter maturation periods than even those achieved in research stations. While research stations claim it takes three to five years before the yield stabilizes (Paramathma et al., 2007; Rao et al., 2006), the NMB2003 reports it as two years. Another argument in favor of the poor has been that less water, fertilizers, and labor are required for Jatropha cultivation. Part of the harvest season coincides with the non-agricultural season, which enables employment at different periods than for the rest of the crops (Kumar Biswas et al., 2010). Such characteristics should benefit the poor, especially small or marginal farmers and the landless, who will have more income opportunities. Finally, the pro-poor discourse includes arguments that highlight the potentialities of 'decentralized energy production for local use'. By-products (such as the seed-cake) can be used as green manure or as feed for cattle (Openshaw, 2000). Small-scale decentralized oil mills can improve the rural off-farm sector (Francis et al., 2005). However, to do so, the oil extraction and by-products should be extracted and detoxified by small-scale industries located at the village level. Under contract farming, the by-products are kept under private companies' control in industrial poles, and the oil extraction is highly centralized.

Summing up, the two discourses, the 'pro-wasteland' and the 'pro-poor', operate together as a way to get either common or private lands for Jatropha. They involve starting with fuzzy concepts and stretching them in various ways, selective use of data, and transgressing, in practice, boundaries that were laid down in earlier policies (such as not leasing out commons and forest lands, investing in rainfed lands, etc.) through obfuscation. The next sections

[19] While about two million hectares of wasteland has been transferred to eligible people in Andhra Pradesh, about 150,000 ha in Karnataka, and 180,000 ha in Kerala, the wasteland distributed in Tamil Nadu is less than 100,000 hectares (Viswanathan, 2003).

deconstruct the above mentioned arguments, especially the 'pro-poor' discourse. After presenting the field setting context, we draw on the interpretation of empirical field data about the actual performance of Jatropha contract farming in Tamil Nadu.

2.5 Jatropha development in Tamil Nadu state of India: the context

The Tamil Nadu policy: actors, roles and interactions.

Tamil Nadu state in southern India is one of the leading states in Jatropha development with a well articulated Biodiesel Policy (Government of Tamil Nadu, 2007a, 2007d, 2009). This policy, launched in 2007–08, was built upon a pilot scheme launched in 2006, and has set a target of promoting 100,000 ha of Jatropha plantations over a period of five years, with district-wise differential targets. The policy involves providing 50% input subsidies (for saplings and drip irrigation).

Under the State Agricultural Department as a nodal office, but with the involvement of the Forest Department and the Rural Development Department, nurseries have been built, saplings have been planted on the degraded edges of forest, and watershed development programs have been undertaken. However, the greatest effort has been put into developing contract farming on private lands to grow Jatropha. The State Agricultural Department collects planting area details from each farmer and supervises the legal documentation needed for the subsidy component. Tamil Nadu Agricultural University (TNAU) provides quality seeds to government and private nurseries, which it monitors and inspects. TNAU also provides training and technical advice to farmers and entrepreneurs. Eleven companies are identified by the Agriculture Department for supplying planting material to the farmers under contract farming.

Field setting: ecological and socio-economic conditions of production

Coimbatore is, after Chennai, the second most urbanized and industrialized district of Tamil Nadu, with 66% of its population living in urban areas. Forty percent of the district's approximately 7500 sq km land area is under agriculture. The main crops are cereals and millets and coconut. In contrast, Thiruvannamalai is among the districts with the highest fraction of rural land, about 80%. Although less industrialized, Thiruvannamalai has, like Coimbatore, 40% of its approximately 6300 sq km under agriculture, the main crops being cereals and millets and oil seeds, especially groundnut. Coimbatore and Thiruvannamalai form part of the inland belt, which together with the southern and northern coastal areas constitutes the 'dry' agrarian ecotype of Tamil Nadu. The average annual rainfall is 690 mm and 1040 mm, respectively.

The 'dry' areas historically have had a less inegalitarian structure, with peasant proprietorship as the dominant mode (Krishnan and Thangaraj, 2003). Thiruvannamalai follows this expected trend towards the marginalization of holdings. Seventy percent of the agricultural land is held by small or marginal landholders (holding size two ha or less), who constitute 94% of farmers. The other 30% of the land is held by big landholders (holding size greater than two ha), who constitute 6% of the farmer population (Government of India, 2001). Coimbatore, however, has historically reflected less of a trend towards marginalization of holdings than Tamil Nadu as a whole and the rest of 'dry' areas (Krishnan 2003). Thirty percent of the total agricultural land is held by marginal or small farmers, who represent 70% of landholders in Coimbatore (Government of India, 2001).

The ecological, bio-physical, and socio-economic conditions of production constrain livelihood systems. As repeatedly reported by interviewed farmers, the study area is characterized by a prevalent water and agricultural labor scarcity. Overexploitation of ground water is widely reported in both districts (Palanisami and Venkatram, 2008a, 2008b). Water scarcity limits the production from the land and constrains households in terms of the land that they can actually cultivate, forcing them to flexibly allocate labor to off-farm activities. Timely sowing, planting, weeding, and harvesting in dry land are major problems due to labor and water scarcity. The existence of wild pigs, cattle, and other wild animals that damage the crops at night also shapes the ability of the household to allocate labor.

In Thiruvannamalai, farmers usually follow a crop pattern of one or two seasons of irrigated cash crops during the rainy season (sown in June-July and harvested in September-October), according the water availability, followed by a season of short term crops more oriented to subsistence. They also combine multiple crops through intercropping. The main cash crops are groundnut and rice, and more subsistence-oriented crops are pulses such as green gram, black gram, horse gram, and pigeon peas. The main cropping system (paddy-groundnut, paddy-pulses) followed in the district enriches the soil and maintains soil fertility (Palanisami and Venkatram, 2008b). Moreover, diversified livelihood strategies and short term crop rotation help the households cope with climatic shifts and fluctuations in the semi-arid tropical environment, as well as the prevalent rural poverty, characterized by short-term needs, that endangers daily subsistence.

After the agricultural season, landless laborers and small and marginal farmers usually migrate to nearby towns or to other states or districts to work as daily wage laborers either in the building and manufacturing sector or in commercial agriculture. However, nowadays such migration is particularly affected by broader political economic processes. Both districts are affected by a structural economic transformation. The structural transformation of the rural economy as an indirect consequence of local and regional industrialization is characterized by (i) a growing non-agricultural sector in rural areas, (ii) seasonal migration, and (iii) pluriactivity (Djurfeldt et al., 2008). Such transformation diminishes the availability of agricultural labor for farmers. Wage increases in the building and manufacturing sector attract agricultural laborers. In the case of Coimbatore, the establishment of industrial complexes and multinational companies attracts people from agriculture towards industry and promotes rural-urban migration. In both districts farming is in the grip of an agrarian crisis that is characterized or triggered by increased input costs, poor credit availability, labor problems, and low prices for agricultural produce (Palanisami and Venkatram, 2008a).

Jatropha plantations in Coimbatore and Thiruvannamalai districts

Coimbatore and Thiruvannamalai are leaders in Jatropha plantations. Coimbatore is a centre of Jatropha cruces research and Thiruvannamalai is the leading district in Tamil Nadu in terms of area under Jatropha (3,876 ha in 2007) (Government of Tamil Nadu, 2007b). In Thiruvannamalai, Assistant Directorate of Agriculture extension work and the contract farming developed by companies coexist. The District Watershed Development Agency has implemented the NWDPRA project through more than 70 watershed committees and has achieved about 350 ha under Jatropha plantations, mostly on farmers' private lands. There are several private companies promoting Jatropha in the district, including D1 Mohan Bio Oils

Ltd.,[20] the biggest company promoting Jatropha in Tamil Nadu. By 2007, the company had reached 12000 ha all around Tamil Nadu, about the 25% of them in Thiruvannamalai district. Apart from D1 Mohan Bio Oils Ltd, other small companies, such as AGNI NET Biofuels Pvt. Ltd and AHIMSA, are forming farmers clubs and clusters of farmers' plantations in the district. Our fieldwork in Thiruvannamalai is focused on two clusters of plantations. One consisted of a group of plantations promoted under the NWDPRA scheme, some under contract farming with AGNI-NET Biofuels Ltd. Another cluster of plantations originated through aggressive promotion by D1 Mohan Bio Oils Ltd. In Coimbatore, plantations are more scattered, and, although the public agricultural extension system works, farmers are mostly contacted by private companies that offer farming contracts. Our fieldwork focused in Shiva Distilleries-BAG[21] plantations. Shiva Distilleries had reported planted around 1200 ha all around Tamil Nadu, covering eight districts and involving around 500 farmers,[22] of which 700 ha had been planted in Coimbatore district alone (Government of Tamil Nadu, 2007b).

The farming contract developed by the companies mentioned is as follows. Saplings are given to farmers for free. During and after the plantation establishment there is technical guidance, twice monthly, by the company's field staff. A price of 5–10 Rs/kg is assured, although it is linked to the market prices. A buy-back agreement is arranged. While the company promises to buy the produce, farmers promise to sell by agreeing to pay back the loans with part of the harvest. A loan is given in three installments. Out of approximately 15,000 Rs/ha, two-thirds are given the first year and the other third is given in the next two years, in two installments. The companies' Jatropha promotion strategy is to convince farmers village by village through an active field staff that provides the technical assistance needed as part of the farming contract. The companies' officials visit the villages in cycles, coming back to the same village on a regular fortnightly to monthly basis. While coming back to the villages, companies' field staff has a registered tracing of farmers' plot conditions and the associated need for assistance. The recurrent visits are also used for trying to convince disappointed farmers that had entered into Jatropha through government programs (such as NWDPRA) or other companies' buy-back agreements. Promises are made to convince farmers to shift to an improved version of contract farming. The promises are mainly for the provision of loans for improving irrigation infrastructure and technical assistance to do intercropping or apiculture.

2.6 Performance of Jatropha at farm level

Despite the publicity given to Jatropha as a 'miracle crop', our empirical data show a great distance between its expected performance and the actual one. They show how yields of Jatropha, as reported by farmers, and the yield related agronomic parameters observed by us in the field are far lower than the expected yield and agronomic performance according to research agricultural stations, i.e. TNAU. Such low agronomic performance made the crop

[20] D1-Mohan Bio Oils Ltd. is a joint-venture (at 50:50) between D1 Oils plc, a UK-based multinational company, and Chennai-based Mohan Breweries & Distilleries Limited. (http://www.d1plc.com/)

[21] BAG is one of the largest Industrial conglomerates of South India with a wide spectrum of manufacturing and trading (sugar, alcohol, ethanol, biodiesel, liquor, granite, cotton yarn), distribution (automobiles and related accessories of renowned brands), and financing activities. The group is involved in the service sector through wind power energy, IT services, education, health care, and real estate. (http://www.bannari.com/)

[22] Interview with Shiva distilleries privately-owned plantation manager, at Gudimangalam,17 June 2008.

economically unviable. In this section, thus, we address the details of physical productivity of Jatropha plantations and its economic viability.

Agronomic performance: survival, growth and yield

We found that overall survival rates were reasonably high (see Table 2)[23]. But survival rates in rainfed plots were statistically lower than those in irrigated plots. The average number of nuts per plant was twice as high in irrigated plots as compared to rainfed ones (see Table 3), even though there was high variability within plantations[24].

Table 2. Survival rates of Jatropha cruces plantations under different irrigation conditions

Irrigation	Plantations sampled	% of Jatropha plants surviving	
		Min -Max	Median
Rainfed	9	45-99	80
Irrigated	5	90-100	99
Combined	14	45-100	90

Note: Differences between medians were significant at p<0.01 using Mann-Whitney U-test.

Table 3. Variation in number of nuts produced per plant by water use (pooling all plant samples across farms and selecting those plants bearing nuts).

Plot type	Plants bearing nuts		
	N	Mean	Std.Dev
All	227	33	45
Rainfed	171	28	37
Irrigated	56	49**	60

** Mean is significantly higher at p<0.014 in an F-test

[23] Although this is partly a selection effect: where Jatropha did not do well, farmers had already removed the crop and so were not picked up in the preliminary survey.

[24] Data on the remaining parameters (nuts per terminal branch, height, canopy diameter, and number of branches) are not presented to avoid redundancy. Their variations are in consonance with variations in survival and nuts per plant.

Yield data were obtained through oral recall and show that in both 2-year and 3-year old plantations, average yields were higher by a factor of two to three in irrigated plantations as compared to rainfed ones (see table 4). The highest yield in 3-year old plantations in rainfed conditions was only 450 kg/ha compared to 750 kg/ha for irrigated conditions. Similarly, the percentage of non-yielding plots was much higher in rainfed conditions (82 %) than in irrigated conditions (44%).

Table 4. Yield of Jatropha plots collected in the sampled plantations (from oral recall data)

Age	Water application	Total plots	Yielding plots	Yield (kg/ha)	
				Median	Min-Max
2 years	Irrigated	16	8	98	31-500
	Rainfed	33	4	56	25-500
	Total	49	12	73	25-500
3 years	Irrigated	16	1	750	750
	Rainfed	33	2	231	13-450
	Total	49	3	450	13-750

The literature suggests that the plant needs water mainly during the first year if rains are irregular, implying that irrigation is required for initial survival only (Paramathma et al., 2007). However, as both yield recalls and the average number of nuts per plant show, the continuous irrigation makes a clear difference between growth and yields in rainfed as compared to irrigated conditions. The continuous irrigation determines the number of fruiting periods per year, which can vary from one to three depending on the level and frequency of irrigation (Tomomatsu and Swallow, 2007). The importance of irrigation for Jatropha is also shown by its high water footprint. The water consumption per unit of energy produced from Jatropha has been reported to be 1.5 times higher than soybean and 5 times higher than ethanol from sugarcane or maize (Gerbens-Leenes et al., 2009b). Thus, the water demands of the crop due to the need for continuous irrigation, for favoring and ensuring high productivity, completely contravenes the idea of undertaking plantations in marginal lands with no irrigation infrastructure.

More important than the difference between irrigated and rainfed, is the gap between the yields reported by our sample farmers and those reported in the literature. Globally, reported yields show high variability, ranging from 0.4 to 12 t ha^{-1} yr^{-1} (Openshaw, 2000). The age of maturity also varies from 2.5 to 5 years (Achten et al., 2008). In India, agronomists have, however, consistently reported yields in the range of 7500 kg/ha for irrigated plots and 2500 kg/ha under rainfed conditions after 3-5 years (Paramathma et al., 2007; Prajapati and Prajapati, 2005). Thus, by looking at the maximum yields reported by farmers in our sample

(750 kg/ha irrigated, 450 kg/ha rainfed for similarly aged (three-year-old) plantations), they are nearly one-tenth of that expected from agricultural stations.

A possible bias[25] of the farmers' oral recall is very unlikely to bridge the very large distance between the reported yields and those in the literature. Our figures are also supported by other findings in the literature. Rao (2006), estimated that the average yield of Jatropha seeds in dry lands is unlikely to exceed 1000 kg/ha per year in Maharashtra after the third year. The National Oilseeds and Vegetable Oils Development Board (NOVOD) reported that actual yields without irrigation or fertilizer inputs tend to be well below 2500 kg/ha (Altenburg, 2009; NOVOD, 2007). Furthermore, BAIF Development Research Foundation has reported that in their six years old plantations the highest seed yield under rainfed conditions was about 500 kg per ha in the fifth year. After regular irrigation was introduced in the sixth year the yield was about 1200 kg/ha (Daniel, 2008). Our conclusion about under-performance is therefore robust.

Economic performance

The economic analysis, based on survey data from 45 farmers, attempts to assess the economic returns from Jatropha cultivation. Economic costs include initial investments (land preparation and plantation establishment) and the annual maintenance costs (weeding, pruning, fertilizers, pesticides and irrigation)[26]. The main factor influencing annual maintenance costs is whether farmer uses diesel pump sets for irrigation or not.[27] The costs and returns for three cultivation scenarios (irrigation with electric pump set, irrigation with diesel pump set, and rainfed) assuming the best case yields reported in the previous section, are given in Table 5, along with estimates of what the returns might have been if the yields matched those obtained in the experimental stations.

Our data show that, at current yields, net returns are always going to be negative, even for irrigated farmers (because annual maintenance and harvest costs themselves are higher than the best case gross returns). This is true even if we assume that the best case yields will be reached in year 3 itself, and do not factor in any interest payments, time discounting, or opportunity costs of land. This is primarily because of the extremely low yields. The interest burden on initial investment and the need for subsistence support during the first few years would make the crop even more unviable.

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[25] Farmers could report strategically lower or higher yields, in search of government help, compensation or subsidies. Farmers could be reporting a lower or higher yield depending on their perception of what the researcher wishes to listen.

[26] In calculating costs, we only focus on paid out costs, so the net returns include returns to own labour and pure profit. Since small farmers use more family labour, this means the average of input costs for the full sample are lower than those incurred by small farmers, making the economic assessment more favorable to the Jatropha crop.

[27] We also had some farmers who 'rented' wells (8%) or irrigated by hand (14%) rather than pump sets. The cost calculations for these scenarios are not given here, as they do not change the results significantly.

Table 5. Comparative results of economic analysis of Jatropha cultivation under different cultivation scenarios

Eonomic parameter	Cultivation scenarios		
	Irrigated plot		Rainfed plot (N=23)
	Electric pumpset, own well (N=11)	Diesel pumpset (N=4)	
Field data			
Initial investment Rs/ha [a]	7,773	9,225	7,154
Annual maintenance costs Rs/ha/yr [b]	8,077	9,456	3,128
Harvesting costs Rs/ha/yr [c]	1,645	1,645	1,588
Annual costs during yielding years Rs/ha/yr	9,722	11,101	4,716
Best price (Rs/kg)	10	10	10
Best yield (kg/ha/yr)	750	750	450
Best gross returns (Rs/ha/yr)	7,500	7,500	4,500
Best net returns, ignoring initial investments (Rs/ha/yr)	-2,222	-3,601	-216
Total initial investments, if yield starts in year 3 [d]	23,927	28,137	13,410
Total initial investments if yield starts in year 5 [d]	40,081	47,049	19,666
Plots not yielding at all	5	3	18
Plots which stopped irrigation prematurely [e]	-	3	-
Experimental station data (Paramathma et al)			
Yield at maturation stage (kg/ha)	7,500	7,500	2,500
Gross returns (Rs/ha/yr)	75,000	75,000	25,000
Annual costs during yielding years Rs/ha/yr [f]	9,722	11,101	4,716
Net returns, ignoring initial investments (Rs/ha/yr)	65,278	63,899	20,284

[a] Initial investment figures differ across the two irrigation scenarios simply because of statistical variation. Figures are in Indian rupees (66 INR= 1€ in May 2008). [b] The operating costs of all types of irrigated plantations were higher than rainfed plantations due to the tendency of farmers to invest more in the application of fertilizers in irrigated plots. [c] Due to large variation in use of hired labor versus own labor, paid out costs for harvesting varied enormously across farmers. We therefore used an average cost based on total estimated labor input (own and hired) and prevailing wage rates. [d] Not including any interest burden. [e] Thereby incurring high initial costs, but low yields. [f] Assuming same costs as sample farmers, although actually input costs are likely to be higher.

On the other hand, if farmers were to obtain the yields reported by TNAU, the cultivation of Jatropha at the level of costs indicated above might be profitable. Even if one assumes that this yield is reached not in year 3 but in year 5, the last row in Table 5 shows that the total investment of the first four years would be recouped in the first yielding year itself. Even if additional costs were involved for family subsistence through the first 4 years, the huge net returns starting year 5 would make it economically viable. However, several caveats are in order. First, it is likely that to obtain anything like the TNAU yields, farmers would have to provide much higher inputs (primarily fertilizers) which would increase their input costs compromising the final net economic and energy returns[28]. Second, we have not factored in the opportunity cost of land in the above calculations. A single season crop of groundnut provides a net return of about 20,000 Rs/ha under irrigated conditions, which means a foregone return of Rs.40,000/ha/yr right from year 1. Under these circumstances, as the last column of the last row shows, Jatropha cultivation may not be profitable for rainfed farmers even under the experimental station yields. Third, this analysis assumes that the prices assumed are actually received and that credit for surviving through the gestation period is not a problem. All of these are major assumptions.

To summarize, under current levels of yields, prices, and cultivation costs, Jatropha cultivation is simply not profitable. A ten-fold increase in irrigated yields (or combination of yield and price) is required to make it profitable, and even then it is not clear that it would exceed the opportunity costs of groundnut cultivation for rainfed farmers. Even if it to become remunerative the capacity to irrigate Jatropha lies only with bigger or better-off farmers. Given the poor agronomic and economic performance of Jatropha, it is not surprising that Jatropha farmers in this region have begun to drop out of this crop. In our own sample, 30% of the plantations had been removed, and 50% are being kept without maintenance, waiting for better institutional frameworks to develop Jatropha or for good conditions to shift back to previous cultivation. Finally, 25% are keeping the plantation, absorbing the losses with the production from the rest of the landholding.

The low agronomic performance made the crop economically unviable even in the current situation, in which the electricity for irrigation is fully subsidized. If farmers were to get the expected yields the crop could become profitable at the current level of costs. However, the need for more inputs to reach such an increase in yield makes difficult to predict a positive balance, even with subsidies and without counting the opportunity costs of labor and land.

Facing these circumstances, agricultural scientists are trying to develop new high-yielding varieties[29]. If these varieties spread, and if their adoption is combined with increased output or subsidized input prices, they could perhaps make Jatropha economically viable and attractive to farmers. Even in such a scenario, and assuming possible, desirable and worthwhile the compensation of increased environmental impact and reduced energy returns (due to the high inputs), one still needs to consider the multi-dimensional livelihood impacts and their

[28] From a public policy perspective at larger scale than local farmers concern, it must be pointed out that the low performance of the crop reduces the Energy Return on Investment (EROI) (Hall et al, 1986, Odum, 1971).

[29] Direct communications from Dr. Paramathma and observations from interviews with agricultural scientists and field visits to TNAU and Forest College and Research Institute in Coimbatore shows that progress in *J.interregima* and *J.curcas* cross breeding seems to bring a considerable shorter gestation period and therefore less need for credit.

distribution across income groups before arriving at a positive assessment. This is precisely, the focus of the next section.

2.7 Distributive livelihood trade-offs and marginalization: uneven consequences of Jatropha failure

In this section we investigate differential adoption and wider livelihood impacts and trade-offs across socio-economic classes, using survey data for 45 farmers, identifying changes that are valued outside formal markets. This whole section, thus, deals with the other impacts on livelihood that one should worry about, even if the government was to announce high support prices for Jatropha and the agronomic yields were improved, making cultivation profitable on an average. We investigate then, if in such a scenario Jatropha will work for all farmers, and if it will be pro-poor.

Differential adoption and distribution of outcomes

Despite Jatropha being presented as a 'pro-poor' crop, we found that there are major biases in who adopts Jatropha and in who can potentially benefit from it. The results show a bias towards big farmers with irrigation infrastructure, and it is present from the beginning in terms of who adopts the crop. Although in Thiruvannamalai, 70 to 80% of farmers are small or marginal in the Jatropha cultivators' villages,[30] small or marginal farmers and big agriculturalists were equally represented in our sample (50% each), which included all Jatropha cultivators in each selected village.[31] It shows, therefore, that Jatropha tended to be adopted more often by big rather than small farmers. In Coimbatore, Jatropha cultivators were mainly big farmers (88%) scattered in different villages.

The implications of this differential adoption are easy to illustrate when breaking down the sample by landholding category, well-tenancy and caste. Since we chose the sample only from among all those who had adopted Jatropha, this categorization of the sample allows us to better know 'who are the Jatropha farmers' and how their characteristics are correlated to each other.

There are clear correlations in resource endowments of the surveyed 45 adopters: large landholders (holding > 2 ha) tend to also be well owners (the breakup being 96:4), owning electric pump sets (93:7), and not from a scheduled caste (SC) (96:4)[32]. On the other hand, small and marginal landholders (holding ≤ 2 ha) have an even distribution of well ownership (40:60) and are largely from the SCs (89:11). And when one compares the percentage of large landholders in the sample (56%) with that in the population (30% in C and 6% in T, using district-level data), we see clearly that large landholders are disproportionately represented amongst the adopters today.

Furthermore, given that irrigation is essential for higher yields, it is clear that Jatropha (if and when it becomes remunerative) will preferentially benefit large landholders and non-Scheduled Caste farmers. In our survey, among the 15 who got yields 13 owned electric pumpsets, and only 2 rented a well. The small farmers have mainly seen their plants to get

[30] Records of Village Administrative Officers (VAO).

[31] There were a few exceptions, due to farmers' migration, unwillingness to answer, illness, or death.

[32] Scheduled castes are Indian population groupings explicitly recognized by the Constitution of India, previously called the "depressed classes" which lie out-side of the traditional Indian caste system.

dried or have removed voluntarily the crop due to the high costs of ensuring irrigation. The 71% of the plantations that dried (plants shed their leaves and barely survived) were held by small farmers, mainly in T. It shows how there is an entry barrier that makes it impossible for small and marginal farmers to have enough infrastructures for Jatropha cultivation.

Although nowadays Jatropha is not profitable for any kind of farmer, Jatropha would only be, potentially, a viable option for those who control groundwater, land, and capital, not for the rural poor. For this reason, those plantations that continued, even in the absence of direct and short-term benefits were managed by big farmers with electric pump sets (85%), most of them in Coimbatore (64%). The field staffs of the companies and the managers of their field stations are starting to acknowledge that the crop is more suitable for big farmers with good irrigation infrastructures.[33]

Food, fodder and firewood trade-offs

The literature on poverty and development has highlighted that rural agrarian households in countries like India tend to have a diversified livelihood[34], a diverse and inter-linked portfolio of activities and assets (Ellis, 1998). Food crops are grown for self-consumption along with marketed crops. Livestock provide both inputs of dung and draught power and also consume agricultural residue/stubble. Some crops generate residues that substitute for firewood. Household labor also has to be distributed across different activities, and crop choice has complex implications for labor demand. Increase in off-farm work and the seasonal migration of wage laborers (temporary or daily rural-urban commuting) are important components of a livelihood diversification strategy(de Haan, 1999). Many of the activities in the livelihood portfolio are complementary and address different needs of the household; hence they cannot be conceptually aggregated into a single measure of income. Thus, we investigated the trade-offs between different intertwined dimensions of Jatropha cultivators livelihood.

The first dimension of the livelihood impact of Jatropha cultivation is on food self-sufficiency. Expecting to get the promised loans, technical advice, and profits promised by the companies, 82% of farmers planted Jatropha as a substitute for food crops. Only 18% used barren land or sacrificed non-food cash crops (see Table 6). Thus, a very large fraction of the interviewees were substituting food crops. Furthermore, in half of the sample, the Jatropha plot covered more than 50% of the total landholding of the household, making a major dent into their previous food production.

Of those planting in barren land, most were in Coimbatore (63%), and most were big commercial agriculturalists (80 %). In Thiruvannamalai, groundnut was the most frequent foregone crop (77% of the farmers).

[33] Interview with Shiva Distilleries' privately-owned plantation manager, at Gudimangalam,17 June 2008.

Table 6. Livelihood trade-offs generated by Jatropha plantations

Livelihood parameter	% of households reporting the change
Households substituting food crops with Jatropha	82
Households affected by edible oil shortage	42
Households affected by fodder shortage	53
Households affected by firewood shortage	20
Households intercropping Jatropha with food crops	44

It is important to note here that groundnut, a major crop in the region, is seen as both a food and a cash crop, as it typically provides the household with a whole year's edible/cooking oil—an expensive commodity otherwise. Four kilograms of groundnuts normally yield a liter of oil, and the annual consumption of a 5-member household is around 50 liters. The 42% of the respondents reported that they were significantly affected by the loss of edible oil. Purchasing the 50 liters of oil from outside implies 3500 Rs of extra cost per year.

Groundnut oil accounts for 20–25% of the edible vegetable oil produced in India,[35] and it is therefore the most important edible oil crop (Damodaran and Hegde, 2005). The government promotes Jatropha so as to avoid the diversion of precious edible oil to biodiesel manufacturing and for not worsening the shortage of edible oil that India is already facing. However, Jatropha cultivation itself leads to reduction in oilseed production.

Further importance of groundnut as a food (protein) source is indicated by the wage laborers willingness to accept in kind payment with part of the groundnut harvest. Thus, loss of the groundnut acreage to Jatropha means more than just loss of income, food and cooking oil, it also means loss of an important medium of exchange, and in effect results in the payment of higher wages in cash. In other cases, Jatropha replaced paddy, sorghum, or vegetables, which were all contributing to the food sovereignty of the household. Where Jatropha replaced pigeon peas or cotton (20% of the cases), the larger livelihood impact (apart from the loss of the food or fiber of the crop) was loss of fuel. An acre of pigeon peas could provide firewood for six months for an average household of five members.

Another trade-off relates to fodder benefits. One acre of paddy or groundnut yields a cart load of paddy straw or groundnut feed for a pair of bullocks for two months. 50% of the sample reported that their access to fodder was definitely reduced by the shift to Jatropha,

[35] According to data from the Solvent Extraction Association of India (2008).

while the remaining 50% either did not own cattle or were able to obtain fodder or grazing from other lands (private or common). As it is, many parts of rural India have been affected by fodder shortage —also called the 'other food crisis' (Narain, 2005) - and the cultivation of Jatropha might exacerbate the crisis. While the market value of the fodder provided by the crop that Jatropha replaces can be factored into a marginal economic assessment, the non-marginal effects of large-scale Jatropha cultivation on fodder availability and prices cannot be easily factored in.

Finally, Jatropha cultivation also leads to reduction of crop diversity. Pre-Jatropha, farmers typically followed one of three rotations: between groundnut and short term rainfed crops (cereals and pulses) (63% of sample farmers), between groundnut, rice and pulses (13%), vegetables and other fruit crops (6%). Although 44% of the households decided to intercrop between Jatropha the first year, the next two years, after the crops has grown tall enough, all farmers had largely a monoculture. Diversity of crops buffers the household against vagaries of climate, pest and other problems. Cultivation of Jatropha as a perennial monocrop would reduce the sustainability of the household's livelihood.

For all the different dimensions of livelihood impact discussed above, it is important to note that there are differences in impact across socio-economic classes. For instance, relatively large farmers devoted only the 35% of their land to Jatropha cultivation (in average Jatropha plots of 1.6 ha), as compared to smaller farmers where Jatropha occupied 75% of their landholding (in average Jatropha plots of 0.6 ha). The food sovereignty impacts of shifting to Jatropha would therefore be sharper for the smaller farmers. Similarly, being an SC farmer increased the likelihood of the household facing fuel-Jatropha trade-offs[36] because these households tend to have a more subsistence oriented rationality in their plot cultivation.

Changes in employment and migration

One-third of the households reported increasing their off-farm activities as wage laborer's coolies[37]during the period of Jatropha cultivation. The increase in off-farm activities was more prevalent amongst small and marginal farmers[38]. As stated by some of the interviewees, the farmers were unable, for a lack of reliable knowledge, to assess how many days of additional off-farm work they needed after the adoption of Jatropha. In other words, the uncertainty about Jatropha's performance and labor requirement meant that farmers decided to engage more in off-farm activities even if they could not get high value long-term contracts, only short-term daily wage work. This strategy could help to achieve enough income in case of Jatropha failure.

As regards seasonal migration, we observed that, normally, after the agricultural season (October-January), the laborers (mostly landless, small and marginal farmers) used to migrate to the nearby cities (Chennai, Tiruppur or Bangalore) or to other rural areas of neighboring

[36] In a logit regression with fuel-Jatropha trade-off reported (Yes/No) as the dependent variable, schedule caste was a significant independent variable ($p<0.055$).

[37] The term '*coolie*' is applied to the class of daily wage workers. This term is often used pejoratively. In Tamil *kuli* means *'wages'* and in Hindi *qūlī* means '(day-)labourer'.

[38] In a logit regression with increasing off-farm activities (Yes/No) as the dependent variable, the landholding (being small or marginal farmer (Yes/No) was a significant independent variable ($p<0.041$).

Kerala state to work as daily wage laborers. Previously, when they were planting short-term crops they had to stay in the village to guard and irrigate the crops. Now, after Jatropha was introduced, in case of total substitution they were leaving the management of the crop especially in the second and third year, staying in the towns for longer periods.

Jatropha cannot be, in the current context, the only cause of households' increase in off-farm activities and the consequent reduction of their agricultural work. However, groundnut is also a commercially oriented short-term crop whose by-products and direct contribution as food kept by the household allows greater complementary with the wage labor in agriculture, building, and manufacturing. Jatropha does not leave by-products for the household and requires a long gestation period with no income from the land. Good maintenance of the crop requires the household to dedicate labor to such activity. However, there is in the meantime the need to get income from other sources to compensate for the long period with no productivity from the land. There is then a trade-off as to whether the household prefers to allocate labor to improve Jatropha performance or to ensure income from off-farm activity while the crop is still not mature.

It is possible that the low labor requirement of Jatropha, if accompanied by high returns from it, will lead to a double dividend through increased returns from off-farm work. But as of now, the increased income (coming from low-value work) is probably used for compensating for the loss on other livelihood dimensions (food, fuel, fodder). However, from a "strong sustainability" approach, all trade-offs in several livelihood dimensions cannot be necessarily reduced to a single measure. The reduction of crop, income and food sources diversity could lead small farmers to be more vulnerable to changes and fluctuations.

2.8 Causes and consequences of Jatropha failure: the politics of Jatropha promotion, marginalization and latent conflict

In this section, we discuss our findings interpreting them to find out causes and consequences of the Jatropha failure and its unevenly distributed impact on farmers' livelihood. First we start by analysing the potential causes of failure associated to broader politics of Jatropha promotion. Later we reflect on why these politics have possibly ignored distributional concerns, leading to marginalization and third and the least, we relate the Jatropha failure to the daily conflictive nature of rural livelihoods in a vulnerable water scarce area, such as Tamil Nadu.

The politics of Jatropha promotion

Company officials, in our interviews with them and even in newspaper articles[39], explained away the failure or poor performance of Jatropha in these districts as stemming from 'lack of required inputs' or 'inadequate management' by the farmers. But our analysis above shows that this bland assertion hides the failures of the 'pro-poor' and 'pro-wasteland' development benefits that promoters claim Jatropha to have. Our results cannot be explained simply in terms of farmers' incompetence, since even the best, big, irrigated farmers in Coimbatore are getting poor yields. While the crop experienced difficulties with regard to growth and yield due to the higher than expected need for irrigation and fertilizers, such difficult circumstances get

[39] Interview with AGNI-NET Biofuels Ltd. Manager in Pondicherry, 3 July 2008, and statements of Credit Carbon Farming (CCF) manager in Milmo and Wasley (2010)

reinforced by the lack of government involvement and the non-fulfillment of companies' promises in contract farming.

Government officials at the district level agree with the idea of Jatropha not being the most suitable crop for rural poor. However, they are guided by targets fixed at higher bureaucratic levels: 'We have to comply with the targets from the Central Government, even if we know that it is not a good crop, profitable for farmers'.[40] However, complying with the targets has not meant, in practice, ensuring that farmers will get assured markets and advice during the period of cultivation. The hard-sell and ambitious targets of the government promotion contrast with how the policy is implemented at farm level. During the official first year of program implementation (2007-2008) only 20% of the annual target was achieved (Government of Tamil Nadu, 2007b). Although the Government of Tamil Nadu was supposed to give 50% subsidies for saplings and drip irrigation, through companies' facilitation, no farmer received the latter subsidy and 16% did not receive the subsidized saplings. Contract farmers get a loan that should cover the long period of investment that Jatropha cultivation implies. In practice, companies were not giving the installments at the promised time and in some cases the loan did not arrive at all. As mentioned, the long gestation period makes it difficult to face the costs without proper financial resources. There is no income from the land for at least three to five years.

Facing this circumstance, 30% of the households were appealing to the locally called *kaymathu* (asking cash from the neighbors without interest) more than relying on *tandals*[41] or pawn brokers.[42] Seventy percent of them were small or marginal farmers. Even if farmers would get the required amount of credit and at the proper time, it is still very difficult for them to repay a loan without increasing their off-farm work due to the long time period with no income from agriculture. Given the already heavily indebted situation of Indian farmers, and the high input costs (if Jatropha is to have high yields), opting for Jatropha cultivation will lead to still greater indebtedness. Other cropping systems, such as groundnut cultivation rotated with cereals, require short-term credit only as the farmer harvests the crop in three months. This does not work with Jatropha. The abandonment by the companies reached its peak, in Thiruvannamalai, when the few that were able to get yields (23%) were not able to sell the produce to them. Why did companies step into biodiesel production, sign agreements with the government and contracts with farmers, but then not deliver the technical support and buyback that they had promised? The answer lies in the pro-investor, rather than pro-farmer and pro-poor, approach adopted by the TN government.

Tamil Nadu Biodiesel Policy set favorable conditions for industrial biodiesel processors. According to the policy, the oil extraction and transesterification have to be undertaken only by the biodiesel manufacturers. The need for extraction units with modern machinery make the local operators inefficient. Oil extraction by local operators leads to poor quality of raw oil and affects the conversion process and biodiesel standards (Government of Tamil Nadu, 2007d). Furthermore, it is argued that the detoxification of the cake to be used as fodder is

[40] Interview with Assistant Directorate of Agriculture in Thiruvannamalai, 21 May 2008.

[41] *Tandal* is a kind of broker who takes interest from the beginning, delivers some cash, and then asks weekly for a fixed constant part of the loan.

[42] The pawn broker gives some amount of cash after some assets are left as deposit. The asset is returned when the amount is repaid.

impossible at the local level and should be done by industrial processors, and the small-scale batch type of etherification plant cannot produce uniform and constant fuel standards to meet the BIS/Euro III norms. All by-products should be commercially valuable. Thus, the policy prioritizes the industry and 'defer[s] purchase and sales tax for a period of five years to the bio diesel industry to encourage and sustain the business being an agro industrial project involving farmers' interest'. The Tamil Nadu Industrial Policy (2007) has declared that Jatropha seeds will be exempted from purchase tax and Jatropha oil will be exempted from VAT for a period of 10 years from the date of commercial production. Industrial policy, as well, states that a 50% subsidy for planting material for Jatropha and other biofuel crops will be given and extends the subsidy available to the agro-processing industry to bio-fuel and bio-diesel extraction plants (Government of Tamil Nadu, 2007c).

Companies can enter into agrofuels ventures because of the long term subsidies and the pro-industrial environment of the policy. The big corporations and multinational companies have the ability to wait for some years to recover their investment due to their other multiple-sector benefits. Jatropha plantations are a small fraction of their operations as big corporate groups. Pro-industry rather than pro-farmer policies have created a framework in which companies have a priori substantially more to win than to lose, and even what they can lose is still a small fraction of what they gain. Their time frames are long and their risks are low. Meanwhile the risk and uncertainties for farmers are substantially higher and the timeframes are driven by the short-term needs of the poor. The real Jatropha policy seems to rely on big farmers and companies, and the 'pro-poor' rhetoric is acting as window dressing.

The uneven distribution of risks among producers and buyers allowed the companies to enter into agrofuels ventures, and benefit from the experience the small farmers have offered at their own cost. While big farmers were able to cope with the associated risks of a Jatropha trial, small and marginal farmers faced higher risks. The 'Promotion of Jatropha cultivation in Tamil Nadu' program is implemented by the TNAU Center for Excellence on Biofuels working in partnership with eleven biofuel companies. The research institutions have an important role on the development of new varieties and the generation of the fittest germplasm for Jatropha development. The R&D programmes capture a substantial amount of funds for biofuels development, to the extent that the companies are created that are exclusively dedicated to R&D, such as D1 Plant Science Ltd. The relation between companies and researchers is another fundamental point for understanding the distance between the enthusiasm for Jatropha promotion and its results in the ground. While for farmers the failure of Jatropha has become a loss, the R&D branches of the companies and the research institutions (i.e TNAU) learn from farmers' experiences, using them as multi-location trials from which to get growing and breeding material or to test which are the best varieties. For instance, D1 Mohan Bio Oils Ltd and Bannari Amman Group have been exchanging seeds at a considerable higher rate than the one paid to the farmers. Seeds collected from farmers have been provided to TNAU and Forest College Research Institute (FCRI).[43] After evaluating the unsuccessful experience of small-scale plantations managed by farmers, D1 Mohan Bio Oils Ltd. has withdrawn from Thiruvannamalai and has shifted down to the South to Tiruchirapalli district. Not finding it convenient to collect

[43] Interview with an ex field staff worker of D1 Mohan Bio Oils Ltd in Thiruvannamalai on 30 June 2008.

from farmers' scattered plots, it is in search of government wasteland to lease for planting Jatropha on a large-scale.[44]

The pro-industrial approach of the policies is clearly in contradiction with the 'pro-poor' rhetoric. None of the announced benefits have existed in the current implementation of contract farming. Although it failed, contract farming was designed to favor the export of the seeds from the rural areas to be crushed in industrial poles. Even if Jatropha performed better in agronomic terms, it would not benefit the poor. Apart from the already mentioned causes, there is a lack of clear agricultural policy measures to ensure that Jatropha will benefit the poor on a priority basis. If a newly introduced crop is remunerative to cultivate on previously uncultultivated land, then the crop is going to be even more remunerative on fertile farmland. Farmers with fertile land will get more profit than those with marginal (previously uncultivable) land. Subsidies for drip irrigation and land improvement and Minimum Support Price (MSP) that could only go to the poor or be used on marginal lands would be needed for the 'low-input' crop to really become 'pro-poor'.

Marginalization

The pro-industry approach of the policy presented above has added difficulties to the already existing low agro-economic performance of farmers' Jatropha cultivation. However, framing the next point in the discussion, around small farmers' marginalization as consequence of Jatropha failure, we raise here an important contradiction in the discourse in favor of Jatropha. Jatropha is presented by the government as a source for employment generation in rural areas. Meanwhile, companies convince farmers to adopt Jatropha as a good way to cope with the reduced availability of agricultural laborers. This contradiction seems to be ignoring the diversity among farmers and their livelihood strategies. The role that land and on-farm activities perform in a small or marginal farmers' (who are closer to being peasants) livelihood strategy is different from that of big farmers, who are closer to being capitalist cultivators.

Small or marginal farmers' households allocate a greater share of their own labor time to the land, while big farmers tend to hire wage laborers. The small or marginal holders are both agriculturalists and the labor force for other activities. Big farmers, meanwhile, have more access to capital and their diversification tends to come from managing small businesses. In the present scenario, a failed Jatropha crop contributes to changes in livelihood strategies that are increasingly based on off-farm activities. The increase in off-farm activities cannot be considered as prejudicial for farmers getting out of poverty per se. Becoming building and manufacturing workers increases the wages of small and marginal farmers. However, losing income and all the other non-monetary benefits coming from the land reduces the capacity of the small and marginal farmer to keep his or her own piece of the land. This process favors rural capitalists as it eliminates small peasants as competitors in agricultural production and transforms them into cheap labor which capitalists can employ (Kay, 2006). In the case of Jatropha, the land does not produce for a long period. Production, when it comes, is not substantially more remunerative than for other crops. Farmers lose farm income and the multiple benefits from other crops. While the big farmer can still maintain the income from the rest of the farm, the small and marginal landholder suffers more in proportion from a failed crop. He must resort to off-farm opportunities. Keeping to this strategy for the whole period of

[44] Ibid.

Jatropha maturation, and thereafter due to its failure, can potentially contribute to processes of increasingly permanent deagrarianisation (Bryceson et al., 2000), or proletarianization of small and marginal farmers. Jatropha also damages access to household produced food, increasing the need for money for market access to food.

Land and water uses and latent conflicts

Jatropha plantations in Thiruvannamalai and Coimbatore districts have failed to perform anywhere close to the hype and expectations raised by government agencies and private companies. To add insult to injury, companies have now abandoned the buyback contracts they had signed with the Jatropha farmers. Moreover, as seen above, Jatropha cultivation has different impacts for different sections of farmers. All these have led to various forms of tension and conflict.

Ecological distribution conflicts (Martinez-Alier, 2002) are usually in the form of tussles between the state or corporate entities and local communities, and take the form of public protests, movements, or agitations. It is possible, however, to think about environmental conflicts as being multi-level and more latent compare (Dahrendorf, 1958; Lukes, 2005 [1974]). Environmental conflicts may exist not just with a company but also within a community and within a household. They may take the form not of open agitation as much as hidden tensions and loss of trust. We observe a mixture of tension and open conflict at multiple levels in the case of Jatropha cultivation in Tamil Nadu.

At one level, some tensions and conflicts have emerged within households over what should be the response after the failure of Jatropha. Two joint families reportedly got trapped in a conflict over whether they should split the landholding in different parts for fathers and sons, thereby allowing each to decide for themselves about Jatropha cultivation, or should resort to the permanent migration of some disgruntled member.

Much greater conflict ensued between farmers and local promoters of Jatropha. Companies and NGOs promoting Jatropha contacted key individuals in the villages for helping them. These 'promoters' agreed to do not so much for money as for social recognition. But as soon as the crop failed, social recognition turned into scorn, as they were seen by the adopters as responsible for the loss in livelihoods[45].

At a third level, conflict is brewing between farmers (including promoters) and the private companies who had promoted Jatropha cultivation. The companies did not abide by promises of giving special loans for getting improved water infrastructure, income complements during gestation period (goats rearing or apiculture), and buying the produce at remunerative prices. Farmers responded both formally and informally. Formally, they lodged a collective protest at the Thiruvannamalai District Collectorate against D1 Mohan Bio Oils Ltd. But it generated no response, either from the government or from the company. Informally, there has been tension with local company staff posted in the region. But this anger could not find an outlet, because company staff was comprised of other villagers from the region. They were hired

[45] In Alattur village, in Thiruvannamalai, a handicapped villager was contacted by a woman who facilitated Women Self Help Groups of an NGO called SCOPE. He was convinced to plant Jatropha due to its low labour requirements. He helped the woman to promote Jatropha at village level. After the failure of Jatropha he has been scorned by several villagers than even beat him in some occasion.

temporarily and dropped off by companies when they abandoned their contracts. Indeed, some villagers employed by the companies did not get full wages from the companies either.

Finally, there is the potential conflict that may follow if Jatropha actually becomes remunerative and therefore widespread adoption takes place. Irrigation remains the key input for a profitable Jatropha cultivation. This has two implications. First, it automatically excludes the poorest farmers, the rainfed cultivators. Second, it increases demand for irrigation in a region where water is already scarce. (Janakarajan and Moench, 2006) have argued that degradation of groundwater resource base through over-extraction and pollution contributes to inequity, conflicts, competition and, above all, to indebtedness and poverty. The declining water tables, further promoted by policies providing free or highly subsidized electricity, force farmers to competitively dig deeper wells undermining the collective effort to manage common rain water harvesting systems (Reyes-García et al., 2011; Vaidyanathan, 2001). Although tank water property rights are unequal as well, groundwater extraction is in open access leading to overexploitation compromising intra and intergenerational equity. Besides, there are informal markets between well-owning farmers and non-well-owning farmers and, as water becomes increasingly scarce, dependency relations intensify with purchasers in an ever-weaker bargaining position. Jatropha, although presented as a crop that can be pro-poor and respond to water scarcity, is more part of the problem than the solution. Jatropha-induced conflicts at the household and village level can go hand-in-hand with the already existing conflicts over water access due to the crop water requirements and the differential nature of livelihood impacts.

2.9 Conclusions

This thesis chapter has tried to elucidate the main causes and consequences of Jatropha plantations' failure in Tamil Nadu through an interdisciplinary framework based on a political ecology approach. We analyzed the social construction of Jatropha plantations (as pro-wasteland and pro-poor) and its contrast with the uneven disruption that the crop has visited on farmers' livelihoods, reinforcing processes of marginalization. Furthermore, the interaction of the actual performance of Jatropha with already existing structural factors of rural Tamil Nadu's transformation would seem to push small and marginal farmers to proletarianise, accelerating land ownership concentration and deagrarianisation.

Through the case study of Jatropha plantations in Tamil Nadu we have tried to develop and illustrate how political ecology helps us to understand the politics of agrofuels and explain its boom. The original impulse came from an attempt to supply a new source of energy for transport given the increased social metabolism of the Indian economy in parallel to economic growth, and given the expectation that biofuels could substitute for fossil fuels and are 'carbon neutral'. At a more local level, as agrarian policy, Jatropha came together with 'pro-wasteland' (or pro-environment) and 'pro-poor' discourses because of its promotion of active engagement with small and marginal farmers in the so called 'wastelands', rather than through large-scale monocultures (such as the case of palm oil or soybean).

The unclear classification of 'wastelands' and the ambiguity of Indian agrofuel policies set up a framework that allows government and corporations to flexibly get available lands for agrofuel development. Under the guise of developing 'wastelands' there it is a unique economic rod of valuation that denies the multi-functionality of land use. The 'pro-poor' discourse linked to Jatropha presents the crop as multi-functional and suitable for all the diverse agro-climatic zones of India. Jatropha is small and marginal farmer friendly. It needs little water and labor. This discourse is used to legitimize the real implementation of the crop as contract farming, as with other commercial crops. The 'pro-poor' discourse is also used as a means of building 'consensus' that local rural development is compatible with growing agrofuels for industrial economic growth.

A political ecology approach, however, calls on the analyst to contrast the discourses at the national and state levels with the actual political processes and outcomes at local and regional levels that drive environmental change to be unevenly distributed.

The field agro-economic analysis of plantations' performance shows how Jatropha irrigation inputs were higher than expected, and the yield of the crop one-tenth of the expected according to research stations experiments.

The impacts on livelihood strategies showed how the crop was a poor fit with the ecological and socio-economic conditions of production in the study area. The conversion of the land to a monocrop of Jatropha suppressed crop diversity and eliminated the benefits of the multi-functionality of the other crops through the provision of food for self-consumption, fodder, firewood, and cash. The loss of diversity increased farmers' vulnerability and more severely affected small and marginal farmers. The long gestation period of Jatropha – three to five years – makes the crop unsuitable for farmers' temporal frameworks, in which short-term cash rotation allows them to cope with fluctuations in socio-environmental conditions of production and with the short-term needs recurrent in conditions of poverty. The high credit requirement generated dependency. The non-fulfillment of farming contracts, due to the lack of proper advice and the failure to provide loans at the expected and needed times, combined with the agronomic and ecological factors to drive the failure of Jatropha plantations. While the failure of Jatropha has currently created conflicts between farmers, biodiesel companies and their promoters within the villages, the water demand of Jatropha and the uneven distribution of the gains from and livelihood impacts of the crop can trigger or exacerbate the conflicts over water and resource access between farmers.

Political ecology helps to analyze the dynamics of knowledge at local levels, in particular how the introduction of a new crop that had not been well studied was shaped by uneven relations of knowledge transfer in which farmers depend on companies not only for growing material but also for technical expertise. Farmers then supplied new knowledge free of charge to companies, at the cost of crop failure. In a political ecology analysis the uneven distribution of risks and uncertainties and the timeframes of economic processes engaged in by different actors are very helpful for understanding actors' interactions and their final outcomes. We contrasted the local farm reality to the motivation of companies, which are driven by generous subsidies in the industrial side of the policy. Companies and government have low risk, high incentives, longer time-frames, and broader options and strategies for their own reproduction. Farmers have high risk and high incentives but are very much conditioned by their limited room for action and agency and their short-term timeframes and narrowed options for survival. Such circumstances allowed companies to benefit from the experiences of small farmers as part of their experiments to generate better varieties of the crop with higher yield and oil content. Companies can wait and can afford the failure of the current model of contract farming and the low performance of the varieties of Jatropha cultivated presently. Farmers, however, require immediate success with what is being implemented currently.

The political ecology analysis of Jatropha plantations has allowed us to reveal the incongruence of the approach for small-holders. It was too good to be true and this is borne out by the fact that only rich farmers are actually able to adopt it (if at all). In the current context of agrarian crisis, further research is needed to understand the long term consequences of Jatropha promotion in terms of proletarianization or deagrarianisation. Time use surveys of small and marginal farmers (adopting Jatropha and not adopting Jatropha) would have to be collected during several years to see the evolution of household land-time budget decisions (Grunbuhel and Schandl, 2005). This information will have to be contextualized within the labor dynamics and the political economy of the region. Interviews with big farmers, landless workers, and building and manufacturing entrepreneurs would help in conducting the research.

The current experience can then have implications for future agrofuel developments and for renewable energy and rural development policies in India and other parts of the World. On the one hand, it can push Jatropha promoters to prioritize the development of Jatropha on a large scale through company-owned block plantations in government ‘wasteland’ or enclosed peasant or pastoralist lands, with associated irrigation infrastructures development to ensure its better performance. While the ‘pro-poor’ or ‘pro-farmer’ model is not performing, the large-scale cultivation could become economically profitable although its Energy Return On (Energy) Investment (EROI) would be probably very low (Lam et al., 2009). The energy input will have to increase in order to get more energy out. The current situation shows the contradiction of trying to get the 20% blending target through low input cultivation in marginal lands. The environmental and social impacts and the resource competition with food production will be still in place, and even increase. On the other hand, the current experience can be used as a lesson to focus more on rural development based on small-scale decentralized renewable food and energy production for meeting local needs first.

3. Wind Farm Siting and Protected Areas in Catalonia: Planning Alternatives or Reproducing 'One-Dimensional Thinking'?[46]

Abstract

Wind energy is an emblem of sustainability with the potential to promote a qualitative alternative to current energy systems and nuclear options for CO_2 reduction. However, wind farm siting often conflicts with aspirations to conserve traditional landscapes and wildlife habitats. In this paper we adopt a Critical Theory perspective, informed by Herbert Marcuse`s work, to study the discourse concerning wind energy siting in Catalonia, Spain. We give particular attention to how tensions between potentially conflicting sustainability objectives are addressed and by whom. Based on a review of this siting discourse and the application of Marcuse's theory, we find that the Catalan wind energy siting discourse is both influenced by and reproducing what Marcuse referred to as the 'one-dimensional thinking' of technology as ideology: erasing the possibility of critical dialectical thought by subsuming the question of "what should be" under the question of "what is". This has implications both for how these conflicts are investigated and for the sustainability of decisions taken. We conclude that closer attention to the role of 'one-dimensional thinking' in wind energy siting discourses could improve not only the understanding of their logic but might also have the potential to help make them more democratic.

Keywords: *wind energy; protected areas; one-dimensional thinking; wicked problems; discourse analysis; post-normal science.*

3.1 Introduction

Renewable energy has become, in recent years, an emblem of sustainability—an icon of the much-anticipated new 'green economy'—and windmills and wind farms serve as one of its ideal types. Wind power is particularly attractive because it offers both a different basis for organizing energy supplies and a concrete alternative to the nuclear option for reducing anthropogenic CO_2 production. Advocating wind energy can be understood as part of a broader effort to liberate late-industrial political subjects from their dependence upon large scale, centralized (mainly nuclear and fossil fuel based) energy systems. Wind energy, which can be used on site or transferred to a central electricity grid, presents this subject with a chance to regain direct control of power production.

However, the dispersed, site-based character of wind energy production carries with it complications that highlight a basic, often underplayed aspect of sustainability problems: Suitable locations for wind farms can, and often do, conflict with other sustainability-oriented land use aspirations, such as the conservation of traditional landscapes and wildlife habitats. This type of clash between environmentalisms (Jessup, 2010; Warren et al., 2005) has been repeatedly observed in wind energy studies, where general agreement on the need to promote wind energy is often found to turn into conflict during implementation (Nadai and van der Horst, 2010).

Much attention has been given to public attitudes towards wind energy (Devine-Wright, 2005; Gipe, 1995; Pasqualetti, 2001) and the motives behind the opposition to wind farms (Pasqualetti, 2011). It is now generally agreed that these are not adequately explained by the

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Not In My Back Yard (NIMBY) concept (Devine-Wright, 2005; Wolsink, 2006, 2007) and that there is a need to study the associated planning and decision making process more closely, in order to better understand the origin and logic of these conflicts (Wolsink, 2007; Zografos and Martinez-Alier, 2009). Previous research has highlighted a tendency for wind energy siting policies to be framed around scientific arguments and disagreements about facts, prioritizing an instrumental type of rationality (Jessup, 2010; Zografos and Martinez-Alier, 2009). Here we pick up on that observation and endeavor to tease out its origins and implications by using a set of analytical categories developed with the help of theory drawn from Marcuse (2007[1964]) and Hajer (1995), which we use to examine the discourse concerning wind energy siting in Catalonia, Spain.

Following Marcuse, this tendency to rely only on facts can be understood as a de facto rejection of normative considerations that are not compatible with the "given state of affairs" (Marcuse, 2007[1964]:119). In Catalonia that "given state" is centralized electricity distribution and a heavy reliance on nuclear technology: An archetypical example of late-industrial technological rationality. Based on our review of the wind energy siting debate in the region over the past 30 years, we propose that this discourse is both influenced by and reproducing what Marcuse (2007[1964]) referred to as the 'one-dimensional thinking' of technology as ideology: Erasing the possibility of critical dialectical thought by subsuming the question of "what should be" under the question of "what is". The erosion of dialectical thought can be observed in this case through a dearth of value-based argumentation and a strong tendency for the discourse to be centered on fact-based propositions, concerning what is technically or scientifically appropriate.

We structure this paper as follows: In Section 2 we present our theoretical points of reference and our analytical framework; Section 3 then provides details of our research design and empirical methods; Section 4 presents a short history of the wind energy siting process in Catalonia and the results of a discourse analysis inspired by Hajer's concept of discourse coalitions (Hajer, 1995); in Section 5 we apply our analytical framework, classifying these discourse coalitions and the historical progression of the siting process according to *types of argumentation*; in Section 6 we then juxtapose the *types of argumentation* assigned to discourse coalitions with those assigned to the overall discourse on wind energy siting in Catalonia, in order to assess the influence and reproduction of "one-dimensional thinking"; in Section 7 we discuss our findings and in Section 8 we present our conclusions and some recommendations for future work.

3.2 Framing Complex "Wicked Problems": One-Dimensional Thinking and Discursive Closure

We propose that deciding where to site wind farms can be understood as what Rittel and Webber (1973) have called a "wicked problem", which is persistent, complex, and difficult or perhaps even impossible to solve. Such problems are presumed to arise in late-industrial societies; where straightforward planning problems have largely been resolved; those that remain unsolved are presumed to be so because they are embedded in the logic of how late-industrial society operates.

Here we find Hajer's approach to the study of such problems, which he describes as "the new environmental conflict", to be particularly helpful for guiding our work: it "should not be conceptualized as a conflict over a predefined unequivocal problem with competing actors pro and con, but is to be seen as a complex and continuous struggle over the definition and the meaning of the environmental problem itself" (Hajer, 1995:14). Bringing Hajer's insights to bear here, we explore how interactions between four key discourse coalitions, and their relationships to the overall debate, have led to some languages of valuation being imposed over others (Martinez-Alier, 2002).

One-Dimensional Thinking and Discursive Closure: "Types of Argumentation"

In order to apply this analysis we adopt a Critical Theory perspective centered on the concept of "one-dimensional thinking" (Marcuse, 2007[1964]). This enables us to consider systematically, how and to what end the wind energy siting discourse in Catalonia has developed over time and what type of discursive closure has been achieved.

One-dimensional thinking can be understood as a mode of reflection that erases the possibility of critical thought by subsuming the question of "what should be" under the question of "what is". Debate is confined to the dimension of "facts", the actuality or appearance of things, and debate about the dimension of "values", the potentiality or purpose of things, is suppressed or rejected outright (Marcuse, 2007[1964]: 119). We extract from Marcuse's works this one pivotal concept, as we find it shares many presumptions and descriptors with Rittel and Webber's idea of wicked problems (Farrell, 2011b).

Table 7. Four basic types of argumentation classified using Marcuse's concept of "one-dimensional thinking"

	Topic of the **Discourse**	
	Means *the procedures used to make wind mill siting decisions*	**Ends** *the layout of wind mill siting: where, what kind/number/density*
Realm of **Justification**		
Facts-based Arguments: *concerned with the question of "what is"*	**Facts-Means** *Fact-based arguments concerning the means for reaching end results*	**Facts-Ends** *Fact-based arguments concerning end results*
Values-based Arguments: *concerned with the question of "what should be"*	**Values-Means** *Value-based arguments concerning the means for reaching end results*	**Values-Ends** *Value-based arguments concerning end results*

The analytical framework presented in Table 1 is informed both by our readings of Marcuse, from which we draw the realm of justification categories "facts-based" and "values-based" arguments, and by the data that we collected in the field, where we found two basic standpoints concerning the topic of the discourse: (1) how to make decisions about wind farm siting, which we here call "means" and (2) what these decisions should be, which we here call "ends"[47]. Juxtaposing these two axes provides us with four possible *types of argumentation*: (1) Values-Ends—arguments concerning the end result of where and according to what criteria wind mills are located, based on justifications that reflect social values and desires such as a moral imperative to protect the natural environment; (2) Facts-Ends—end result oriented arguments based on technical criteria, such as wind speeds, and/or compatibility with the status quo, e.g. grid connections; (3) Values-Means—value-based arguments concerning the means to be used for reaching decisions about end results, i.e. regarding desires and preferences for how the discourse should be organized, including for example demands for fairness and democracy; and (4) Facts-Means—fact-based arguments concerning how decisions about end results should be reached, i.e. justifications based on the technical characteristics of the problem and/or the status quo with regard to established siting procedures.

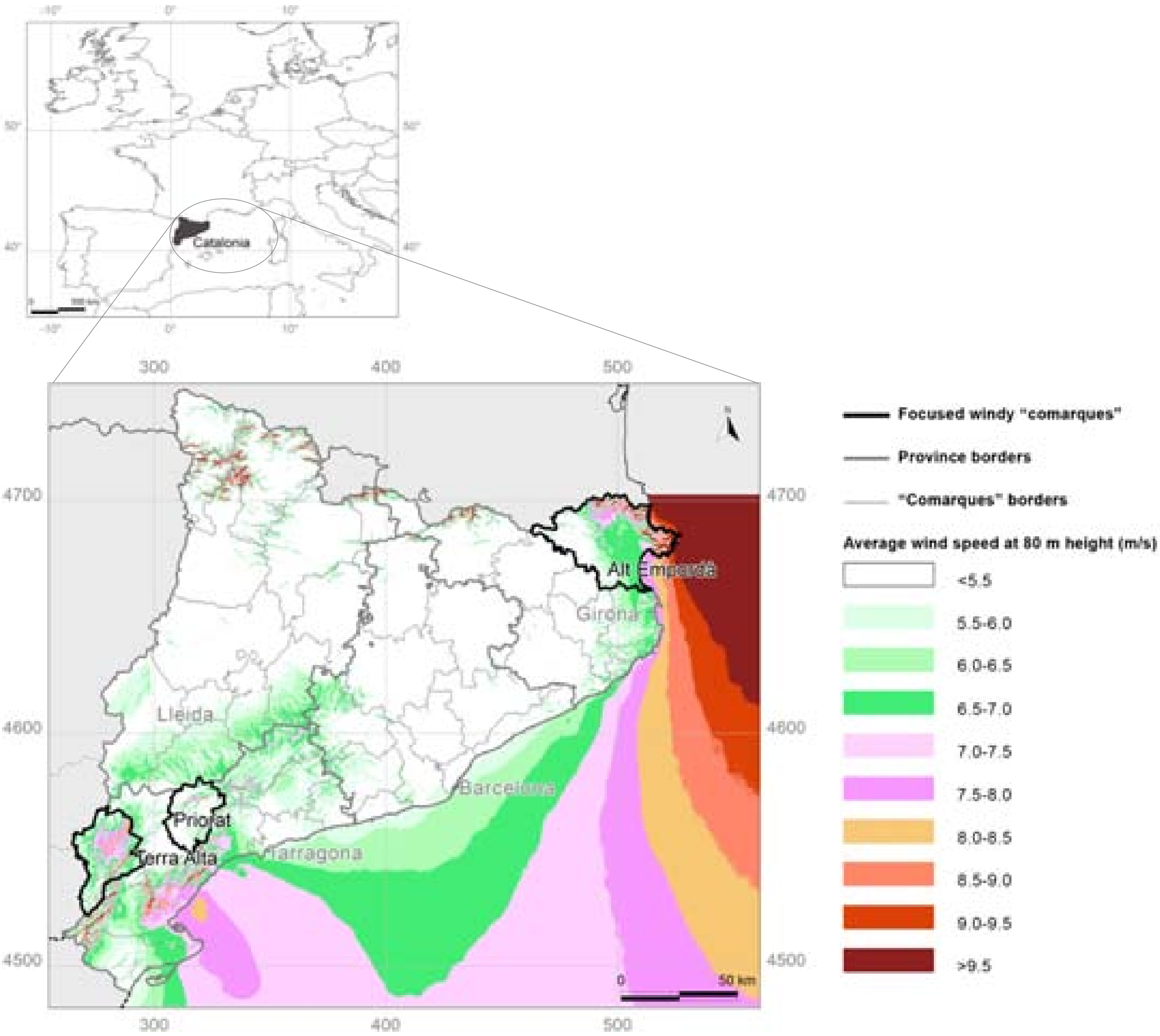
3.3 Research Design and Methodology

The research reported here is based on data collected in the form of a case study, as described by Yin (2003), targeting key affected localities, in order to build a general picture of the wind energy siting debate across Catalonia. Wind intensity in the study region is concentrated in two exceptionally strong wind corridors: One to the south, coming down from the southern extreme of the Catalanides Mountains, in Tarragona, and the other at the northeastern extreme of the region, where the Catalanides end and the Pyrenees begin (see Figure 3). Although the first wind farm in Catalonia was close to Costa Brava, it was dismantled in August 2007 following adoption of the "Special Plan for the protection of the environment and landscape of the Natural Park of Cap de Creus" ("Pla especial de protecció del medi natural i el paisatge del Parc Natural del Cap de Creus"), which forbid wind farms in the Natural Park and therefore also the renovation of this wind farm, which had, by that time, become obsolete (GENCAT, 2006). At the present time, all of the operating wind farms in Catalonia are located in the south corridor. Considering this skewed distribution of wind resources, we visited several key wind farm siting conflict areas in various *comarques*[48] located both throughout the southern (especially Priorat and Terra Alta) and northern (Alt Empordà) high-wind regions of Catalonia (see Figure 3). Criteria used to choose which siting areas to study were: the presence of social mobilization; the importance given to the case by both the media and gray documentation; and either the relatively high (Terra Alta) or low (Empordà and Priorat) degree of wind farm siting projects permitted and constructed in the area. In addition, wind farm projects identified either by the media or respondents as marking turning points in the wind energy siting discourse were studied, regardless of their location in Catalonia.

[47] We are indebted to Alain Nadaï and Olivier Labussière for suggesting that we use the terms Means and Ends here when commenting on an earlier draft of this text, which was presented at Energy, Territory and the Socio-technical (EST), Seminar sery celebrated in the Centre International de Recherche sur l'Environnement et le Développement (CIRED), Paris 25 June 2012.

[48] A "comarca" is a territorial-administrative division one level below province and one level above municipality; roughly equal to the British "county".

Figure 3 Situation and Wind Maps of Catalonia. **Sources:** (ICC 2012, DIVA-GIS[49], GENCAT 2004)



Methods of data collection included participant observation, informal interviews and semi-structured interviews, which were conducted with the aim of identifying the key elements in dispute. Local civil servants, local politicians, landowners in favor of wind farm development and representatives of local community platforms opposing the current siting policies were interviewed. We also conducted a second phase of semi-structured interviews with civil servants in the Catalan Department of Environment, environmentalist non-governmental organizations (NGOs) (including both conservationist-territorially focused and generalists pro-wind NGOs), representatives of the Catalan Institute for Energy (ICAEN), environmental consultants, members of the Catalan parliament, wind entrepreneurs and representatives of the wind industry lobby association Eoliccat. In total 68 interviews were conducted.

Interview data was examined using qualitative content analysis, as described by Bryman (Bryman, 2008). We identified key topics highlighted by interviewees and their perceptions of the relationships between these topics. Interview content was then compared and contrasted

[49] The world map with countries administrative boundaries to elaborate the situation map is extracted from DIVA-GIS. Available online: http://www.diva-gis.org/ (accessed on date 08 July 2012).

with relevant legal, gray and scientific documents on the topic. Further analysis of the collected data was then carried out through a discourse analysis inspired by Hajer (1995), with the aim of identifying "social discourse] coalitions on specific meanings" (Hajer, 1995). Here we understand discourse to mean "a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities" (Hajer, 1995:.44). We presume that discourse coalitions are not necessarily based on formal alliances and that actors may be coordinating their arguments even in the absence of conscious intentions to do so. In order to identify discourse coalitions we looked first for story-lines—"narratives on social reality through which elements from many different domains are combined and that provide actors with a set of symbolic references that suggest a common understanding" (Hajer, 1995: 62) and then identified the actors participating in their construction, based on the content of their interventions and the character of their actions (Hajer, 1995: 65).

We then applied the analytical framework outlined above by assigning *types of argumentation* to the statements comprising the storylines we had observed and to each of the four planning phases identified in our review of the history of the overall discourse. In a final stage we examined to what degree the *types of argumentation* employed by the various discourse coalitions were, or were not compatible with the *types of argumentation* found to be dominant in each of the four planning phases.

3.4 The Planning Process of Wind Energy Siting in Catalonia: Phases and Discourse Coalitions

Catalonia, in the northeast of Spain, is one of the country's most industrialized regions and consumes nearly 20% of the country's electricity, placing it first among the regions in electricity consumption (REE, 2010). The majority of the region's electricity (56%) comes from nuclear power, with three of Spain's eight nuclear power plants located in the region. In 2010 renewable energy (comprised almost entirely of wind power) covered 3% of the region's electricity demand, in contrast to 16% of Spain's electricity demand being covered by wind energy in that same year and coverage rates between 25 and 40% in other Autonomous Communities such as Galicia, Castilla-La Mancha, Castilla León, Navarra and La Rioja (REE, 2010). Power plant siting is heavily skewed towards the south. Energy consumption, by contrast, has always been highest in the central urban and northern touristic regions and anti-nuclear protests in the south have consistently included reference to this inequality.

The existence of two strong wind corridors (see Section 3 and Figure 3) and an uneven distribution of operating wind farms skewed towards the south have raised new political concerns that the existing uneven development is being reinforced through the locating of new infrastructure in the south.

Both wind corridors overlap with regions of special environmental status. The southern corridor, in Tarragona, overlaps with the habitat of 8% of Europe's endangered Bonelli's Eagle (Aquila fasciata) population (BirdLife-International, 2004; Bosch et al., 2010; Del Moral, 2006; European Comission, 1991; Parellada, 2012; Zozaya, 2007), 80% of which (920–1100 pairs (BirdLife-International, 2004)) is concentrated on the Iberian Peninsula, where this raptor has suffered an average decline of 50% over the last three Eagle generations (Bosch et al., 2010). Wind corridors also overlap with areas of touristic importance especially in the north, including the picturesque landscape of the foothills of the Pyrenees, which run along Spain's world famous Costa Brava. In spite of having been one of the first regions to experiment with wind energy, with Spain's first modern wind farms connected to the grid near Girona some thirty years ago, Catalonia currently has only 4.5% of the country's total installed capacity (AEE, 2011).

Wind Energy Siting Planning Phases

Looking back over the history of wind energy siting in Catalonia, we have identified four distinct planning phases, which we use to help orient our discussion. Summaries of each phase are presented in Table 2, followed by a brief overview of how the overall discourse has progressed over time (detailed information of each phase can be found in Annexes IV (descriptive) and VI (analytical)).

The first phase of modern wind power development in the region, starting in the late 1970s, was initially backed by the government of the Autonomous Community of Catalonia (the Catalan Government). Between 1990 and 1999 the wind turbine manufacturing cooperative Ecotècnia, the private power company Endesa, various local authorities, the Catalan Government and the Spanish Ministry of Energy and Industry joined together to create public limited companies for five different projects. In 1998, a first attempt was made to formalize planning, when a Director's Plan for Wind Farms was adopted. This plan identified 75 sites as technically suitable for wind energy generation, with 69% of this potential capacity located in natural protected areas. Liberalization and tariff regulation introduced in 1997 (Ley 54/1997 (BOE, 1997)) provided incentives for private wind farm development and hundreds of projects entered into the permitting process, mainly taking the form of bilateral agreements between wind promoters and local councils. There is no clear and transparent public report with the exact number of projects of this period. However, interviews revealed that they were on the order of magnitude of hundreds: i.e. between 80 and 400 projects (see also Annex IV for more details). The contents of these agreements were not regulated and public review of these agreements was not conducted.

Table 8. Phases of the Wind Energy Siting Debate in Catalonia: Summary with Main Events.

Phase I: Wind mills as new wizard players (1978–1999)
Key events and projects: - First wind studies (1978–1995) - Pioneer non-commercial (Garriguella-Vilopriu, 1984) and commercial (five farms from 1990–1997) projects Regulatory-planning instruments: - Ley 54/1997 Sector Eléctrico (liberalization and regulation of "special generation" of electricity) (BOE, 1997). - Pla Director de Parcs eòlics de Catalunya for 1997–2010 established (first regional plan for the siting of wind farms in Catalonia) (GENCAT, 1998).

Table 8. Cont.

Phase II. Political fight around values (1999–2003)
Key events and projects: - Local platforms constitution (1999) and mobilization in "Terres de l'Ebre" (PHN and ENRON, 2000) - Debate and public consultation regarding the wind energy environmental restriction siting map (ME2002) (2000–2002) Regulatory-planning instruments: - Decret 174/2002, d'11 de juny, regulador de la implantació de l'energia eòlica a Catalunya (first wind farm siting procedure (GENCAT, 2002b) - Mapa d'implantació ambiental de l'energia eòlica a Catalunya 2002 (ME2002) (environmental zoning map for the location of wind energy in Catalonia: red (incompatible), yellow (Environmental Impact Assessment (EIA) conditioned) and white (compatible)) (GENCAT, 2002c).
Phase III. Battle between "facts": "rational siting" (2003–2010)
Key events and projects: - New left coalition government elected in Catalonia (2003) - Moratorium on new wind farm projects (2005) (GENCAT, 2005a). - ZDP map government agreement (Acord 108/2010) (GENCAT, 2010a). Regulatory-planning instruments: - Pla de l'Energia de Catalunya 2006–2015 (new energy planning for the region: 3500 MW target for wind energy in 2015) (GENCAT, 2005b) - Natura 2000 Network (draft 2004, final 2006) - Decret 147/2009 Siting procedures for wind farms and photovoltaics and ZDP (Priority Development Zones) regulation (GENCAT, 2009)
Phase IV. Reasserting "values"? (2010–2012)
Key events and projects: - Temporary court restraining order barring the use of the ZDPs map (2011) - Court sentences resulting from Phase II (2011–2012) Regulatory-planning instruments: - Real Decreto Ley 1/2012 (removal of the feed-in tariff by the government of Spain) (BOE, 2012).

In 1999, the first local platforms opposing wind farm sitings began to take shape in the southern comarques of Priorat and Terra Alta. Shortly thereafter, at the close of 2000, the Catalan Government published a draft zoning map intended to regulate conflicts between natural protected areas and wind energy development. Both wind promoters and environmentalist critiqued the map, and a group of environmental NGOs, lead by the Group for the Study and Protection of the Ecosystems of the Countryside (GEPEC: Grup d'Estudi i Protecció dels Ecosistemes del Camp), prepared an alternative map which proposed an extension to the zoning in the draft and identified recommended and tolerable siting options (GEPEC-AEEC, 2000), (see Figure IV.1 in Annex IV). At the same time opposition arose to two other infrastructure projects in “Terres de l'Ebre”[50]: The Plan Hidrológico Nacional (PHN), which was a Spanish government initiative to redirect water from the Ebro River to other regions; and a proposed privately operated gas fired power plant. In response, the Catalan Parliament cancelled its support for both projects and decided to revise the proposed wind energy zoning map. However, efforts to achieve a definitive version of the map were widely critiqued, both by wind power promoters and by conservationists. From both sides, the main critique was that the map must set “clear rules of the game” and zoning rules must define the procedures to be followed in each zone, without leaving discretionary decisions to be taken in the late stages of siting. Local platforms, for their part, were critical of a grandfathering clause that allowed projects located in restricted zones to proceed if they had been started or publicly debated before the new zoning rules came into effect.

In 2003 a new government was elected in Catalonia, and it was decided that wind farm planning would be rationalized, coordination improved and wind energy targets revised upward to 3500 MW by 2015 (GENCAT, 2005b). The new government’s actions included a moratorium on new siting applications and a review of existing projects, with the aims of ensuring good access to wind resources and reducing the environmental impacts of planned turbines. This rationalization effort was also intended to lead to agreements with Red Eléctrica, the transmission system operator (TSO), regarding the boosting of grid connectivity. During this planning phase, installed capacity increased by a factor of ten, from roughly 100 MW in 2005 to nearly 1000 MW in 2010. At the end of this phase, a new permitting procedure (Decree 147/2009 (GENCAT, 2009)), based on the auctioning of rights to build in designated Priority Development Zones (ZDP in Catalan), was established in an effort to rationalize and speed up siting. Catalonia’s Natura 2000 Network (see Figure. VI.2 in Annex VI) was also proposed, debated and finalized during this planning phase.

Following final approval of the ZDP map in 2010, conservationist, local residents in affected areas and even some members of the Catalan Government contested in some cases its final results and in others the process used to reach them. In March 2011 an order temporarily blocking the use of the ZDP map was issued by the superior court of Catalonia (TSJC, 2011a). Subsequent court disputes concerning the regulations for providing permitted sites with suitable access to grid connections have been resolved in favor of wind promoters (TSJC, 2011b). In addition, since the start of 2011, several pending court cases relating to decisions taken between 1999 and 2010 have also been decided in favor of local residents and conservationists (Europa-Press, 2012; García, 2012; Pérez-Pons, 2012; SJCA, 2011; TSJC, 2011c, 2012a, 2012b).

Discourse Coalitions around Wind Energy Siting

We have identified a series of story-lines contributing to the overall Catalan discourse on wind energy siting, around which four discourse coalitions can be understood to have coalesced. Figure 4 shows the actor composition of each coalition, with areas of overlap providing a space for actors with ambiguous positions. The closer an actor is to an area of

[50] “Terres de l'Ebre” comprises the four meridional comarques of Catalunya (Baix Ebre, Montsià, Terra Alta i Ribera d'Ebre). The four comarques of “Terres de l'Ebre” simultaneously belong to the Tarragona Province.

overlap, the more ambiguous their position. Below we provide a brief overview of the composition of each coalition, with further details to be found in Annex V.

Figure 4 Discourse coalitions around wind energy siting. **Source:** own elaboration inspired from (Mander, 2008; Stevenson, 2009)

Building a sustainable industry—bringing rural development opportunities to Catalonia: The wind power industry is a flourishing and environmentally friendly economic growth sector that achieved a worldwide average annual growth rate of 20.5% from 2000 to 2005 (Szarka, 2007); it constitutes a development opportunity for Catalonia.

Here the wind power industry association of Catalonia, Eoliccat, emphasizes the contribution wind energy can make to society and the environment. Eoliccat is the most visible actor in this coalition, with civil servants from the Catalan Institute of Energy (ICAEN), local politicians and some parliamentarians also highlighting these perceived benefits.

100% renewables now! Stop climate change; shut down nuclear power: Urgent action is needed to stabilize greenhouse gas emissions in order to avoid the most dramatic consequences of climate change by stabilizing atmospheric CO_2 concentrations at between 445 and 490 ppm, and this should be done without resorting to other polluting options, such as nuclear power.

Fighting against climate change and its causes (Metz, 2007; Moomow et al., 2011; NOAA, 2010), perceived as excessive reliance on polluting power sources, is the main thread of this storyline, which also gathers together a strong historical set of anti-nuclear claims. The coalition is comprised mainly of pro-wind environmentalist NGOs associated with the campaign Tanquem les Nuclears—Nova Cultura de l'Energia (Shut down nuclear power stations: New Energy Culture).

Protecting the landscape—retaining the locals` control: Landscape is a common good with a symbolic importance; it contains both material and inscribed cultural values that are reflected in how it has been transformed (Nogué, 2005); it is part of a community's identity and a basis for securing one's livelihood.

Wind farms are called "wind power stations" in this discourse, in an effort to highlight their industrial character and link them to the larger issue of power supply based inequalities in the region. This story-line brings together small resistance platforms, mostly in the south, composed of residents in areas targeted for development, intellectuals and researchers working on landscape protection and also some civil servants from the territorial planning and public works departments of the Catalan Government.

Protecting biodiversity—wind farms cannot go everywhere! The Bonelli's Eagle is threatened by wind farm development (European Commission, 2010; Parellada, 2012); biodiversity conservation should not be negatively affected by wind energy.

Here the Bonelli's Eagle (Aquila fasciata) of southern Catalonia, which is affected by modern wind mills mainly through habitat displacement (European Commission, 2010; Parellada, 2012) serves as an emblematic rallying point[51] (Hajer, 1995: 20) for a complex set of interventions concerning environmental conservation in Catalonia. This storyline, although nuanced by controversies, brings together a broad array of environmentalist and conservationist NGOs, most of which belong to the "Ecologistes de Catalunya" federation, environmental consultants working on biodiversity issues and technicians from two specialist divisions in the Catalan Government's Department of Environment.

3.5 Types of Argumentations in Discourse Coalitions and Planning Phases

The discourse coalitions we found are similar to those found in other studies, as is the general tendency for the argumentative language to become technical and rational (Jessup, 2010; Mander, 2008; Stevenson, 2009; Szarka, 2004; Woods, 2003; Zografos and Martinez-Alier, 2009). By employing the analytical framework presented in Section 2, regarding *types of argumentation*, we are, over time, able to systematically analyze how this tendency has manifested, both within each of the respective discourse coalitions and across them. We do this first by considering which of the four *types of argumentation* presented in Table 1 (i.e. Facts-Ends; Facts-Means; Values-Ends; Values-Means) are being used by which coalitions, and then by looking at how they manifest in the overall discourse over time, across the four planning phases (further detail about the content of this section can be found in Annexes VI and VII).

[51] Following Hajer, we start from the assumption that "the environmental problematique is hardly ever discussed in its full complexity ('in the round'). Environmental discourse tends to be dominated by specific emblems: issues that dominate the perception of the ecological dilemma in a specific period. [...] The political importance of emblems in environmental discourse is that they mobilize biases in and out of the environmental debate. They are the issues in terms of which people understand the larger whole of the environmental condition. As such, they thus effectively function as a metaphor or, to be more precise, as a metonym (mistaking a part for the whole)". Thus, every story-line has its own emblems. (Hajer 1995: 20)

Types of Argumentation Observed in the Discourse Coalitions

Starting again with the "Building a sustainable industry" storyline, we find numerous key Values-Ends type interventions, concerning what should be the purpose of wind energy: to reduce CO_2 emissions; to reduce dependency on foreign energy suppliers; to reactivate the economy by providing income and employment; to stop rural-to-urban migration (Deloitte, 2010; GEE, 2006). However we also found numerous Facts-Ends interventions: Global impacts are more important than local ones, which are reversible; landscape claims are "subjective"; the Bonelli's Eagle is protected by other compensatory measures; government support is required to make investment attractive. Interventions regarding what means are required for reaching these ends are consistently formulated in terms of facts and the status quo (Fact-Means): Regulation is required to ensure stability; permitting procedures must be fast and simple to ensure reliable returns on investments; planning and siting are technical matters to be guided by expert knowledge.

Moving next to the "100% renewables now!" storyline we find that one Values-Ends position—there is a moral imperative to urgently establish a 100% renewable electrical system—serves as this coalition's central rallying point. More generally, however, the coalition relies on a reasonably balanced mix of Facts-Ends and Facts-Means interventions, arguing, for example, that there should be no limits on wind energy expansion because it is the most mature renewable technology and its environmental impacts are very low when compared with other technologies (IDAE, 2000; Morron, 2005) (Facts-Means); and that the limited effectiveness of demand reduction initiatives, combined with a basic social need for energy, make wind power a necessity (Facts-Ends). Wind energy siting is viewed as a technical problem and objective scientific knowledge is presumed to be the appropriate foundation for addressing technical problems (Facts-Means). On this basis, it is argued that increased public participation in wind energy siting should be based on objective, scientifically contrasted arguments (Values-Means): (1) because the only important impact is on birds and this is a technical problem that must be addressed on a case by case basis (Facts-Means) and (2) because the dynamic character of landscape transformations means that all visual impact concerns are subjective and reversible (Facts-Means).

The "Protecting the landscape" storyline is characterized by a large number of interventions concerning the equity and fairness of wind mill siting objectives (Values-Ends) and procedures (Values-Means). It is argued, for example, that wind energy siting should not reproduce the uneven geographical development of the current Catalan energy system (Values-Ends), that promoters should not take advantage of comparatively poor, remote rural communities (Values-Means), that the economic benefits from wind farms should be better and that they should be fairly distributed (Values-Ends), that diversification of supply and reduction of demand should lead to a distributed energy generation system (Alanne and Saari, 2006) where renewables serve a self-sufficiency agenda (Values-Ends) and that local public participation in siting decisions should come earlier in the process and have more influence (Values-Means). However, some fact-based interventions are also to be found in this discourse, particularly in the form of objections to direct local impacts such as night lighting, shadow flicker and noise pollution from the wind mills, concerns about the environmental effects of building new roads and power lines (Facts-Ends) and the need to tailor siting criteria to local situations in order to take into account cumulative impacts (Facts-Means).

Interventions contributing to the “Protecting biodiversity” storyline frequently refer to the moral imperative to protect Bonelli`s Eagle in particular and the under-valued biodiversity of Tarragona Province more generally[52] (Values-Ends). Here we also observed numerous fact-based arguments, claiming, for example, that wind energy development is incompatible with good management of special protected areas (Facts-Ends) and that environmental experts should be more involved in the early stages of strategic planning, in order to ensure that the most biologically important sites are the ones that receive protection (Facts-Means) (European Commission, 2010).

Types of Argumentation Observed in the Planning Phases

Since the beginning of the 80s the discursive topic of wind energy siting in Catalonia has been formulated, contested, negotiated and reformulated several times. In Section 4 we identified four discrete planning phases that allowed us to talk about how this discourse had developed over time. Here we combine that information with our analytical framework by considering which *types of argumentation* have served to shape the overall discourse during each phase.

Phase I: Wind mills as new wizard players (1978–1999) was characterized mainly by a lack of regulatory planning. Initially wind farms sites were selected based on the Facts-Ends criterion that they had a good availability of suitably strong winds. At the end of this phase, in 1997, the Director’s Plan for Wind Farms expanded the siting criteria to include connectivity to the electricity grid and attention to those special natural protected areas, as defined under Catalan law—i.e., national parks, natural places of national interest, reserves (integral and partial) and natural parks (DOGC, 1985)—that had already been established, thereby reinforcing the Facts-Ends orientation of the discourse. Environmental Impact Assessments (EIA), to be approved by the government on a case by case basis, were designated to be the appropriate way to ensure compatibility between wind energy siting and natural protected areas (Facts-Means). Values-based arguments were articulated mainly in terms of ends, with wind energy touted as an economic and environmental win/win solution, and bilateral siting agreements between companies and local councils were treated as a mere technical matter (Facts-Means).

Phase II: Political fight around values (1999–2003) was characterized by the expression of values, both with regard to how the siting processes should operate (Means) and what the final results should be (Ends). Values-Ends arguments were advanced mainly from within the “Protecting the landscape” discourse coalition, where concerns relating to the fairness of site distribution were raised, and the “Protecting Biodiversity” coalition, where concerns were raised that biodiversity protection should not take a back seat to development. This highly political (Values-Ends) discussion, which eventually reached the regional Parliament, led to the Facts-Means solution of a wind farm siting map designed to provide technical information about how to coordinate site development and nature protection. From that point forward siting was cast as a mainly technical problem and actors were required to formulate their opposition to siting decisions using facts-based *types of argumentation*.

[52] A hint at the under-valued biodiversity in Tarragona is illustrated by highlighting that two out of the three Natural Parks in the Tarragona province were declared in the beginning of 2000s, in 2001 (“Els Ports”) and 2002 (“Serra del Montsant”). The Delta de l'Ebre Natural Park was declared in 1983. “Els Ports” and “Serra del Montsant” were declared after the wind farm siting conflicts arrived.

Phase III: Battle between "facts": "rational siting" (2003–2010), which was ushered in with the finalization of the siting map mentioned above, was dominated by discussions concerned with finding suitable places to locate wind farms. This pushed contentious value-based arguments to the side and sped up the siting process, ensuring a substantial growth of installed capacity, as compared to the two previous phases. The conversion of value concerns raised in the previous phase into facts-based objective criteria was considered to be both possible and appropriate. Ensuring that wind energy would be developed in all those areas with suitable wind resource was seen as a way to simultaneously correct the unbalanced distribution of installed capacity, which was skewed toward the south, and to meet steadily increasing production targets. Value based interventions regarding the need for territorial consensus (Values-Means) and the need to cancel permits for projects located in some natural protected areas (Values-Ends) were criticized as obstructive (Cerrillo, 2010). The inclusion of criteria relating to visual impact on the landscape (Values-Means), though Decree 147/2009 (GENCAT, 2009), was contested by both the "100% renewables now!" and the "Building a sustainable industry" coalitions, who argued against what they saw as the imposition of subjective concerns onto an objective planning process. In contrast, both of these coalitions were able to use fact-based arguments to reassert their original value-based positions, by talking about the density of sites required to meet installed capacity targets (Facts-Ends) and the importance of speeding up the siting process to ensure their economic viability (Facts-Means). In the end, the Catalan Government's Facts-Means based approach of designating Priority Development Zones, which had served as the main discursive object of this planning phase, was finally adopted in 2010 (GENCAT, 2010a).

Phase IV: Reasserting "values"? (2010–2012) has been characterized, so far, mainly by political stalemate and a shower of court decisions regarding failures to comply with the legal status quo during earlier planning phases. Following Marcuse, these court decisions can be understood as fact-based interventions, where the referent is not "what should be" but rather "what is": in this case, what is the law. The most influential intervention of this phase has been the Fact-Means superior court decision to temporarily prohibit the use of the Priority Development Zone map. While this, and a series of other decisions against several individual sitings, have opened up an opportunity for value-based interventions to be reintroduced into the discourse, so far there have been only a few marginal interventions like this, coming from the "Protecting the landscape" coalition.

3.6 Reproducing 'One-Dimensional Thinking'?: Comparing Types of Argumentation of Phases and Discourse Coalitions

By juxtaposing our preceding analyses of storylines and planning phases, we can now evaluate the degree of discursive compatibility between each discourse coalition and each progressive phase of the overall wind farm siting process. As shown in Table 3, we use a simple four value ordinal scale to measure this compatibility and a simple weighting system of 0, 1, 2, or 3 *'s to indicate the degree of emphasis given to each type of argumentation within each discourse coalition. The dominant *types of argumentation* observed in each of the planning phase are listed to the right and the composition of each discourse, to the left. These qualitative indicators are based on the data reported in Annexes VI and VII.

This historically contextualized representation of how the interactions between the four discourse coalitions and the overall site planning discourse have changed over time allows us to address our main proposition: that technology as ideology has influenced how the Catalan wind farm siting discourse is developing. This influence has led to the suppression of value-based arguments in favor of fact-based ones that are compatible with "one-dimensional thinking".

As indicated above, we found that Phase I of the planning discourse—"Wind mills as new wizard players"—was dominated by a Facts-Ends type of argumentation advanced mainly by the "Building a sustainable industry" coalition. During this first phase the "Building a sustainable industry" coalition had a strong compatibility with the prevalent type of argumentation as did the "100% renewables now!" coalition. "Protecting biodiversity" was not actively involved in the discourse during Phase I, arriving first during Phase II, when impacts on the Bonelli`s Eagle were detected. However, this coalition had a moderate compatibility with the Facts-Ends orientation of Phase I, which can be understood to have created opportunities for it to collaborate with the first two in pulling the overall discourse back toward a facts basis in Phase III. Similarly, many of the value-based arguments of the "Building a sustainable industry" coalition were easily converted into facts based ones (MW targets and selection of the most efficient sites) in later phases. The "Protecting the landscape" coalition, which came about as a response to the unregulated siting that took place during Phase I, not surprisingly, was found to employ *types of argumentation* that were not compatible with the prevalent discourse of that Phase.

Table 9. Juxtaposition of types of argumentation in Planning Phases and Discourse Coalitions.

					Planning Phases				
					Phase I 1978–1999	**Phase II** 1999–2003	**Phase III** 2003–2010	**Phase IV** 2010–2012	
					Predominant *type of argumentation*				
								Contested	
					Facts Ends	Values Ends	Facts Means	Facts Means	Values Means
Discourse Coalitions					**Compatibility Ratings**				
Weightings of argumentation types employed					*Discourse Coalition against Planning Phase*				
	Facts Ends	Values Ends	Facts Means	Values Means					
Building a sustainable industry	***	*	**		**Strong**	Weak	Moderate	Moderate	
100% renewables now!	***	**	***		**Strong**	Moderate	**Strong**	**Strong**	
Protecting the landscape		***	*	**	None	**Strong**	Weak	Weak	Moderate
Protecting biodiversity	**	*	***		Moderate	Weak	**Strong**	**Strong**	

The upheaval of value-based claims in Phase II—"Political fight around values" forced a shift in the prevailing type of argumentation towards final causes (Values-Ends). This favored mainly the "Protecting the landscape" coalition but it also provided a moderately compatible discursive context for the "100% renewables now!" coalition and a point of entry for the "Protecting biodiversity" coalition. During this phase, all four coalitions had some degree of compatibility with the prevailing type of argumentation, making it possible for each of them to hold a position within the discourse. However, only one, "Protecting the landscape", prioritized the Values-Ends type within their coalition, whereas all three of the others prioritized fact-based positions.

Among the two coalitions that were involved in Phase I, "100% renewables now!" had stronger compatibility with the Phase II discourse. It was also the only coalition to have two equally weighted top priorities in terms of argumentation type; one of which it shared with the "Building a sustainable industry" coalition (Facts-Ends), the other with "Protecting biodiversity" (Facts-Means). This suggests that there may be some logic to the shift toward a Facts-Means orientation in Phase III. Although the debate in Phase II was mainly about Values-Ends, a strong fact-based orientation remained present among these three discourse coalitions. With the entry of the “Protecting biodiversity” coalition, which strongly prioritized Facts-Means *types of argumentation*, this fact-based tendency was reinforced. For example, while the “Protecting biodiversity” coalition argued that there was a moral imperative to protect the Bonelli`s Eagle (Values-Ends), these actors also preferred that the discussion not be led by what they referred to as “subjective” landscape criteria. Instead, they favored developing tools that could objectively identify “the right thing to do”.

In Phase III—“Battle between “facts”: “rational siting” the discourse was dominated by arguments about facts. Rational siting was seen by all coalitions as an opportunity to achieve closure in the debate, finally making successful wind energy siting possible. However, this process of rationalization excluded democracy and justice value claims, which could not be justified in terms of efficiency or appropriateness. This favored coalitions with fact-based position and those that were able to translate their value-based arguments into facts-based ones. For example, Values-Means positions of the “100% renewables now!” and "Building a sustainable industry” coalitions, such as “Business and environmentalism should work together: green business is good” (“100% renewables now!” coalition) and “Wind farm siting should be facilitated through the mediation of the regional government. Local councils should not have the right to take the final decision.” (“Building a sustainable industry” coalition) can be found in the structure of the Priority Development Zones (ZDP in Catalan). There, prioritization of wind speed criteria, attention to grid connectivity and the centralized auctioning of permits are all justified as things that new sites need, in order to be economically competitive.

Although the main Values-Ends desire of these two coalitions—to have unrestricted wind energy development—was no longer an option after the political upheaval of Phase II, the core of this position could be converted into a Facts-Means criterion concerning the technical question of how to optimize renewable electricity generation. Similarly, the Values-Ends moral imperative of the "Protecting biodiversity" coalition—avoiding impacts on the Bonelli’s Eagle—could be articulated in the concrete, objective language of environmental impact assessment (Facts-Means), which had a clear place within this ‘rational siting’ discourse.

The “Protecting the landscape” coalition was less successful with this translating work. For example, while the ZDP eventually included rules regarding the minimum distance of new sites from villages and of new sites from existing wind farms, this did little to address the concerns of southern communities regarding uneven development, which was a region-wide, not a local matter. Their arguments for distributed energy generation and more local democratic participation in the siting process were left largely unaddressed or vaguely formulated in the ZDP (see Annex VII). Where these were incorporated, it was in terms that were compliant with the “given state of affairs”. The agreement negotiated on the coalition’s behalf by the Left Republicans of Catalonia (ERC: Esquerra Republicana de Catalunya) political party guaranteed local representation in the form of two local councils members who were to sit on the commission responsible for project selection at the permit auction (see Annex VII).

During Phase III claims that the planning procedures were legally wrong and threatened the existence of endangered species (Facts-Means) were viewed by actors as strategically more effective than appeals based on value-based motivations, such as respect for local communities or protecting the environment. Several interviews with actors inclined toward the "Building a sustainable industry" and "100% renewables now!" storylines included the accusation that local platforms were "dressing visual impacts as environmental impacts that don`t exist". Actors involved in the "Protecting the landscape" discourse, for their part, found that emphasizing increased efficiency, brought about through distributed energy generation, was more important than addressing the political aspects of decentralization because this made it easier for them to reach agreement with others. A similar pattern could be seen in the argumentative strategy of the "100% renewables now!" coalition. Although their value-based argument regarding changing "the given state of affairs" by breaking up the Catalan energy supply oligopoly was a primary motivation for this coalition, these actors chose to argue in Phase III with the comparative environmental and economic benefits of wind energy as compared to other technologies. Value-based arguments about generating qualitative changes were progressively marginalized during Phase III and the discourse concerning what should be the place of wind energy in the Catalan economy turned into a discussion about how to improve the traditional electricity sector. As stated by a politician that we interviewed, this was because the electricity sector "is, logically, in reality, dedicated to energy generation" and therefore the appropriate context for talking about wind power.

Phase IV—Reasserting "Values"?, as discussed above, has been characterized by political deadlock and a number of interventions by the courts. Here the Values-Means arguments of the "Protecting the landscape" coalition, regarding the democratic accountability of the siting process, have been brought back into the discourse, through the help of the Facts-Means intervention of a court decision, in which it was ruled that the ZDP map was not prepared in a manner compliant with Catalan law. However, as can be deduced from Table 3, the other three discourse coalitions, whose argumentation tends to be more toward fact-based positions, have preferred to push the discourse back towards Phase III. We can understand Phase IV as an attempt to reassert value based positions that had been silenced in Phases II and III. However, the Ends orientation of earlier arguments has now been translated into Means (e.g., critiques that the ZDP map development procedure was not participatory) and values-based arguments have been translated into fact-based ones (e.g. the environmental impacts associated with prioritizing energy efficiency). For the "Protecting the landscape" coalition, the result of Phase III meant that a change in the argumentation type of the overall discourse would be required before they could once again achieve standing for their values. Their claims in Phase IV can be understood, following Marcuse (2007 [1964]), as an attempt to express a refusal of the political fait accompli resulting from Phase III. However, even this refusal has now been translated into a type of argumentation that is more compatible with technology as ideology, with their interventions now making reference to what is allowed under existing law and what can be proven based on scientific studies (Fact-Means).

3.7 Discussion

The results reported in Section 6 support our original proposition: that the wind farm siting discourse in Catalonia has both been influenced by and is reproducing what Marcuse referred to as the 'one-dimensional thinking' of technology as ideology. Political concerns raised in Phase II, which were subordinated to the technical criteria of 'rational siting' in Phase III, have now, in Phase IV, been replaced by technical and juridical arguments, with facts and the 'given state of affairs' serving as reference points. We understand this tendency—to replace disagreements about values with disagreements about facts—as an indication that the politics of the siting discourse are being shaped by technology as ideology. Technological rationality is bearing such a strong influence on how the discourse is proceeding that it may be understood to be functioning as an ideology in its own right (Farrell, 2008, , 2011a; Marcuse, 2007[1964]), leading to a discourse focused almost entirely on facts and things, dominated by what Marcuse has called an ‘overwhelming concreteness’ (Marcuse, 2007[1964]: 98).

In the Catalan discourse upon which we report here, being pro or con wind mills has become a synonym for agreeing with, or opposing the wind energy model that is technically possible today: grid-based and commercially cost efficient. Inside this technical debate there is no space for discussion of social-environmental goals such as using wind power as the basis for building an alternative energy system. Nor is it possible to place the existential question of how to manage the balance between human and non-human uses of natural resources onto the table for discussion. Within a discourse where argumentation is performed in fact-based language, these value-based interventions are classified as complaints rather than valid standpoints: egoist NIMBY; human hating bird lover; utopian cooperativist. Our findings suggest that there is a need for studies of wind farm siting conflicts to give closer attention to the dynamics, both temporal and spatial, of relationships between facts and values in the associated discourse(s). This also has implications for determining the sustainability of planning decisions taken under such conditions. In particular, it raises the possibility that the existential question of how a society chooses to manage its relationship with the non-human environment is being reduced to a mere technical problem.

Assuming that value-based positions should have a standing in the Catalan wind energy siting discourse, which we do, we are then left with the question: How might this be possible? In his classic text One-Dimensional Man, Marcuse proposed that a New Science, a new idea of what constitutes Reason, originating from within the scientific logic that brought technology as ideology into being, might offer a route of escape from ‘one-dimensional thinking’ (Marcuse, 2007[1964]:230-250). His discussion of this New Science can be interpreted as an anticipation of the recently developing discourse on post-normal science (Farrell, 2008, , 2011a, 2011b; Funtowicz and Ravetz, 1993, , 1994b) Post-normal science takes its name from the Kuhnian concepts of normal-science and scientific revolution (Kuhn, 1970[1962]) with the revolutionary proposition of post-normal science being that “under certain conditions, ‘‘normal’’ puzzle-solving science is not a scientific approach, because sometimes the puzzle in question cannot be solved” (Allen, 2001; Farrell, 2008; Rittel and Webber, 1973). Coming from within the fact-based discourse of science, the ensuing proposition, that it is necessary to democratize expertise concerning some types of complex, late-industrial scientific problems (Funtowicz, 1990; Funtowicz and Ravetz, 1994b), presents a logically grounded position from which to resist the tendency of hard scientific facts to achieve the kind of discursive closure we observed in this case. If the assessment of fact claims employed in the wind energy siting discourse in Catalonia were to be opened up to an extended community of actors, beyond the experts, who were allowed to participate in the work of determining what constituted a valid fact (Farrell, 2011b; Funtowicz and Ravetz, 1994b; Ravetz, 1971), then the guiding presumption of Phase III of this discourse—that scientific arguments are automatically right and uncomplicated—would need to be abandoned. By creating a discursive context where fact and value-based arguments can be discussed side by side, such an ‘extended’ peer-review process could perhaps help open up new possibilities for Catalonia to think and go beyond the “given state of affairs”.

3.8 Conclusions

Our findings suggest that the analytical framework we developed, using Marcuse`s concept technology as ideology and Hajer’s definition of discourse coalitions, can indeed provide new understanding regarding the logic of conflicts about wind energy development. We began with a proposition: that wind energy siting can be understood as a “wicked problem” without a definitive formulation or solution (Rittel and Webber, 1973), where environmental conflicts are performed as disputes over discourse hegemony and discursive closure (Hajer, 1995). Following Hajer (1995), we conducted a discourse analysis of the last 30 years of wind energy siting in the Spanish region of Catalonia, through which we identified four key discourse coalitions and four key historical phases within the overall siting discourse in the region. Based on four analytical categories of *types of argumentation* (Facts-Ends; Facts-Means; Values-Ends; Values-Means), inspired by Marcuse’s concept of “one-dimensional thinking”, we analyzed the argument styles of each discourse coalition and each phase of the discourse. We then juxtaposed these results, one against the other, in order to study the patterns of compatibilities across discourse coalitions, and between coalitions and the overall discourse over time.

We found that actors have coalesced around four reasonably clear storylines that are similar to those found in other wind and renewable energy studies(Mander, 2008; Stevenson, 2009; Szarka, 2004): “Building a sustainable industry”; “100% renewables now!”; “Protecting the landscape”; and “Protecting biodiversity”. We also found that the dynamics of interactions between these discourse coalitions during the different planning phases showed a tendency towards increasing “disagreements about facts” (Jessup, 2010), which favored reliance upon the instrumental types of rationality (Facts-Ends; Facts-Means) (Zografos and Martinez-Alier, 2009) that are most compatible with technology as ideology.

We proposed, at the close of our discussion, that Marcuse’s idea of a New Science (Marcuse, 2007[1964]: 230-250), as manifested in the discourse on post-normal science (Funtowicz and Ravetz, 1994b), might provide ways to avoid the trap of “one-dimensional thinking” in wind energy siting and we have recommended further research in this direction. More generally, we find that considering the place of the value-based propositions in discourses concerning wicked problems may help reveal ways to escape the ‘overwhelming concreteness’ (Marcuse, 2007[1964]: 98) of discourses that are focused only on what is ‘true’ and possible according to the ‘given state of affairs’ (Marcuse, 2007[1964]: 119). We believe that this approach could help to advance democracy and environmental protection in energy planning because it would allow both scholars and political subjects to raise questions concerning: (1) what constitutes fair democratic control over the production of power and (2) what is the appropriate balance between human and non-human use of natural resources.

4. Integrating energy and land use planning: Exploring a typology of energy metabolism along the rural-urban continuum of Catalonia, Spain[53]

Abstract

Abandoning fossil fuels and increasingly relying on low density, land intensive renewable energy will increase demand for land, affecting current global and regional rural-urban relationships. Over the past two decades, rural-urban relationships all over the world have witnessed unprecedented changes that have rendered their boundaries blurred, and have lead to the emergence of "new ruralities". In this paper we analyze the current patterns of electricity generation and consumption in relation to socio-demographic variables related to the use of time and land across the territory of Catalonia, Spain. Through a clustering procedure based on multivariate statistical analysis we found that electricity consumption is related to functional specialization in the roles undertaken by different types of municipalities in the urban system. Municipality types have distinctive metabolic patterns in different sectors depending on their industrial, services or residential role. Villages' metabolism is influenced by urban sprawl and industrial specialization, reflecting current "new ruralities". Segregation between work activity and residence increases both overall electricity consumption and its rate (per hour) and density (per hectare) of dissipation. A sustainable spatial organization of societal activities without the use of fossil fuels or nuclear energy would require huge structural and socio-demographic changes to reduce energy demand and adapt it to regionally available renewable energy.

Keywords: *Energy metabolism, electricity, MuSIASEM, Distributed energy generation, functional urban specialization, renewable energy*

4.1 Introduction

The end of cheap fossil energy and the growing consequences of climate change are setting the scene for current and future political disputes about society's energy transition towards renewable energies (Abramsky, 2010).

Abandoning fossil fuels and increasingly relying on dispersed and low power density renewable energy will increase demand for land to generate energy (Scheidel and Sorman, 2012; Smil, 2008). The spatial dimensions of energy provision, previously externalized and dismissed by the highly consuming global North, will regain importance affecting global and regional rural-urban relationships.

Thanks to abundant fossil fuels, neoliberal globalization has brought about multi-dimensional unprecedented changes in rural-urban relationships (Brereton et al., 2011; Smith, 2007). A growing scales of networked interconnections and spatial mobility (Marsden, 2009) have rendered the traditional boundaries between rural and urban areas more blurry (Tacoli, 2003). Diffuse urbanization, particularly in western industrialized societies, has lead to the emergence of "new ruralities", in terms of rural areas that increasingly share urban features. The sustainability of such a rural-urban relationships based on fossil fuels is, thus, directly related to the transition to RES.

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Most of modern renewable technologies generate electricity, which is claimed to be versatile and ideal for managing uncertain future mobility (European Commission, 2013; Gilbert, 2010). Growing debate has focused on desirable, feasible and efficient models of transforming electrical grids. Combining advances in information and communication technology (ICT) and in electrical grids design, "smart grids" are proposed to enable bi-directional communication along with power flow between the consumer and the grid (Farhangi, 2010; Rifkin, 2011; Usman and Shami, 2013). Distributed energy generation has also been presented as a new paradigm to relocate generation and consumption of energy closer one another (Ackermann et al., 2001; Alanne and Saari, 2006; Pepermans et al., 2005). Reducing overall consumption and environmental impacts, distributed generation emphasizes decentralization and small and medium-size renewable power plants facilities.

The above referred literature on re-design of electrical grids is mainly concentrated into the technical feasibility of implementing such technological systems. Although mentioning environmental benefits for sustainable development, few references are made to the spatial and socio-demographic societal reconfiguration they may imply or they may require. The promotion of such a new paradigm means, taking low density, land intensive renewable energy, as the basis of the energy system. This requires careful consideration of both the spatial and social distribution of present and future scenarios of energy consumption and their compatibility with available renewable energy resources. In this paper, we aim to contribute to that work by studying the present situation in Catalonia, Spain.

We analyze the current patterns of electricity generation and consumption in relation to socio-demographic variables related to the use of time and land across the territory of Catalonia for the year 2001, the most suitable date for obtaining all required data. Thus, we study patterns of “societal metabolism”, understood as the set of conversions of energy (and material) flows occurring within a society which are necessary for its continued existence (Giampietro et al., 2009).

By identifying differences in land- and time-use and their associated energy flows within the Catalonian region, we derive a typology of municipalities through a clustering procedure based on multivariate statistical analysis. This enables us to identify processes explaining the relationship between spatial distribution of energy metabolic patterns and socio-demographic structures and land uses. Comparison across this typology highlights the relevance of urban sprawl and the related emergence of "new ruralities" typical of late-industrial societies where villages are connected to urban centers through commuting. Functional urban specialization in industrial, services or residential activities increases the rate (per hour) and density (per hectare) of electricity consumption both in market and household sectors and depends upon a centralized generation system.

After presenting details about the Catalonian case study and our methodological approach in sections 2 and 3, we present in section 4 the typology of municipalities and the metabolic patterns it helped to identify. In section 5 we discuss the main findings, identifying plausible qualitative changes in the settlement pattern that could help adjusting current energy consumption patterns to increase their compatibility with a distributed energy system. We close, in section 6, with a set of reflections on the strengths and weaknesses of the approach employed here and provide some recommendations for future work.

4.2 Background: Urbanization and the spatial dimension of Catalonia's energy metabolism

Catalonia (see Figure 5) is one of the most densely populated, urbanized and industrialized regions of Spain. With a population of 7.5 million it represents 16% of the Spanish population (INE, 2012) and it accounted for 18.7% of total GDP (INE, 2007) as well as for 19% of primary energy consumption in Spain in 2009 (ICAEN, 2009; IEA, 2012b). Regarding electricity, Catalonia accounts for 20% of total consumption in Spain, thus being the largest electricity consumer in Spain (REE, 2010).

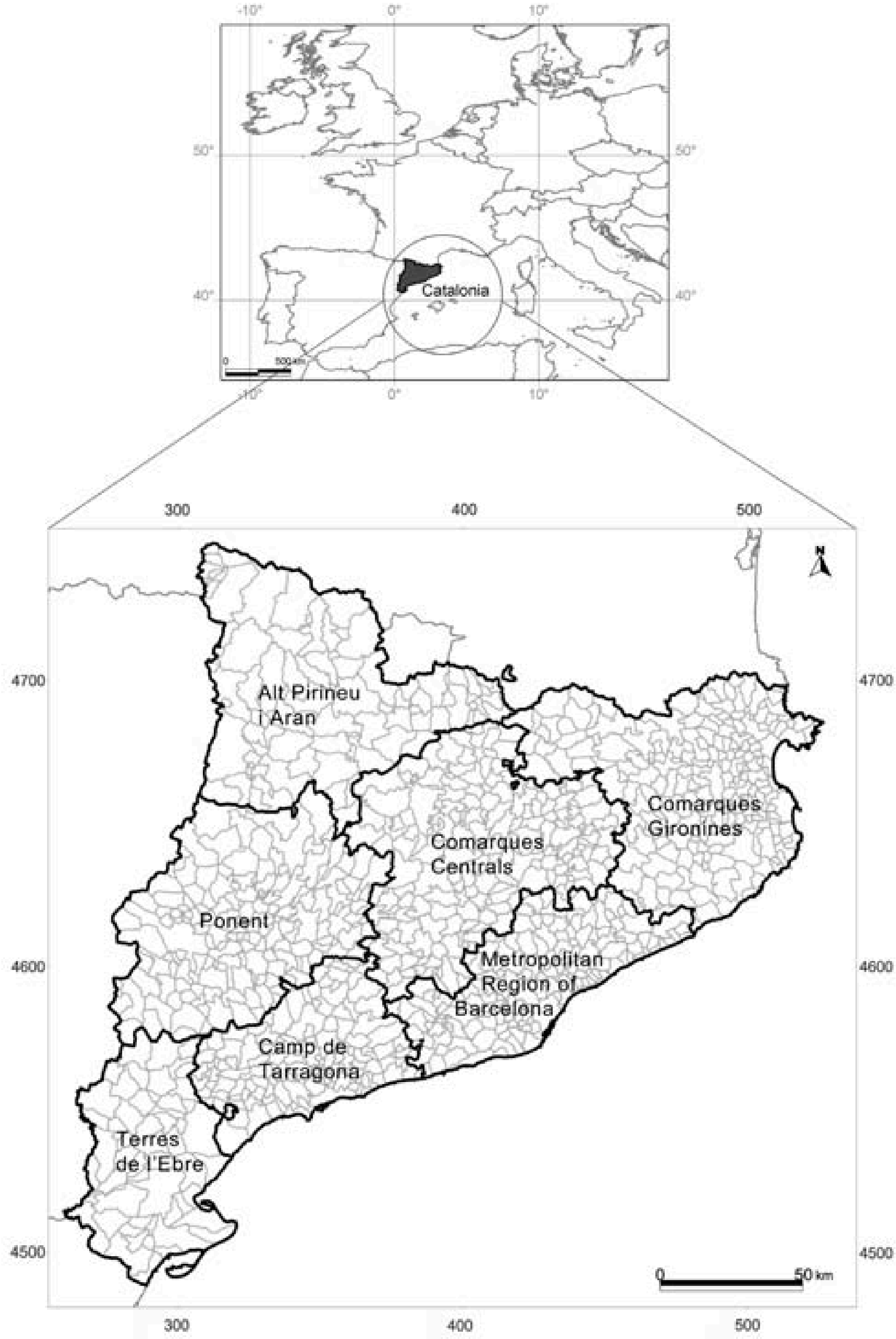
Several studies have shown the influence of different socio-economic sectors in driving the high energy demand of Spain and Catalonia, highlighting the importance of the transport and residential sectors (Alcántara and Duarte, 2004; Alcántara and Padilla, 2003; Ramos-Martín, 2009.; Ramos-Martín et al., 2009; Roca and Alcántara, 2001). Growing energy consumption in the market economic sectors has been used for employing a larger active population in low labor productivity activities such as construction and services[54] (Ramos-Martín et al., 2009). The household sector, meanwhile, has increased its energy consumption due to: i) Catalonia's convergence with European material standard of living and ii) the increase on the total number of households (31% growth between 1981 and 2001) which reflects not only population growth but also structural change from nuclear families towards more single-parent and single person households (Gamboa, 2009; Ramos-Martín et al., 2009). Catalonia's energy metabolism, thus, faces a great difficulty of increasing labor productivity to sustain an aging population without increasing energy consumption[55] (D'Alisa and Cattaneo, 2012; Ramos-Martín et al., 2009).

This growing energy consumption in both market and household sectors is related to the increased value of real estate and the urbanization boom, especially to urban sprawl. The urban sprawl of Catalonia, with its main focus in the Barcelona Metropolitan Region (BMR) but also reproduced in other smaller metropolitan centers (Reus-Tarragona, Girona-Figueres and Lleida-Segrià) has established a network of urban systems (FMR, 2009; GENCAT, 1995; Nel·lo, 2001). The growth of urban areas has meant not only the growing occupation of land, but also new urban-rural relationships and the diffusion of new lifestyles in rural areas which have been converging with urban ones. Urban centres influence more and more the development of the surrounding rural areas through new patterns of mobility, tele-working, second homes and new eco-tourist activities associated to natural protected areas (FMR, 2009).

[54] High correlation between energy consumption and GDP, in Catalonia and Spain, as in many other Western industrialized countries explains why growing GDP, despite low productivity of labour, has led to growing energy consumption, see Ramos-Martin et al (2009).

[55] An aging population and the increasing isolation of citizens in single-person households puts a growing burden either on unpaid work for maintenance and care, or through its substitution by services bought in the market which would increase the overall energy consumption (D'Alisa and Cattaneo, 2012).

Figure 5 (a) Location map of Catalonia within Europe; (b) administrative division of planning spatial entities "àmbits territorials" (regions of the general territorial planning of Catalonia (GENCAT 1995)). **Sources:** ICC (2012) and GENCAT (1995).



These changes have been energetically fuelled mainly by fossil energy, consumed through the rise of private automobile mobility and the industrialization of agriculture. However, they are also dependent on an a centralized electricity generation system characterized by a great distance between generation and consumption (see Figure 6). Power plant siting is heavily skewed towards the south (nuclear, combined cycle, large hydro and recently wind farms) and towards the mountains in the North with hydropower production. Energy consumption, by contrast, has always been highest in the central urban, industrial and northern touristic regions (Saladié, 2011). Moreover, the system is concentrated in few power plants that are responsible for most of the generation. 70% of the generation in 2009 originated from just three nuclear power plants, seven combined cycle units and five thermal stations. About forty large hydropower stations (bigger than 10MW of installed capacity) accounted for an additional 8%. The remaining 22% of electricity is generated through power plants of less than 50 MW of installed capacity mainly of renewable energy, waste-to-energy plants, small hydro stations (less than 10 MW) and combined heat and power (CHP) [56] (ICAEN, 2009).

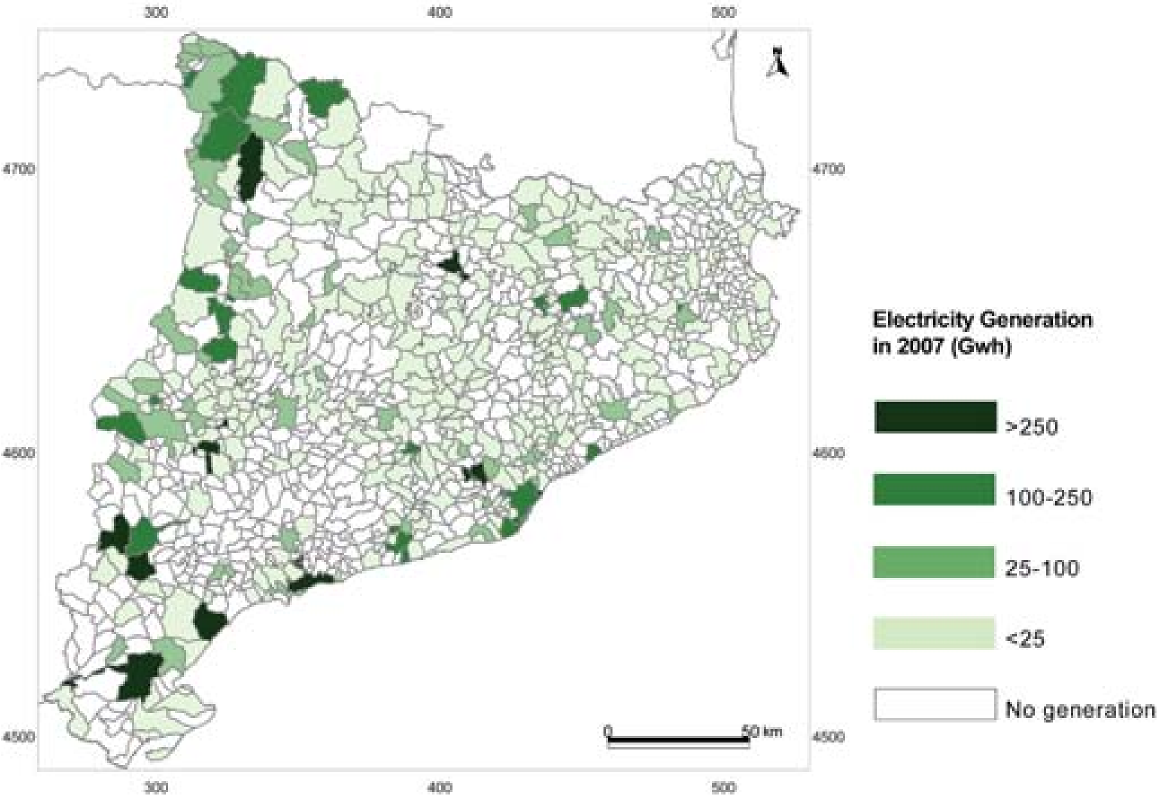
The interaction between the energy metabolism and the creation of landscapes has been studied in the Barcelona Metropolitan Region. Research has developed tools for quantifying the relationship between urbanization, the historical loss of energy efficiency of agriculture and the functional disconnection between land-uses previously integrated in the agro-forestry mosaic[57] (Cussó et al., 2006; Marull, 2007; Marull et al., 2010). This has usefully assessed the environmental impact of urbanization on the immediate surrounding environment[58] and has mainly explored the metabolism of the agricultural sector. By mapping hours of available human time and energy throughput, using GIS techniques, Lobo and Baena (2009) identified a spatial segregation between work and residential activity in the Metropolitan Area of Barcelona. They found three clusters of activity, two of mutual exclusion and a third large area of work and residence co-occurrence. Total energy throughput tended to concentrate in areas of fast growth coinciding with exclusivity of either industrial work or residential activities. Here, we follow Lobo and Baena (2009) initiative in combining spatial and socio-economic data in order to complement these previous studies by relating socio-demographic structural characteristics to energy metabolic patterns across the rural-urban continuum of whole Catalonia.

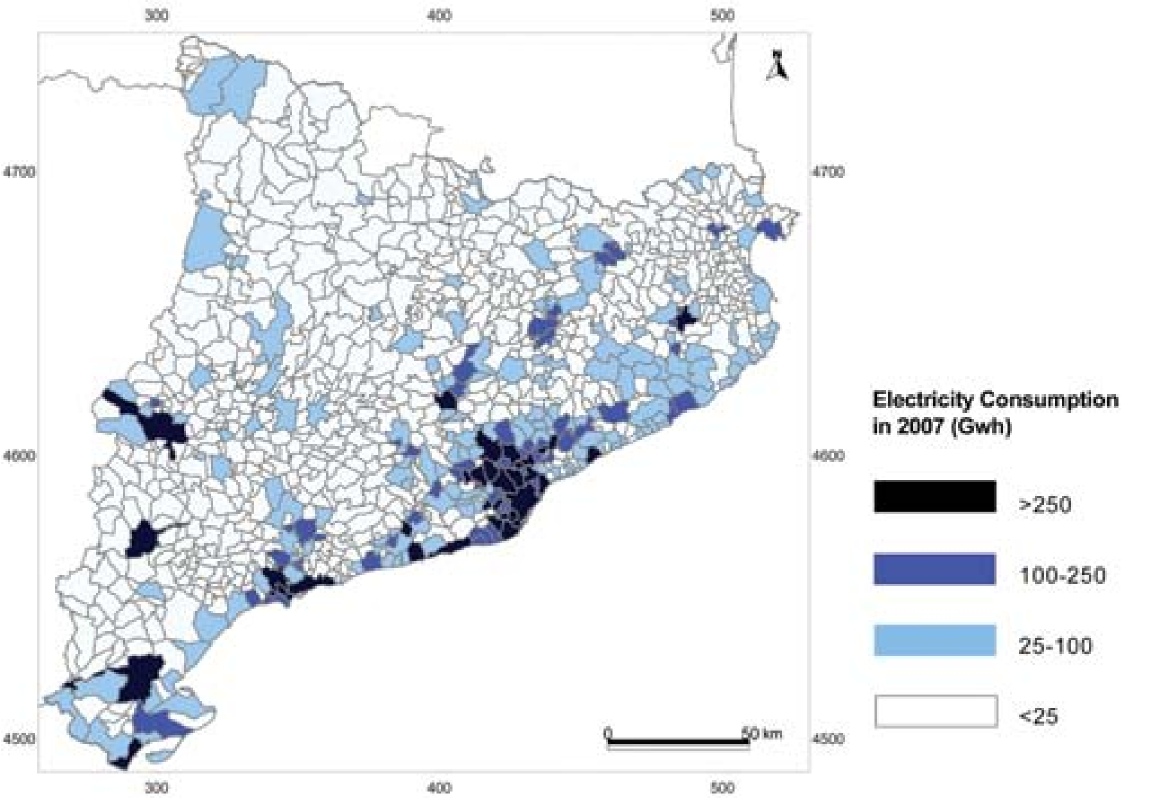
[56] Although Spain is net exporter of electricity, providing 8.333 Gwh to France in 2010, within Spain, Catalonia is a net importer of electricity, demanding from other regions of Spain 5.545 Gwh in 2010 (REE 2010).

[57] The historical loss of energy efficiency of agriculture is expressed by the progressive reduction of the Energy Return On Investment (EROI) from mid-19th century to present, brought about by the introduction of fossil fuel inputs and the functional disconnection of forest, pasture and agricultural lands previously managed integrally (Cussó et al, 2006, Marull et al., 2007).

[58] The growth of built-up areas and infrastructure sites occupying more and more space in the land matrix while the rest of the landscape remaining residual in the Barcelona Metropolitan Region (BMR), has reduced the "landscape efficiency", the ability of the landscape to satisfy human needs while maintaining the healthiest ecological patterns and processes, such as ecological connectivity (Marull et al 2010).

Figure 6 Geographic distribution of electricity generation (a) and consumption (b) in Catalonia in 2007, at municipality level. Source: Own elaboration from (ICAEN, 2010; ICC, 2012).





4.3 Methods: applying MuSIASEM to relate metabolic patterns to a typology of municipalities

In order to explore relationships between energy metabolism and the spatial distribution of socio-demographic and land use characteristics, we apply a two-steps methodological design. First, we calculate a combination of conventional indicators capturing multiple characteristics usually associated to "rural" and "urban" areas with indicators derived from the Multi-Scale Integrated Analysis of Societal and Ecological Metabolism (MuSIASEM) approach (Giampietro et al., 2009). Second, using multivariate statistical techniques applied to the set of indicators we derive a typology of municipalities with distinct metabolic patterns.

Indicators of rural-urban characteristics

In the Spanish and Catalan context, as in other European regions, certain characteristics in municipalities have been identified as relevant indicators of contemporary "ruralities". Low population density, progressive aging of the population and a high degree of farming-related occupation are among the foremost characteristics, followed by second homes ratio or self-employment (Entrena-Durán, 1998; Ocaña-Riola and Sánchez-Cantalejo, 2005; Prieto-Lara and Ocaña-Riola, 2010). Table 10, shows the indicators we specifically used to characterize municipalities regarding their urban-rural characteristics. Some variables, such as agrarian people's occupation and land use are already captured by MuSIASEM indicators.

Table 10. Rural-urban indicators with their description, unit of measurement and dimension they formally represent.

Variable name	Variable description and unit of measurement	
	Socio-demographic characteristics	**Indicators of...**
Dependency ratio	Ratio between active population (15-65 years old) and the dependent part (0-15 and over 65). Expressed in percentage (%).	Aging and population structure
%Residing Workers	Fraction of paid work human activity coming from population living in the same municipality. Expressed in percentage (%).	Economic dynamism Role played in the urban system
%Commuting Workers	Fraction of paid work human activity taking place in the municipality coming from population living in other place. Expressed in percentage (%).	Daily labor mobility needs
%Active Residents working outside	Fraction of the active population living in the place which works outside. Expressed in percentage (%).	
	Land use and settlement pattern	
Distance to >5000 inhab. population centers	Distance to other population centers of more than 5000 inhabitants. Expressed in kilometers (Km)	Access to services Daily labor mobility needs
%Nucleated urban area	Proportion of the urbanized area being core centers of population. Expressed in percentage (%)	Structure of the settlement pattern
%Low density dispersed urban area	Proportion of the urbanized area being low density dispersed urbanizations. Expressed in percentage (%)	
%Industrial park area	Proportion of the urbanized area being industrial parks. Expressed in percentage (%)	
%of apartment buildings	Proportion of housing buildings being apartment complexes. Expressed in percentage (%)	
%of second homes in housing	Proportion of housing buildings being second homes. Expressed in percentage (%)	
Population density urban area	Density of population in the urbanized area. Expressed in inhabitants per square kilometer (inhab/km^2)	
Population density municipality	Density of population in Total Available Land of the municipality. Expressed in inhabitants per square kilometer (inhab /km^2)	

The MuSIASEM approach at municipality level

In the MuSIASEM approach, information is combined from three different domains - demographic, economic and biophysical (i.e., exosomatic energy consumption) - at different hierarchical levels in order to generate intensive variables for characterizing the societal metabolism of a particular system.

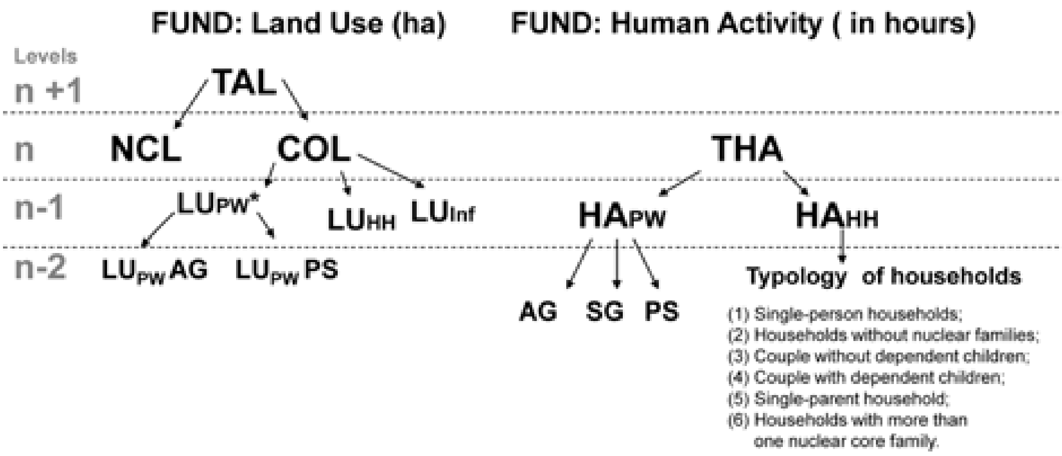
Based on Georgescu-Roegen's flow-fund model (Georgescu-Roegen, 1971), different types of variables are distinguished, depending on the role undertaken in the production process. "Flow" elements enter but do not exit the production process or, conversely, exit without having entered the process. The main flows analyzed here are electricity generation and consumption (Total Electricity Consumption, TEC and Total Electricity Generated, TEG see Table 11)."Fund" elements are agents that enter and exit the process, transforming input flows into output flows. In our case, the main funds are human activity and land use (Total Human Activity, THA and Total Available Land, TAL see Table 11). By using ratios between flows and funds we can derive intensive variables, useful to generate benchmarks for comparison, such as the Exosomatic Metabolic Rate (EMR) (MJ/hour of activity) or the Total Electricity Consumption per hectare (MJ/ha) (see Table 11). In our case, because electricity is mainly consumed in urban area, and agricultural sector does not play a major role in electricity consumption[59], we always calculate Total Electricity Consumption per hectare referred to urban area (the sum of all paved land in the municipality being residential complexes, population centres or industrial parks).

Figure 7 shows the different fund elements we have considered at different hierarchical levels: the whole system (municipality) with the Total Human Activity (THA) (Level n) and the Total Available Land (TAL) (Level n+1), the colonized (COL) and non-colonized land[60] (NCL) (Level n), the market (paid work, PW) and household sectors (HH) (unpaid work and all the rest of non-working human activities) (Level n-1) and the sectoral distribution of land and time use in agriculture (AG), services (SG) and productive sectors (PS) (industry or building and manufacturing activities) and household types (Level n-2). Table 2 provides a detailed overview on the associated indicators in terms of description, calculation and purpose within our analysis.

[59] As later shown in Table 15, in average, the maximum electricity consumption in agriculture is around 10% in small villages.

[60] We consider forests and water bodies as "non-colonized land" with the aim to follow the initially developed cathegories of MuSIASEM. However, in our case, a Mediterranean area in South Europe, forests and water bodies are strongly influenced by human activities. Here "non-colonised" is used with the meaning of non-agricultural, non-urbanized land.

Figure 7 Dendograms of the different fund elements at different hierarchical levels. **Source:** own elaboration inspired from (Sorman, 2009). TAL stands for Total Available Land, THA for Total Human Activity, COL for colonized land and NCL for non-colonized land, PW for paid work, HH for household, AG for agriculture, SG for Service and Government, PS for Productive Sectors (industry plus building and manufacturing activities) and Inf for Infrastructures. * Land Use dedicated to Service and Government activities is not considered in our analysis because this activity usually takes place in residential areas and where it is segregated there is no a clear differentiation of it from the rest of urban area in the available data sources. This is so, because commonly a same building in core urban areas dedicates some floors to households and others to service activities.



MuSIASEM can be applied at different geographical scales, either a nation-state (Eisenmenger, 2007; Falconí-Benítez, 2001; Gasparatos et al., 2009; Iorgulescu and Polimeni, 2009; Ramos-Martín, 2001; Ramos-Martin et al., 2007; Sorman and Giampietro, 2011) a region (Ramos-Martín et al., 2009)or a municipality. Aiming to get the highest possible resolution of spatial patterns we have conducted our analysis at the municipality level. This was the lower geographical scale where the most disaggregated data of all dimensions considered was available.

Table 11. MuSIASEM indicators with their description, calculation and usefulness for the purpose of the analysis.

Level	Acronym	Variable name and explanation	Unit and calculation	Usefulness for our purpose/ Fund or flow?
		Socio-demographic characteristics		
n	THA	**Total Human Activity,** Total human time a society has available for conducting different activities.	Hours (h) (total population times 8760h of a year)	**Fund**
n-2	$HA_{PW\ i}$	**Human Activity dedicated to work, paid through the market, in the given sector ("i") and municipality**. We divide the working population in agriculture (AG), productive sector (PS) and Services and Government (S&G).	Hours (h) or share (%) (total population employed in the sector times the average daily working hours a year)	The sectoral distribution of activity indicates degrees of "rurality-urbanity"
n-2	% HHTypei	**Fraction of the population living in a given household type "i".** We divide the household types in the six categories given by Census data (IDESCAT 2001): (1) unipersonals; (2) households without nuclear core families; (3) Couple without dependent children; (4) Couple with dependent children; (5) Single-parent household; (6) Households with more than one nuclear core family.	Expressed in percentage (%)	
		Land use		
n	TAL	**Total available land**: Total available surface of the municipality	Expressed in hectares (ha)	**Fund**
n-1	NCL	**Non-colonized land:** surface covered by forests and water bodies.	Expressed in hectares (ha) or in percentage (%)	The land use pattern indicates degrees of "rurality-urbanity"
n-3	$LU_{PW}AG$	**Agricultural land:** surface dedicated to agricultural activities	Expressed in hectares (ha) or in percentage (%)	
n-3	$LU_{PW}PS$*	**Surface dedicated to productive sector (out of Total Available Land)**	Expressed in hectares (ha) or in percentage (%)	
n-2	LUinf	**Surface dedicated to infrastructures**	Expressed in hectares (ha) or in percentage (%)	
n-2	LU_{HH}	**Surface dedicated to residential areas.**	Expressed in hectares (ha) or in percentage (%)	

Table 11. *Cont.*

		Energetic metabolism indicators		
n	TEC_{SA} (or TEC_i)	**Total Electricity Consumption**: total electricity consumed in a year in the aggregate level of the whole municipality ("Societal Average, SA") or in a given in a given socio-economic sector ("i")	Expressed in megajoules (MJ)	**Flow**
n / n-1	EMR_{SA} (or EMR_i)	**Exosomatic Metabolic Rate:** electricity consumption per hour of human time available to the municipality ("SA") or per hour allocated to a given socio-economic sector ("i")	TEC_{SA}/THA (or TECi/HAi) Measured in megajoules per hour (MJ/h)	**Flow-Fund**
n-2	TEC per ha_urban area	**Total Electricity Consumption** in urban area: electricity consumption in household, services and industrial sectors per hectare of urban area	$\Sigma TEC_{S\&G,IS,HH}/\Sigma\ LU_{HH,\ PWPS}$ Measured in megajoules per hectare (MJ/ha)	**Flow-Fund**
n-1	TEC per HH	**Total Electricity Consumption per household**: total electricity consumed in a year per household	TEC/number of households (HH) (MJ/HH)	**Flow-Fund**
n-1	TEC per person in the HH	**Total Electricity Consumption per person living in the household**: total electricity consumed in a year per person living in a household	TEC/ person in the household (MJ/person in the HH)	**Flow-Fund**
n	Balance Generation/Consumption	**Ratio of electricity generated in respect of the electricity consumed**	TEG_{SA}/TEC_{SA} Measured in %	**Flow-Flow**
n	TEG_{SA} (or TEG_i)	**Total Electricity Generated**: Electricity generated by all technologies (SA), or by a given type ("i")	Expressed in megajoules (MJ)	**Flow**

Multivariate statistical analysis to identify and characterize typologies of municipalities

Municipality typologies were built through the application of Principal Component Analysis (PCA) (Abdi and Williams, 2010) and Hierarchical Cluster Analysis (HCA) (Härdle, 2012) to a selection of the above introduced indicators for a sample of 945 municipalities[61]. PCA represents inter-correlated quantitative dependent variables as a set of new orthogonal variables called principal components (or factors). Principal components group variables according to important patterns of similarity among them (Abdi and Williams, 2010). HCA further groups the data in different clusters according to such patterns of similarity (Härdle, 2012)). In order to produce a meaningful clustering we needed to select indicators relevant for accomplishing our goal of relating rural-urban characteristics and metabolic profiles of energy consumption. We selected eleven indicators (see Table 12 and Figure 8) with the aim to represent all relevant dimensions (socio-demographic structure, land use distribution, energy metabolic patterns) and at the same time key variables related to *economic dynamism* (understood as employment attraction), the *daily labor mobility needs*, the *role* within the network of cities or the relative *access to services* (as indicated in Table 1, last column). When selecting indicators we considered those with higher number of correlations with variables of other dimensions and dismissed those highly correlated with variables representing the same dimension. Further details of applying clustering procedures based on multivariate statistical analysis can be found in (Köbrich et al., 2003; Mingorría, 2010; Siciliano, 2012; Usai et al., 2006).

The municipality typologies found through PCA and HCA were further characterized through the help of statistical tests for variance analysis. After conducting the normality test Shapiro-Wilk (Shapiro and Wilk, 1965) all variables were found to follow a non-parametric distribution. Thus, the non-parametric test Kruskall-Wallis one-way analysis of variance by ranks (Kruskal and Wallis, 1952) was used to identify significant differences between municipality types, this time using all the indicators of Table 10 and 11.

The study was conducted using data of all dimensions at the date of year 2001, the closest date to the most recent available census data, 2001 (IDESCAT, 2001) and the most updated land use map, 2002 (GENCAT, 2002a). Generation and consumption of electricity was provided by ICAEN upon request (ICAEN 2010).

4.4 Municipality types and metabolic profiles along the rural-urban continuum

The clustering procedure based on multivariate statistical analysis derived four types of municipalities with distinct metabolic profiles regarding their socio-demographic, land use and electricity consumption characteristics: (a) *cities* (b) *small villages* (c) *suburban towns* and (d) *industrial villages*. These types covered the broad range of the rural-urban continuum and resulted from the grouping of the most significant indicators around three significant principal components (factors) explaining the 77% of the variability of the sample (see Table 12). By looking at the contribution of each variable to the factors, we see that factor F1 is composed of variables whose

[61] Catalonia has 946 municipalities. Barcelona, however, was left aside due to the relative big difference in size as compared with all the rest of municipalities and also due to the lack of disaggregated data about electricity consumption by neighbourhoods. Its initial inclusion distorted any meaningful result. Barcelona, with 1,503,884 inhabitants in 2001 (23% of Catalonia's population), was about six to eight times larger than their neighboring second and third most populated cities of Catalonia (Hospitalet de Llobregat and Badalona), and ten times larger than the other three province capitals of Catalonia: Tarragona, Lleida and Girona.

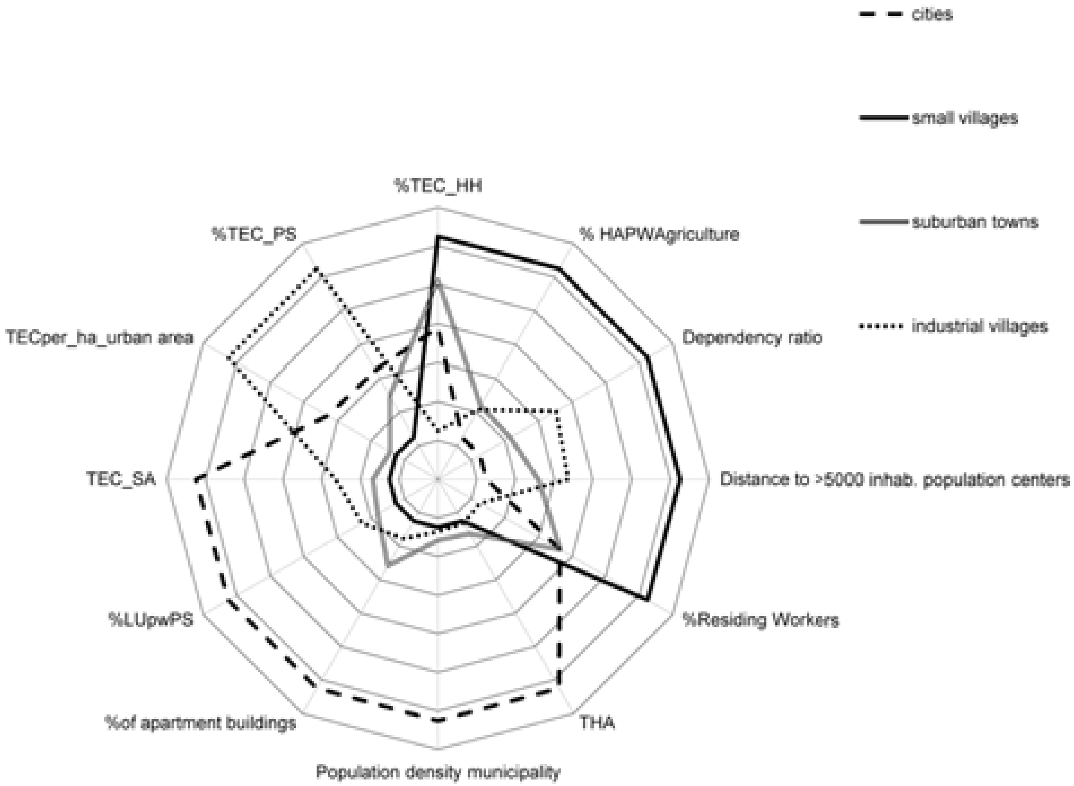
maximization indicates either "rural" (i.e. negative underlined variables) or "urban" (i.e. positive variables in bold) characteristics.

Table 12. Main results of Principal Component Analysis: Factor loadings of each variable contributing to each identified factor and their eigenvalues and variability explained. Values in **bold** are those factor loadings higher than 0.4 and values <u>underlined</u> are those higher than 0.4 but with negative values.

	F1: "rural-urban"	**F2: "%TEChh-suburban"**	**F3: "TECper ha_urban area-industrial"**
Eigenvalue	5.77	1.57	1.11
Variability explained (%)	52.45	14.31	10.10
% accumulated	52.45	66.76	76.86
THA	**0.825**	**0.420**	0.195
$\%HA_{PWAG}$	<u>-0.748</u>	0.174	0.288
%Residing Workers	<u>-0.488</u>	**0.621**	0.399
Dependency ratio	<u>-0.614</u>	-0.001	**0.580**
$\%LU_{PW}PS$	**0.840**	0.019	0.042
Population density municipality	**0.808**	**0.401**	0.060
Distance to >5000 inhab. population centers	<u>-0.773</u>	-0.150	0.320
$\%TEC_{HH}$	<u>-0.459</u>	**0.754**	-0.300
TEC_{SA}	**0.871**	0.102	0.295
TEC per ha $_{\text{urban area}}$	**0.656**	<u>-0.415</u>	**0.443**
% of apartment buildings	**0.747**	0.215	0.112

Factors F2 and F3, although less relevant in explaining sample variability, are key for understanding the formation of the other two intermediate categories. F2 illustrates the creation of *suburban towns* where municipalities with an intermediate size (THA), population density and share of workers living in the same village have a big share of electricity consumption in the household sector ($\%TEC_{HH}$) and a low electricity consumption per hectare of urban area (TECper ha $_{\text{urban area}}$). F3 groups the sample towards the creation of the "rural industrial village" category where villages with the rural characteristics of a high dependency ratio and a big distance to populated centres have high electricity consumption per hectare of urban area. The radar graph of Figure 8 shows the relevant variables used in PCA and HCA and the % TEC_{PS} (which facilitates types distinction) to illustrate the differences between typologies according the grouping tendencies expressed by principal components (factors). F1 explains the tendency to go either to the upper right quadrant (indicating "rural" characteristics) or to the lower left quadrant ("urban" characteristics), forming the two extreme ideal types of *cities* and *small villages*. F2 and F3 explain the formation of the two intermediate categories of *suburban towns* and *industrial villages* by combining rural-urban characteristics with distinctive patterns of electricity consumption, either in the industry or the household sectors.

Figure 8 Typology profile according to the main clustering variables. **Source:** own elaboration. Values are normalized to values ranging from 0 to 1 using the formulae: $X_i-X_{min}/X_{max}-X_{min}$



Spatial distribution of municipality types: functional urban specialization

Figure 9 shows the spatial distribution of the four municipality types throughout Catalonia. *Cities*, *suburban towns* and *industrial villages*, concentrate along the highly urbanized coastal areas and around the main infrastructure corridors in the centre and north of Catalonia. *Small villages* occupy the most of the territory (67%) in three large areas: the southern countryside, the northern mountain areas of the Pyrenees and the central and northern interstices between urban systems.

This spatial distribution of municipality types has important consequences for electricity consumption. Municipalities have different patterns of electricity generation or consumption depending on their role in the urban system. Such metabolic profiles are related to functional specialization in industry, services or residential sectors.

The relative importance of electricity consumption in the paid work sectors (industry and services) is higher in municipalities with economic dynamism (employment attraction) such as *cities* or *industrial villages*. In contrast, the household sector plays a major role in electricity consumption in *suburban towns* and in *small villages* (see results of Kruskall Wallis test, Tables 13 and 15). Geographical separation of working activities and residence leads to higher electricity consumption per hour of human activity and per hectare in both the employment attraction and the residential municipalities.

Figure 9 Spatial distribution of municipality types along the rural-urban continuum of Catalonia. **Source**: own elaboration.

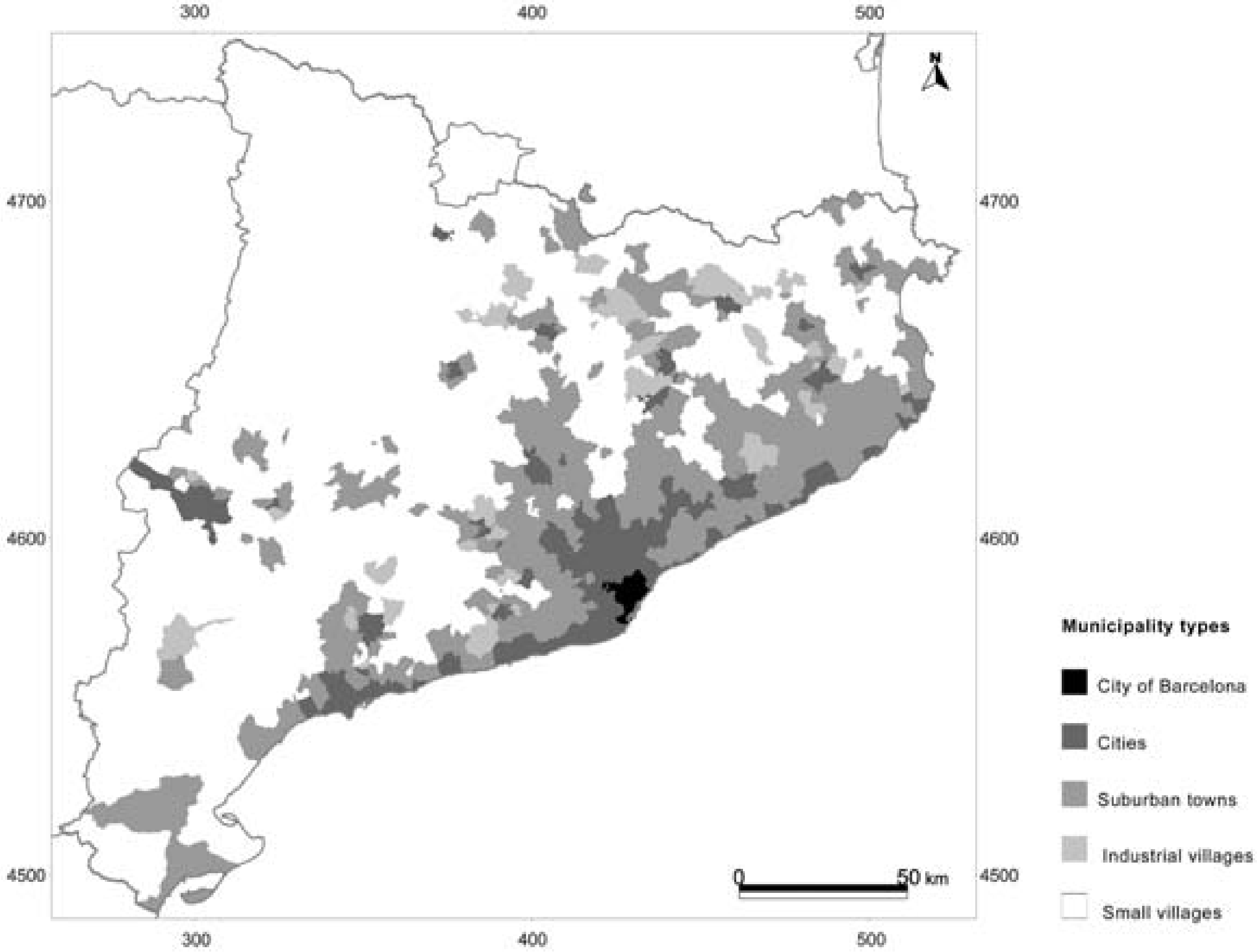


Table 13. Results of Kruskall Wallis test in socio-demographic variables (All variables showed a non-normal distribution under Shapiro-Wilk test. All results had 7.814 as critical value of K, a p-value <0. 0001, an alpha value of 0.05, and 3 degrees of freedom). The values highlighted in bold correspond to the typology having the maximum or minimum average values of the given indicator. Letters ([A,B,C,D]) indicate the significantly different groups existent along the values of the sample, which aggregate typologies according significant differences.

Type	**1:cities (n=100)**		**2:small villages (n=537)**		**3: sub-urban towns (n=265)**		**4:industrial villages (n=43)**		
Variable	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	χ^2
THA	**3.07E+08 [D]**	3.77E+08	6.69E+06 [A]	9.04E+06	2.93E+07 [C]	3.03E+07	1.09E+07 [B]	1.04E+07	445.780758
% HA_{PW} AG	1.63 [A]	1.65	**35.19 [C]**	20.80	8.02 [B]	7.46	7.18 [B]	5.51	536.46
% HA_{PW} PS	44.32 [B]	14.12	29.11 [A]	14.95	46.75 [A]	14.04	**66.18 [C]**	12.35	304.15
% HA_{PW} S&G	**54.05 [D]**	13.57	35.70 [B]	15.56	45.23 [C]	12.95	26.64 [A]	11.75	191.54
Dependency ratio	41.79 [A]	5.47	**61.06 [D]**	12.07	45.27 [B]	7.36	50.56 [C]	7.84	438.70
%Residing Workers	51.79 [C]	18.00	**73.48 [B]**	14.16	51.94 [B]	16.83	32.09 [A]	13.37	357.25
%Commuting Workers	48.21 [B]	18.00	**26.52 [A]**	14.16	48.06 [B]	16.83	67.91 [C]	13.37	357.25
%Active Residents working outside	54.15 [A]	16.04	54.42 [A]	13.49	**61.65 [B]**	15.27	56.53 [A,B]	12.61	55.19
%HHType1: Single-person households	6.59 [A]	3.43	**9.63 [C]**	3.87	7.66 [B]	5.05	7.08 [A,B]	2.58	139.47
%HHType2: Households without nuclear families	2.81 [A]	0.82	**4.20 [B]**	2.51	3.00 [A]	1.58	3.30 [A]	1.99	93.00
%HHType3: Couple w/o dependent children	16.87 [A]	1.64	**18.23 [B]**	4.86	17.24 [A]	3.35	16.65 [A]	3.53	22.22
%HHType4: Couple with dependent children	**60.42 [A]**	**4.93**	48.03 [C]	9.23	57.31 [B]	7.67	56.73 [B]	7.34	314.31
%HHType5: Single-parent households	**8.58 [B]**	**1.40**	8.21 [A]	3.66	7.73 [A]	2.25	7.79 [A]	3.19	19.96
%HHType6_More than one nuclear family	4.73 [A]	1.13	**11.70 [C]**	8.03	7.07 [B]	4.20	8.45 [B.C]	4.69	189.03
Average Number of People by HH (a) total	2.83 [B]	0.16	**2.76** [A]	0.33	2.82 [B]	0.28	2.91 [B]	0.25	35.21
(b) HHtype2	**2.71 [C]**	0.23	2.37 [A]	0.63	2.54 [B]	0.47	2.52 [A,B]	0.42	96.66
(c) HHtype3	2.22 [A]	0.04	**2.38 [C]**	0.22	2.28 [B]	0.14	2.34 [B,C]	0.16	137.16
(d) HHtype4	4.00 [A]	0.07	**4.18 [C]**	0.29	4.05 [B]	0.13	**4.18 [C]**	0.25	122.68
(e) HHtype5	3.03 [B]	0.10	**2.91 [A]**	0.50	3.00 [B]	0.29	3.08 [B]	0.45	27.87
(f) HHtype6	6.03 [A]	0.27	5.79 [A]	1.23	5.87 [A]	0.77	5.93 [A]	0.67	7.03

Table 14. Results of Kruskall Wallis test in land use pattern variables (All variables showed a non-normal distribution under Shapiro-Wilk test. All results had 7,814 as critical value of K, a p-value <0. 0001, an alpha value of 0.05, and 3 degrees of freedom). The values highlighted in bold correspond to the typology having the maximum or minimum average values of the given indicator. Letters (^{A,B,C,D}) indicate the significantly different groups existent along the values of the sample, which groups typologies according significant differences.

Type	**1:cities (n=100)**		**2:small villages (n=537)**		**3: sub-urban towns (n=265)**		**4:industrial villages (n=43)**		
Variable	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	χ^2
Distance to >5000 inhab. population centers	1.32 ^{A}	1.05	**15.56** ^{C}	12.01	5.14 ^{B}	3.73	7.34 ^{B}	6.08	538.80
TAL (ha)	2106.96 ^{A}	2463.22	**4005.06** ^{B}	3956.82	2673.35 ^{A}	2510.73	3042.08 ^{A,B}	2827.36	54.61
% LUForest	34.47 ^{A}	20.13	54.22 ^{B}	33.98	53.09 ^{B}	27.63	**55.44** ^{B}	30.05	34.38
% LUPWAG	28.91 ^{A}	20.49	**44.02** ^{B}	33.10	35.52 ^{A}	26.72	38.85 ^{A,B}	27.72	18.08
% LUinf	**6.89** ^{A}	6.65	0.35 ^{C}	1.08	1.92 ^{B}	2.62	1.61 ^{B}	2.53	303.58
% $LU_{PW}PS$ (out of TAL)	**8.48** ^{C}	8.94	0.15 ^{A}	0.29	1.05 ^{B}	1.61	1.85 ^{B}	3.21	398.79
% LU_{HH}	**21.25** ^{C}	12.90	1.25 ^{A}	1.54	8.43 ^{B}	9.65	2.24 ^{A}	2.27	464.28
%Nucleated urban area	65.98 ^{A}	28.13	**84.47** ^{B}	28.12	55.27 ^{A}	33.96	64.92 ^{A}	34.65	152.73
%Dispersed rural residential	1.38 ^{A,B}	5.13	4.51 ^{A}	17.17	3.92 ^{B}	12.28	**12.01** ^{B}	26.29	15.26
%Low density dispersed urban area	17.74 ^{B}	20.91	10.47 ^{A}	22.81	**37.46** ^{C}	34.17	15.93 ^{A,B}	24.35	183.34
%Industrial park area (out of urbanized (paved) area)	**14.90** ^{C}	20.45	0.18 ^{A}	1.59	2.97 ^{B}	9.23	7.14 ^{B}	17.90	264.77
Population density urban area	7992.61 ^{C}	5966.76	3076.64 ^{B}	3415.42	**2388.18** ^{A}	2172.50	3433.08 ^{B}	4605.75	156.04
Population density municipality	**2654.75** ^{D}	3538.52	29.27 ^{A}	36.78	205.05 ^{C}	302.49	88.15 ^{B}	144.79	494.66
%of apartment complexes in housing	**74.62** ^{C}	15.82	20.65 ^{A}	16.54	35.05 ^{B}	20.16	26.33 ^{B}	17.91	313.53
%of single-family main homes in housing	25.38 ^{A}	15.82	**79.35** ^{C}	16.54	64.95 ^{B}	20.16	73.66 ^{B,C}	17.91	313.53
%of second homes in housing	12.23 ^{A}	14.29	**27.06** ^{C}	19.53	23.07 ^{B}	20.84	14.09 ^{A,B}	11.27	71.03

Table 15. Results of Kruskall Wallis test in electricity consumption variables (all results had 7,814 as critical value of K and a p-value <0. 0001 and an alpha value of 0.05, and 3 degrees of freedom). The values highlighted in bold correspond to the typology having the maximum average values of the given indicator. Letters ([A,B,C,D]) indicate the significantly different groups existent along the values of the sample, which groups typologies according the significant differences.

Type	1:cities (n=100)		2:small villages (n=537)		3: sub-urban towns (n=265)		4:-industrial villages (n=43)		
Variable	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	χ^2
TEC_SA (MJ)	**7.49E+08** [C]	8.37E+08	1.36E+07 [A]	2.21E+07	7.70E+07 [B]	9.92E+07	2.18E+08 [B]	3.71E+08	504.968764
TEC_PS (MJ)	**3.78E+08** [C]	6.58E+08	4.36E+06 [A]	1.19E+07	3.45E+07 [B]	7.09E+07	**2.02E+08** [C]	3.60E+08	466.423171
TEC_S&G (MJ)	**2.17E+08** [C]	2.43E+08	4.02E+06 [A]	7.82E+06	2.08E+07 [B]	2.80E+07	9.00E+06 [B]	8.73E+06	455.823
TEC_HH (MJ)	**1.50E+08** [C]	1.60E+08	4.27E+06 [A]	6.61E+06	2.05E+07 [B]	2.23E+07	6.06E+06 [A]	5.73E+06	458.167
%TEC_AG	0.558 [A]	2.505	**9.613** [C]	12.331	1.255 [A,B]	2.174	2.508 [B]	4.786	197.517393
%TEC_PS	42.987 [C]	24.181	16.001 [A]	21.415	32.756 [B]	25.105	**83.869** [D]	18.208	261.102
%TEC_S&G	31.425 [B]	14.013	31.184 [B]	17.974	30.378 [B]	15.692	10.125 [A]	16.791	76.6572767
%TEC_HH	25.031 [B]	13.704	**43.015** [D]	18.539	34.358 [C]	16.746	4.752 [A]	2.608	205.274489
TEC per ha_urban area	1.608 [C]	1.316	0.422 [A]	0.541	0.522 [B]	0.487	**3.341** [C]	3.336	299.007281
EMR_PS (MJ/h)	40.788 [C]	66.034	22.197 [A]	58.115	28.984 [B]	51.044	**206.642** [D]	280.293	194.229269
EMR_S&G (MJ/h)	19.214 [A]	20.370	**36.109** [C]	58.734	24.815 [B]	18.757	**38.255** [B,C]	67.810	44.401618
EMR_SA (MJ/h)	3.743 [B]	5.910	1.838 [A]	1.463	2.674 [B]	1.655	**17.405** [C]	12.595	229.764905
EMR_HH (MJ/h)	0.586 [A]	0.157	0.694 [B]	0.366	**0.818** [C]	0.461	0.637 [A,B]	0.165	66.3097474
Average TEC per HH (MJ/HH)	1.32E+04 [A]	3.20E+03	1.54E+04 [B]	7.80E+03	**1.80E+04** [C]	9.48E+03	1.49E+04 [B]	4.41E+03	66.1092883
Average TEC per person in the HH (MJ/personinHH)	4700.862 [A]	1253.269	5608.433 [A,B]	2914.216	**6483.005** [C]	3773.444	5112.146 [B]	1357.920	56.7138334

Electricity consumption in working activities: specialized cities and industrial villages

High density of electricity consumption per hectare of urban area (TECper $ha_{urban\ area}$ (MJ/ha)) concentrates in *cities* mainly in the Metropolitan Region of Barcelona (MRB) (see numbers 1to 3 in Figure 10), Tarragona metropolitan area (number 4) but also in *industrial villages*, in the South (5 and 6) and in the North (7, 8 and 9).

Cities and *industrial villages* are those with higher electricity consumption at the level of whole municipality (TEC_{SA}) (see Table 15). In both cases industry is the major consumer of electricity (see $\%TEC_{PS}$ in Table 15). Although *cities* consume more in absolute terms, both at the level of whole municipality and at the level of productive sectors, *industrial villages* consume more per hour of human activity (both in EMR_{SA} and in EMR_{PS}) and per hectare of urban area (TECper $ha_{urban\ area}$). As industrial employment attractors (66% of activity), but with lower proportions of land dedicated to industrial parks, they consume electricity almost entirely through a highly intensive industrial sector (accounting for the 84% of TEC_{SA}) (see Tables 14 and 15).

The high consumption of *cities* is related to their size and their specialization. *Cities* have contrasting values in energy consumed per hour of activity (EMR_{SA}) (see Figure 11), depending on their functional specialization.

Cities in the northern part of the MRB, "Comarques Centrals" and "Camp de Tarragona" (see Figures 5, for area location, and values around numbers 1 to 4 in Figure 11) are more oriented to industry and have higher energy metabolic rates (6,402± 8,712 MJ/h, in average), mainly explained by their higher proportion of industrial workers and electricity consumption in productive sectors (high EMR_{PS}) (see values around numbers 1-4 in Figure 12). *Cities* located along the coastal areas or urban centres in the countryside are more oriented to services and have lower EMR_{SA} (1,895±0,771 MJ/h, see numbers 10 to16 in Figure 11). "Industrial cities" consume a lot of energy per hectare due to their industrial parks (see numbers 1to 4 in Figure 12). "Service cities", on the contrary, do so, because of high density of population and service activity. They are big compact cities with high concentration of apartment buildings that, although consuming less per hour of human activity, bring them to have intermediate densities of electricity consumption (see the contrast between numbers 10 to16 and Barcelona city in Figures 10 and 11).

Electricity consumption in the household sector: suburban towns and small villages

Suburban towns and *small villages* consume less electricity as compared to *industrial villages* and *cities* and have a distinct complementary metabolic pattern (see Table 15). *Suburban towns* and *small villages* tend to play the residential role, sending workers to *cities* and *industrial villages* (%Active Residents working outside in Table 13). The more that people live and work in the same village (%Residing Workers in Table 13), the higher is the relative importance of the household sector ($\%TEC_{HH}$) and the lower is the total electricity consumption (Table 15). *Suburban towns* and *small villages*, however, consume more electricity per hour spent in the household (EMR_{HH}) and less per hectare of urban area (TEC per $ha_{urban\ area}$) than the other two types. While the average number of people per household is similar across municipality types, *suburban towns* have the highest average consumption of electricity per household and per person living in the home. High EMR_{HH} and low TEC per $ha_{urban\ area}$ thus, seems to be related to a lifestyle characterized by consumerism in low density urban sprawl (37% of urban area of this type, see Table 14).

Figure 10. Spatial distribution of Total Electricity Consumption (TEC) per hectare of urban area (MJ/ha) and municipality types along the rural-urban continuum of Catalonia. **Source**: own elaboration. Intervals are represented following the (Jiang, 2012) proposed method of head/tail breaks, a classification scheme for data with a heavy-tailed distribution.

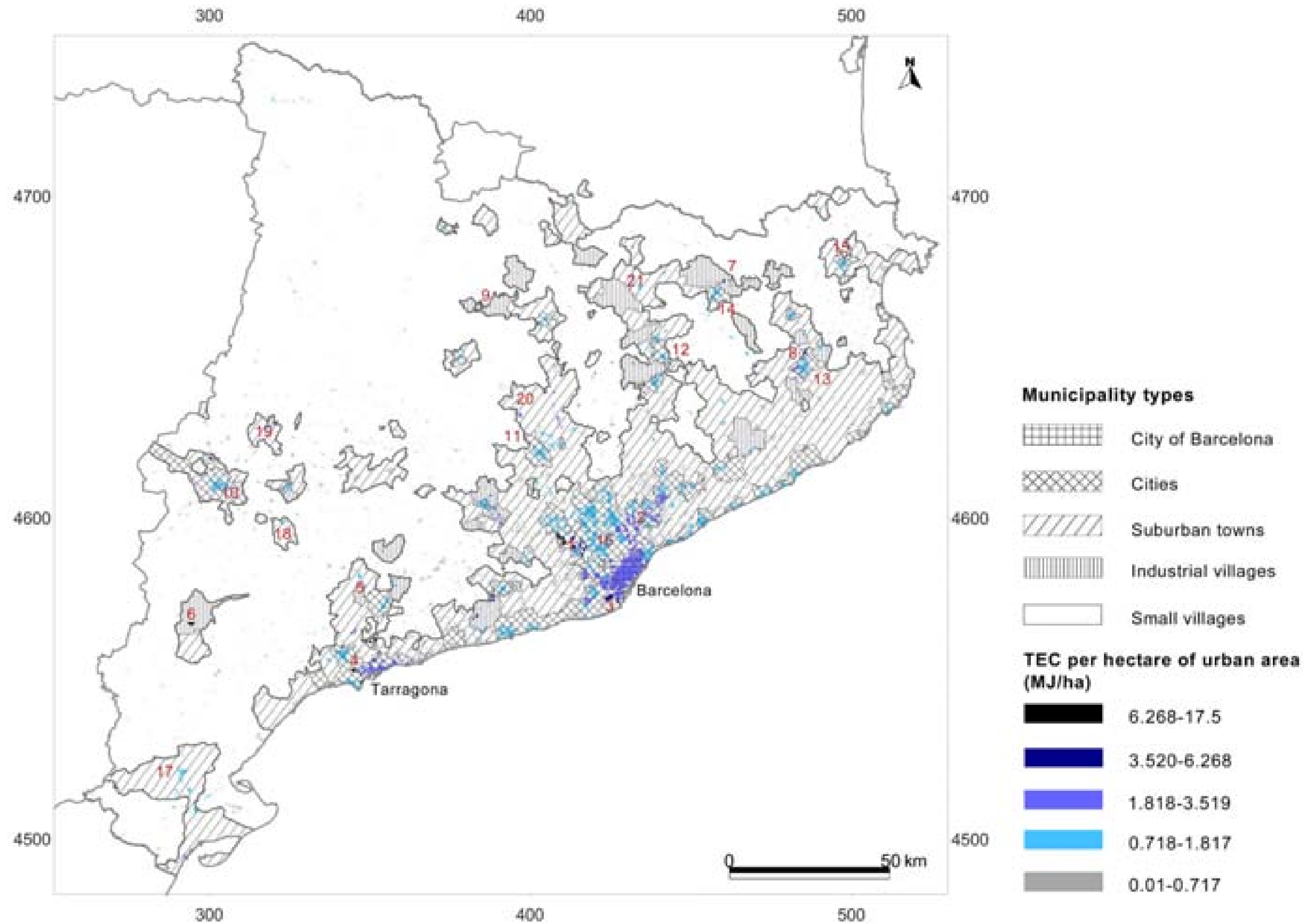


Figure 11. Spatial distribution of Energy Metabolic Rate (MJ/h) at the level of the whole municipality (EMR_{SA}) and municipality types along the rural-urban continuum of Catalonia
Source: own elaboration. Intervals are represented following the (Jiang, 2012) proposed method of head/tail breaks, a classification scheme for data with a heavy-tailed distribution.

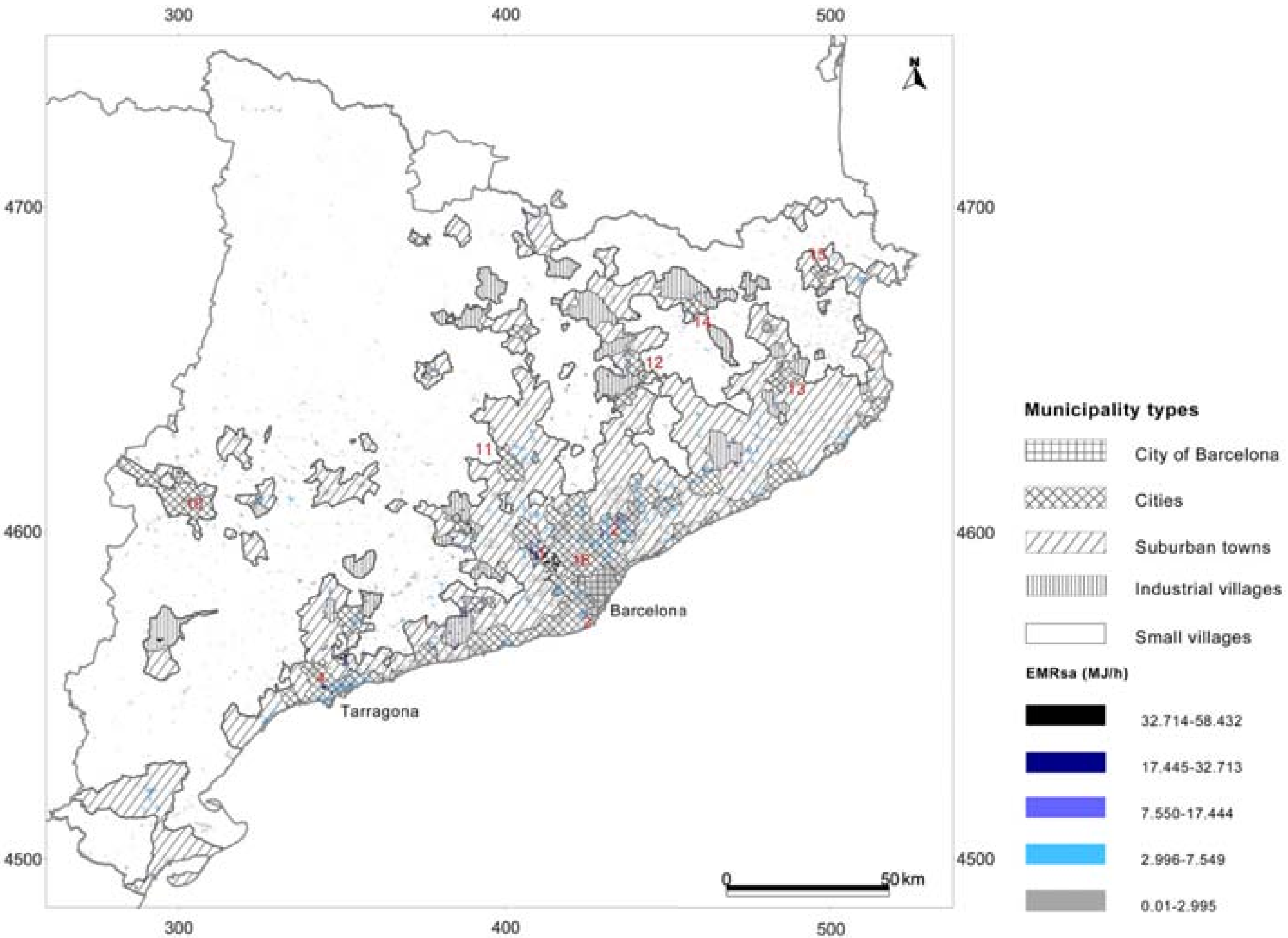
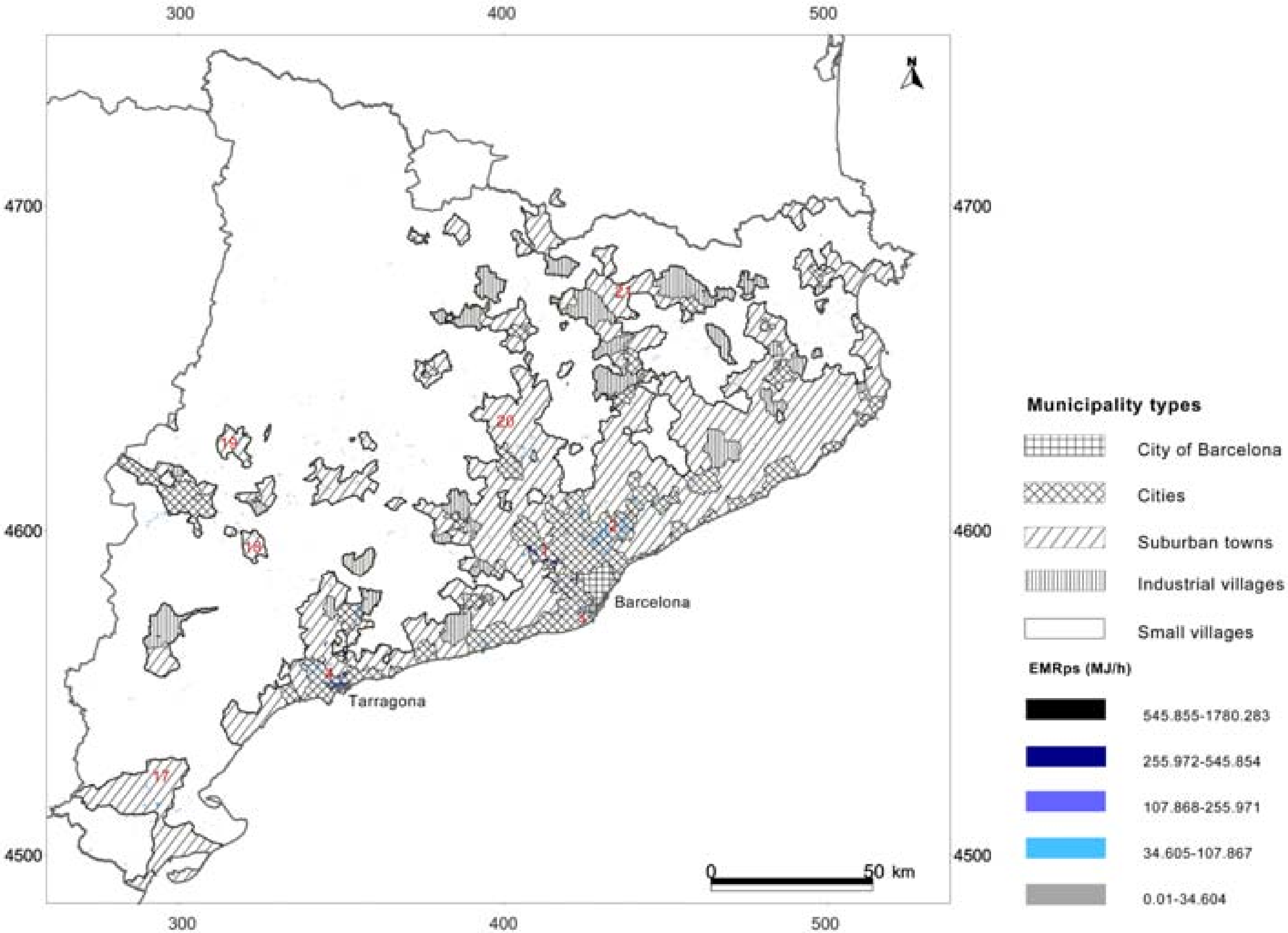


Figure 12. Spatial distribution of Energy Metabolic Rate (MJ/h) at the levels of the productive sectors (EMR$_{PS}$) and municipality types along the rural-urban continuum of Catalonia. **Source**: own elaboration. Intervals are represented following the (Jiang, 2012) proposed method of head/tail breaks, a classification scheme for data with a heavy-tailed distribution.



A closer look at the spatial distribution of EMR_{HH} (see Figure 13) reveals that further specialization takes place among *suburban towns* depending where they are located in the urban system. The highest energy consumption per hour in the household takes place in the northern mountain areas (numbers 1 and 2 in Figure 13) and in coastal areas to the north ("Costa Brava" in "Comarques Gironines", see values around numbers 3 to 5) and to the south ("Costa Daurada" in "Camp de Tarragona", values around numbers 6 and 7). *Suburban towns* in these areas are touristic, with high income per capita and, on average, more than 60% of the urban land is low density urbanization with a high proportion of single-person households (16%) and of second homes (60%). There is scant industrial activity and most of the population works in services. Households in such high-income, touristic areas consume, per hour of activity, the triple the electricity of *cities* or *small villages* in the southern countryside. *Suburban towns* play a different role in the southern countryside, where they serve as local capitals and economic centres, or where they form part of the industrial fabric of the centre and north. In these cases, they consume half as much electricity per hour in the household sector (see numbers 17-21 in Figure 13) and have higher density urban areas, less urban sprawl and lower percentages of second homes. Their human time is dedicated less to services and more to industry, which explains their higher electricity consumption per hectare and higher EMR_{PS} compared to the touristic or high income towns or the commuter dormitories surrounding metropolitan centres (see numbers 17-21 in Figures 10 and 12).

Small villages reproduce the influence marked by the specialization of the nearest *suburban towns*. Villages closer to high-income and touristic towns have more urban sprawl, more percentage of second homes, and more service activity. Consequently, they have higher energy consumption rates per hour and per hectare, as compared to more agrarian oriented small villages of the southern countryside, which are among the lowest energy consumers per hectare and per hour of activity.

Electricity generation

This spatial segregation of functions along the urban system is fed by a centralized and concentrated system of electricity generation. Power plants in southern *suburban towns* and northern *small villages* generate around 1000 times more electricity than these municipalities consume. Although there is, on average, some balance between generation and consumption in *cities* and *industrial villages* (mainly due to the distribution of fossil-fuel based Combined Heat and Power (CHP)) (see Table 16), summing up all types of electricity generation, *suburban towns* generate twice as much electricity as these two higher consumers. Renewable electricity generation in 2007 was ten times higher in *small villages* and *suburban towns* than in *cities*. Although from 2001 to 2007, renewable energy supply grew in the high consuming *industrial villages,* it is still seven times lower than renewable generation in *small villages* and *suburban towns*. Renewable generation in *cities* and *industrial villages* is entirely photovoltaic, while wind energy is generated only in *small villages*.

Figure 13. Spatial distribution of Energy Metabolic Rate (MJ/h) at the level of household (EMR_{HH}) and municipality types along the rural-urban continuum of Catalonia **Source**: own elaboration. Intervals are represented following the (Jiang, 2012) proposed method of head/tail breaks, a classification scheme for data with a heavy-tailed distribution.

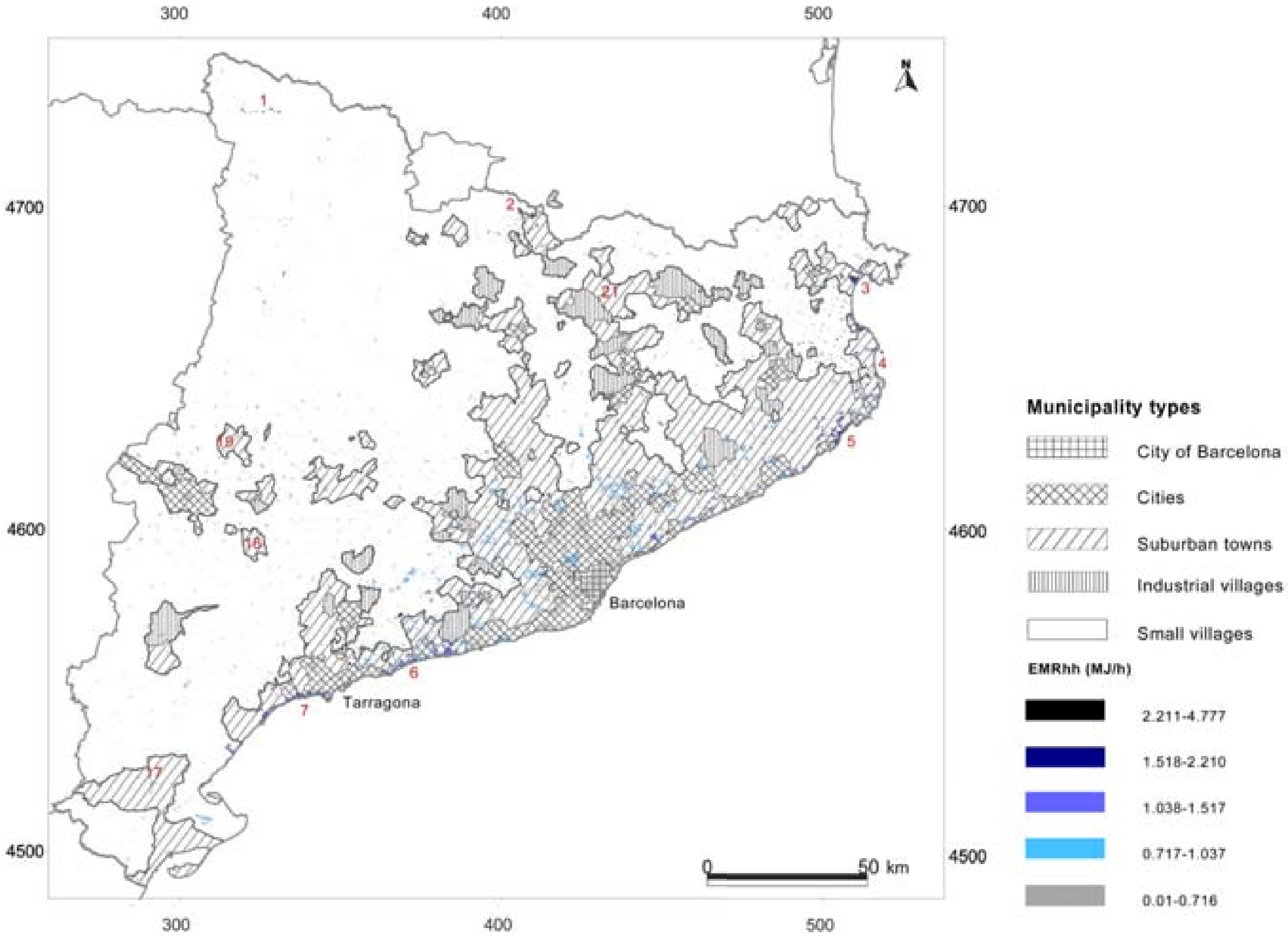


Table 16. Results of Kruskall Wallis test in electricity generation variables (correlated results are found in installed capacity) (all results had 7.814 as critical value of K and a p-value <0. 0001 and an alpha value of 0.05, and 3 degrees of freedom). The values highlighted in bold correspond to the typology having the maximum or minimum average values of the given indicator. Letters (^{A,B,C,D}) indicate the significantly different groups existent along the values of the sample, which groups typologies according the significant differences.

Type	**1:cities (n=100)**		**2:small villages (n=537)**		**3: sub-urban towns(n=265)**		**4:industrial villages (n=43)**		
Variable	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	**Mean**	**Std.dev.**	χ^2
Balance Generation/Consumption in % (2001)	100.812^{B}	826.385	**1778.818^{A}**	11615.231	852.691^{A}	11462.916	117.626^{A,B}	514.741	26.4146825
TEG (MJ net prod.) (2001)	1.81E+08^{C}	6.76E+08	3.30E+07^{A}	1.69E+08	**3.62E+08^{B}**	3.98E+09	1.75E+08^{C}	5.03E+08	94.0733563
Combined heat and power (CHP) (MJ net prod.) (2001)	1.07E+08^{C}	3.22E+08	2.01E+06^{A}	1.67E+07	6.75E+06^{B}	4.01E+07	**1.54E+08^{C}**	4.90E+08	194.040359
Renewable generation (MJ net prod.) (2001)	**2.10E+03^{B}**	1.62E+04	1.03E+06^{A}	1.69E+07	1.11E+05^{A}	1.62E+06	0.00E+00^{A}	0.00E+00	32.651
Fotovoltaica (MJ prod.neta) (2001)	**2.10E+03^{B}**	1.62E+04	0.00E+00^{A}	0.00E+00	5.01E+02^{A}	4.81E+03	0.00E+00^{A}	0.00E+00	51.651
Wind power (MJ prod.neta) (2007)	0.00E+00^{A}	0.00E+00	1.02E+06^{A}	1.69E+07	1.11E+05^{A}	1.62E+06	0.00E+00^{A}	0.00E+00	1.02*
Balance Generation/Consumption in % (2007)	125.03^{C}	840.43	**695.79^{A}**	5054.19	1717.81^{B}	25159.90	70.86^{B,C}	162.86	48.07
TEG (MJ net prod.) (2007)	**4.26E+08^{C}**	2.29E+09	2.71E+07^{A}	1.33E+08	3.33E+08^{B}	3.68E+09	1.73E+08^{B}	5.67E+08	98.18
Combined heat and power (CHP) (MJ net prod.) (2007)	9.16E+07^{A}	3.11E+08	1.43E+06^{A}	1.45E+07	6.73E+06^{B}	5.30E+07	**1.56E+08^{B}**	5.59E+08	116.102
Renewable generation (MJ net prod.) (2007)	2.38E+05^{C}	4.72E+05	2.18E+06^{A}	2.37E+07	**2.39E+06^{B}**	3.71E+07	3.20E+05^{A,B}	1.62E+06	118.010
Solar Photovoltaic (MJ prod.neta) (2007)	**2.38E+05^{C}**	4.72E+05	6.40E+04^{A}	3.65E+05	9.99E+04^{B}	3.36E+05	3.20E+05^{A,B}	1.62E+06	133.574034
Wind power (MJ prod.neta) (2007)	0.00E+00^{A}	0.00E+00	2.11E+06^{A}	2.37E+07	2.29E+06^{A}	3.71E+07	0.00E+00^{A}	0.00E+00	2.72*

* The statistical test was deploying no significant difference between typologies of wind energy generation due to the low amount of wind farm in operation at the date of the analysis, all being located in small rural villages

4.5 Distributed energy generation vs. functional urban specialization: on the need for qualitative changes

The identification of four types of municipalities has helped us to characterize them by their relevant sector of electricity consumption. Differences found in metabolic rates relate to the role undertaken by municipality types in the urban system, illustrating current urban functional specialization[62] (Duranton and Puga, 2005) and spatial segregation of working and residential activities. We find that segregation between *cities* and *industrial villages*, where the work activity takes place, and *suburban towns* and *small villages*, where the workers reside, increases both electricity consumption and the speed and density of electricity throughput. As Lobo and Baena (2009) have suggested, we find that areas with faster growth and more economic dynamism, whether in residential or industrial activity, located at the edge of urban sprawl, concentrate higher energy dissipation.

On the other side of the coin, our analysis shows an unbalanced pattern of electricity generation, concentrated in towns close to the municipalities with the lowest consumption, in the Southern countryside. With both, paid work and household sector metabolic rates of electricity consumption higher in the north and center of Catalonia, the current distribution of electricity consumption depends upon large centralized grids, incurring non-negligible losses through transmission and distribution. The high electricity consumption of northern *industrial villages* and *suburban towns* suggests that these areas should be prioritized for the development of renewable energy projects. We argue that both on efficiency grounds and with reference to environmental justice (Ortega and Calaf, 2010), which suggests that high consumption areas should bear the brunt of generation. This had begun to happen, with an increase in photovoltaics in *industrial villages* between 2001 and 2007. However, merely generating closer to consumption does not address the intensity differential that we observed, which appears to be related rather to the segregation of residential and productive activities. Co-occurrence of residence and work reduces electricity consumption and would also reduce mobility related energy demand.

The data suggest that urban planning targeted toward a structural qualitative change is needed, if overall energy consumption is to be reduced. Our results confirm that dispersed urban land use, associated with larger houses and more detached units, which consume more energy (in heat and electricity), is correlated with higher intensity electricity consumption (Ewing and Rong, 2008). *Suburban towns*, with higher per capita income and greater degrees of urban sprawl, are consuming more electricity per hour of activity. These are also the municipalities with a higher percentage of single-person households, which are growing in number regionally in Catalonia and in Spain (Gamboa, 2009; Ramos-Martín et al., 2009) and elsewhere (Liu, 2003; Williams, 2007). Although economies of scale are less pronounced in electricity than in natural gas consumption for heating (Brounen et al., 2012), the data suggest that the more people live alone and the higher the proportion of detached houses in a municipality, the more electricity will be consumed. The increasing number of appliances in single-person households, no matter how efficient they are, lies behind the reported findings that efficiency gains are offset by demographic changes in household size and household area (detached households in urban sprawl areas) (Freire, 2011; Gram-Hanssen

[62] Technological progress in transport and telecommunications has made it less costly for firms to separate their production facilities from their management headquarters. Manufacturing sites are clustered in smaller but more numerous cities, while business and services centres are few and large cities that concentrate abundant business service employment (Duranton and Puga 2005)

et al., 2004; Kaza, 2010), which can be attributed to the rebound effect or Jevons Paradox (Giampietro and Mayumi, 2008; Jevons, 1866).

The results also suggest that urban planning measures should be aware of the risk of mistakenly supporting the promotion of "smart cities" oriented to services (Domingue et al., 2011). While service cities consume less electricity per hour of activity, such measures would be once again externalizing high throughput agricultural and industrial activities, to be developed elsewhere. Instead, our data suggest that low-energy future urban planning should focus on balancing the spatial distribution of land and time uses.

Recovering Howard's (1898) (Howard, 1985 [1898]) idea of promoting the creation of polycentric urban systems (Catalán et al., 2008), composed of networked compact medium-size cities, towns and villages, Catalonia could aim to relocate existing nodes of dense electricity consumption towards a diversified collection of centres. Promoting diversified economic activity, including concrete work opportunities in the agrarian sector, could help to revitalize rural areas and balance urban growth. The recovering of integral management of the agro-forestry mosaic can be expected not only to provide new opportunities for young people who nowadays are moving to the cities but would also represent an efficient relocation of electricity consumption in rural areas.

However, polycentric compact medium-size cities and revitalized rural areas should not be confused with urban sprawl and the "consumption countryside", where urban residents consume the amenities of an "untouched" rural landscape (Marsden, 1999). Urban sprawl diffuses urban life-styles to a very interrelated network of *small villages* promoting a "liquid rurality" where commuting is the principal mode of integration into labor markets (Camarero, 2009). Part of the current blurring of traditional boundaries of rural and urban areas has been the result of the urbanization of the countryside. In our study we have found that co-occurrence of work and residence is correlated with lower intensity and lower overall electricity consumption. Urban and spatial planning for a renewable energy transition, thus, should promote such co-occurrence, transforming both city and countryside together, through an integral management.

4.6 Conclusions

A typology of municipalities was characterized according to demographic, spatial and energy metabolic patterns. We found that electricity consumption is related to functional specialization in the roles undertaken by different types of municipalities in the urban system of Catalonia, Spain. Municipality types were found to have different household and paid-work sector metabolic patterns, depending on whether they serve mainly an industrial, services or residential role. Segregation between work activity and residence was found to increase both overall electricity consumption and its rate (per hour) and density (per hectare). The higher the coincidence of paid work activity and place of residence the lower is a municipality's electricity consumption per hectare and per hour of human activity. This suggests that future energy system planning should pay attention not only to where new generation facilities are located but also to where and how economic activities and residential settlements are distributed across a region.

Our study began with the presumption that energy generation will be more distributed in the coming energy scarce future. Our results suggest that this will need to be complemented by structural and social transformations that coordinate the energy system with spatial planning. In particular, a distributed generation plan that fails to reverse the spatial segregation of residential and work activities, which promotes not only higher transport demands, but also higher electricity consumption, seems unlikely to reduce overall consumption and maximize efficiency of distribution. Living in a society based on renewable energy requires new thinking concerning overall energy supply and individual demand. However, this is not enough. Careful attention to social and demographic transformations is needed and cumulative energy demands need to be adjusted to the spatially differentiated capacities and constraints of a distributed energy system.

Applications of the approach presented here to the study of heating and transport demands could provide new and useful insights regarding how overall energy demands can be reduced. An update of the present analysis, using data from after the 2007 financial crisis also seems recommendable, as current energy demands in Catalonia have certainly been impacted. Future research could also, for example examine how smart-grid installations might be used to help gather anonymous disaggregated, geo-referenced data on energy consumption by household type at the level of municipality. Our study suggests that the availability of such data could be quite useful for better understanding how household sector composition, human settlement patterns and energy consumption are related.

5. Discussion[63]

The transition towards a renewable-based energy system is a highly contested terrain. There are multiple and possible paths that could be followed. (Lovins, 1977) at the 1970's energy crisis of United States, distinguished between the hard path, based on fossil and nuclear energy and the soft path based on renewable energy to secure a reliable energy supply in the United States. As introduced in the first chapter, the same distinction is possible within the renewable energy transition. The emphasis could be in large-scale plants and centralized supergrids controlled by utilities (the hard path), or in a decentralized small-scale distributed generation democratically controlled (the soft path) (Szarka, 2007).

However, in our case studies some we observed signals of an incipient preponderance of the hard path in renewables implementation In this chapter, I summarize and discuss the main findings and methodological conclusions of the thesis. This chapter ends with suggestions for future research and a discussion of the political implications of this research.

5.1 Discussion of key findings intersecting the case studies

Findings throughout the assessed cases denote a growing consolidation of ecological modernization as hegemonic paradigm in environmental policy (Hajer, 1995).

It manifests itself in various interlinked elements: (i) the preponderance of techno-economic reductionism over multi-dimensional perspectives; (ii) the preponderance of facts-based argumentation over value-based argumentation; (iii) the preponderance of technological solutions over structural socio-demographic and political economic transformations. Next, I discuss the results of the case-study chapters in light of these three overarching themes appearing across cases. Throughout this discussion, I make a reflection on conflicting definitions about the appropriate scale (both of energy technologies and from geographical and decision-making perspectives) depending on actors' perspectives and how do they relate to the three overarching themes. Since the overarching topics are interrelated, we refer to one another in several passages of the text, even though we structure the discussion in thematic subsections.

Preponderance of techno-economic reductionism over multi-dimensional views

Deciding who, where and how in the implementation of renewable technologies requires land use planning schemes. Energy targets need to crystallize into concrete places for siting facilities or developing agrofuel plantations. Research has highlighted how environmental, and especially energy policy issues tend to be split between the technical and the social, the technical being decided from top-down nation-state level and the social treated as a 'local' siting issues, regarded as obstacles to overcome at the end of the process (Cowell, 2004, , 2010; Owens, 2004; Shove, 1998). As raised in the planning literature, this poses questions about the balance between different scales local, regional, nation-state and global (Owens, 2004). The implementation of wind farms or biodiesel plantations, as any other technologies, have benefits and impacts both at the local level of rural areas and at the urban, national and global levels. Thus, the framing of the

[63] I would like to acknowledge here the fruitful discussions held with Katharine Nora Farrell in several occasions since 2011. They have provided brilliant insights on the methodological, theoretical and political relevance of this thesis that have helped in the writing of this chapter.

problem and criteria used for its assessment depends on whether the planning process prioritizes a single-scale or a multi-scale approach. The dimensions under consideration depend also on which actors' perspectives are considered and which are not.

The two cases of renewables implementation analyzed take place in very different world-region contexts and with different technologies. However, here we identify some commonalities in the conception of the policies particularly in the privileging of narratives and representations.

Despite the win-win-win multi-objective framing of both policies, we found that, at least at initial stages, governments approached renewable energy as a sectoral policy, not as part of an integral multi-dimensional and multi-scale planning. In the National Biodiesel Mission of India, the priority was to develop "wastelands" that were considered as "empty" and "unproductive" from the techno-economic criteria of revenue generation and biophysical productivity. Biodiesel plantations would regenerate them while bringing revenue for farmers and for biodiesel manufacturing companies. The wind farm permitting process in Catalonia, gave priority to the quality of wind resource and grid connectivity over other social and environmental criteria (incorporated at later stages) to decide about suitable locations.

The superiority of the techno-economic view over the multi-dimensional one, also affected the conceptualization of rural development at local level. RES, precisely due to its dispersed character and smaller scale than thermal power plants (fossil and nuclear, and also than big hydropower plants), are considered by their promoters as both benefiting the global environment through reducing CO_2 emissions and the local environment by bringing about rural development. Promoters of both biodiesel plantations and wind energy do so, partly, in the name of rural development. Jatropha is claimed to be 'pro-poor' in South India and wind farms are claimed to be a solution for sustaining and revitalizing aged and declining rural areas in Catalonia. There are some commonalities in the conception of rural development and consequently the role renewable energies played in it.

Next, we discuss the overall construction of *suitable locations* to implement renewable energies both at the nation-state (or regional) and at the local level. We discuss first the singularities of each case and later their commonalities.

The global rise of agrofuel promotion in the last two decades has positioned the concept of 'marginal land' as a suitable solution to the food vs. fuel debate (Fargione et al., 2008; Field et al., 2008; Tilman et al., 2009). Remote sensing is the main technique to estimate the area that falls into the "marginal land" category. The applications of remote sensing to this purpose estimate the biophysical productivity of the land. However, they fail to consider the multi-functional use and socio-cultural value that land has at the local level. Biophysical productivity is just one socio-ecological dimension and other environmental services are not taken into account. Remote sensing categorization can and usually conflates land cover and land use, forgetting that remotely considered unproductive lands can be of much use and need for the sustenance of local communities and ecosystems (Nalepa and Bauer, 2012). Moreover, the category of 'wastelands' gathers together land with different property rights which allows and facilitates processes of 'land grabbing' in the name of 'wasteland development' (Baka, 2013). As we have explained in the Indian case and further studies have shown (Baka, 2013), the Government of India defines 'wastelands' through two different processes: (a) the 'top-down' remote sensing production of the Wasteland Atlas of India and (b) the 'bottom-up' agricultural census, the Nine-Fold Classification. The later, through the records of the Village Administrative Officers (VAOs), assesses the extent of 'culturable wastelands', which are "either fallow or covered with shrubs and jungles which are put to any use"(Directorate of Economics and Statistics, 2010). Shrubs and jungles however are often, especially in the case of *Prosopis juliflora*, sources of fuel wood for local villagers and usually are spread after social forestry programs which previously attempted, precisely, to 'develop' such wastelands(Robbins, 2001a; Robbins, 2001b). As we see in our concrete study, there are multiple trade-offs entailed in the substitution of biodiesel plantations for food crops. We have studied private wastelands, but in the case of common property, the "energy trade-off" and the "water trade-off" between traditional biomass and commercial agrofuel production have even higher relevance.

The process of urbanization and industrialization of India is driving their fast and growing metabolism (Singh et al., 2012).The abandonment of traditional biomass for Liquified Petroleum Gas (LPG) and other modern energy sources is considered beneficial by some authors, which consider wood use as unhealthy and locally deforesting (DeFries and Pandey, 2009). Others highlight the multiple benefits of the use of locally available biomass (Jodha, 1990). However, such trade-offs are much more significant when they are seen from a reflection in alternative models of development. As in many other countries in the South, the opening up of agricultural markets in 1991 oriented Indian agriculture towards exports. If this process of agriculture industrialization continues, this would generate dramatic changes in Indian villages where there is still a multi-functional use of agriculture. As we have seen in our case study, the introduction of Jatropha has meant a disruption. Government technicians and corporations introduced Jatropha to maximize yields. They extrapolated the results obtained in experimental plantations predicting to get similar results in farmers' plots. Jatropha was also presented as compatible with multi-functional agriculture. The potential for intercropping and the use of the seed-cake for manure were not fulfilled and not valued by farmers adopting Jatropha. Unaware of local views and local conditions of production, Jatropha implementation was not part of a broader strategy for rural development. It was water intensive, competed with food crops and gave little money.

Research on strategic spatial planning for wind farm siting in Europe has evaluated the processes of constructing 'acceptable locations' through which varied environmental qualities of territory come to be represented in instruments of strategic planning (Cowell, 2010). The process of finding suitable sites for wind farms resembles the process of defining "wastelands" in the role of the state guiding centralized planning (Scott, 1998). The representation of the territory from regional and national perspectives requires a certain degree of abstraction, to allow the state to 'act at a distance' (Murdoch, 2000) based on certain attributes and criteria. However, democratic and sustainable planning should aim to balance such an abstraction with local contexts and 'local place identifications' (Devine-Wright, 2005). This balance requires a bottom-up approach promoting mechanisms to make renewable projects come from the local level and enhance participation.

As explained in section 3.4, about the phases and discourse coalitions present in the planning process of wind energy siting in Catalonia, de-regulation of the siting procedures was the main characteristic of the first phase. At that time, wind speed was the leading criterion and the permitting of wind farms set a prerogative to promoters conditioning the later incorporation of other criteria. Bilateral agreements between councils and promoters without broader public participation and planning beyond the municipality generated a distribution of permits that was very difficult to readdress at later stages. The 'rational siting' phase tried to *rationalize* the situation by revising projects and creating new Priority Development Zones (ZDP in Catalan). ZDP however were planned through Geographic Information Systems (GIS) to do 'sieve mapping', which, through the aggregation of spatial data, seeks out areas free of land-use constraints (Labussiere, 2007). This process lacked active local participation and consolidated a top-down approach to renewable energy.

Woods (2003) described, for the case of Wales, the conflicting environmental visions of the rural when looking at wind farm siting. Similar conflict was observed in Catalonia. Village elites and local council representatives in Southern Catalonia welcomed the wind farm developments because they were consistent with their productivist view of the countryside. Monetary compensation to landowners and local councils was, according to their view, a good strategy to sustain their aged and declining population. Income and job creation were the main objectives of their view on rural development. This view, however, contrasted with a growing sector of coupled wine production and tourist promotion, which saw the current landscape as an economic resource. This view is similar to what Woods (2003) and Marsden (1999) refer to as the "consumption countryside". The rural countryside as a space where services and consumption activity takes place. Such a conflict, however, is a bit more complex because, as reported by other authors public acceptance of wind energy is related to wind farm ownership, procedural justice in decision-making and the origin of the initiative (Musall and Kuik, 2011; Wolsink, 2007). Wind farm proposals originated exogenously to the siting areas and were negotiated through procedures lacking transparency and early-stages participation. Differential compensation to landowners depending on how they were affected by wind mills, power lines or roads, treating wind farm benefits and impacts as a private matter, instead of a public benefit or harm for everyone, fuelled conflict. Wind farms, instead of becoming an opportunity to change local power structures by prioritizing village common benefits became a source of income for affected landowners and a source of money for local councils whose purpose was not debated as part of a broader strategy for rural development.

Thus, we see how in both cases renewable energy implementation was lead by the priority of developing an industrial sector rather than becoming part of broader strategies of rural development. Furthermore, in both cases we have observed that those farmers and rural populations welcoming renewable projects did so by arguing that agriculture was declining. In one case, Indian farmers considered that their revenues from what the government labels 'wasteland' were scant. In another case, some villagers in Southern Catalonia welcomed the substitution of rainfed and 'unproductive' crops such as olive and vineyards to site wind farms. Rural populations contesting wind farms used arguments related to the multi-functional characteristics of agriculture. Sustaining landscapes and biodiversity, as active assets for hosting leisure and tourist activities where agricultural activities can and should be bound to rural tourism.

Although the case studies were in different world regions and undergoing different complex processes, in both cases, there is an agrarian crisis. Renewable energy technologies arise in rural spaces, which, in an urbanizing world, are reshaping the societal roles they play. López-i-Gelats and Tàbara (2010) analyze the competing discourses in the agro-food domain in the European Union. They argue that, "what is in crisis is neither agriculture, nor rural areas as a whole, but the role society wants agriculture and rural areas to play". They distinguish between 'free-tradism', 'multifunctionality' and 'agroecology' and their differing worldviews, nature's conception, principles of social organization and strategies to cope with uncertainties. We found their analysis useful to relate how the 'hard' path to renewable energy (and its associated preponderance of techno-economic reductionism over multi-dimensional views), relates to models of rural development. The introduction of renewable energy could have followed different perspectives on rural development to cope with changes in the role of agriculture and rural areas. Our results suggest that the policy framing of both cases was more consistent with a chrematistic and market oriented view of 'free tradism' than the other two perspectives. The objective is to generate biodiesel for distant regional or global cities and wind energy for centralized grids that transport power to conurbations and urban sprawl. Rural areas receive compensation in monetary terms and wind farm maintenance jobs. They are kept as producers rather than becoming new spaces where to rethink production, consumption and reproduction. Some of the observed fact-based arguments are closer to a technocratic view of multifunctionality, which sees environmental problems as solvable through better expert management instead of democratic negotiation. The agroecological view, which prioritizes bottom-up initiatives that enhance social and ecological diversity (Guzmán et al., 2000) would be more consistent with a 'soft' path of a regional and integrated perspective to renewables (Droege, 2009). However, bottom-up implementation is framed in both cases as an issue of secondary importance.

Preponderance of 'facts-based' over 'value-based' argumentation

The relationship between science and politics in decision making was covered throughout the thesis under different theoretical frameworks. The deconstruction of wastelands concept in India used a wider political ecology framework and the discourse analysis of wind farm siting in Catalonia used the post-normal science approach[64]. We can observe in both cases the common feature of the prevalence of fact-based argumentation over value-based argumentation, in a circumstance where a clear distinction between facts and values is very difficult to make. Such are the conditions of post-normal science situations we have referred to in the introduction of the thesis and retaken in the discussion of *chapter 3*.

The dearth of value based propositions is observed and systematically analyzed in the public policy for wind energy in Catalonia. However, we can observe it as well in the promotion of biodiesel plantations in Tamil Nadu. Farmers did not have any chance to know in advance about the policy formulation and targets, until they were offered to plant Jatropha. Farmers chose themselves to plant Jatropha in contrast to other villagers who didn't. However, this does not mean that values other than pecuniary benefits would not be valued, because they experienced and reported livelihood trade-offs after Jatropha failure. After the loss of income from the land as potential substitute of all the other benefits from former crops, the multi-dimensional consequences of planting Jatropha become more evident. Livelihood trade-offs and farmers' risks in planting Jatropha were not considered. Thus, the value-based proposition that threats to farmers' livelihood should be minimized when planting an experimental crop were not part of the policy conception. The dearth of value-based propositions can also be seen when the benefits of marginal lands for local communities are not systematically considered when evaluating the availability of wastelands by the regional and national governments. The 'malleability' of the wasteland concept allows the government to label under the same category pieces of land under different property rights. Wasteland classification is presented as a process of contrasting scientific facts that demonstrate the degraded status of land. This makes possible to argue for regeneration of *all kinds* of

[64] As argued by Farrell (2008, 2011a), 'one-dimensional thinking' as described by Marcuse (1964) can be considered as an early description of the empirical observation that facts-based and value-based claims in technology entailed problems in late-industrial societies are not clearly distinguished (Funtowicz and Ravetz, 1994a).

wastelands which are considered 'unproducitive'. This hides an underlying ideological belief: common property and small farmers' private property for self-sufficiency use land inefficiently. A value discussion of land ownership, access and use, is framed as a scientifically contrasted discussion about how to make such lands more efficient.

López-i-Gelats and Tàbara (2010) use Murdoch (1998) distinction between 'spaces of prescription' and 'spaces of negotiation'[65] to analyze discrepancies between policy discourses about the agro-food crisis in the EU. 'Free tradism', 'multifunctionality' and 'agroecology' discourses dissent on the preferred strategies to cope with uncertainties and "unwanted surprises". While the first two " suggest the generation of ''spaces of prescription,'' that is, the development of more control over actors (e.g., internalization of externalities, adjusting institutions); *agroecology* prefers the opening up of ''spaces of negotiation'' (Murdoch, 1998) to enhance the autonomy of stakeholders (e.g., precautionary principle, bottom-up approaches to create new rural development strategies)" (López-i-Gelats and David Tàbara, 2010). We see the preference for 'spaces of prescription' instead of 'spaces of negotiation' as an expression of the preponderance of fact-based over value-based argumentation. By rejecting a discussion about political purpose (value-based) dominant policy discourses push towards using normal science (fact-based) as a way to overcome and suppress conflicting views on *what, who, how and why* should be done. (Strand, 2002) emphasizes, following (Ravetz, 1971) how modern societies are characterized by a belief in the strategy of reducing *practical problems*[66] to a set of *technical problems* to be handled by the *appropriate* institutions and expertise.

Both our cases, although in distinct contexts, are characterized by lack of early-stage public participation. Public debate on broader societal goals where facts and values are disentangled, acknowledge and discussed side by side from the beginning is absent. Public participation and the relationship between science and other forms of knowledge such as the 'activist knowledge' (Martinez-Alier et al., 2011) of social movements is of great importance if 'extended-peer review' processes are to ensure the quality of decision-making.

The preponderance of fact-based argumentation (or technology as ideology in Marcuse's terms) could have had an effect on the role of social movements within the dominant ecological modernization perspective on wind farm siting in Catalonia. Reflecting on (Toke, 2011) study about the relationship between social movements and the consolidation of the wind power sector, we suggest that the integration of pro-wind environmentalists in the industrial sector seems to have gone hand in hand with the decay of the original cooperative and small-scale wind farm model of Danish pioneers. The original anti-nuclear movement of the 1970s promoted the wind energy ideal of autonomy and decentralization based on straightforward value-based arguments (Droege, 2009). However, arguments increasingly based on the benefits of a technology instead of the value-based

[65] Such analytical categories draw on actor-network theory (ANT), developed by Bruno Latour and other science studies theorists such Michel Callon and John Law. Our position is inspired by Marcuse who shares with Latour "the call for a new anthropological conception of humans in technological society" (Pierce 2009). Latour and Marcuse differ in their conceptualization of social and political agency, their view on dialectics and on the subject-object distinction (Pierce, 2009). However, we found here the two analytical categories of 'spaces of prescription' and 'spaces of negotiation' as attunable to our findings on the preponderance of facts-based argumentation over value-based argumentation.

[66] Ravetz (1971) distinguishes between *practical problems*, defined in terms of ultimate purposes such as human welfare, and *technical problems*, defined in terms of specifications such as growth in GNP (gross national product).

argumentation in favor of political and socio-economic alternative systems, seems to have favored the integration of renewable energy to the existing centralized system. In 2008, a pioneer Catalan cooperative, Ecotecnia was bought by Alstom, a corporate giant. Some of the interviewees belonging to the anti-nuclear movement of the 1970s in Catalonia they saw this fact as 'the price of success'. Others affirmed that the priority was to see nuclear power plants shut down and it could only be through siting as much as wind energy as possible, even if done by utilities before reluctant to do so. Other arguments pointed out that local groups opposing wind farms in Catalonia have slowed down, through judicial disputes, the wind farm permitting procedures financially exhausting small pioneer entrepreneurs. Small entrepreneurs could not resist the financial burden of ten years of permitting (without returns on investment) and were forced to sell permits to bigger companies. Of course, broader political economic measures made things more complex and speculation and illegal agreements between local councils and companies have also been reported afterwards (pers.comm landowner Fatarella July 2011).

The decentralization claim was also part of the South Indian NGO proposals of Jatropha and other oil bearing tree plantations as a way to extract Straight Vegetable Oil (SVO) from small-scale oil mills for village use in diesel pump-sets or other applications. Such Gandhian perspective on bottom-up development from villages to the country was finally used more as window dressing of the 'pro-poor' discourse than a serious application of biodiesel for village use as happens elsewhere, such as in Brazil's MST (Movimento dos Trabalhadores Rurais Sem Terra, Landless Workers' Movement) use of sunflower oil at small-scale (Waldron et al, 2009).

Here, the purpose of this discussion about social movements role in energy policies is to reflect on how technocracy tends to manifest in the disempowerment of citizens (Laird, 1990), when conflicting values of alternative development models are dismissed and subsumed under the experts prescription of "the right thing to do".

Preponderance of technological solutions over structural transformations

Energy flows either within the energy sector, in its generation of energy carriers (electricity, fuels or heat), or in the rest of society, are associated to structural and functional relations between sectors which constitute different scales or subparts of societies (Giampietro et al., 2009; Ramos-Martín et al., 2009). Thus, addressing energy consumption and generation towards a more sustainable society involves both technological improvements and structural transformations. Technological solutions promote renewable energy and energy efficiency. Contrary to that, structural transformations include, on the contrary, changes in social and economic activities organization.

One structural transformation which seems promising but still underinvestigated, and we have studied in *chapter 4* is the spatial adjustment of population and economic activities to available renewable energy (Oceransky, 2010).

In the cases analyzed here, renewable energy policies are sectoral policies aimed at fostering a sustainable industry, independently of broader regional planning. A fossil-fuel based society relies on centralized networks with high power density nodes of extraction or generation (e.g. oil fields, coal mines or natural gas power plants). Such a fossil-fuel based society can ignore the land use planning of the immediate consuming or extraction areas because the energy sector is globalized and deterritorialized from the local environment. The energy system based on fossil fuel and nuclear energy relies on the expansion of 'commodity frontiers' in distant peripheries of the South.

It also relies on "internal colonialism" or uneven development, especially in India. In western industrialized countries, peripheral areas are also exploited to feed the growing economy (Blowers and Leroy, 1994). Our analysis in *chapter 4* suggests that promoting renewable energy, as the base of the energy system would require integrated energy and land use planning at regional levels. We identified socio-demographic structural constraints that would require qualitative changes to make possible an energy system based on distributed generation of renewable energy.

The discourse analysis of *chapter 3*, revealed discussions around uneven development, distributed energy generation and local level inclusion in renewable energy projects. Interestingly, in *chapter 4* we found that Corbuserian functional urban specialization, and the segregation of working and residential activities entails more electricity consumption in absolute (total) and relative (per hectare and hour of activity) terms. Thus, the promotion of multi-functional land uses and co-occurrence of socio-economic activities seems to be a reasonable recommendation to reduce electricity consumption. In fact, this fact-based proposition, could be consistent with value-based claims of reducing energy demand posed in *chapter 3* by the *Protecting the landscape* discourse coalition. The results of *chapter 4* contrast with the lack of consideration of the spatial distribution of electricity consumption and generation of the dominant discourse on wind energy planning revealed in *chapter 3*. Reflecting on the urban model behind current patterns of energy (in this case electricity) consumption is not part of dominant policy narratives. *Protecting the landscape* discourse coalition critiqued the lack of broader energy and land use planning within which to contextualize wind farm siting. These critiques were more successful when talking about the efficiency of distributed energy generation than its democratic potential.

Local people complaints in Southern Catalonia villages about the paradox between the lack of industrial development in the South and their being simultaneously the highest generators and the lowest consumers of electricity is consistent with the bio-physical description of *chapter 4.* Reflecting on the spatial distribution of electricity consumption and generation requires a discussion on urban sprawl, functional urban specialization and uneven development. At the same time, such discussion requires bringing the focus on environmental justice issues such as who generates more and who consumes more. Containing urban sprawl requires reducing income inequalities and enforcing urban planning instead of fostering real estate speculation. The dominant policy discourse (*chapter 3*), however, dismisses and suppresses political discussion. Renewable energy implementation focuses on individual wind farm sitings, without broader discussion about the demand of energy that the spatial organization of society requires.

The case of Jatropha plantations in South India is less illustrative of the preponderance of technological solutions over structural transformations. It takes place in early stages of the process of industrialization rather than in advanced stages such as in the Catalan case. In Catalonia the discussion is about reformulating the role of rural areas in a society with 2% of the active population working in agriculture. In the Indian case, on the contrary, if urbanization and industrialization of agriculture continue at the current pace, they will likely displace a large part of agriculturalists, nowadays the 51% of the population, to cities. However, despite this difference, biodiesel is part of a conceptualization of rural development as boosting flows instead of reproducing funds (Giampietro et al 2009). This means that the priority is to generate commodities for cities (biodiesel) rather than ensuring quality of life of rural populations and the conditions for soil fertility and water availability.

Reducing energy demand is not at the center of energy policies in any of the cases analyzed. In India the reason seems clear because economic growth is of much priority for Indian partisans of industrialization. However, the way India develops is of key importance as an energy giant. Following alternative paths to western industrialization would provide opportunities for India to become a trendsetter in sustainable transitions (Singh et al., 2012).

Overall, we can say that both cases reinforce the divide between rural and urban areas in their narratives and in their actual implementation. Rural areas produce energy for urban areas in a "center-periphery" divide (Zografos and Martinez-Alier, 2009). Such division focuses the problem on how to develop rural areas through implementing renewable energy. Dominant narratives do no question the consumption of urban areas and do not consider the need of an integral rethinking of both urban and rural areas and their relationships. "New ruralities" in western industrialized societies as shown in *chapter 4,* arise from the diffusion of urban life styles to the countryside. Cities, on the contrary, are seldom 'ruralized' through the introduction of agricultural activities. Further research on the rise of community gardens in metropolitan regions such as Barcelona (Domene and Saurí, 2007), can explore their potentialities as an incipient step towards reconceptualizing rural-urban relationships and fostering the co-occurrence of activities in multi-functional land uses.

5.2 Methodological discussion

How can the discursive-symbolic and the biophysical domains of social metabolism be integrated when studying renewable energy policies? This was the main methodological question of the thesis. We have attempted to integrate discourse analysis (section 2.4 and *chapter 3*) with quantitative analysis of social metabolism (sections 2.6 and 2.7 and *chapter 4*). In *chapter 2*, we have not used methods for material or energy accounting, but have studied the impacts that energy flows (Jatropha yields to be converted into biodiesel) have on land and time use, and consequently on farmers' livelihood. In *chapter 4*, we have used a methodological approach designed for purposive quantitative assessment of sustainability, MuSIASEM. Here, we discuss how such an attempt to integrate these methodologies is useful to explain how discursive hegemony relates to the political use of descriptive representation. Dominant narratives based on particular normative perceptions influence the representation of reality and therefore its transformation. By discussing the potential of our methodological contributions, we set the ground to discuss further research paths.

Our discourse analyses aimed at distinguishing *storylines* or *narratives*. In *chapter 2,* we inquired about: What is the aim of regenerating 'wastelands'? Why are Jatropha plantations good for doing so? Why would marginal farmers benefit from it? What do 'wastelands' mean for different actors? In *chapter 3* we looked at actors' multiple-legitimate perspectives on: What are wind farms benefits and/or impacts? What problems wind farms solve or create? How should wind farm siting be?

These discourse analyses allowed us to identify what particular dominant narratives tend to be hegemonic in the implementation of Jatropha plantations in Tamil Nadu and wind farms in Catalonia. In the second part of *chapter 2* and the entire *chapter 4* we *chose*[67] to provide *one*[68] alternative representation to the implementation of each of the renewable energies analyzed.

[67] Italics and underline style are used here to emphasize that 'we choose our frameworks' (Cilliers 2005)

In the second part of *chapter 2* we first tested the validity of the 'pro-poor' and 'pro-wasteland regeneration' narrative on Jatropha plantations (section 2.6). We analyzed the viability of Jatropha plantations according to the most important criteria according to this dominant narrative: yields and economic returns. If yields and economic returns were high, this would generate income for farmers and biofuel for the society at large, compensating for other socio-ecological dimensions. However, in a second part of our assessment (section 2.7) we provided *one* alternative representation by exploring the impacts of Jatropha plantations on farmers' livelihood. We considered other dimensions than economic and agronomic productivity, such as food, water firewood and fodder self-sufficiency or time use management between on-farm and off-farm activities. Such an analysis, revealed a different picture regarding the success of Jatropha as 'pro-poor' and 'pro-wasteland regeneration': the multi-dimensional trade-offs of Jatropha plantations render the crop unsustainable from a narrative that values the preservation of the multi-functionality of agro-ecosystems.

In *chapter 4*, we decided to provide a description of metabolic patterns at the level of municipality with the aim to assess constraints and potentials for distributed generation of renewable energy. This decision was based on a particular narrative which considers that land use planning matters for energy issues and that bottom-up participation in renewable energy is desirable and feasible. Thus, the analysis of *chapter 4* was based on a representation which tried to be consistent with silenced perceptions we observed in wind farm siting discourse analysis, in *chapter 3*. Voices calling for a qualitative alternative to the structure and purpose of the electrical system of Catalonia and Spain based on political, ethical or normative argumentation (values) were progressively left out of the dominant discourse guiding decisions. However, our alternative representation of *chapter 4* reveals that their claims were not necessarily 'wrong', but required a different representation than the one used in official decision-making.

Such combined analysis helped to find the prevalence of reductionism and technological solutions over multi-dimensional and structural transformations (covered in section 5.1). We observe that this takes place through a conflation between the normative and descriptive aspects of the analytical and implementation stages of renewable energy policies. National and state governments of India and biodiesel companies use the concept of 'wastelands', as unproductive spaces, to justify the promotion of Jatropha plantations in 'marginal lands'. Such lands, however, are useful for local populations in securing their livelihoods. Thus, the introduction of Jatropha has had serious consequences on their livelihoods. The technical definition of appropriate locations for wind farm siting in Catalonia, Spain, has progressively left out vale-based claims for qualitative alternatives in energy and land use planning. This has had consequences both for the procedural and substantive outcomes of the policy.

In both cases, the dominant narratives reduced renewables implementation to technical problems. Such narratives assumed that scientific assessment by government technicians could reach a substantive definition of 'the best course of action'. However, in the post-normal science conditions of 'wicked' problems (Farrell, 2011b; Rittel and Webber, 1973), when facts are uncertain, stakes are high and decisions are urgent, this is not adequate and leads to poor quality decisions (Funtowicz and Ravetz, 1994a). This is so, because scientists can only provide one representation, or experience of the reality at the time and it is impossible to have a substantive representation of

[68] Italics and underline style are used here to emphasize that we provided one of the multiple possible representations of a complex system.

the sustainability of complex systems (Giampietro et al., 2013). The decision of where, how and by whom to implement a renewable energy technology (a value judgment) is intertwined with uncertain facts (such as impacts on birds, impacts or benefits of landscape changes on rural development, yields of a poorly studied new crop) but also with high stakes on who will be benefited or disadvantaged. Facing this empirical observation, proponents of post-normal science (Funtowicz and Ravetz, 1993, 1994a, 1994b) call for a democratization of expertise through an extended-peer-reviewed process. This would ensure that non-experts participation validates through value criteria what is a relevant and valid fact (Ravetz, 1971).

Critical discourse analysis identifies different narratives that could further be used to generate alternative representations of the metabolism of a system, revealing distinct trade-offs for diverse actors. Furthermore, the *types of argumentation* framework developed in *chapter 3* distinguishes between normative (value-based) and descriptive (fact-based) argumentation over time. This helps to understand how discursive closure is achieved and what narratives are considered and what are left out. As argued by Farrell (2011b) the distinction we have made between fact-based and value-based *types of argumentation* could be:

> *"... a response to situations where the empirical conflation of facts and values may be exploited to advance a politically unjust and/or scientifically dubious position, [...] making it possible to explicitly discuss who is advancing or being silenced by an argument that needs to be evaluated, according to both adequacy and value criteria".*

Next, I discuss challenges for further research based on our empirical findings and methodological conclusions.

5.3 Future research

We believe that within the findings of the thesis there are several insights that could inspire further research. We find potential for further inquiry on both the topic of renewable energy implementation and the methodological integration between discourse analysis and purposive quantitative assessment of societal metabolism.

In *chapter 2* we have highlighted how ecological distribution conflicts are not always an open and visible struggle between those in power and those subject to it. Environmental conflicts can be experienced, following what Lukes (2005 [1974]) would call a tridimensional view of power, as a suppressed conflict that is kept as a *latent conflict*. The conflict is *latent* in a sense that 'there would be a conflict of wants or preferences between those exercising power and those subject to it, were the latter to become aware of their [*real*] interests' (Lukes, 2005 [1974]: 153). Viewing environmental conflicts as *latent* does not mean to say that silenced people are absolutely manipulated and dominated without chance to subvert the situation. On the contrary this view is useful for understanding how discursive closure is achieved by giving privilege to a narrative benefiting those in power under the *status quo*. The *latent conflict* thus, lies on the struggle to subvert the forces that push disempowered people to conform to languages of valuation (narratives) contrary to their interests and their material and bio-physical consequences. Jatropha farmers are the first interested on getting high income from new crops. That is why they choose to plant it. But, are they really moved by private self-interest rationality? Do they really agree with free-market agriculture? Are they not motivated by the search of wellbeing and sustainable livelihoods? Of course these are complex questions difficult to answer. However, I highlight here how the imposition of commercial agriculture over peasant agriculture reduces the option space for

Indian farmers to choose between different agricultural models. Our findings suggest that representing the bio-physical, socio-ecological and political-economic consequences of different rural development models (facts), according to different narratives (values), would help to inform decision-making with higher quality and more democratic and fairer (procedural justice) processes. However, our results allow us to go one step further and provide suggestions for further research that could provide an honest answer to critiques about the excessive functionalistic approaches of societal metabolism accounting methods.

Chapter 3 has extensively developed a framework for accounting for the narratives that get privileged by a discursive closure which prioritize fact-based argumentation. The elucidation of this discursive closure provides a better explanation of what are the energy and material flows used for, and who uses them.

In *chapter 2* we have shown the contrast between the time frames of companies and farmers. While the time horizons of biodiesel companies are long, farmers deal with the short-term needs of the poor. A crop failure for biodiesel companies is a first trial-and-error step to develop high-yielding varieties. For farmers a crop failure is a threat to daily livelihoods. The same can be seen in *chapter 3* regarding the conflicting time horizons between opting for a fast wind farm siting with short time economic returns or choosing a longer siting process entailing direct and active participation, rather than a consent, consultation and compensation role for the local population. Diverse actors, with distinct time horizons, consider and give value to different economic and social processes.

These results in *chapters 2* and *3* suggest further research potential in combining discourse analysis and meaningful quantitative analysis of societal metabolism. (Farrell and Mayumi, 2009) reflection on Nicholas Georgescu-Roegen's general production theory is useful to illustrate our proposition for further research.

Farrell and Mayumi (2009) add new conceptual tools to the analytical (flow/fund model explained in *chapter 1* and *chapter 4*) and dialectical (process- not process) parts of Georgescu-Roegen (1971) general theory of economic production. They introduce a third dimension of time, which name '*economic Anschauung* (visualization/perspective)', a concept introduced by (Georgescu-Roegen, 1971: 362). The perception of time T (endless time) which parameterizes time t (clock time) is influenced by the conceptualization of time, the *Anschauung*, time $\mathfrak{T}$. The *Anschauung* refers to "the tradition, consciousness and abstraction that construct the relationships between past, present and future". It is the time horizon of an actor, which defines the purpose of production processes. This third dimension of time influences the boundary setting of the production process (versus the non-process) which is fundamental in the distinction between funds and flows. The purpose of the production process sets the boundaries that define what are flows (elements that enter but do not exit the process in the same form), and what are funds (elements that enter and exit the process unchanged transforming input into output flows (Mayumi, 1999)). Moreover, the flows and funds of a production processes are related to meta-funds, which are "all intents and purposes, timeless, with respect to the duration of the process" and provide services outside of it (Farrell and Mayumi, 2009: 304). Examples of meta-funds are social institutions or broader ecosystem services sustaining the context were the production process takes place.

These conceptual tools of *Anschauung* and meta-funds seem to be useful for integrating discourse analysis with biophysical accounting. Different time horizons and purposes (*Anschauung*) would affect what is a fund, a flow or a meta-fund for different actors, which would value different social and economic processes. Madrid (2011) and Madrid et al. (2013) developed a framework for MuSIASEM (Multi-Scale Integrated Assessment of Societal and Ecological Metabolism) applied to water. In doing so, they remark how our perception of water use, our perspective, influences its definition. Water represents a flow or a fund element depending on their attributes and the focus of analysis (either society or the ecosystem). This is important to our discussion because competing priorities in the use of resources, such as water, energy or materials entail different definitions of their use and thus their status as flows or funds. This lies at the heart of environmental conflicts. Revealing through discourse analysis how one narrative becomes hegemonic over others and representing the biophysical consequences of the dominant and the others dismissed, can help to incorporate conflicts in the quantitative assessment of societal metabolism. This would allow incorporating the antagonistic character of the social processes that shape the evolution of emergent complex systems. Funtowicz and Ravetz (1994a) illustrate this by considering the role of "contradiction" in emergent complex systems, such as socio-ecological systems. Contradiction can end up in a destructive collapse instead of in a dynamic balance, which means that awareness about the agency and reflexivity of the system can overcome deterministic and functionalistic analysis.

Returning to one of our cases as explanatory example, we can see how actors value different processes. As described in section 5.1, our results suggest that renewable energy, particularly in the case of biodiesel plantations (*chapter 2*), although pretending to favor rural development does so only by increasing income (a flow), not by providing and reproducing multi-dimensional livelihoods (funds). It is so because individual farmer Jatropha plots seem to be treated as funds for the farmers, and as flows for the companies, which see failing plots as trials of a broader process which includes ulterior planting of new varieties in private company-owned plantations in leased public 'wasteland'.

Thus, a combination of discourse analysis with semantically open quantitative analysis tools such as MuSIASEM or Social Multi Criteria Evaluation (SMCE) (Munda, 2004, 2008) could help to assess renewable implementation considering the conflicting perspectives on the model to follow and the purpose to fulfill.

Further research could focus on understanding how exploitative capitalist relations treat people and land, not as funds, but as flows. The struggle for putting peoples' and land (ecosystems) needs at the center characterizes most grassroots movements claiming for environmental justice, food sovereignty, degrowth and Sumak Kawsay ('buen vivir'). This struggle is in part, the struggle to confront dominant representations of people and land as flows to exploit or energy issues as supply problems (about boosting flows). Advancing alternative representations that consider the reproduction of people and ecosystem needs as the central societal purpose is an important part of this struggle. Further research could go in this direction. In Marxist terms, one could perhaps say that what is needed is emphasis on the reproduction of the conditions of production and existence than on the production of excessive flows of surplus values.

In *chapter* 3 we have analyzed the evolution of *storylines* over time at the regional level, looking how some valuation languages count more than others. This can help to retain the struggle between different political projects, between different 'purposes'. Our results suggest that this kind of analysis can be useful for further integrations with methodologies such as MuSIASEM or SMCE (Munda, 2004, 2008).

Valuable research has been conducted on local conflicts over wind farm siting by using SMCE (Gamboa and Munda, 2007). Some interviewees at the village level in Catalonia, valued the structure and purpose of former SMCE applications to wind farm siting. However, some questioned the unequal power relations that entail the use of alternatives created by companies that restrict the facts to be discussed to a limited set of options. Our analysis suggests that SMCE could be combined with political ecology studies such as the one conducted by (Zografos and Martinez-Alier, 2009) which studies the broader power relations behind the wind farm siting conflict. Our research has been a first step in this direction. Further research could use SMCE and MuSIASEM at regional and national level to evaluate energy policy scenarios. An analysis of discursive hegemonies that distinguish between values and facts argumentation in discourse coalitions, could inform the development of such scenarios. The discourse analysis would provide narratives that would describe differently the energy system and its purpose.

Separating values and facts supporting conflicting narratives would connect concrete claims to broader worldviews (*Anschauung*). This would help to represent energy scenarios according to different values. Deliberative extended-peer-reviewed processes, would then discuss these different descriptions, such as the one provided in *chapter 4*. The confrontation of different representations where values and facts would stand side by side will help to uncover the underlying assumptions of proposed scenarios. An example of this would be the uncovering of the reductionist narrative of NIMBY ('Not in My BackYard') opposition and the policy *cascade* (Wolsink 2006, Owens 2004) in facility siting. This narrative assumes that "policies are supposed to 'cascade' down from national level, raising only detailed local issues when it comes to approving specific projects on the ground" (Owens 2004: 102). This perspective characterizes conflicts over facility siting "in terms of 'national need versus local amenity'". It "overlooks the fact that need itself – and conceptions of 'the national interest' – are often contested; it implies, falsely, that issues raised in the forum of a local inquiry must thereby be 'local' in nature; and it assumes that generic and local considerations can be separated, and dealt with in a neatly hierarchical fashion" (Owens, 2004: 110). Researching on both the narratives and languages of valuation and providing alternative biophysical representations according to them could facilitate the hearing of value-based wider debates on social purpose.

Hajer (1995) at the close of "The politics of environmental discourse" proposes to foster 'reflexive ecological modernization'. His proposal has relevant connections and similarities with the post-normal science 'extended peer-review processes':

> *"In this model ecological modernization automatically ceases to be a primarily techno-administrative affair in which the objective reality of expert discourse determines what is out of place and where solutions are selected that respect the implicit social order of expert discourse. Alternatively, ecological modernization fosters a public domain where social realities and social preferences determine which actions should be taken, which social practices are to be respected, and which conventions or practices should be changed. Here a reflexive ecological modernization stands face to face with the familiar techno-corporatist regime. A techno-corporatist ecological modernization above all seeks to find one universal language to facilitate the search for the most effective and most efficient solutions to unequivocal problems. For this purpose it ordains the creation of new expert organizations where the best people can work in relative quiet. The challenge for reflexive ecological modernization lies much more in finding new institutional arrangements in which different discourses (and concerns) can be meaningfully and productively related to one another, in*

finding ways to correct the prevailing bias towards economization and scientification, and in active intersubjective development of trust, acceptability, and credibility".(Hajer 1995:281)

Many questions could arise about the extent to which a 'reflexive ecological modernization' becomes an overcoming or even negation of the very basis of 'ecological modernization'. However, such a discussion it is impossible to cover here in its deserved quality and extent. We highlight how the new research challenges under post-normal science conditions, brought us irremediably to the political realm and thus, requires a reflexive and democratic approach. Privileged advice from experts' councils, operating beyond direct and accountable democratic control, erases the critical dialectical thought in societies. In such a situation, transforming the fossil-fuel addict energy system towards a new renewable energy system should treat the organization of scientific and broader knowledge practices as a political problem, which only enhanced and direct democracy can face. In the next section, we highlight the political implications of our inquiry and the future research agenda we have suggested here.

5.4 Political implications

There is a worldwide 'consensus' that renewable energy is necessary and desirable and should be implemented as fast as possible as part of a transition to a post-oil energy system. However, as our limited research has started to show, such a consensus is just a shallow vision, because conflicts arise at the time of concrete implementation. Questions of where, how, who and for what societal purposes arise all the time in the implementation of renewable energy.

Our findings suggest that the urgency of climate change mitigation and the end of cheap oil risk being used as arguments for legitimating a top-down, technocratic, corporate-led or state-led implementation of renewable energy. Authors such as Scheer (2011) emphasize how delays in implementing renewable energy benefits fossil-fuel and nuclear lobbies. However, fundamental structural and democratic transformations require time. We have seen that the focus on technological solutions instead of structural transformation benefits the development of centralized systems which preserve current power relations.

Mitigating climate change by abandoning fossil-fuels towards renewables is a highly political endeavor. Technologically entailed and characterized by high uncertainties, high stakes and urgency of decisions they can be seen as 'wicked' problems or 'post-normal science' problems. Such problems can only be faced throughout a democratization of expertise without participatory exclusions (Agarwal, 2001), what at the end means the democratization of the society at large.

I have labeled this subsection as '*Political* implications' instead of the commonly used 'policy implications', with the aim to stress that the challenge lies not only in the current established institutions but on the ontological level of 'the political', on how society gets constituted according to power relations (Mouffe, 2005).

The prevailing power relations of future energy systems are likely to depend on which model of renewable implementation becomes hegemonic. Struggles for 'climate justice' in its distributive terms but also in the recognition, procedural and capabilities dimensions are related to the global claim for democracy. Democracy in the sense of broader political constitution of society, which not necessarily (and are likely not to) correspond to existing institutions (the realm of *policies*).

Implementing renewable energy should be consistent with a broad multi-dimensional view of justice and democracy. As our research shows, this is not only a 'normative prescription', it is also an 'empirical description' (Farrell, 2011b; Funtowicz and Ravetz, 1993). The empirically and widely observed conflation of facts and values confuse the quality of scientific representations supporting decision-making. This has political implications. Democracy is normatively necessary but it is also needed for understanding our complex world. This means the inclusion of multiple-legitimate perspectives in a way that instead of suppressing conflict, acknowledges it recognizing plurality and difference (Mouffe, 2005; Young, 1990).

Thus, the main political implication that our work suggest is: The wide-spread adoption of a decentralized and small-scale model instead of a techno-corporatist and large-scale model is intertwined with the future of democracy. Promoting distributed energy generation at small-scale should face the urgency vs. democracy contradiction.

Making decisions under urgency bears the risk of excluding perspectives and falling into the trap of reproducing the 'given state of affairs'. Prioritizing democracy is slow and means to value multiple dimensions. Reductionism can leave aside them and 'speed up' its success as leading pragmatic voice. Facing this contradiction we have some questions to share:

Is it reductionism (and its neo-liberal capitalist applications) able to produce adequate and feasible solutions to climate change and peak oil? If it is so, do we prefer such solutions to just and democratic ones? If it is unable, and we need instead multi-criteria and multi-scale representations (and its democratic use and implications), is it not worth to try it despite the difficulties we face to avoid a possible but maybe evitable collapse?

6. Conclusions

We have assessed the implementation of renewable energies in two different world regions, India and Europe. We have selected two of the most mature and booming renewable technologies: agro-biofuel (in Tamil Nadu, South India) (*chapter 2*) and wind energy (in Catalonia, Spain) (*chapter 3*). We have complemented our analysis with an assessment of the potential and constraints for distributed energy generation in Catalonia (*chapter 4*).

Our aim was to conduct an interdisciplinary study of current conflicts and trade-offs in renewables implementation, with a special interest on the relationships between energy and land use. In doing so, we had the particular methodological objective to integrate discourse analysis with biophysical accounting approaches to society's metabolism. We have found throughout the cases analyzed several commonalities with regard to empirical findings and methodological conclusions.

Throughout the research we have found that conflicts and trade-offs in renewable energy implementation, rather than acknowledged and negotiated, are suppressed by the imposition of reductionist perspectives. The superiority of a "weak" over a "strong" sustainability approach (Martinez-Alier et al., 1998) is revealed in the inability of renewable energy policies to tackle *technical* and *social incommensurability* (Giampietro et al., 2006a). The *technical incommensurability* is expressed in the acknowledgment of genuine trade-offs between different dimensions. The *social incommensurability* is expressed on the existence of multiple legitimate perspectives which are in conflict.

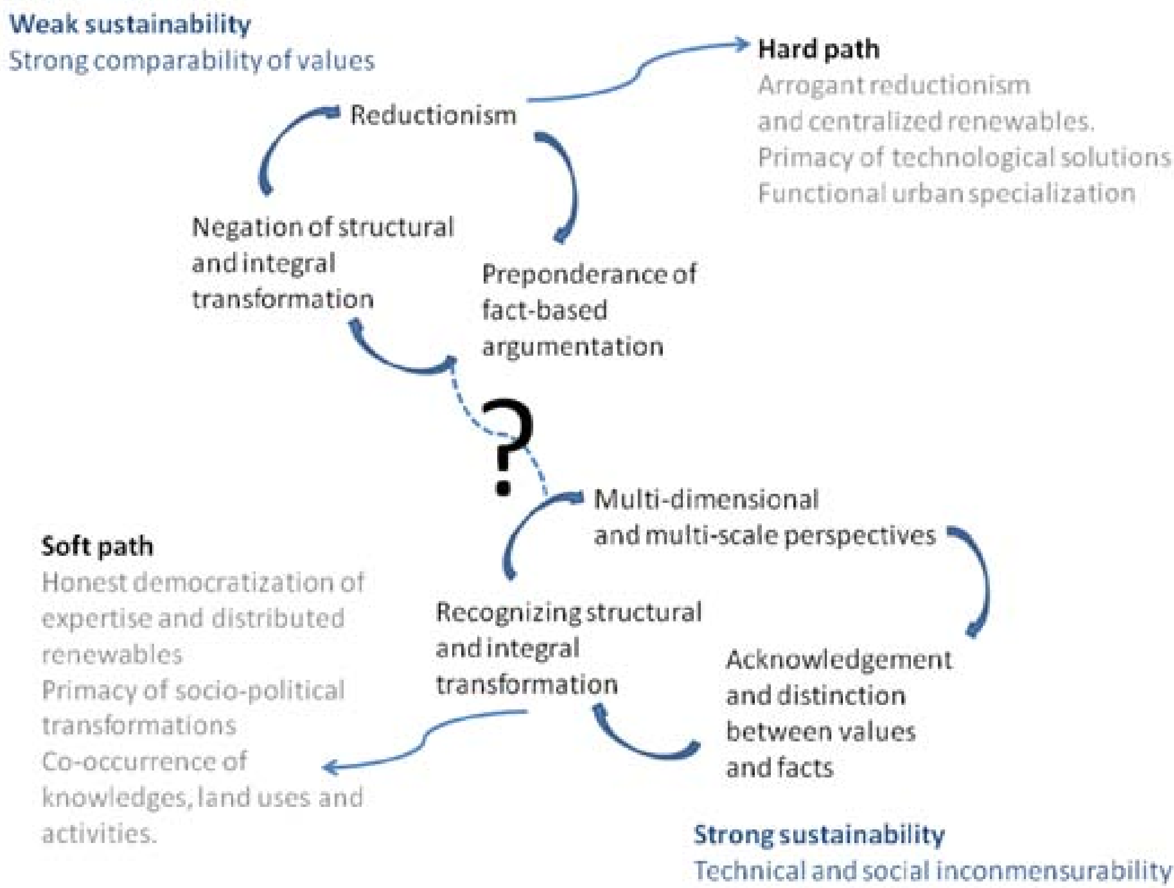
Moreover, we have seen how the neglect of *social and technical incommensurability* is part and parcel of a process of privileging technical and fact-based argumentation over political and value-based argumentation. The characteristic feature of post-normal science conditions (when facts are uncertain, values at stake are high and decisions are urgent) is the conflation between facts and values. It is very difficult to distinguish between what is argued because of political belief and what is argued as part of analytical research. This situation where facts and values conflate is "solved" quite often through hanging on to hard fact-based argumentation which privileges political positions whose arguments are more compatible with the *status quo* rather than societal transformation. In our case studies, we perceive the use of this strategy.

The suppression of conflicts and the negation or even imposition of trade-offs, disregarding incommensurability of values, seem to be beneficial and coherent to the current neo-liberal hegemony and particularly to the discourse of ecological modernization. The presentation of renewables as a 'positive-sum' game seems also compatible with the post-political *Zeitgeist* of presenting environmental decision-making as a harmonious and non-conflictive endeavor.

Renewable energy is promoted, in the cases under study, as commercially oriented and as an industrial sector rather than as a strategic part of broader multi-functional reconfiguration of land use planning. Land use planning and socio-demographic transformations (fund centered) are secondary, in front of boosting energy and revenue flows, which are the priority. This approach seems to be beneficial to the consolidation of a 'hard' path to renewable energies rather than a 'soft' path. The 'hard' path seem to be benefited as well by the preponderance of technological solutions over structural socio-demographic transformations that would make distributed renewable energy systems to be the basis instead of a marginal addition to the existing centralized energy system.

The 'hard' path is dominated by techno-corporatist ecological modernization promoting large-scale power plants, centralized grids for 'bulk power' transmission and the unquestioning of conurbations. Corporations can be private or public enterprises. This path is common to neoliberal policies and state capitalism such as the Chinese modality. The 'soft' path would emphasize distributed energy generation through small-scale facilities matching to end uses and prioritizing nested integration of distribution grids (instead of high-voltage transmission lines). This also would entail a reconfiguration of land use planning from urban functional specialization to a multi-functional co-occurrence of land uses, activities and knowledge. A 'soft path' would probably mean to challenge the rural-urban relationships by a simultaneous transformation of urban and rural areas, rather than through the existing diffusion of urban sprawl towards rural areas that the growth of conurbations is entailing. In figure 14 we present an interpretative summary of our findings, presenting how positive feed-backs can push towards the consolidation of either the 'soft' or the 'hard' path to renewable energy.

Figure 14. Interpretative summary of the relationships between findings of the thesis. **Source**: own elaboration.



Our aim of integrating discourse analysis and biophysical approaches to metabolism has also brought us to relevant methodological conclusions. Interdisciplinary synergies in the analysis of societal metabolism can arise from conducting different biophysical representations according to different narratives or story-lines of discourse coalitions. Fact-based arguments in an environmental conflict come from contingent representations that respond to value-based or ideological *choices* of what is considered relevant. Metabolic configurations result from particular discursive closures that make some narratives hegemonic. The relevance of energy and material flows accounting for policy is a value-laden question. Retaining awareness on the distinction between fact-based arguments and the values that originate them and even the existence of arguments which are not supported by facts would further help to understand how this process takes place.

Further research, thus, could focus on understanding how different actors view the same metabolic system depending on their conflicting values. This kind of analysis would help to inquiry in the extent to which land and people (human time) are treated as flows instead of funds by actors aimed at boosting productivity and maximizing capital accumulation. Actors with a multi-functional and integral perspective, on the contrary, could consider land and people as funds whose reproduction and care is the priority. Other important strand of research could be enhancing integration between MuSIASEM and quantitative assessment of Environmental Justice. As our analysis in *chapter 4* show, the distinct metabolism of either the paid work sector or household sector along the territory is related to the spatial distribution of environmental and social inequalities. Such inequalities can be seen from the sides of generation (where are the energy facilities) consumption (who consumes more and where) or social reproduction (who is exploited to sustain the system). As our first exploration of integrating energy and land use planning reveals, the spatial segregation between consumption and generation benefits the consolidation of the 'hard' path to centralized renewable energy. This also reveals a procedural injustice of materializing only the representation of those interested in the continuation of 'bulk power' generation for mass industrialization.

Our findings also suggest some political implications. There was an old debate, around 1900-1930 on "organic" town and country planning inspired by Patrick Geddes (who was well-known in India and also in Catalonia (Guha and Martinez-Alier, 1997; Martinez-Alier, 1996).Mumford was a disciple (at a distance) from Patrick Geddes, on the "organic side". He criticized Corbuserian functional specialization at urban and regional levels. Later, parallel to the rise of the environmental movement in the 1960s and 1970s decades, an intellectual discussion took place around the meaning of technology with remarkable authors such as (Mumford, 1967, 1970), (Ellul, 1980), (Illich, 1974), (Marcuse, 2007[1964]) and (Habermas, 1971) (the two later debating within the Frankfurt school). The discussion pivoted around the extent to which the raise of the technological system could end up in a progressive erosion of freedom and the elimination of the centrality of purpose and finality in society. The "alternative" or "appropriate" technology movement of the 1970s with important connections to the environmentalist promotion of renewable energy had at its core the political claim to adjust technology to a democratic society.

Examining renewable energy implementation in a scenario of growing consolidation of the growth of a 'hard' path requires critical thinking on the role of technology in industrial societies. Especially the advents of peak oil and climate change are threatening the very foundations of it. The growing research on post-normal science (Funtowicz and Ravetz, 1994a; Funtowicz, 1990; Funtowicz and Ravetz, 1993, 1994b) can be understood as part of a growing reexamination of the role of science and technology in sustainability. Research on how the world's system unequal exchange is at the core of the technological system (Hornborg, 2001) is also relevant in reconsidering the organization of technology for sustainability in the fields of energy and land use planning.

The sustainability of the energy system is intimately connected to the construction of a direct or "real" democracy, as social movements have kept claiming for. The democratization of the science and technology upon which the energy systems rests is a normative prescription, a value claim, but also a claim for the need to ensure quality in science. The empirical description of the existence of multiple-legitimate perspectives about a reality that nobody can grasp in its complete round, requires democratic deliberation between different representations. This deliberation, however, instead of considering that a *rational* consensus is possible, would likely require accepting antagonic positions that are often not reducible to each other. Accepting difference and diversity on the political projects the energy sector could work for would require decision-making structures that recognize *social and technical incommensurability* (Giampietro et al., 2006a; Munda, 2008). We hope that acknowledging *incommensurability* would help us to face the question "What do we want to sustain?"

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Annexes

Annex I. Questionnaire for Jatropha plantation assessment (*Chapter 2*)

Questionnaire data				Village name and location
Number of survey		Date		Block
Context and observations				Taluk
				Panchayat

Part 1: Socio-economical survey and general information about the household

Personal data of respondent			
Name		Gender	
Age		Education	
Caste		Phone number	
Political party or other organization affiliation		Observations	

Household general data				
Members of the family		Adults		
		Children		
		Total		
Type of house		Energy	Gas	Firewood
		Water facilities		

Occupation						
Current economical status:	Employment	Unemployment	Retired	Domestic activities	Student	
Economical activities:	Agriculture	Diary and livestock rearing	Construction	Industry	Services	
Sources of revenue and livelihood (ordered per importance)	Income (good and bad year)	Members of the family	Wages	Financial status of loans		
1.				Loans	Interest	Monthly repay
2.						
Total						

Part 1. *Cont.*

Family member sending money?	How much?	How often?

Land						
Total landholding	Ac.	Ha	Type of farmer			Leasing land or patta?
Nanjai (irrigated)	Ac.	Ha	Punjai (rainfed)	Ac.		Ha
Same place land and house?						

Land use management

Crop or activity	Last season allocation surface (Ac)	Labor (external/internal) (No of days)	Irrigation	Seasons At year	Energy (tractor and livestock use)	Output (yield) % own consump. % selling	Income
1.							

Capital

Well	**Livestock**		Tractor or vehicles
Type (electric/diesel engine)	Cows		
Hours of pumping each time	Goats		
Depth	Buffalo		
Power (hp)	Chicken		
Water table	Selling?	Milk/Livestock	

Fodder:	Source:	Requirement:	Purchased or own production?	Rate (in case of selling or purchase):
			How much time you dedicate to rear the cattle?	

Household expenditures

Food (last month)	
Agricultural investment (last year), machinery or wells	
Fertilizers	
Pesticides	
Labor	
Others	

Part 2: Assessment of the performance, requirements and EROI of the crop

Jatropha curcas plantation (Katamanake chedi)				
Surface	Ac.	Ha.	% total land	
Years of plantation			% punjai land	
Previous land use			Status of the crop	
Model of plantation			Type of soil	
(i) Marketing channels & costs (transport and other exoenditures):			Minimum Support Price(MSP) and actual rates:	
Performance of the crop				
Number of plants (theory)			Real number of plants	
Crop pattern (theory)			Number of samples taken	
Average height of the plants			Average number of nuts	
Average number of branches				
Pests				
Agricultural practices				
Plowing	Tractor?		Livestock?	Manpower?
Planting	How?			
	Fertilizers application			
	Labor (Hours, days, members, wages)			
Weeding	Labor (Hours, days, members, wages)			
Pruning				
1st pruning	Height of the plant			
	When (month), 6 months? Before dormacy?			
	Labor (Hours, days, members, wages)			
2nd pruning	Height of the plant			
	When (month), 6 months? Before dormacy?			
	Labor (Hours, days, members, wages)			

Part 2. *Cont.*

Harvesting	Labor (Hours, days, members, wages)		
	Next planned harvesting period		
	Imputs		
	Drip	Frequency	
	Flood or canal	Amount of water	
		Well: how many hours pumping (energy)	
		Labor	
Irrigation	Rainfed	(Hours, days, members, wages)	
		Frequencyv	
		Amount	
		Labor	
	Organic	(Hours, days, members, wages)	
		Frequency	
		Amount	
		Labor	
Fertilizers	Inorganic	(Hours, days, members, wages)	
		Frequency	
		Amount	
		Labor	
	Organic	(Hours, days, members, wages)	
		Frequency	
		Amount	
		Labor	
Pesticides	Inorganic	(Hours, days, members, wages)	
Energy-fuel	Tractor?	Hours/acre	Diesel consumption
Rent cost			
	Outputs		
Yield 2nd year		Income 2nd year	
Yield 3rd year		Income 3rd year	

Part 2. *Cont.*

Management, costs and institutional arrengements		
Investments done during the 3 years		Loans (amount, interest, repaying)
Information received about practices		
Total costs associated to the crop	Concept	Cost
1	Plowing	
2	Planting	
3	Weeding	
4	Pruning	
5	Harvesting	
6	Capital investment	
7	Others:	
	Total	
	Other information	

Part 3: Economic Opportunity costs assessment

<u>Opportunity costs by alternative use for leasing or selling the land</u>

For how much would you…	Guide line	Actual rate
…sell all your land?		
...sell Jatropha part?		
…lease all your land?		
…lease Jatropha portion?		

Opportunity cost by alternative use for growing other direct competitors of Jatropha (groundnut, millet, pulses, etc.)

		Competitor of Jatropha:		
Surface	Ac.	Ha.	% total land	
Years/months of plantation			% punjai land	
Previous land use			Status of the crop	
Model of plantation			Type of soil	
(i) Marketing channels & costs (transport and other exoenditures):			MSP and actual rates:	
		Agricultural practices		
Plowing	Tractor?		Livestock?	Manpower?
Planting	How?			
	Fertilizers application			
	Labor (Hours, days, members, wages)			
Weeding	Labor (Hours, days, members, wages)			
Harvesting	Labor (Hours, days, members, wages)			
	Next planned harvesting period			
		Imputs		
Irrigation	Drip		Frequency	
	Flood or canal		Amount of water	
	Rainfed		Well: how many hours pumping (energy)	
			Labor (Hours, days, members, wages)	
Fertilizers	Organic		Frequencyv	
			Amount	
			Labor (Hours, days, members, wages)	
	Inorganic		Frequency	
			Amount	
			Labor (Hours, days, members, wages)	

Part 3. *Cont.*

		Frequency	
		Amount	
		Labor	
	Organic	(Hours, days, members, wages)	
		Frequency	
		Amount	
		Labor	
Pesticides	Inorganic	(Hours, days, members, wages)	
Energy-fuel	Tractor?	Hours/acre	Diesel consumption
Rent cost			
	Outputs		
Yield before 2 seasons		Income before 2 seasons	
Yield last season		Income last season	
	Management, costs and institutional arrengements		
Investments done during the crop for 3 years		Loans (amount, interest, repaying)	
Information received about practices			
Total costs associated to the crop	Concept	Cost (to which are associated)	
1	Plowing		
2	Planting		
3	Weeding		
4	Pruning		
5	Harvesting		
6	Capital investment		
7	Others:		
	Total		
	Other information		

Opportunity cost by labor dedicated to other activities, opportunity costs in time

1) How much time you usually dedicate everyday to the plot? How much did you dedicate before Jatropha? How much during the plantation? Did you increase your time dedicated to the plot during Jatropha plantation? Did you reduce it? If it is so, to what activity you diverted the time?
2) Did you increase your days of wage labour (agricultural labor or "coolie" work) in other activities, during the period of planting Jatropha? Did you reduce them? Was it for maintaining the Jatropha crop?
3) How is a normal day in each of the seasons what are the main activities and how much time do you dedicate to each one, approximately? Can we construct an small crop and agricultural activities calendar?
4) How much time are you or your wife dedicating to domestic activities?

Part 4: Socioecological opportunity costs assessment

(Qualitative observation in the field and interpretation of Part 2 in physical terms)

1) Be aware about the water and fertilizer consumption and the comparison with other crops as an indicator of environmental impact
2) In case of barren land as previous use, the following questions:
    a. For how long the land was left as barren?
    b. What was its use? Were the cattle grazing here? Did you allow somebody else to graze the cattle here?
    c. Was there some people collecting firewood?
    d. Were there some "natural" vegetation growing?
    e. Were there to some extend some cover of Vellikattan (Tamil), Prosoppis Juliflora? How many plants approximately?

Guide for Jatropha assessment in the field

1) See homogeneity in the plantation, and identify the different homogeni parts of the plot (be aware about where are located the water sources if it is an irrigated one).
2) Take a representative sample (crop growth) in each homogenous area of the plantation

    1 sample=5 plants

    4-10 samples per acre:

    < 5 acres=10 samples per acre

    5-10 acres= 4 samples per acre

    ≥ 10 acres= 2 samples per acre

3) The indicators chosen will be:
    1. Survival, real population and real crop pattern: in 1 acre of each homogenous part
    2. Number of branches per plant
    3. Number of fruits (nuts) per branch
    4. Height of the plant
    5. Weight of the seeds
        i. If there is no enough per plant to be measured, all the sample, if not all the samples together measured
        ii. Other way will be to measure the weight of the seeds that the farmer were collecting and still were not weighted.

Field assessment	Page	Date	Code	Farmer	
Village	Block		status crop		Area
Soil	crop pattern		plants (theory)		

Sample	Plant	Survival	No. Branches	(No. pests)	No.nuts/plant	Height	Weight seeds
1	1						
1	2						
1	3						
1	4						
1	5						
2	1						
2	2						
2	3						
2	4						
2	5						
...	...						
...	...						
...	...						
...	...						
...	...						

Part 5: Social opportunity costs assessment

Perceptions, emotions and general information

(Jatropha story, General information about the village case study, Other information and other informants, Opinions)

Process of implementation and adoption

1) From whom you come to know about Jatropha, a part from the company field staff?
2) Do you have a close relation with other people planting in the village? Is this relation prior to Jatropha plantation?
3) What were your expectations?
4) What was the information and training that you have received for planting this crop?

Social consequences of adoption and development of Jatropha

5) Was there any change in the household, in the relationship and task organization between the members of the family in the decision of planting Jatropha? Was there some member in the family who was not enthusiastic and wanted to remove the crops?
6) Was there somebody in the village who is now asking you about why you were promoting Jatropha? Is this difference of opinion affecting your relationship?
7) Is there the opposite case, it means, somebody who now takes you in more consideration, increasing then your social recognition?
8) What do you think about starting to cultivate a new crop? If the loans were given properly would you continue planting Jatropha after your experience?

Trust and resilience

9) How do you considerate the changes that Jatropha has introduced?
    a. Good, improving my economic and social situation
    b. I am not feeling that it has modified really my economic and social situation
    c. Bad, worsening my social and economic status
10) As you already know, the Government of India is pushing for planting Jatropha at large scale. Do you think that the massive introduction of Jatropha could be harmful for your traditional agriculture and for the food availability? And for the prices of the food?
11) What do you think that is the most important problem that are the farmers facing? And the laborers? And in all the village?
12) Does Jatropha have any relation to this problem?
13) Would you feel confident doing other activities than agriculture?

Annex II. Interview schedule for the study of biodiesel policies in South India (*Ch. 2*)

a) Explain the purpose of the interview and purpose of the research + you would like to record
b) Mutual presentation (her own history and yours)

c) Key open questions (order: important): Standard to all actors	**Prompts / Potential probes**
Part 1: Actor's activities and projects about biodiesel	
1) Could you explain me the main objectives and activities of your projects? 2) Did you promote SVO (Straight Vegetable Oil) projects or biodiesel projects? With which plant species? 3) Are your projects coordinated or in relation to some other projects such as the BERI and SUTRA ones?	Are you part of some government scheme or get benefit from it? Other actors collaborations, NGOs, researchers, companies? Which model of plantation are you following? Own plantations? Small farmers contract farming?
Part 2: Broader biodiesel policy implementation in Southern States of India	
4) What is your general opinion about the success and promises of Biofuel National Mission and other Southern Indian states biodiesel policies, particularly the Biodiesel Policy of Tamil Nadu? 5) What is the current status of biofuel projects implemented in Southern States in India?	How are them performing? Are they successful? How old are them? What are the species promoted? Where are them being implemented? - Geographical area, , district and villages if it is possible - Type of 'wasteland": common or private?

6) What are the institutional models that are being prioritised in the implementation in the field?

What are the main **stakeholders** involved in these projects?

- What about the role of the **companies** (Reliance, Garware, Naturol, Southern Biotechnologies, Indian Railways, KSRTC, Labland Biotech, D1 Oil) involved on it? Are they really getting land for their own cultivation? Are they leasing public land, taking common land, doing contract farming?

- What about **researchers and NGOs** working in this issue?

- What are the relations between them in the process of Jatropha implementation?

Are these projects implemented by Joint Forest Planning and Management (JFPM)? For meeting energy needs of the villages or for commercial exporting purposes?

Are plantations implemented to watershed development projects or policies about 'wasteland' regeneration?

Part 3: Actor's views and position about viability and desirability of biodiesel

7) What do you think about biodiesel feasibility as a substitute for fossil fuels?

8) And as source of Rural Development?

9) And as way to cope with Climate change?

Part 5 Broader link of biodiesel initiatives to other policies and schemes

10) What about linkages of these projects with another related to organic farmer, renewable energy supply and biomass?

11) What about Clean Development Mechanism?

Part 6: Contacts and arranging field visit to the projects

12) Could I visit your projects?

13) Could you facilitate me some contact to go to the field settings of your projects?

14) Could you suggest me some field settings to do my research?

Some place with Jatropha plantations older than 3 or 5 years and ideally with different models of implementation.

d) Summarize and reviewing

a) Getting feedback on her impression of your own summary and conclusion (it is of major significance)

e) Key contacts s/he suggests

f) Explaining the data analysis and the research writing: you will send you the results.

Annex III. Interview schedule for the study of wind farm siting in Catalonia (*Chapter 3*)

a) Explain the purpose of the interview and purpose of the research + you would like to record
b) Mutual presentation (her own history and yours)

c) Key open questions (order: important): Standard to all actors	**Prompts / Potential probes**
Part 1: Planning of wind farm siting chronology. Actor's story-line about the process: what, how and why happened?	
1) How do you value the current success in wind farm siting in Catalonia?	Is it a success? Is it a failure? Is it a lost or well-taken opportunity?
2) What have been the key events in the process of wind farm siting in Catalonia?	When did you enter in the process? *(Remember to the interviewee moments you have valued as important: wind farm siting restriction map 2001, 2002, alternative GEPEC map, Moratorium in 2005, ZDP and government agreement 2010...)* What wind farm projects have been of singular importance or relevant controversy, why? *(Remember key conflictive cases and court sentences: Tallat, ZDP, etc.)*
3) What are the main causes or factors that have brought to the present situation and the observable outcomes such as ZDP restraining court order, uneven siting towards the South, court sentences against wind farm siting in some cases?	What have been the right and wrong decisions in this process? What have been helpful, benefitial and harmful to a successful implementation? Can you differenciate between different phases or stages? What do they have meant? What have been the role of formal and informal institutions? The role of governments, local agreements and referendums, etc. Who have been promoting wind energy? Are there different kinds of promoters? Have the wind energy sector diversified or is monopolized? What about permitting procedures?

What about industrial policies and overall wind energy sector development?

What about grid connectivity?

What about the local processes for wind farm siting? How it was the relationship between local actors and La Generalitat and Promoters?

4) What are the peculiarites of Catalonia in respect to other Autonomous Communities?

5) What have been the key factors influencing wind farm siting, eithre towards success or failuree?

Part 2: Benefits and impacts of wind farms?

6) What are the main positive and negative characteristics of wind energy?

7) What are the main benefits and inconvenients that the proposed model of wind farm siting could contribute to a new development model at different levels, either from local to regional , national and global level?

Part 3: Actor's views and position in the conflict

8) What is your view about the conflict that have arisen around wind farm siting?

Uneven development? Climate change?

Future of the energy system: power of utilities and qualitative changes in ownership and control?

Rural development? Which kind? Landscape Biodiversity

Siting criteria

- Wind resource
- Grid connection
- Urban planning
- Landscape integration
- Environmental impact
- Cultural heritage

9) Wind energy is associated to the search of solutions to different problems such as climate change, the energy system or rural development. There are many issues related to that, such

- Stake
- Problem definition

as landscape, biodiversity conservation, and land use planning and territorial model, etc. Can be all these dimensions be reconciled? How do you position yourself in front of each of them? What do wind energy do and don't do about them? How the reconciling of this dimensions relate to the conflict?

10) What role you have played as organization in the development of wind energy in Catalonia? What evaluation would you make about your success?

11) What are the main contradictions of wind farm siting?

12) How could be the wind farm siting conflict better addressed?

- Global and process objectives
- Power resources
- Strategies
- Perception about the behaviour of other actors
- Role: activities, practices and relationships with other actors.

Part 4 Democracy, participation and procedural justice

13) Renewable energies have been traditionally associated to the decentralization and democratization of renewable energies. Are we walking in the desirable path of wind farm siting in this respect?

What about public participation?

What about early-stages debate?

14) Have there been an effective participation in the wind farm siting process? Have the process been fair and transparent? What would you improve?

15) Unfortunately, many conflicts have had a judicial resolution. Why do you think it end up as such?

Part 5 Future view

16) What is at stake regarding the future of wind farm siting and the problems that intent to solve?

17) How do yo se the future of the environment and of energy? Which scenarios do you think will come and what scenarios do you wish to come?

Part 6: Concrete key questions to the given actor

This section was adjusted to concrete questions depending on the knowledge and position of the actor.

Different actors knew about certain concrecte events of the process helpful for overall understanding

d) **Summarize and reviewing**
    a) **Getting feedback on her impression of your own summary and conclusion (it is of major significance)**
e) **Key contacts s/he suggests**
f) **Explaining the data analysis and the research writing: you will send you the results.**

Annex IV. Description of historical events during the wind farm siting planning phases in Catalonia (*Ch. 3*)

In the following Annex we provide one table (see Table VI.1) and two maps (Figure VI.1. and Figure VI.2), which provide details about the four planning phases discussed in the text. Key regulations and events are highlighted, in order to give the reader a sense for how the overall wind farm siting discourse has developed over time. Points when controversy arose, such as discussions, debates and disputes about mapping are traced throughout the overview.

Table IV.1. Phases of planning and siting of wind energy in Catalonia: key regulations, events and controversies.

Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
I. Wind mills as new wizard players (1978–1999)	→ First studies of wind resource availability	→ Atles Eòlic 1978-1983 → Pla director de parcs eòlics 1991–1995	Studies about the wind resource availability in Catalonia undertaken together by La Generalitat de Catalunya and ENHER-ENDESA company from 1978 to 1995.
		→ Pioneer non-commercial (Garriguella-Vilopriu, 1984) and commercial (five farms from 1990–1997) projects	The wind turbine manufacturer cooperative Ecotècnia, ENHER-ENDESA, local councils and Consells Comarcals (i.e. administrative body for "comarques"), La Generalitat de Catalonia and the Ministry of Energy and Industry of Spain joined together creating public limited companies for the first five projects undertaken from 1990 to 1999.
	→ Ley 54/97 Sector Eléctrico (BOE, 1997)		The liberalization and tariff regulation arrival with the Ley 54/1997 del Sector Eléctrico which benefited the increasing wind farm projects.
	→ Pla director de Parcs eòlics a Catalunya 1997–2010 (GENCAT, 1998)		75 sites technically suitable for the hosting of 1329 MW of installed capacity wind energy (with 69% of this targeted installed capacity located in natural protected areas). Targets of 300 MW by 2005 and 1000 MW for 2010 were adopted. The "Pla director de Parcs Eòlics 1997–2010" referred to 30 solicitudes already presented, which totalized 460 MW at the time of writing the Plan (GENCAT, 1998)

Table IV.1. *Cont.*

Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
II. Political fight around "values" (1999-2003)	.	→ Local platforms constitution (1999) and mobilization in "Terres de l'Ebre" PHN and ENRON, 2000)	In 1999, the first local platforms around the story-line of "Protecting the landscape" (see Section 4.2 in the text and Annex II) were constituted in the Southern "comarques" of Priorat and Terra Alta. Parallel to this process, social mobilization arose around two projects in "Terres de l'Ebre". The Plan Hidrológico Nacional (PHN), concerning the diversion of water from the Ebro River and the combined heat and power gas fired power plant planned by ENRON, deepening the threats to the collective identity of "Terres de l'Ebre".
		→ Debate and public audience around the wind energy environmental restriction siting map (ME2002) (2000–2002) → Alternative map from GEPEC (GEPEC-AEEC, 2000)	A first version of the "Mapa d'Implantació ambiental de la energia eòlica a Catalonia" (Map of environmental wind energy siting of Catalonia) was opened for public commentary in December 2000 (GENCAT, 2000). This version received critiques both from promoters and environmentalist NGOs and environmentalist NGOs (GEPEC and AEEC) presented an alternative map including propositions for places where wind farms should be located (see Figure VI.1. in this Annex) (GEPEC-AEEC, 2000).
		→ Catalan Parliamentary motion (March 2001) about PHN, ENRON and wind farm siting map (Parlament de Catalunya, 2001).	In response to social mobilization, a Catalan Parliamentary motion was approved in March 2001 agreeing to promote territorial planning of Terres de l'Ebre; voting against PHN, discarding the ENRON project and agreeing to remake the proposed map of wind energy siting. Although this final point was the most controversial, a new process was opened to develop a definitive version of the map, which was agreed in 2002, together with the Decree 174/2002 which regulated the wind energy siting of Catalonia.

Table IV.1. *Cont.*

Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
		→ Comarcal agreement Priorat[69]	The process of citizen mobilization around the "Protecting the landscape" story-line brought about several informal agreements and referendums. One of the most relevant was the Comarcal agreement in Priorat, which was taken by five political parties and the local platform "Plataforma en Defensa del Patrimoni Natural del Priorat" on the 1st of June 2001 . This agreement, by emphasizing the importance of landscape, cultural and natural heritage for the future development of Priorat, restricted wind energy development to two concrete areas that were separated from a wind farm already existing in the area. A short summary of the agreement is: 1) Landscape, natural and cultural heritage are key resources for the local development of quality agriculture and tourism. 2) Two wind farms can be build in a commonly agreed area. Other projects can't be developed. 3) A commission has to keep track on the accomplishment of this agreement.
	→ Decret 174/2002, d'11 de juny, regulador de la implantació de l'energia eòlica a Catalunya (GENCAT, 2002b). → Mapa d'implantació ambiental de l'energia eòlica a Catalunya 2002 (ME2002) (GENCAT, 2002c).		The map (see Figure VI.1. in this Annex) zoned Catalonia in a white "compatible", yellow "conditioned" (by an EIA verdict from the Government) and red "incompatible" areas. The definition of these zones however, was again controversial and highly contested by both wind promoters and conservationists. The distance between the first technical version (which never reached the public eye), the version of 2000 and the definitive in 2002, created a feeling of legal insecurity because excluding areas from the map did not mean that their environmental values on the ground had disappeared. The 2002 map, however fixed the basic rules of the game for projects to keep advancing in the permitting process. This map was not retroactive and all projects already started, as well as those that had already finished the public commentary stage, were allowed to proceed, even if they were located in red or yellow zones.

[69] The "Acord comarcal sobre la implantació de l'energia eòlica al Priorat ("Comarcal" agreement about siting wind energy in Priorat)" is a local agreement signed by Political parties, mayors and Plataforma en Defensa del Patrimoni Natural del Priorat in Falset, Priorat, on the 1st of June in 2001.

Table IV.1. *Cont.*

Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
III. Battle between "facts": "rational siting"		→ New Left coalition government elected in Catalonia (2003)	
(2003–2010)	→Natura 2000 Network versions (first in 2004, definitive in 2006)		The process of wind farm siting took place at the same time as other important conservation policies were being developed, such as the Natura 2000 Network (see Figure. I.2. in this Annex). Natura 2000 Network definitions were denounced by conservationists and local platforms as having been adapted to accommodate wind farm projects.
	→Pla de l'Energia de Catalunya 2006-2015 (GENCAT, 2005b)		"Pla de l'Energia de Catalunya 2006-2015" set a target of 3500 MW of wind energy to be installed by the year 2015 (GENCAT, 2005b).
		→Moratoria on new wind farm projects (2005) (GENCAT, 2005a)	A moratorium on new wind farm projects was adopted, with the objective being to allow the reinforcing and reordering of policy and the rationalization of outcomes already in progress. Although the decree which formalized the moratorium was only presented to public consultation but never definitively adopted, several interviews revealed that the moratorium was de facto adopted through the actions undertaken by the government at that period.
		→Agreements between Red Eléctrica Española, and La Generalitat (2007 and 2010)	Two subsequent agreements between Red Eléctrica Española, the transmission system operator, and the Government of Catalonia, in 2007 and 2010, and the building of power lines by associations of promoters, ensured the availability of grid connection points. From around 100 MW of installed in 2005 the installed capacity multiplied by a factor of ten, coming close to the present 1000 MW by the close of this phase in 2010.

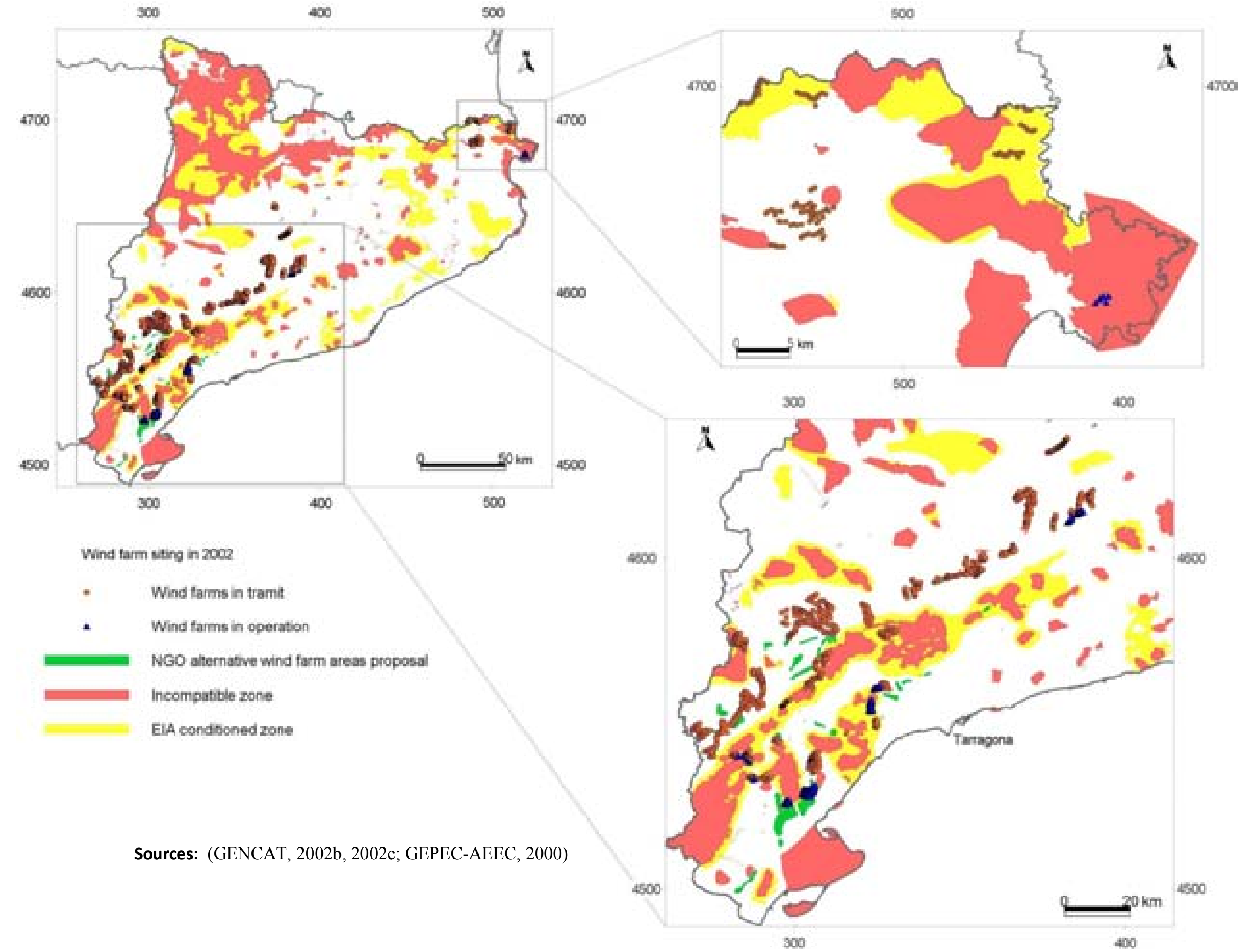
Table IV.1. *Cont.*

Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
	→Real Decreto 661/2007 (BOE, 2007)		The Spanish government updated the regulation of the so called "special generation" of electricity (power plants <50MW, cogeneration, renewable and waste) (BOE, 2007).
	→Real Decreto 6/2009 (BOE, 2009)		The Spanish government set a compulsory pre-assignation register for wind farms to receive the regulated tariff in the RD 661/2007(BOE, 2009).
	→Decret 147/2009 Siting procedures for wind farms and photovoltaics and ZDP (Priority Development Zones) regulation (GENCAT, 2009).		The Decree 147/2009 had the objective of creating a new permitting procedure, based on a new map of Priority Development Zones (ZDP in its acronym in Catalan), with permits to be auctioned by public tender. This new procedure was deemed to be useful for speeding up the siting process.
		→ZDP map approved under government agreement by La Generalitat (Acord 108/2010) (GENCAT, 2010a)	

Table IV.1. *Cont.*

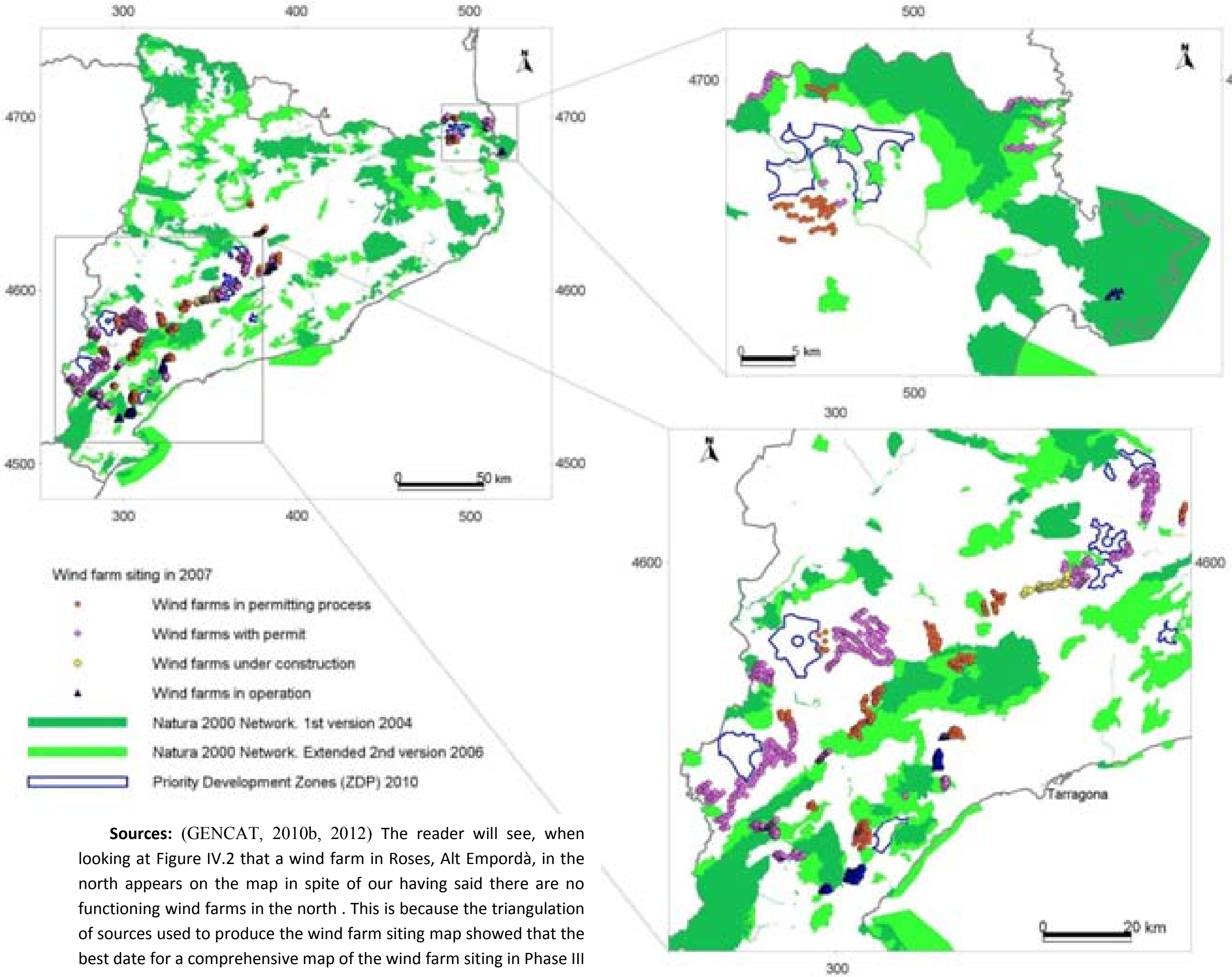
Phase of planning-siting	Regulatory-planning instruments	Key events and projects	Description
IV. Reasserting "values"? (2010–2012)		→Temporary restraining court order to the ZDPs map (2011) (TSJC, 2011a).	The legal validity of the Priority Development Zones map (see Figure. VI.2. in this Annex) was contested in an appeal to the courts by two NGOs from Alt Empordà (a windy comarca in Girona province, see Figure 1 in the text). These NGOs claimed that the Government did not follow the compulsory Strategic Environmental Assessment of Plans and Programs when preparing the map, thereby escaping the process of public participation. In March 2011 the superior court of Catalonia issued a temporary restraining order on the use of the ZDP map, pending a definitive resolution of this dispute.
		→Court sentences resulting from Phase 2 (2011-2012)	Several emblematic sentences illustrate the conflict in Phase 2: - In 2011 the wind farm Coll de la Garganta was declared illegal for procedural shortcomings in project modification and environmental reasons, due to potential impacts on the Bonelli's Eagle and migratory routes (lack of appropriate studies), with the wind farm affecting an Important Bird Area (IBA) and with a turbine in Natura 2000 Network (Pérez-Pons, 2012; TSJC, 2011c). - In 2011, the wind farm Serra del Tallat was declared illegal because urban planning for the Vallbona de les Monges municipality did not include consideration of this land use (García, 2012; Pérez-Pons, 2012; SJCA, 2011; TSJC, 2012a). - In July 2012, another sentence cancelled the permit of the Horta de Sant Joan wind farm "Els Pesells," again due to procedural shortcoming in project modification and potential impacts on the Bonelli's Eagle (Europa-Press, 2012; Giralt, 2012; TSJC, 2012b). - Grid connection judicial disputes are also being resolved in favor of wind promoters (TSJC, 2011b).
	→Feed in tariff removal (Real Decreto Ley 1/2012) (BOE, 2012)		60,9% of the installed capacity that can be expected in Catalonia in the coming years (2.334,31 MW as against a potential capacity of 3.830,8 MW) will be affected by the removal of the feed-in tariff subsidy (Deloitte, 2012).

Figure IV.1. Environmental restrictions siting map (ME2002) overlaid with wind farm siting statuses for 2002 and the proposal from the NGOs in 2000. The NGOs map (GEPEC-AEEC, 2000) is reproduced only partially, including the identified recommended and tolerable siting options. (The extensive NGO critiques regarding areas where wind farms should be prohibited have not been reproduced, as these are not immediately relevant to our argument here.). Wind farm siting is an approximate representation based on projects review, field work, interviews and data kindly facilitated by interviewees.



Sources: (GENCAT, 2002b, 2002c; GEPEC-AEEC, 2000)

Figure IV.2. Map of the Priority Development Zones, overlaid with the Natura 2000 Network and the wind farm siting statuses for 2007. Wind farm siting is an approximate representation based on projects review, field work, interviews and data kindly facilitated by interviewees.



Sources: (GENCAT, 2010b, 2012) The reader will see, when looking at Figure IV.2 that a wind farm in Roses, Alt Empordà, in the north appears on the map in spite of our having said there are no functioning wind farms in the north . This is because the triangulation of sources used to produce the wind farm siting map showed that the best date for a comprehensive map of the wind farm siting in Phase III was June 2007.

Annex V. Main actors of discourse coalitions in wind farm siting in Catalonia (*Ch. 3*).

* we are including here both actors we have interviewed and also actors who have been particularly active or are mentioned by interviewees as being important actors in the process, even if we have not interviewed them.

Discourse coalition	Centrality of actors		Description
"Building a sustainable industry"	**Main actor Groups**	**- comprised of…***	
	Eoliccat (Wind Industry Lobby)		Association of turbine manufacturers, wind promoters, utilities, small and medium size companies and banks advocating wind energy70
	ICAEN Civil Servants		Catalan Institute of Energy (ICAEN): a public entity of The Government of Catalonia, promoting technological innovation in the field of energy71
	Big Wind Industry*	ACCIONA, ALSTOM-WIND (former Ecotècnia), ENDESA, ACS, Iberdrola, Nec-Micon (Vestas), EdP.	Large local, Spanish and multinational companies involved either traditionally or as new late-comers in the wind energy sector.
	Small wind entrepreneurs*	ESBRUG, SL, Promoters of Alta Anoia wind farm	Small entrepreneurs promoting or participating in a few and generally small wind farm projects.
	Big wind entrepreneurs*	COPCISA, FERSA, Ros Roca, Tarraco Eòlica, BERTA and AERTA (associations of promoters to enhance grid connection)	Entrepreneurs coming from previous sectors such as real estate, now involved in promoting wind farm projects.

[70] Eoliccat. Official website. Available online: http://www.eoliccat.net/ (accessed on 16 August 2012).
[71] ICAEN. Official website. Available online: http://www20.gencat.cat/portal/site/icaen (accessed on 16 August 2012).

Annex V. *Cont.*

Discourse coalition	Centrality of actors		Description
	Other actors		
	Local politicians of regions hosting wind farms		The discourse of this group of actors is ambiguous and depending of the particular discursive hegemony of the area. We have located this actor here considering the majority of mayors in Tarragona Province.
	Local council civil servants		
	Local landowners		We refer here to those landowners hosting wind farms in their land. Landowners affected by roads and construction works have a point of view closer to "Protecting the landscape".
	Renewable energy cooperatives	Som Energia	A recently formed (in 2010) cooperative with the aim of building a 100% renewable energy system in Catalonia[72]
	Parliamentarians of political parties involved in " rational siting"	Partit dels Socialistes de Catalunya (PSC)	Among all parties involved, PSC is the one that has referred most to the industrial and business part of wind energy discourse.

[72] Som-Energia. Official website. Available online: http://www.somenergia.coop/ (accessed on 16 August 2012)

Annex V. *Cont.*

Discourse coalition	Centrality of actors		Description
"100% renewables now! "	**Main actors**	**- comprised of…***	
	Pro-wind environmentalist coalition (Tanquem les Nuclears-Nova cultura de l'Energia)*	Greenpeace, Grup de Científics i Tècnics per un Futur no Nuclear, Ecologistes en Acció	An advocacy coalition formally constituted to agitate for the dismantling of nuclear and fossil fuel power plants, the increasing of energy efficiency, energy demand reduction and 100% renewables[73]
	Other actors		
	Renewable energy cooperatives	Som Energia	
	Eoliccat (Wind Industry Lobby)		
	Parliamentarians of political parties involved in " rational siting"	Iniciativa per Catalunya-Verds (ICV)	Among all parties involved, ICV is the one that has referred the most to the global environmental benefits of wind energy
	Environmental Dept. Civil Servants		Environmental Assessment technicians and civil servants employing consistent at times with the argumentation of biodiversity conservation and at times those of climate change mitigation advocates.

[73] TLN-NCE. Official website. Available online: http://www.tanquemlesnuclears.org/ (accessed on 16 August 2012).

Annex V. *Cont.*

Discourse coalition	Centrality of actors		
"Protecting the landscape"	**Main actors**		
	Local platforms *	Plataforma en Defensa del Patrimoni Natural del Priorat Plataforma en Defensa de la Terra Alta Plataforma Cívica Anti-Molins de Portbou Plataforma en defensa de les serres de Feixes i Orpinell Plataforma Salvem el Tallat Plataforma Salvem Senan	Diverse group of local residents in rural areas hosting wind farms
	Other actors		
	Territorial Planning: Landscape Dept.Civil Servants		Staff working in a new division in the Public Works and Territorial Planning Department of the Catalan Government - Landscape and Architecture division - created in 2005 with the aim of ensuring the observation of the landscape protection law ("Llei 8/2005, de 8 de juny, de protecció, gestió i ordenació del paisatge")(DOGC, 2005).

Annex V. *Cont.*

Discourse coalition	Centrality of actors		
"Protecting the landscape"	**Main actors**		
	Observatori del Paisatge (Landscape Watch)		An advisory for the Catalan public administration, with responsibilities, among others, to raise awareness about landscape issues among the general public and to serve as the centre for the study of the evolution of landscapes in Catalonia[74].
	Parliamentarians of political parties involved in " rational siting"	Esquerra Republicana de Catalunya (ERC)	Among all parties involved, the ERC intended to be the voice of the "Protecting the landscape" story-line in the Catalan parliament.
	Envrionmentalist NGOs with conservationist-territorial focus (Ecologistes de Catalunya (EdC))*	Grup d'Estudi i Protecció dels Ecosistemes del Camp (GEPEC), Institució de Ponent per a la Conservació i Estudi de la Natura (IPCENA), Institució Alta Empordanesa per a la Defensa i l'Estudi de la Natura (IAEDEN), Associació Respectem l'Albera (ARA)	Environmentalist organizations for which the main objective is: defending and studying the environment and human health and diffusing environmental awareness, generally or with specialization in one or another specific area. These organizations are independent from any other public or private institution[75].
"Protecting biodiversity"	**Main actors**		
	Envrionmentalist NGOs with conservationist-territorial focus (Ecologistes de Catalunya (EdC))		
	Other actors		
	Flora and Fauna Dept. Civil Servants		Technicians and civil servants dedicated to Flora and Fauna Impact Assessment, who are more inclined to protecting biodiversity
	Birds EIA Consultants		
	Environmental Dept. Civil Servants		

[74] Observatori-del-Paisatge. Official website. Available online: http://www.catpaisatge.net/cat/observatori.php (accessed on 16 August 2012).
[75] EdC-Ecologistes de Catalunya. Official Website. Available online: http://www.ecologistes.cat/aeec/docs/aeec98.html (accessed on 16 August 2012).

Annex VI. Types of argumentation in the story-lines in wind farm siting of Catalonia (*Ch.3*)

This annex shows the predominance of each of the four types of argumentation by recording the presence/absence and relative importance of key statements made by actors contributing toward each story-line. Summary data on statements, draw from the interviews that we conducted and supplementary material collected, is reported for each planning phase. The emphasis given to each statement is recorded both with respect to its importance *within* the discourse coalition that has come together around the story-line to which it contributes (weighted as Primary or Secondary) and with respect to its place in the overall wind farm siting discourse (Primary, Secondary, Absent, Contested).

		1) Evaluation of statements within the story-line				**2) position of the statement within the overall discourse*** **		
		Weighting of importance	**Presence/absence in each phase**					
Story-line	**Statements*** *		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
Building a sustainable industry	Wind energy is good and desirable because it is a locally based source of energy, which will reduce dependency on foreign energy sources	Primary	x	x	x	Secondary	Secondary	Secondary
	Wind energy is desirable because it is a clean way to improve energy supply while reducing pollution and CO_2 emissions.	Primary	x	x	x	Primary	Primary	Primary
	Wind energy will bring rural development through income and jobs	Primary	x	x	x	Secondary	Contested	Secondary
	Wind energy helps to stop the undesirable trend of rural to urban migration by developing backward rural areas	Secondary		x	x	Secondary	Contested	Secondary
	Wind energy provides an important development opportunity to improve infrastructures in rural areas	Secondary		x	x	Secondary	Contested	Secondary

Annex VI. *Cont.*

Story-line	Statements**	Weighting of importance	Presence/absence in each phase: Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
	Type of argumentation Values-Ends							
	Wind energy should be compatible with other activities and promotes income diversification	Secondary		x	x	Secondary	Contested	Secondary
	Innovative and strategic technological sectors, such as wind energy, are desirable to ensure the progress of our region	Secondary	x	x	x	Secondary	Secondary	Secondary
	Wind energy is important, desirable and for the benefit of the whole society	Secondary		x	x	Secondary	Secondary	Primary
100% renewables now!	Achieving now a 100% renewables energy system is a moral imperative	Primary	x	x	x	Secondary	Secondary	Secondary
	Stopping climate change and shut down nuclear power is a moral imperative	Primary	x	x	x	Secondary	Secondary	Secondary
	Wind energy is desirable because it will provide a solution for the urgent problem of fighting climate change	Primary	x	x	x	Secondary	Secondary	Secondary
	We should urgently act to mitigate climate change!	Primary	x	x	x	Secondary	Secondary	Secondary
	"Think global, act local," which reflects the essential values of environmentalism, should be reflected in the siting patterns, not local claims that lack global contextualization	Primary	x	x	x	Secondary	Secondary	Secondary

Story-line	Statements**	Weighting of importance	Presence/absence in each phase: Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
	Type of argumentation Values-Ends							
	Environmentalism has broader values and purposes than those expressed by conservationism; it is different to be an environmentalist than a conservationist; wind farm siting decisions should be about environmentalism not just conservation.	Primary	x	x	x	Secondary	Secondary	Secondary
	Wind farms are more distributed generation than nuclear, therefore they should not be the target for claims of energy system injustices. This is a mistake which blocks the first step to change	Secondary		x	x	Secondary	Secondary	Secondary
Protecting the landscape	Landscape industrialization is a threat; fast and unregulated landscape transformation is a problem and should be stopped	Primary		x	x	Absent	Primary	Secondary
	Landscape is important because it is a common good*	Primary		x	x	Absent	Secondary	Secondary
	Landscape is valuable both because of its material importance (it constitute the place we live in) and its cultural value in reflecting the values embedded in the relationship of a society with its environment	Primary		x	x	Absent	Secondary	Secondary
	Landscape is important for preserving the environment and the wellbeing of local population	Primary		x	x	Absent	Secondary	Secondary
	Uneven territorial development is not fair	Primary		x	x	Absent	Secondary	Secondary
	Wind energy is a business for profit, therefore, it should be regulated and limited, in order to protect the common good*	Primary		x	x	Absent	Contested	Secondary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	Monetary fair compensation should be ensured	Primary		x	x	Absent	Secondary	Secondary
	Distributed energy generation is more democratic and fair than the concentrated energy model	Secondary		x	x	Absent	Absent	Secondary
Protecting biodiversity	Wind energy development should be achieved without affecting biodiversity conservation: it can not go everywhere	Primary		x	x	Absent	Contested	Primary
	There should be more investment and more protection of biodiversity by increasing the quality and quantity of protected areas	Primary		x	x	Absent	Contested	Secondary
	Protecting biodiversity is important for the common good* not for private interest	Secondary		x	x	Absent	Contested	Secondary
	Landscape impacts should be considered but they should not be the priority	Secondary		x	x	Absent	Secondary	Secondary
	Type of argumentation Facts-Ends							
Building a sustainable industry	Wind farms must go where there is the best wind resource	Primary	x	x	x	Primary	Contested	Primary
	Electricity generation through wind energy has more environmental benefits than negative local environmental impacts	Primary	x	x	x	Primary	Contested	Secondary
	Global environmental impacts are more important than local ones	Primary	x	x	x	Secondary	Secondary	Secondary
	Catalan society must accomplish 3500 MW of installed wind energy capacity, as settled in Pla de l'Energia 2006-2015	Primary			x	Absent	Absent	Primary
	Wind energy is inexhaustible and renewable	Primary	x	x	x	Primary	Primary	Primary

Annex VI. *Cont.*

Story-line	Statements**	Weighting of importance	Presence/absence in each phase Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
	Type of argumentation Values-Ends							
	Wind energy is 100% reversible; it can be easily dismantled and the associated material wastes can be recycled	Primary		x	x	Primary	Contested	Secondary
	Landscape is dynamic and subjective	Primary		x	x	Primary	Contested	Secondary
	Climate change is a global problem and it is solved through reducing fossil fuel consumption	Secondary	x	x	x	Primary	Secondary	Secondary
	Wind energy saves costs in fossil fuels imports and in emissions rights acquisition	Secondary		x	x	Secondary	Secondary	Secondary
	Wind energy will help to reach European targets in renewables	Secondary	x	x	x	Secondary	Secondary	Secondary
	Wind energy helps to accomplish the Kyoto Protocol targets and serves the aims of the Climate Convention	Secondary	x	x	x	Secondary	Secondary	Secondary
	In the Catalan region, consumers are paying tariffs and not recovering them through wind farms in our region	Secondary		x	x	Secondary	Secondary	Primary
100% renewables now!	Wind energy must be the base of electricity generation, not the margin.	Primary	x	x	x	Secondary	Secondary	Secondary
	Landscape is dynamic and subjective	Primary		x	x	Primary	Contested	Secondary
	Wind energy is 100% reversible; it can be easily dismantled and the associated material wastes can be recycled	Primary		x	x	Primary	Contested	Secondary
	Global impacts are more important than local impacts	Primary	x	x	x	Secondary	Secondary	Secondary
	Comparative impacts of wind energy, with respect to other technologies, are very low	Primary	x	x	x	Primary	Contested	Primary
	Impacts on birds must be demonstrated case by case	Primary		x	x	Absent	Primary	Primary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	The climate won't wait for a revolution: the cooperative wind farm model is desirable but very unfeasible in the time period we have to act	Secondary		x	x	Secondary	Secondary	Secondary
	What counts in biodiversity are populations and ecosystems not individual eagles or pairs of eagles	Secondary		x	x	Absent	Absent	Secondary
Protecting the landscape	Landscape has economic importance because it is a tourist resource	Primary		x	x	Absent	Secondary	Secondary
	Wind farms must be prohibited in protected areas	Primary		x	x	Secondary	Primary	Primary
	Distributed energy generation is more efficient	Secondary		x	x	Absent	Secondary	Secondary
	Diversity of renewable energy sources is needed	Secondary		x	x	Absent	Secondary	Secondary
Protecting biodiversity	The impact of wind energy on birds (Bonelli's Eagle) must be minimized	Primary		x	x	Absent	Primary	Primary
	The priority sites are those in places that are less valuable from a biodiversity perspective	Primary		x	x	Secondary	Primary	Primary
	Emblematic protected areas must not host wind energy	Primary		x	x	Secondary	Primary	Primary
	Type of argumentation Values-Means							
Building a sustainable industry	Project by project public consultation is participative enough and excessively open and binding public participation should be avoided because it will block infrastructure development because of NIMBY syndrome	Secondary		x	x	Absent	Contested	Secondary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	Wind farm siting should be facilitated through the mediation of the regional government. Local councils should not have the right to take the final decision.	Secondary		x	x	Absent	Contested	Primary
	The representatives of villages are the mayors; current institutions are democratic enough	Secondary	x	x	x	Absent	Contested	Primary
100% renewables now!	Business and environmentalism should work together: green business is good	Primary	x	x	x	Absent	Primary	Primary
	The State should be the institution to guarantee wind energy as an environmental good for the whole society*	Primary	x	x	x	Absent	Secondary	Secondary
	Increased public participation in wind energy siting should be based on objective scientifically contrasted arguments	Primary		x	x	Absent	Contested	Secondary
	Opulent societies, like the society of Catalonia, should stop fossil fuel consumption because of the injustice it means for the poor people in 'Third World'	Primary	x	x	x	Absent	Secondary	Absent
Protecting the landscape	Territory based consensus should be used to make siting decisions	Primary		x	x	Absent	Primary	Primary
	People's rights to social participation in early-stages of planning should be enforced	Primary		x	x	Absent	Secondary	Secondary
	The State cannot void its obligation of defending the common good* over the interests of private business	Primary		x	x	Absent	Secondary	Absent
	Access to information and transparency should be ensured	Primary		x	x	Absent	Absent	Secondary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	Endogenous development should be placed ahead of exogenous investments in rural areas. We, the local people, should have the right to decide our development model	Primary		x	x	Absent	Contested	Absent
	Planning with participation is required: not only because it is the law but also because it is just	Secondary		x	x	Absent	Contested	Secondary
	Local people's economic participation in the ownership of wind farm projects should be promoted	Secondary		x	x	Absent	Contested	Secondary
Protecting biodiversity	Political decisions in wind energy siting should be based on improved technical support	Primary		x	x	Absent	Secondary	Primary
	Type of argumentation Facts-Means							
Building a sustainable industry	The appropriate role of the government is to maintain regulation stability in order to ensure that investments pay-back their costs	Primary	x	x	x	Absent	Secondary	Primary
	Governments must have political will in order to effectively concretize their discourse in favour of renewables	Primary	x	x	x	Absent	Secondary	Primary
	The needed amount of wind farms requires large financial investment; the large-scale wind farm model is needed	Primary	x	x	x	Absent	Contested	Primary
	The permitting process must be fast and easy	Primary	x	x	x	Absent	Secondary	Primary
	The appropriate role of the government is to guarantee and facilitate power lines construction and grid connection, in order to achieve a successful wind energy siting	Primary		x	x	Absent	Secondary	Primary
	The appropriate role of the government is to facilitate the expansion of wind energy	Primary	x	x	x	Primary	Secondary	Primary

Annex VI. *Cont.*

Story-line	Statements**	Weighting of importance	Presence/absence in each phase: Phase I	Phase II	Phase III	Phase I	Phase II	Phase III
	Type of argumentation Values-Ends							
	There must be no limit to the expansion of renewables	Primary	x	x	x	Absent	Contested	Contested
	Experts must plan wind energy siting. People don't know enough.	Secondary		x	x	Absent	Contested	Primary
	Law and judicial processes are appropriate tools for conflict resolution	Secondary		x	x	Absent	Primary	Primary
	Wind energy is in the nation's public interest*; local opposition does not have the right to obstruct the public interest*	Secondary		x	x	Absent	Secondary	Primary
	The role of participation in wind energy siting is to identify the maximum possible capacity	Secondary		x	x	Absent	Secondary	Secondary
	Government must educate and communicate about the importance of wind energy to facilitate its acceptance and the final execution of wind farm construction at appropriate sites	Secondary		x	x	Absent	Secondary	Secondary
100% renewables now!	The needed amount of wind farms requires large financial investment; the large-scale wind farm model is needed and the most feasible model to be materialized in the time period we have to act	Primary		x	x	Absent	Contested	Primary
	The appropriate role of the government is to launch an agenda for achieving 100% renewables	Primary	x	x	x	Absent	Secondary	Secondary
	Debate must be about the most effective way to achieve 100% renewables	Primary		x	x	Absent	Secondary	Secondary
	Demands on the impacts of renewable siting can't be higher than for the rest of energy technologies. A less polluting infrastructure such as a wind farm can't be treated in the same way as nuclear and fossil fuel power plants.	Primary		x	x	Absent	Contested	Secondary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	Wind energy siting is a technical problem and objective scientific knowledge is the appropriate tool to address it	Primary		x	x	Absent	Contested	Primary
Protecting the landscape	Rational siting helps to avoid overcrowding and cumulative environmental and landscape impacts	Primary			x	Absent	Absent	Primary
	It is more appropriate to coordinate siting at the regional, rather than municipality level	Primary		x	x	Absent	Secondary	Primary
	Laws enforce the right thing to do	Primary		x	x	Secondary	Primary	Primary
	Technical environmental evaluation of local impacts need to be enforced in the final building activities	Secondary		x	x	Absent	Secondary	Primary
	Reducing energy demand is more effective and so must be prioritized	Secondary		x	x	Absent	Secondary	Secondary
Protecting biodiversity	Strategic planning from the beginning will help to reconcile wind energy and biodiversity objectives	Primary		x	x	Absent	Secondary	Primary
	Law improvement and enforcement is needed for biodiversity conservation	Primary		x	x	Absent	Secondary	Primary
	Scientific studies must help to make wind energy and biodiversity conservation compatible	Primary		x	x	Absent	Secondary	Primary
	Technical studies about environmental impacts are the most helpful tool to improve decisions	Primary		x	x	Absent	Secondary	Primary
	Efforts should concentrate in developing better, appropriate and common methods to enhance Environmental Impact Assessment	Primary		x	x	Absent	Primary	Primary

Annex VI. *Cont.*

		Weighting of importance	Presence/absence in each phase					
Story-line	**Statements****		**Phase I**	**Phase II**	**Phase III**	**Phase I**	**Phase II**	**Phase III**
	Type of argumentation Values-Ends							
	Decisions about planning must be taken at the national or regional level in order to balance impacts and avoid subjective localism in the evaluation of the importance of biodiversity	Primary		x	x	Absent	Contested	Primary
	Law and judicial processes are appropriate tools for conflict resolution	Primary		x	x	Absent	Primary	Primary

* There is a dispute around the contested meaning of "interès públic" or "interès general" in Catalonia. Some actors were using these words with a meaning close to the meaning institutionalized in Article 52 of "Ley 54/1997, de 27 noviembre, del Sector Eléctrico" (BOE, 1997), and in Articles1 and 9 of "Ley de 16 de diciembre de 1954, de Expropiación Forzosa" (BOE, 1954) and article 33.3 of the Spanish constitution, which is related to the primary authority of the state to take actions in the public interest. Other actors, however, were referring to this concept in an effort to reclaim a democratic right to determine the State's general obligations or by trying to repossess it through bringing to the fore the final purpose of the common good. To reflect this conflict over the meaning of this word we have used "common good" in the later case, and the direct translation of the institutionalized term, i.e. "public interest," for the former.

** The statements reported here are intended to capture the essential messages given by the discourse coalitions in the data we analysed. The written statements capture ideas which have either been formulated as such or condense the idea given in several similar passages of data. The interview source material for this table was collected in Catalan and translated by the first author, who is a native Catalan speaker, in consultation with the second author, who is a native English speaker.

*** The position of the statement within the overall discourse can be understood as the degree of success of an intervention to be heard, reproduced or critiqued by other actors. For example, a statement labelled as "Primary" or "Secondary" within a story-line can end up as "Absent" in a particular phase of the overall discourse because it has not been considered by the rest of actors or because it has been abandoned.

Annex VII. Types of argumentation in planning phases in wind farm siting in Catalonia (*Ch. 3*).

This Annex shows the details of how we have applied the analytical *types of argumentation* to evaluate the specific prevalent *type of argumentation* in each phase of the overall siting discourse.

Phase of planning-siting	**Dates**	**Prevailing type**	**Values-Ends** (value based arguments concerning end results, e.g. purpose of wind mill siting)	**Facts-Ends** (fact based arguments concerning end results e.g. technical criteria for decision-making)	**Values-Means** (value based arguments concerning means for reaching end results, e.g claims about participation)	**Facts-Means** (fact based arguments concerning means for reaching end results e.g. technical tools and siting procedures)
I. Wind mills as new wizard players	1978-1999	**Facts-Ends**	Optimize positive effects in clean locally based energy generation; Development of backward areas, generating employment. Generate a solid and pioneer industrial sector. Limiting the environmental impacts of wind farms (GENCAT, 1998)	**Energetic:** Wind speed (6.5 m/s, 10 m height), maximization of installed capacity, local energy use, and optimal connection to the existing grid **Environmental:** Affection for protected areas, public forests and Habitats of Communitarian Interest (HCI); concerns about access roads and power line impacts, and additive impacts. **Landscape:** visual basin and distance to inhabited areas; affection for cultural heritage. **Socio-economic:** upgrading the local economy, guaranteeing appropriate management (GENCAT, 1998)	Few debates about citizen participation and democracy: agreements with municipalities that include neither public consultation, nor citizen participation. There is no broader plan to set up participatory bodies or procedures.	**Permitting procedure:** Led by the Energy and Mining division of the Industry Department of la Generalitat. Bilateral agreements between promoters-local councils **Environmental impact tools:** EIA case by case

Phase of planning-siting	**Dates**	**Prevailing type**	**Values-Ends** (value based arguments concerning end results, e.g. purpose of wind mill siting)	**Facts-Ends** (fact based arguments concerning end results e.g. technical criteria for decision-making)	**Values-Means** (value based arguments concerning means for reaching end results, e.g claims about participation)	**Facts-Means** (fact based arguments concerning means for reaching end results e.g. technical tools and siting procedures)
II. Political fight around "values"	1999-2003	**Values-Ends**	Local conflicts should be taken into account and solved through more attention to the local environmental impact (GENCAT, 2000, , 2002b, 2002c). Territorial planning of Southern Catalonia should be addressed in order to respond to the social tension in Terres de l'Ebre (Parlament de Catalunya, 2001).	**Energetic:** Wind speed (5 m/s, 10 m height, 2100 equivalent hours), optimal connection to the existing grid **Environmental:** Incompatibility with special protected areas, except partial reserves and new natural parks, <1000 ha PEIN and Birds SPAs and vital areas of threatened raptors (Annex I Birds Directive). Conditioned to EIA: partial natural reserves, no specially protected PEIN > 1000 ha, edges of incompatible areas, biological corridors and highly dense raptor vital areas (GENCAT, 2000, , 2002b, 2002c).	"Comissió d'Asessorament sobre l'impacte ambiental de la energia eòlica" An advisory commission concerning the environmental impacts of wind energy is set up with participation of 16 members from various departments of the Government of Catalonia, municipalities, wind promoters and members of civil society. The commission has a very marginal role. The decision making authority lies in "La Ponència Ambiental(GENCAT, 2000, , 2002b, 2002c). Informal activities take place with the aim to promote alternative means for decision making: "Acord Comarcal del Priorat" is an example of a "Local deal" between political parties and civil society[76].	**Permitting procedure:** The procedure is led by the Energy and Mining division as in the previous phase, but "La Ponencia Ambiental" is created. This is a body composed of 3 members of the Energy and Mining Division and 3 members of the Environmental Department. Other departments are consulted if needed. "La Ponencia Ambiental" declares the environmental impact of wind farms (GENCAT, 2002b). **Environmental impact tools:** Zoning map (compatible, conditioned to EIA and incompatible zones are identified) according the mentioned criteria (GENCAT, 2000, , 2002b, 2002c).

[76] The "Acord comarcal sobre la implantació de l'energia eòlica al Priorat ("Comarcal" agreement about siting wind energy in Priorat)" is a local agreement signed by Political parties, mayors and Plataforma en Defensa del Patrimoni Natural del Priorat in Falset, Priorat, on the 1st of June in 2001.

Annex VII. *Cont.*

Phase of planning-siting	Dates	Prevailing type	**Values-Ends** (value based arguments concerning end results, e.g. purpose of wind mill siting)	**Facts-Ends** (fact based arguments concerning end results e.g. technical criteria for decision-making)	**Values-Means** (value based arguments concerning means for reaching end results, e.g claims about participation)	**Facts-Means** (fact based arguments concerning means for reaching end results e.g. technical tools and siting procedures)
III. Battle between "facts": "rational siting"	2003-2010	**Facts-Means**	Arguments are advanced regarding the need for territorial consensus in determining suitable locations for wind farms. Concerns about geographical inequalities were accepted in the debate, however only on the basis that first ZDP zone for development was to be located in the North. Promoting distributed energy generation through photovoltaics in building roofs was left out of the discussion on the grounds that it was outside the direct competence of the Catalan government. Restrictions on the ownership of multiple contiguous mini-wind farms by the same wind promoter were rejected because they violated the European Directive on free market competition.	**Environmental:** ZDP creation: Exclusion of: Special protected areas, PEIN out of Natura 2000, Natura 2000 Network (Sites of Community Importance (SCI), are conditioned to EIA, SPAs are excluded, Bonelli's Eagle territories (nests and breeding areas are excluded; living areas are conditioned), Conditioned to EIA are: Geosites, Biological corridors, public forests, and habitats of Community interest (HCI). **Landscape:** Exclusion: 900 m distance from villages, 1000 m distance from other wind farms in operation or in project. Conditioned to EIA: cultural heritage. **Energetic:** Wind speed (5.5 m/s, 80 height); grid connection optimization (GENCAT, 2009, , 2010a).	Failed attempt to create a "Participatory table for following the environmental impact of wind energy siting." Two referendums are organized in Pinós (2006) and Horta de Sant Joan (2008) with the majority of voters rejecting the proposed wind farms. The Esquerra Republicana de Catalunya (ERC) political party, the voice of this coalition in internal Government negotiations managed to guarantee that two members of the commission responsible for project selection in the auction would be from local councils (article 8.1. Decree 147/2009) (GENCAT, 2009). However, local representative participation remained very limited. Local economic participation was discussed only in terms of minority holdings in commercial wind farms.	**Permitting procedure:** <u>Already presented projects:</u> the same as in the previous phase but revised through the policy to support existing viable projects (see section 4.1 in the text). <u>New projects:</u> The Decret 147/2009: Siting procedures for wind farms and photovoltaics and the ZDP regulations define a new procedure which is intended to ensure faster permitting through "single window". "La Ponencia Ambiental" is restructured to comprise five members of Environmental Department (one is the president), two members of the department competent in energy, two members of the department of urban planning, one member of the department of culture (GENCAT, 2009). **Environmental impact tools:** Rational siting: The policy to support existing farms and the creation of the ZDP through zoning based on buffers of exclusion criteria. Revision of the outdated environmental siting map starts but is, in the end, not accomplished. **Energetic potential tools:** Wind resources map produced in 2004 (see Figure 1 in the text) (Aymamí, 2004). Two subsequent agreements with the Transport System Operator, Red Eléctrica Española (2007 and 2010) to enhance grid connection.

Phase of planning-siting	**Dates**	**Prevailing type**	**Values-Ends** (value based arguments concerning end results, e.g. purpose of wind mill siting)	**Facts-Ends** (fact based arguments concerning end results e.g. technical criteria for decision-making)	**Values-Means** (value based arguments concerning means for reaching end results, e.g claims about participation)	**Facts-Means** (fact based arguments concerning means for reaching end results e.g. technical tools and siting procedures)
					NGO participation was not accommodated because of Government claims that this Phase was not a new planning process and therefore was not subject to the participative procedure rules pertaining to the Strategic Environmental Impact Assessment of Plans and Programs.	
IV. Reasserting "values"?	2010-2012	**Contested** **Facts-Means** **Values-Means**	Although present, Values-End claims are either translated into Facts-Ends claims of preserving the targets established in Phase III or focused more in the Values-Means or Facts-Means side of how to achieve them.	Criteria settled cumulatively over the previous phases.	The NGOs appeal to the court questions the avoidance of citizen participation through escaping Strategic Environmental Impact Assessment of Plans and Programs. A temporary restraining is ordered by the Court(TSJC, 2011a)	Permitting procedure: The Decret 147/2009 procedure for new projects and the previous regulation for older projects (GENCAT, 2009).

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