Unattainable proximity: Solar power and peri-urbanity in central Burkina Faso

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Abstract

In the community of Zagtouli, close to Burkina Faso's capital, Ouagadougou, lies West Africa's largest solar power plant. This is a 33 MW, on-grid, photovoltaic plant. Operational from late 2017, it produces electricity for Burkina Faso's public energy company, SONABEL. The electric grid built between the plant and Ouagadougou crosses Zagtouli in its middle: however, electricity connections throughout the community are markedly non-homogeneous. In particular, most of the southern half of Zagtouli suffers from a condition known in the literature as 'under-the-grid': namely, close to the grid but unable to connect to it. The benefits stemming from the presence of the nearby plant, therefore, remain unattainable for a large share of the local community. Drawing on an ethnographic investigation of energy practices and uses conducted in Zagtouli, we employ the theoretical framework of energy justice to analyse the connection between local justice issues and national electrification strategies. We claim that the national preference for on-grid, centralised plants may not adequately respond to the need for a more just local energy distribution; and that for peri-urban areas that are not planned to be fully connected to the grid in the short term, smaller-scale, decentralised solutions may be more appropriate to achieve full electricity access.

Keywords: solar energy, energy justice, Burkina Faso, renewable energy policy, under-the-grid communities

1. Introduction

About 2 km west of the mosque of Zagtouli, a peri-urban neighbourhood in the surroundings of Burkina Faso's capital city, Ouagadougou, an inconspicuous side dirt road from the N1 Highway leads to West Africa's largest solar power plant. The plant, endowed with almost 130,000 photovoltaic (PV) panels totalling a capacity of 33 MW, was inaugurated in late 2017, and currently produces electricity for the public electricity company, SONABEL (Burkina Faso National Electricity Company), feeding the national grid. The Zagtouli solar power plant (SPP) is unique in terms of its capacity and is part of an ambitious national plan for renewable electricity production.

The implementation of a renewable energy (RE) strategy is often seen as a major step towards higher energy autonomy for poor areas of the world, endowed with large supplies of renewable resources. Throughout their reports, both international financial institutions and world energy agencies have argued that, thanks to renewables, these areas could leapfrog from the widespread use of biomass or low-grade fossil fuels to clean electricity, without transitioning into high-grade fossil fuels first, and thus avoiding the environmental and health issues related to such forms of energy. A number of programmes and policies have been launched at the international level to address this issue. Examples are the 2012 United Nations and World Bank's Sustainable Energy for All (SEforALL), aimed at achieving universal access to sustainable electricity by 2030; or the 2015 African Development Bank's African Renewable Energy Initiative [1]. Access to clean power, these programmes state, would result in social and economic benefits by relieving some categories of people (mainly, women and children) from physically extenuating daily chores, helping children to study at home after dark, and improving the quality of services provided in hospitals. With respect to solar energy, on which we focus in this study, this narrative applies particularly well to regions of Africa bordering the Sahara desert, because of their high irradiation potential.

In the literature on access to RE in Africa, the most frequent focus is on off-grid solar solutions. Indeed, one of the scenarios recently devised by the International Energy Agency (IEA), based on Agenda 2063, highlights that mini-grids and stand-alone systems, mostly based on renewables, could be essential to achieve universal access [2].[1] Fewer academic publications have instead centred on the consequences of extensions of the electrical grid in non-served areas (e.g. [3]). Works on large SPPs in sub-Saharan Africa's energy transition are practically non-existing. That is not surprising, considering the small number of such plants in the continent [4].

The Zagtouli SPP is not the only PV plant in Burkina Faso: the Ziga SPP, opened in 2017, produces 1.1 MW, while a second one, the Essakane Solar hybrid power plant, inaugurated in 2018, produces 15 MW from PV panels. However, this energy is exclusively used by the country's largest gold mine at Essakane, in the country's northeast [5]. Thus, because of its much larger capacity and the general use of the electricity produced, the Zagtouli SPP is an unique case in West Africa. As we explain in the next section, our study analyses especially the plant's impact on the neighbouring community in terms of energy justice. In using this approach we argue that, while the Zagtouli SPP is contributing to a higher grid stability at a centralised level, it is not significantly benefiting nearby areas, where most households are not connected to the grid. These areas are commonly known as 'under-the-grid,' and are largely understudied. In our analysis, we claim that the preference for on-grid, centralised plants, while it may be favoured by the electricity industry [6], may not adequately respond to the need for a more just local energy distribution. Furthermore, we argue that, for peri-urban areas that are not planned to be fully connected to the grid in the short term, smaller-scale, decentralised solutions are more appropriate to achieve full energy access.

This is the first study of the largest solar power plant in West Africa from the vantage point of energy and social sciences. In addition, it concerns a plant that is symbolic of a very specific mode of energy governance, and could be taken as an example by other states and regions of the Global South. Consequently, analysing the problematic governance aspects of such a project can serve as guidance to improve similar future projects, and possibly encourage alternative development strategies.

The remainder of this paper is structured as follows: in the next two sections we outline our theoretical framework and review some recent works on solar energy in West Africa that we consider useful in building up our

[1] Agenda 2063, adopted in 2015 by the Heads of States of the African Union, is the continent's strategic framework that aims to deliver inclusive and sustainable development

arguments. Next, we focus on the village of Zagtouli and its SPP, and report the results of a population survey on energy practices and uses, conducted in March 2019. These results are discussed on the basis of our theoretical framework. In the last section, we provide conclusions and policy recommendations for a more just energy development in the community.

2. Energy justice in under-the-grid settlements

As reported in a recent World Bank publication, over a sixth of Africa's 600 million people without electricity access live in urban areas, close to or directly under a grid [7, p. 72-73]. According to that study, connection rates for populations living close to a grid is lower than 50% in most countries in sub-Saharan Africa, Burkina Faso being one of them.[2] The main cause of the under-the-grid condition, the IEA argues, is the price of grid connection [2], which is often much higher than households' income. Therefore, being 'under-the-grid' is closely related to economic poverty, resulting in lack of access to energy. This is exactly the kind of problems that programmes such as SEforAll are meant to solve. Because of the diversified configurations they can take, which make them flexible and adaptable to different scalar contexts, renewable energy systems have generally been represented as the main solution to the problem of energy access. In this study we problematise this argument and analyse why even the construction of a large solar power plant may not be conducive to a significant improvement of energy access in nearby locations.

The persistence in the lack of access to energy involves aspects that are linked to what recent scholarship has conceptualised under the label of energy justice, encompassing distributional, procedural, and recognition justice. Over the last decade, energy has increasingly been developing into an object of interest of scholars operating in the social sciences. Inspired by a longer tradition of studies in environmental humanities, and environmental justice in particular [9, 10, 11, 12, 13], students in the energy humanities have started reflecting on possible applications and adaptations of theoretical and empirical tools developed in that older tradition, to their own domain of expertise [14, 15, 16, 17, 18, 19]. These publications have rapidly multiplied

[2] The exact figures vary between the sources considered: the uptake of grid-covered areas in Burkina Faso is 58% according to the 2014/15 Afrobarometer Round VI, and 42% according to 2015 Demographic and Health Surveys [8, p. 41-42]

[20, 21, 22, 18]. Unsurprisingly (more on this point in Section 3), most of them have initially focussed on the Global North, and there is still today a strong bias towards this region [23, p. 21]. Recently, however, interest in countries of the Global South has been on the increase: this is particularly the case for Africa. Our study focuses on a country, Burkina Faso, which has not yet been the object of analysis by energy humanities scholars. More specifically, we focus on the form of RE that is most widespread in the whole of West Africa: namely, solar energy.

As recently highlighted by Boamah and Rothfuß [24], Ockwell et al. [25] and Boamah and Rothfuß [26], the diffusion of solar energy in Africa is problematic in many respects, independently of whether one considers decentralised configurations [27, 28, 29] or grid extension [30, 3]. For example, in their study of a Swedish electricity company operating in rural Uganda, Eder et al. [27] emphasise the frequent neglect by foreign enterprises to engage in collaboration with local actors, meaning not only governmental authorities but local inhabitants as well, who need to be included in decision-making processes and deliberation efforts. Such neglect, the authors maintain, often results in long-term failure of projects led by foreign agencies. A further study by Bos et al. [3], which problematises grid extension in a number of African countries, claim that the substantial costs of this operation (stemming from building lines, improving capacity, and connecting households) make connection impossible for populations of rural areas, and that even reduction in connection costs would not per se solve the access problem. In addition, even the desirability of grid connection should not be taken for granted, as it is context- and scale-dependent. In a study on Ghana, for example, Boamah and Rothfuß [26] show that, while members of remote rural communities consider grid power as preferable to solar home systems, this situation is reversed in urban settings where well-off families value the use of solar home systems to palliate power outages.

The energy justice framework can help analyse these problematic aspects: the problem of the involvement of local actors is linked to both *justice as recognition* and *procedural justice*, while an analysis of the configurations in which to develop a power system, and of who will benefit from each possible configuration, is related to *distributional justice*. These three aspects, as we will explain, are the main tenets of energy justice in its most widespread formulation. For such justice analysis to be properly conducted, greater attention is needed towards social, cultural, and political dimensions of energy access since, as argued by Boamah [31, p. 8], "justice/injustice and desirability terminologies remain speculative without reference to contexts." In this paper we refer to the energy justice theoretical approach as formulated in works by McCauley et al. [14] and Sovacool and Dworkin [15]. We have used mixed, qualitative and quantitative methods in order to evaluate different aspects of energy justice. Mixed methods, as remarked by Sovacool et al. [32], are rarely employed in energy research, which tend to focus on either sets of parameters, depending on the authors' disciplinary backgrounds. Instead, they help drawing a more fine-grained picture of a specific socio-spatial setting.

Based on previous studies on the principles of environmental justice, McCauley et al. [14] have identified a 'triumvirate of tenets' underlying energy justice: namely, distributional, procedural, and recognition aspects. They characterised these three tenets as: distributional justice "includes both the unequal allocation of environmental benefits and ills and the uneven distribution of their associated responsibilities". Procedural justice "manifests as a call for equitable procedures that engage all stakeholders in a non-discriminatory way". Finally, recognition justice "states that individuals must be fairly represented, that they must be free from physical threats and that they must be offered complete and equal political rights."[14, p. 107-108].[3] Similarly, drawing from Walker [12]'s identification of two aspects of environmental justice—who consumes environmental resources at the expense of whom; and how decision-making power is unequally influenced—Sovacool and Dworkin [15, p. 13] define energy justice as "*a global energy system that fairly disseminates both the benefits and costs of energy services, and one that has representative and impartial decision-making*".

While the characterisation of energy justice according to the triumvirate of tenets has been widely adopted in studies on any level of analysis, it has not been exempt from criticism. Essentially, critics argued, energy justice is a Western-originated concept that presupposes an unequivocal definition of the term ' 'justice.' That is far from being the case. In fairness, such culture-dependent epistemic lopsidedness has been promptly acknowledged

[3] A fourth aspect, known as cosmopolitan justice and initially conceived by Darrell Moellendorf in the early 2000s, has later been added to the first three tenets. It holds that "ethical responsibilities apply everywhere and to all moral agents capable of understanding and acting on them, not only to members of one community or another." [22, p. 918] We are not taking this fourth aspect into account, since our focus is exclusively on the community level.

by Global North scholars: thus, for example, Sovacool et al. [16] have conducted an early exploration of non-Western conceptualisations of (energy) justice in African, Asian, and South American religious and philosophical traditions, as well as in non-anthropocentric traditions such as ecocentrism and biocentrism. Even more recently, an edited volume by Bombaerts et al. [18] has further contributed to transnationalise and diversify thinking on global energy justice. These recent studies are fundamental in keeping researchers aware of their cultural situatedness. Healy et al. [33] and Sovacool et al. [34] have also warned that most energy justice approaches do not take into account longer chains of energy injustice, such as upstream design or downstream waste, but mostly focus just on the site of energy production.

Cognizant of this new trend in research, we nevertheless chose, by virtue of our disciplinary and cultural background, to remain within the borders of the three classical principles set out above. Our central research question in this paper will be:

In what ways and to which extent have the tenets of energy justice been respected in the case of the Zagtouli SPP?

To answer this question, we have first adopted a household-level approach, which examines whether and how on- and off-grid households within Zagtouli differ in terms of energy uses and practices. We believe this approach helps understanding the underlying demand for, and fulfillment of energy justice in our case area, as it provides a detailed picture of the livelihoods in Zagtouli. Secondly, in light of our results, we reflect on how, at a community level, a fairer degree of energy justice could be achieved, and provide some policy recommendations. However, before focussing on the Zagtouli plant, in the next section we provide a reflection on the scarcity of existing literature on solar energy in Africa, and more specifically in Burkina Faso.

3. Studies on solar energy in Burkina Faso

Sociological research on the uses and practices of energy sources originated in the Global North. This was the result of a gradual inclusion of socioeconomic expertise in energy projects that had been generally a prerogative of STEM (science, technology, engineering and mathematics) research. Since most research funding has come from institutions and corporations located and operating in this area, a geographical focus on the Global North has been a pragmatic consequence of that. Interest in the Global South only developed at a later stage, mainly because of its being both the area where most people without energy access live, and the area where international organisations and global private companies are aiming to expand their action. An unintended consequence of Global North-centrism is that most of Africa has been left as uncharted territory for academic research for decades, as recently highlighted by Sovacool et al. [23, p.21]. This neglect is particularly patent with respect to newer energy technologies, such as those used in the production of RE.

Contrary to what is generally thought, experimentation with RE in West African countries has a rather long (while discontinuous) tradition: for example, experimental technologies were employed for solar energy production in the 1960s in Senegal and Niger [35]. Burkina Faso, however, has mostly remained on the sidelines of these developments. This trend has been confirmed, more recently, by the number of studies published in scholarly journals focusing on the sociopolitical, planning, economic, and environmental aspects of energy. In almost fifty years, for example, *Energy Policy* has only published four articles specifically addressing Burkina Faso's energy issues, two of which focused on RE [36, 37]. In the more recently established *Energy Research & Social Sciences*, only one work focuses explicitly on this country, specifically on solar cooking [38]. Less unexpectedly considering its generally global or continental approach, Burkina Faso is also absent as a specific focus country from literature on renewables produced by international agencies, such as IRENA's 2014, 2015 and 2016 reports [39, 40, 41].

Two exceptions are represented by a work published by European Commission researchers in 2016 [42] in *Environmental Research Letters* on RE technologies for increasing electricity access in the country, and by a study by Bensch et al. [43] debating the need of promotion programmes to establish off-grid solar energy markets. Through spatial analysis, the former study recommends a more extensive use of distributed RE systems to increase access to electricity. The latter study finds that the adoption rate of non-branded solar home systems is considerably higher (36%) than for branded ones (8%), and suggests that promotion programmes and branded solar products in Burkina Faso might not be needed in order to establish sustainable off-grid solar markets.

Thus, Burkina Faso largely remains *terra incognita* for energy studies, let alone energy humanities. This is, after all, not surprising, for a country that mostly depends on biomass, as this has generally been considered as a 'mundane' energy form not worthy of scholarly attention [44]. However, the recent rejuvenation of the energy sector in Burkina Faso, with the institutionalisation of a RE and energy efficiency agency, and the formulation of a robust RE policy, will very likely change this state of affairs. Burkina Faso's national energy policy and its recent transformation are described in the Appendix. Suffice it to say, here, that at the institutional level, in 2016 the government created three new directorates within the Ministry of Energy, charged respectively with the management of RE, energy efficiency,and conventional energy. These directorates operate as the 'conceptual structures' of the energy sector, whereas SONABEL, the Burkinabe Agency for Rural Electrification (ABER), and the National Agency for Renewable Energy and Energy Efficiency (ANEREE) are the sector's operational arms. An Authority for the Regulation of the Energy Sector (ARSE) was also created in 2007. In terms of production and distribution of electricity, since 2019 these have been opened to any natural or legal person under private or public law holding an authorisation.

4. Methods

4.1. Description of the case study area

4.1.1. The Zagtouli Solar Power Plant

Located in the outskirts of Ouagadougou, bordering the rural community (*commune rurale*) of Zagtouli (Figure 1), the Zagtouli SPP was built by Cegelec, a unit of French developer Vinci Energies [45], and inaugurated in November 2017. Endowed with a capacity of 33 MW, generated by 129,600 solar panels, it spans a surface area of 60 hectares [46]. The project was financed by France's Development Agency (€22.5 million) and by the European Union (€25 million), and is scheduled to supply 5% of the country's total electricity consumption, about 55 GWh per year [47].

4.1.2. The Zagtouli survey sample area

The rural community of Zagtouli is a population settlement about 14 km southwest of Ouagadougou. It is administratively managed as part of one of Ouagadougou's districts (*arrondissements*), and its location qualifies it as a peri-urban area. It is split up into two different sectors, n. 33 (Zagtouli Sud) and n. 34 (Zagtouli Nord, which also includes Zongo and Nabitenga). The N1 highway connecting Ouagadougou to Bobo-Dioulasso marks the limit between the two sectors, as seen in Figure 2. According to the most recent data available (from the 2006 census), the population of the Zagtouli was just over 27,000 inhabitants in 2006 [48].

Unable to study both areas because of time constraints, we chose to focus on Zagtouli Sud for three reasons: 1) it is the area where the Zagtouli SPP is located; and 2) it is the most densely populated area of the two; 3) unlike Zagtouli Nord, it does not include other communities.

Three areas can be identified within Zagtouli Sud, as highlighted in Figure 2: these are a western area (marked by a purple line), a central area (marked by a blue line), and an eastern area (marked by a black line). The central area is characterised by a higher economic level than the other two, as was easily inferred during the population survey by a visual analysis of the size and quality of housing, the presence of family-owned cars, watchdogs, families of servants often living in their landlords' households, better roads and more modern amenities (TVs, fans, etc.). From **Author1**'s fieldwork, it appeared that many of the people living in this area work in Ouagadougou and commute between the capital and Zagtouli, and that they chose to live in Zagtouli mostly because of lower land prices and, therefore, the possibility of buying larger pieces of land where to build their houses. This is, so to speak, the 'urban' part of Zagtouli Sud, as opposed to the two more 'rural' areas west and east of it. A caveat needs to be added: we surveyed households, not commercial activities. The latter are mostly located along the N1 Highway and the electric poles. They are therefore generally connected to the grid, and it is possible that at least some of them may have benefited from the improved stability in the grid, to which the SPP also contributes (as shown in Section 4, the number of blackouts has decreased significantly from 2017 to 2018).

4.2. Survey, sample, and data-collection procedures

Author1 prepared the survey questionnaire at his home institution in Germany, after consultation with colleagues that had already administered surveys in West Africa, as well as after examination of other questionnaires conducted by local authorities in the recent past. The survey included both quantitative and qualitative questions (examples are provided below). We investigated distributional aspects through socio-demographic and economic information, as well as on the energy supply of each household. In particular, we inquired about the presence or absence of connection to the electricity grid, light bulbs (number and typology: filament, LED, neon), solar panels, fans, radios, ovens, TV, mobile phones and other similar equipment. In addition, we collected data on the monthly expenditure per household for each form of energy used, on seasonal variations in the use of these sources, and on the problems generated by their use. We also asked interviewees to assess their degree of energy satisfaction on a graded scale, as well as their preference among existing energy forms as additional energy sources.

Finally, we collected data on the amount of money that each non-grid connected household would be willing to pay to receive grid electricity. For households already connected to the grid, we asked to estimate an average monthly bill, and whether they considered this amount to be fair. We inquired about this parameter so as to compare the stated amount with both the theoretical cost of grid extension and the real cost of grid electricity, and have a measure of whether it would be economically possible for off-grid people to get connected.[4]

With regard to procedural energy justice and as recognition, more specific questions were used, both direct and indirect, regarding the Zagtouli solar power plant. In particular, for the first aspect, it was first asked whether respondents were aware of the existence of the plant and, if so, whether they had been aware of, or involved in, deliberative or legal procedures resulting from the allocation of land for construction. Investigating these aspects also provides an index to assess justice as recognition. Although, in fact, the lack of a procedural constraint on the involvement of affected populations in industrial projects does not automatically lead to a lack of recognition of these populations–since construction companies could, in agreement with the institutions, put in place non-binding consultation measures with citizens–the analysis of the allocation procedures makes it possible to understand which actors are involved in these procedures.

Following further discussion with **Author3**, the survey was tested on ten households on survey day 1. It was then modified to meet context-specific considerations and improve questions' intelligibility. The survey included a hundred households and was conducted in March 2019, more than a year after the Zagtouli SPP had started producing electricity. The surveyed households

[4]Sometimes, when respondents were not able to estimate their willingness to pay, we asked them to estimate the maximum amount they could pay considering their finances–that is, affordability. While we are aware that these are different concepts, during the survey it became clear that respondents were generally using the two terms interchangeably, and that their stated willingness to pay was always compatible with their monthly expenses for other energy sources

were tracked through GPS procedures, so to make sure that their distribution reflected the different population density in the three areas. Since the survey was conducted between 10 am and 7 pm every day for two weeks, many citizens of the central area, who work in Ouagadogou, were absent from home on regular office hours. As a consequence, **Author1** adequately scheduled the interviews in the central area on weekends, so as to minimise the sampling bias. The survey questionnaire was administered by **Author1** and by a fieldwork assistant who could speak both French and the local language, Mossi (also known as Mooré). When in households surveyed by **Author1** no one could speak French, his assistant would join him as an interpreter. After every fieldwork day, **Author1** and his assistant would meet for debriefing and clarifications. Once finalised, the survey responses were coded into SPSS® Version 26, then provided to **Author2**, who conducted statistical analysis in continuous consultation with **Author1**.

Both ethnographic field observations and early statistical analysis seemed to suggest the existence of a marked distinction between different village areas in terms of energy access and use. Thus, following survey collection, we adopted a theoretical focus that would allow us to highlight those critical aspects of the energy situation of the village, and appropriately selected a subset of the answers provided for further analysis.

5. Results

5.1. Household characteristics, energy expenses, energy sources, and appliance ownership

As mentioned in Section 2, our research question centres on an energy justice analysis of Zagtouli's under-the-grid condition. Three preliminary considerations are useful. First, 28% of the surveyed households are connected to the grid (almost exclusively in the central area), while 72% are not. Second, unconnected households are located a few ten or hundred metres from the closest electricity post: they are, therefore, 'under the grid'. Lastly, households that were connected to the grid at the time of the survey, had been connected since before the construction of the SPP; households that were not connected to the grid before the plant was built, did not get connected either during its construction or afterwards up until the survey was conducted.

Descriptive statistics and tests for statistically significant differences between on-and off-grid households in the population survey are reported in

Tables 1-4, which summarise some key variables of our survey. Statistical tests for differences between on- and off-grid households were conducted using non-parametric tests for differences in medians (Wilcoxon rank sum test) and for whether the samples can be assumed to originate from the same population (Kruskal-Wallis test). On-grid households are significantly–we use 'significant' in its statistical meaning in this section–different from off-grid households in terms of several characteristics: the number of children in the household (Kruskal-Wallis test, p=0.018), the sum of educational level in the household[5] (Kruskal-Wallis test, p=0.000), the number of rooms in the house (Kruskal-Wallis test, p=0.001), and the housing type and material–with villas prevailing among the on-grid households, and small houses (with or without courtyard) prevailing among the off-grid ones (Kruskal-Wallis test, p=0.000); bricks largely prevailing as construction material among the on-grid households, and clay slightly prevailing over bricks in off-grid households (Kruskal-Wallis test, p=0.000). The two latter items confirm the on-site observation regarding the difference between sampling areas mentioned in Section 4.1.2. Thus, the results of the statistical tests indicate that there is a link between grid connection and household's socioeconomic level. In our survey set-up, we have no way of establishing causality between access to energy and degree of socioeconomic development, but we do note statistically significant differences between the two groups.

In terms of energy expenses, as seen in Table 2, on-grid households spend significantly more overall on energy (Wilcoxon rank sum test, p=0.000). They spend significantly less on wood (Wilcoxon rank sum test, p=0.006) and more on gas than off-grid households (Wilcoxon rank sum test, p=0.014). We found no significant differences between on- and off-grid households in terms of the money spent on charcoal and batteries. On average, grid-connected households spend around CFA Fr 18,000 (however, the sample standard variation is particularly high, around CFA Fr 14,000) for their monthly electricity bills.

Overall, the most common sources of energy used in Zagtouli Sud are gas and charcoal (used by 85% and 84% of our sample, respectively), followed by solar energy (72%), and firewood (61%). Table 3 shows the differences

[5]The variable capturing the educational level of the household was constructed by assigning levels to the education categories in the survey, thus assigning higher values to the higher educational levels. For each household the variable "*Sum educational level*" is constructed by adding up the educational level of each adult member of the household.

Table 1: Household characteristics

	mean	**sd**	**min**	**max**	**N**	***p-value***
Household characteristics						
Children (0-14)	2.41	1.71	0	11	100	
Off-grid	2.65	1.77	0	11	72	*0.018*$_K$**
On-grid	1.78	1.39	0	5	28	
Generations	2.07	0.43	1	4	100	
Off-grid	2.07	0.39	1	4	72	*0.833*$_K$
On-grid	2.07	0.53	1	3	28	
Share females	53.08	16.79	0	100	100	
Off-grid	52.51	15.31	0	100	72	*0.672*$_K$
On-grid	54.55	20.36	0	100	28	
Sum educational level	3.61	2.94	0	15	100	
Off-grid	2.73	2.28	0	11	72	*0.000*$_K$***
On-grid	5.85	3.27	0	15	28	
No. of rooms	3.27	1.68	1	11	100	
Off-grid	3.06	1.72	1	11	72	*0.002*$_K$***
On-grid	3.78	1.49	1	8	28	
Occupancy	6.22	2.72	1	18	99	
Off-grid	6.52	2.78	1	18	71	*0.320*$_W$
On-grid	5.46	2.47	1	11	28	
Housing material	2.12	0.93	1	3	100	
Off-grid	1.86	0.92	1	3	72	*0.000*$_K$***
On-grid	2.78	0.56	1	3	28	
Housing type	1.3	0.82	0	4	100	
Off-grid	1.01	0.39	0	3	72	*0.000*$_K$***
On-grid	2.04	1.13	0	4	28	

Notes: Significance level: *** $p < 0.01$, ** $p < 0.05$.

Table 2: Household energy expenses

	mean	**sd**	**min**	**max**	**N**	***p-value***
Energy expenses, CFA Fr.						
Total expenses	18748	25519	750	236000	100	
Off-grid	15181	28097	750	236000	72	0.000_W***
On-grid	27920	13809	4099	57500	28	
Wood	6537	23106	0	225000	100	
Off-grid	8327	26944	0	225000	72	0.006_W***
On-grid	1936	4249	0	20000	28	
Gas	4021	3853	0	30000	100	
Off-grid	3561	4095	0	30000	72	0.014_W**
On-grid	5204	2887	0	12000	28	
Charcoal	2981	3351	0	21000	100	
Off-grid	3065	3593	0	21000	72	0.662_W
On-grid	2765	2679	0	10000	28	
Batteries	174	631	0	4000	100	
Off-grid	226	730	0	4000	72	0.097_W
On-grid	33	138	0	700	28	
Grid	5035	10884	0	50000	100	
Off-grid	0	0	0	0	72	*NA*
On-grid	17982	13891	0	50000	28	

Notes: Significance level: *** $p < 0.01$, ** $p < 0.05$.

Table 3: Household energy sources

	mean	sd	min	max	N	***p-value***
Household energy sources						
Total number of sources	3.22	0.91	0	5	100	
Off-grid	3.40	0.89	1	5	72	0.000_K***
On-grid	2.75	0.79	1	4	28	
Wood	0.61	0.49	0	1	100	
Off-grid	0.65	0.47	0	1	72	0.162_K
On-grid	0.50	0.50	0	1	28	
Charcoal	0.84	0.36	0	1	100	
Off-grid	0.81	0.38	0	1	72	0.371_K
On-grid	0.89	0.31	0	1	28	
Solar	0.72	0.45	0	1	100	
Off-grid	0.87	0.33	0	1	72	0.000_K***
On-grid	0.32	0.47	0	1	28	
Gas	0.85	0.35	0	1	100	
Off-grid	0.80	0.39	0	1	72	0.047_K**
On-grid	0.96	0.18	0	1	28	
Batteries	0.20	0.40	0	1	100	
Off-grid	0.25	0.43	0	1	72	0.053_K
On-grid	0.07	0.26	0	1	28	
Frequency of purchase/collection, monthly						
Wood	7.94	11.76	0	30	94	
Off-grid	9.66	12.53	0	30	70	0.006_W***
On-grid	2.92	7.28	0	30	24	
Charcoal	6.44	10.30	0	30	93	
Off-grid	7.54	10.90	0	30	66	0.011_W**
On-grid	3.77	8.22	0	20	27	
Gas	0.93	0.59	0	4	99	
Off-grid	0.89	0.66	0	4	72	0.281_W
On-grid	1.03	0.35	0.5	2	27	
Batteries	0.20	0.55	0	3	94	
Off-grid	0.23	0.60	0	3	66	0.370_W
On-grid	0.11	0.42	0	2	28	

Notes: Significance level: *** $p < 0.01$, ** $p < 0.05$.

between the two groups of households. On-grid households use a significantly narrower variety of energy sources than off-grid households (Kruskal-Wallis test, p=0.000), a finding that corroborates the typical finding that households use a combination of fuel types, even as they move up the energy ladder [49]. The share of off-grid households using solar energy is significantly different from on-grid ones (Kruskal-Wallis test, p=0.000). These make a larger use of solar energy, while on-grid households differ significantly in their higher use of gas compared to off-grid households (Kruskal-Wallis test, p=0.047). The survey also inquired about the frequency with which the different energy sources are purchased/collected. Here we see that off-grid households show significantly higher frequency of wood and charcoal purchase/collection (Wilcoxon rank sum test, wood p=0.006, charcoal p=0.011).

Appliance ownership also differs significantly between on- and off-grid households (4. Overall, the average number of appliances in the households is 13, with on-grid households owning a significantly higher number of them (Wilcoxon rank sum test, p=0.000). In terms of the kinds of lighting system used, and of how and when they are used, the results show that both types of households use LED lights as their main source of lighting. On-grid households own on average 8.5 lighting units, while off-grid households own on average 3.9 units. The difference is statistically significant (Wilcoxon rank sum test p=0.008). Most households report that indoor lighting is mostly used in the evenings, while outdoor lighting is kept on from sunset to sunrise. The nighttime use of outdoor lighting is seen as a safety measure. Furthermore, on-grid households own a higher number of fans, power banks, computers, fridges and freezers (for all, Wilcoxon rank sum tests, p=0.000). Ownership of mobile phones also differs, but not significantly (on-grid households owning over four phones on average, as opposed to three for off-grid households) (Wilcoxon rank sum test, p=0.194).

Data concerning ownership of solar panels shows that off-grid households own significantly more solar panels than on-grid ones (Kruskal-Wallis test, p=0.000). Out of 28 on-grid households in our survey, only 5 owned functioning solar panels, whereas 62 out of 72 off-grid households owned some panels of differing sizes. Interestingly, and similarly to the Ghanaian case analysed by Boamah and Rothfuß [26, p. 5], the few on-grid households owning solar panels did not express an urgent wish to switch completely to grid electricity. Ownership of panels–especially large ones–implies the possibility not to be affected by power cuts, thus enjoying the benefits of lighting even when the rest of the on-grid community cannot. In practice, panels act as a proxy for heightened socioeconomic status.

In terms of self-reported satisfaction with their current level of energy supply, rated on a scale from 1 to 5, with 5 denoting the highest possible level of satisfaction, we find no statistical significant difference between on- and off-grid households. Interestingly, on average, off-grid households report a satisfaction level of 2.77, while on-grid households report a satisfaction level of 2.89.

To sum up, the population survey reveals several significant differences between on- and off-grid households. The higher socioeconomic status of on-grid households can be inferred from both the higher educational level within the household, the ability to incur larger energy expenses, their use of more sophisticated energy sources (gas in addition to grid connection), as well as owning a larger number of electrical appliances.

5.2. Willingness-to-pay analysis

The survey elicited the stated willingness-to-pay (WTP) for electricity for off-grid households. Figure 3 displays the distribution of WTP for 65 off-grid households.[6] The average WTP for off-grid households is indicated by the red, vertical line in Figure 3, and corresponds to 5,637 CFA Fr per month. This constitutes approx. 31% of what the on-grid households, on average, pay for grid-supplied electricity per month (17,982 CFA Fr), as indicated by the black, vertical line in the Figure 3.

The cost of electricity production from the Zagtouli SPP has been estimated at 45 CFA Fr per kilowatt-hour [50], but the price charged by SONABEL to its customers is on average 104 CFA Fr per kWh. Assuming an average monthly minimum of 120 kWh per household as in Deichmann et al. [51], this constitutes a monthly cost of 12,480 CFA Fr., which is more than double the off-grid-households stated WTP.

These results would indicate that off-grid households are not willing to pay the costs of being connected to the grid in Zagtouli. However, it is worthwhile to consider whether the stated WTP actually captures the underlying true demand for electricity for off-grid households. One view is that the stated amount more likely represents an indication of the current *ability to pay* for electricity (see also footnote 5 in 5.1), which does not necessarily

[6] Seven of the off-grid households did not indicate an amount. These observations are thus not considered here.

Table 4: Household electrical appliances

	mean	**sd**	**min**	**max**	**N**	***p-value***
Electrical appliances						
Total number of appliances	13.9	9.90	1	70	100	
Off-grid	10.83	5.84	1	28	72	0.000_W***
On-grid	21.78	13.43	5	70	28	
Solar panels	0.68	0.46	0	1	100	
Off-grid	0.86	0.35	0	1	72	0.000_K***
On-grid	0.21	0.41	0	1	28	
Light units	5.21	4.89	0	36	100	
Off-grid	3.94	2.81	0	15	72	0.008_W***
On-grid	8.46	7.20	1	36	28	
TV	0.77	0.44	0	2	100	
Off-grid	0.69	0.49	0	2	72	0.622_W
On-grid	0.96	0.18	0	1	28	
Mobile phones	3.57	2.41	0	12	100	
Off-grid	3.22	2.14	0	10	72	0.194_W
On-grid	4.46	2.84	1	12	28	
Fans	1.49	1.93	0	12	100	
Off-grid	0.90	1.17	0	5	72	0.000_W***
On-grid	3	2.59	0	12	28	
Radios	0.65	0.60	0	4	100	
Off-grid	0.66	0.65	0	4	72	0.924_W
On-grid	0.60	0.49	0	a	28	
Power banks	0.25	0.71	0	6	100	
Off-grid	0.09	0.29	0	1	72	0.000_W***
On-grid	0.64	1.19	0	6	28	
Computer	0.41	0.88	0	6	100	
Off-grid	0.15	0.43	0	2	72	0.000_W***
On-grid	1.07	1.33	0	6	28	
Fridge and freezers	0.38	0.63	0	2	100	
Off-grid	0.11	0.31	0	1	72	0.000_W***
On-grid	1.07	0.71	0	2	28	

Notes: Significance level: *** $p < 0.01$, ** $p < 0.05$.

correspond to the underlying, latent demand for electricity in the off-grid households. Presumably, including this latent demand would result in a higher WTP. Apart from energy cost, households also have to pay a fee to establish the connection. In Burkina Faso, according to the SONABEL technicians, the average connection cost ranges from 100,000 CFA Fr to 236,000 CFA Fr, depending on residence areas.[7] Since most of Zagtouli's off-grid households experience a condition of poverty, their average monthly income ranging from 12,921 CFA Fr (agricultural sector) to 87,605 CFA Fr (informal sector) [52], they typically cannot afford the costs of connection, and that perpetuates the condition of unattainable proximity. In the next subsection we complete our quantitative assessment with qualitative data responding to questions mentioned our Methods section. Those parameters will provide additional food for thought for our energy justice analysis.

5.3. Energy preferences and solar plant impact

As mentioned, a telling parameter with respect to recognition and procedural justice concerns the citizens' awareness of, and involvement in decision-making processes leading to the construction of the plant. So, we investigated this aspect, as well as the households' perception of the impacts of the Zagtouli SPP on their daily energy practices. The results are particularly interesting, as 32.3% of our sample declared not being aware of the existence of the plant. A further 61.6% declared they were aware, but claimed no impact of the plant on their lifestyle or energy consumption. On the one hand, the difference in awareness between on- and off-grid households is not statistically significant. On the other hand, while one half off-grid interviewees was unaware of the plant, this rate reduced to one third among on-grid residents. Only a small minority would argue that the SPP had an impact (in terms of fewer power cuts), either on the household's energy situation or on buildings other than the household (overall, 5.0%). The latter result is not surprising, since the SPP was not planned to have a specific impact on the Zagtouli community.

We also inquired about preferences in terms of which source citizens would prefer for additional supply of energy: the results are illustrated in Figure 4. This question was meant to elicit the respondents' opinion about the desirability of each source of energy. The majority of households in both

[7]SONABEL website:http://www.sonabel.bf/index.php/nos-services/branchement.

on-and off-grid households would prefer solar energy as the source of the additional energy, followed by gas for off-grid households and additional grid electricity for on-grid households. The latter result explains the medium (as opposed to high) degree of energy satisfaction for on-grid households. Possibly, it is also to be interpreted as on-grid households wishing for higher grid reliability.

The lower preference attributed to charcoal and wood was paralleled by our questions on issues and problems respondents might have experienced with the use of each source. A clear gender effect appeared, as a large majority of women mentioned health consequences (on eyes and breathing) caused by daily use of wood and charcoal when cooking meals for the family. Men, who are mostly not involved in cooking, did not mention any negative effect from these sources. As for gas, both men and women mentioned issues associated with leaks and explosions, whereas the main problem regarding solar panels appeared to be the short duration of panels, presumably related to their low cost and quality. In the light of these quantitative and qualitative results, we have developed our energy justice analysis, which is the subject of the next section.

6. Energy justice discussion

In the previous sections, we have seen how access to grid electricity (or the lack of it) results in statistically significant differences between on- and off-grid households. While these differences are mostly the result of socioeconomic and spatial inequality, they also contribute to perpetuate and aggravate them, since the use of modern appliances generates considerable advantages for those who can access them. In other words, these differences compound energy injustice. In general, energy access is a socially discriminant factor, as it is a prerequisite for general socioeconomic development and poverty elimination in sub-Saharan Africa [53, 51], and varying degrees of access result in energy inequity within the community. Such inequity is offhand striking, considering the settlement's proximity to both the SPP and the electricity poles.

With respect to distributional justice, it is clear that, in terms of energy access, the great majority of the community of Zagtouli is not benefiting from being close to the power plant. Grid electricity remains unattainable for most local households, and the construction of the plant was not paralleled by any dedicated, effective policy that would improve connection rate in the municipality. On the other hand, the 'costs' the population had to endure for the construction and the presence of the plant were not judged as particularly serious. In fact, unlike in other case studies of wind farms [54, 55, 56], hydrodams [57, 56, 58], geothermal [59] or thermal plants [60], in the case of Zagtouli the element of conflict is mostly missing. No organised citizen protest developed in opposition to the plant's construction; no clash, either physical or legal, occurred between the locals and the firms responsible for the building, or the national authorities supporting the construction. However, focus group discussions with key stakeholders (local authorities, households representatives) conducted by World Bank-led PROGREEN project team in 2019 revealed that some minor tensions developed in the community, related to the transport of machinery during plant construction, which produced dust and intense noise, and led to public nuisance and frustration.[8] In these discussions, local residents argued that they should be compensated for the damage suffered, including exposure to safety risks. Moreover, the constructing firms' failure to employ resident labour during construction created further tensions (PROGREEN, 2019). Nevertheless, these tensions did not escalate into an organised protest activity.

The reduced level of conflict was probably also a consequence of the fewer drawbacks experienced by the local population once the plant became operational, with respect to its construction phase. Compared to a wind farm or a nuclear plant, a solar plant is less visible and noisy; compared to a thermal plant, it is much less polluting, and does not emit visible smoke. In addition, survey respondents did not appear to attribute the land where the plant was built with any symbolic value. In addition, while the firms involved in the construction were European, the electricity generated was to be managed by the national electricity company, SONABEL, which enjoys certain prestige in the country. Finally, as argued in Hanger et al. [61] and in Cantoni and Rignall [62] in the case of the Noor Ouarzazate plant in Morocco, narratives about the benefits of zero-emissions plants and their 'modernity' tend to be rather powerful in the marketing of industrial facilities. Together with the plant's inconspicuousness, they may have played a role also in the case of the

[8] PROGREEN is a World Bank multi-donor trust fund that "supports countries' efforts to improve livelihoods while tackling declining biodiversity, loss of forests, deteriorating land fertility, and increasing risks such as uncontrolled forest fires, which are exacerbated by a changing climate" (PROGREEN website: https://www.worldbank.org/en/programs/progreen/overview).

Zagtouli SPP, in the sense of prompting community acquiescence. Scarce awareness of a plant is also positively linked to a high level of acceptance [61].

This last point allows us to analyse aspects of recognition and procedural justice. The first aspect, we remind, deals with fair representation of stakeholder groups in the discussion of an energy project, freedom of individuals from physical threats, and respect of their political rights. This aspect is generally intertwined with that of procedural justice (as argued by Schlosberg [63] among others), which is concerned about the equity of the procedures to the effect all stakeholders are engaged in a non-discriminatory way. The strategy pursued by the government in this respect *did* involve the local authorities at the borough hall (*mairie de l'arrondissement*) level. However, the administrative pathway to authorise the utilisation of the land for the plant's construction did not provide for consultation with the local community. This procedural shortcoming reflects the lack of recognition of the local community as a rightful interlocutor. The central government may have a sound legal justification in this respect, as the plant area is located just outside the geographical borders of Zagtouli, and in a land that is sparsely inhabited. However, a more comprehensive view of the specific industrial project, which could give voice to the community concerns, would have been desirable.

Unlike in the case of Morocco, where *ex-post-facto* recognition to citizens was to some extent taken into account by having the national solar energy company setting up an office responsible for addressing local citizens' complaints about the plant [62], in Zagtouli no similar measure was implemented. The project did not even involve any preliminary information campaign directed to the citizens. In a sense, that helped the government, SONABEL, and manufacturers to present the citizens with a *fait accompli*, and defused the possibility that an opposition campaign could develop during the works for the plant.

In the final section we reflect on alternative solutions that may allow the area, and, more in general, under-the-grid settlements to leave their under-the-grid condition.

7. Conclusions and policy implications

In this study, we have employed the energy justice framework to analyse the impact of the Zagtouli SPP on the local community. Taking into account both the large size of this plant for the region of West Africa and the fast expansion of the solar industry in this area, this study may well set a precedent for emerging procedural standards, as well as public expectations of such projects and desirable institutional deliberation strategies. We have argued that the procedural and recognition justice aspects were lacking, and distributional aspects were mixed, in that benefits to the community appeared as very limited but so did related costs. While this is a single case study and is therefore characterised by a number of well-known analytical limits, our findings may nonetheless provide insight into more general challenges regarding the uptake of grid energy in West Africa.

The results of this study are a warning light for policymakers: they emphasise that, while building a large solar power plant may be an indication of strong commitment towards energy transition on the part of national governments, it is not in itself indicative of the achievement of greater energy justice at the local level. One should not underestimate the positive symbolic effects that endeavours of this magnitude can generate for the countries that promote them. This aspect, however, pertains to the domains of geopolitics and international trade, not energy justice.

First of all, with respect to distributional energy justice, we have shown a substantive gap between on-grid and under-the-grid (or off-grid) households. In our case, one may wonder whether grid extension could be the best solution from a commercial viewpoint, or whether decentralised options could be considered instead, account taken of the criticism that in other African contexts (South Africa, particularly) small scale energy systems did not seem to have alleviated energy poverty [17]. In the latter case, a further question relates to what Burkinabe agency would have to take the lead. On the one hand, since Zagtouli is administratively part of Ouagadougou, it lies within SONABEL's mandate. However, SONABEL's strategic preference goes to the extension of the electrical grid, rather than decentralised, off-grid options, which are part of ABER's rural electrification strategy. On the other hand, since the grid already partly reaches Zagtouli Sud, there is perhaps no perceived urgency to further extend it to the under-the-grid areas where most households are located.

At the same time, extending grid connection should not be excluded as *a priori* economically impracticable. Some common ideas about grid connection need to be reassessed critically, as argued by Lee et al. [30]. In a study on Kenya, they argue that policymakers, NGOs and donors alike assume that most non-electrified areas are so secluded or far from the existing grid infrastructures, that connecting them to the grid would not be economically viable. Moreover, they add, cost-benefits analyses driving large-scale economic investments tend to be based on the assumption that grid extension will result in a higher rate of connectivity of rural households and businesses. Challenging these assumptions, Lee et al. [30] show instead that under-the-grid households could be connected to the grid at a relatively low cost thanks to economies of scale, and that even in areas where grid coverage is high, rural connectivity remains low, mainly as a consequence of local poverty coupled with connection costs. Bos et al. [3] also report similar results from poor urban areas in Botswana, Tanzania and, to a lesser extent, Ethiopia.

A possible objection to out analysis is that the energy injustice suffered by part of Zagtouli's population might be temporary: a decrease in the cost of power, consequence of an increasing flow of solar power in the grid, would help off-grid households to get connected: just, in a longer time frame (say, a decade). This possibility cannot be ruled out. However, since grid extension is currently not part of SONABEL's strategy, we would argue that at least in the short and medium term (up to a few years), most of Zagtouli's population will remain in the under-the-grid condition. Alternative solutions are therefore desirable.

With respect to procedural and recognition justice, we have shown that decisions concerning the assignment of the land for the prospective plant, and the construction of the plant itself, were made at a higher level than the community's, and then implemented in a top-down fashion. Only by including local communities in consultative and deliberative processes early on at the project conception stage–for example, through multi-stakeholder, collective discussion moderated by local authorities, or through focus groups–can a higher level of recognition justice be achieved. In order to improve procedural justice, these initiatives should become formally part of the protocol to be followed in the conception and implementation of industrial projects.

Recent studies have emphasised that access to energy will ultimately depend on three factors: price, household income, and the expected benefit from electricity uptake [8]. In this respect, Lee et al. [30] propose three possible solutions to connect under-the grid households: i) public subsidies to mass connection programs; ii) government support of innovative financing and payment approaches to raising connectivity; and iii) public support of group-based subsidies tied to number of applicants. In the case of Zagtouli, our WTP analysis indicates that the off-grid households we surveyed, did not have a sufficiently high stated WTP to pay for a monthly average minimum supply of 120 KhW per household for grid-supplied electricity. As discussed, this stated WTP is likely not reflecting the real latent demand for electricity, but perhaps rather captures the population's ability to pay for electricity. This ability to pay is of course an essential parameter, as SONABEL has to make sure its customers can pay their bills. However, from a more development-oriented perspective, estimating the true latent demand of under-the-grid households for electricity must be prioritised so that the actual demand is reflected in both policy objectives and design of power access policies.

As mentioned, off-grid households also face high one-off connection costs. To help alleviate this problem, the recently-launched pilot phase of the Electricity Connection Development Project is aiming at connecting 50,000 new homes and points of socioeconomic aggregation such as markets to electricity in the centres of Tenkodogo, Bobo-Dioulasso, Koudougou, Kaya, Ouahigouya, and Ouagadougou. To make the connection affordable, SONABEL will set the cost required for connection at 3,000 CFA Fr, instead of about 160,000 CFA Fr that are usually required on average.

Aside from grid extension coupled with appropriate financing mechanisms, off-grid solutions may represent an alternative solution. As some studies have argued, mini-grids have technical and economic advantage over grid connection in densely populated rural trading areas [42, 64]. These PV-based systems are an established, low-maintenance technology that was proven successful by earlier electrification projects across the region [40]. Mini-grids, renewable-energy-based multi-functional energy platforms, and similar technologies are increasingly common in the global South. An example of this trend is Burkina Faso's selection, in 2016, for a US$ 16 million project scheduled to build a 3.6 MW solar PV mini-grid. This project is being implemented in partnership with ABER, and is scheduled to provide electricity to 42 settlements (12,000 households) in Hauts Bassins and Boucle du Mouhoun through mini-grid, grid extension and solar-home system technologies [64]. Similar policies addressing the communities' specific needs, abilities and energy preferences could be appropriate to achieve a higher level of energy justice not only for rural settlements, but also for peri-urban ones, which may find themselves in an administrative limbo between urban and rural conditions. To compensate for the intermittency of solar energy and improve the system's flexibility, thus making electricity available after sunset or in the rainy season, possible solutions include battery storage or the hybridisation of the system with gas turbines (see also the concept of 'flexy-energy' in [37]). Cost and environmental constraints will be fundamental parameters to decide whether these solutions can be implemented in each under-the-grid context, since, as [31, p. 7] correctly points out: "Self-organised decentralised solar PV electrification cannot contribute to just, development-oriented and low-carbon energy futures in Africa unless sufficient information, technical knowledge and financial resources are available." And, we emphasise, unless a comprehensive understanding of the social patterns of energy use and practices of each target community is achieved.

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Appendix A. The national energy sector's structure and policy

Burkina Faso is a landlocked, sub-Saharan African country with limited access to energy resources and an economy that is heavily reliant on agriculture, with close to 80% of the active population employed in the sector [65]. Despite this, the GDP growth rate was 6.8% in 2018 [66], and has been increasing since 2015, due mainly to the mining sector and the rebound in agricultural production [64]. Biomass is the main source of energy consumption for private households, constituting around 90% of the total. This figure, however, does not describe accurately enough the difference between urban areas and rural areas, as in the latter nearly all of the energy consumed is biomass-based. As far as electricity production is concerned, the country is reliant on thermal-fossil fuel for about 70-80% of the total power generation in the country, and hydropower constitutes around 16% [67, 42]. The rates of access to electricity was 62.3% for the urban population and 4.7% for the rural population in 2018.[9]

[9]https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=BF

In its National Plan for Economic and Social Development (PNDES) for the period 2016-2020, the Government had set several quantitative targets for access to electricity and RE in general by 2020, amongst which: i) an increase in the contribution of renewables to total energy production (from 6.4% in 2015 to 30%); ii) an increase in installed national electricity capacity (from 300 MW in 2015 to 1 GW) and electrification rate (from 59.9% in urban settings, 3.1% in rural ones in 2015 to 75% and 19%, respectively; and iii) the reduction of electricity cost by 25 CFA Fr per kWh. [68, p. 64-65, 70]. The PNDES foresaw investments for US$ 26 billion over 2016-20, and investments in the energy sector alone were expected to amount to 26% of the total [69, cph. 12]. For the longer time horizon in 2030, the National Action Plan for Renewable Energy (PANER) also set quantifiable targets for electrification and RE in general [70]: i) increase in energy access to 42.4% of population; ii) a prospected capacity of renewable power plants of 318 MW; iii) increase in share of RE in total installed capacity to 36% (excluding on-grid electricity imports, the target is 27%); iv) increase in installed capacity of off-grid RE systems: 10%; and v) increase to 26.9% of rural population served by autonomous RE-based systems.

The main electricity supply strategy is to establish interconnections with neighbouring countries, and to extend and repair the existing network [42]. This and other objectives are being managed by the Ministry of Energy according to the *Strategy for the energy domain 2019-23*, published in November 2018[69]. Furthermore, the Burkinabe government has recently fostered an energy policy consisting of two pillars–transition towards RE sources and energy efficiency–aimed at increasing the energy offer and fill the urban-rural gap in energy access. This trend has been institutionalised through the creation of the National Agency for Renewable Energy and Energy Efficiency (ANEREE) in late 2016. It is envisioned that this new policy will allow the country to decrease its dependence on foreign fossil fuel imports, as well as palliate the frequent power cuts experienced during the hot season (March to May).[10] It is expected that the planned higher reliance on renewable sources will be favoured by Burkina Faso's considerable solar potential and by the population's steady interest in solar equipment, as shown by the many solar

[10]On the SONABEL network the number of interruptions was 3,126 in 2017 and the corresponding average break time was 152 hours [69, section 5]. While the average break time substantially increased to 233 hours in 2018, the number of blackouts decreased from 46 in 2017 to 39 in 2018 [71, cph. 7].

energy enterprises of different size created recently.

On the one hand, solar potential is currently much underused, if one considers that the country that has a solar irradiation of 5.5 kWh/m2/day for 3,000 to 3,500 hours per year[69, cph. 8]. On the other hand, the number of solar and hybrid (solar/fuel-based generators) power plants facilities has been growing [72, 73]. Apart from the mentioned Zagtouli, Ziga and Essakane SPPs, the small SPP in the village of Digré in central Burkina Faso is part of a project of 26 off-grid small power stations, conceived by the General Directorate of Renewable Energies (DGRE). This 20.8 kW power plant, endowed with a storage capacity of 32 12V/185Ah batteries, covers a 3 km network: in its test phase, it provided electricity to four consumers.

Off-grid solutions are crucial for rural areas, which are mostly not reached by the national electricity grid. This is a consequence of SONABEL's focus on urban areas and of its grid expansion strategy, which depends on criteria such as population size, economic potential, proximity to a power line and border situation (for territorial security reasons) [69, cph. 12]. Rural areas, instead, fall under the responsibility of the Burkinabe Agency for Rural Electrification (ABER), formerly the Electrification Development Fund. ABER coordinates electrification programmes and provides funding to rural electrification promoters in the form of grants and loans [64].

Legally, the energy sector in Burkina Faso is regulated through Law n. 014-2017/AN of 20 April 2017, whose main innovations with respect to the existing situation can be summarised as: i) reaffirming the liberalisation of the production and distribution segments (once SONABEL's monopoly); ii) allowing the creation of 'electricity independent producers'; iii) taking into account ECOWAS regulations, aimed at building a sub-regional electricity market; iv) suppressing the single buyer of electricity clause; v) introducing dispositions to promote RE and energy efficiency. This law extends a number of existing legislative measures, targeted at simplifying the procedures for importing solar equipment by exonerating it from customs duties and VAT (Law n. 051-2012/AN of 08 November 2012). It also gave legally binding value to the National Action Plans 2015-2030 for Renewable Energy (the mentioned PANER) and Energy Efficiency (PANEE), both adopted in 2015. These two plans operationalised the agenda of UN's SEforAll programme. In particular, with respect to under-the-grid settlements, PANER developed a twofold strategy consisting in: i) optimising and increasing the use of low-voltage grids; and ii) increasing the coverage rate by extending medium- and low-voltage grids in already-electrified areas, but also by electrifying new rural areas. With respect to this second point, the government's plan is both to increase the density of existing medium-voltage grids, and to develop a pre-electrification policy. Such policy would provide access to electrical services for community services and economic actors, with the domestic lighting service being provided by solar kits or lanterns. The demarcation line between electrification and pre-electrification is set around a population size of 1,300/1,500. For settlements larger than this size, but smaller than 2,500, the plan recommends electricity supply by light grid. For settlements with a population of 800-1,300, pre-electrification solutions by mini-grids fed by hybrid, fossil fuel-solar platforms are preferred. Below this threshold, 100% solar solutions are adopted [74, p. 30].

At the institutional level, up until the early 2010s, energy issues were managed by different ministerial departments. That made the decision-making and administrative tasks complex and inefficient. Through the PNDES of 2016, the government created three new directorates within the Ministry of Energy, charged respectively with the management of RE, energy efficiency, and conventional energy. These directorates operate as the 'conceptual structures' of the energy sector, whereas SONABEL, ABER and ANEREE are the operational arms. An Authority for the Regulation of the Energy Sector (ARSE) had already been created in 2007. Today, the institutional and organisational framework of the energy field is governed by the new decree N 2018-0272/PRES/PM/SGG-CM of 18 February 2019. The production and distribution of electricity are now open to any natural or legal person under private or public law holding an authorisation. At the same time, energy policy still favors imports and exports over domestic production.

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