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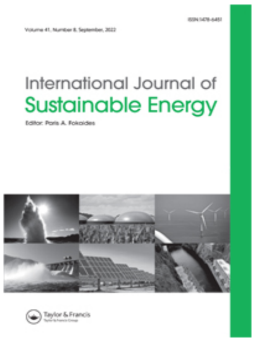

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An assessment of renewable energy development in energy mix for Togo

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ABSTRACT

The Togolese government plans to achieve 100% electrification to all by 2030, to meet the Millennium goals. The Delphi method is used with the experts drawn from policymakers, academic institutions, financial institutions, non-governmental institutions, and private companies. and the results show that raising the renewable energy business share in Togo through accelerated access to small-scale solar photovoltaics and hydropower is the most feasible route for electrification. The monopoly, non-liberalization of the energy sector, and the lack of a trained workforce were identified as the main inhibitors for private investment. The study recommends the optimization of the system for better performance and the creation of local manufacturing plants to promote the national production of solar system components along the assembly lines.

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Renewable energy; Delphi method; socio-economic development; solar power; hydropower; rural communities; Togo

1. Introduction

1.1. An overview of the Togo energy sector

The development of renewable energy is fast advancing, and the commitment of many countries is confirmed by the number of investments and the effort in extra work done to achieve the set targets. Energy systems in many countries, including Togo, is illustrated by a balance between centralised and distributed energy system – which is mostly used nowadays to improve energy reliability and independence by providing a more stable electricity supply (Kursun et al. 2015; Liu et al. 2019; CEET 2020; SOFRECO 2010). Togo relies on biomass energy 71% (firewood, charcoal, vegetable waste etc.), petroleum products (26%), and electricity (3%) (African Development Bank Group 2015). The wood biomasses used in Togo are usually unclean and highly pollutant when burnt, and can slow down economic growth by lowering productivity when unclean and inefficient sources are used as illustrated by Maji, Sulaiman, and Abdul-Rahim 2019. Besides, its excessive consumption may sometimes lead to massive environmental pollution which takes a negative toll on the economy as illustrated by Qudrat-Ullah and Nevo (2021).

Presently, the main source of energy in Togo is electricity. The rate of access to electricity in Togo is increasing (from 17% in 2000 to 45% in 2018), but with large differences between urban (access rate = 88.8%) and rural areas (access rate = 8%) (Energypedia 2020). Total electricity production in 2018 was 385.62 GWh between the Electricity Company of Togo (CEET) and Contour

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Global Togo (CGT) as shown in Figure 1, with the transmission and distribution losses accounting for 15.85% of the electricity generated (CEET 2018).

To meet demand, Togo is forced to import most of its energy (872.64 GWh/yr.) from Ghana, Cote D'Ivoire, and Nigeria (CEET 2018), even though it has significant renewable energy resources potential (PANER 2015) such as solar, wind, and hydroelectric power resources that could be developed to implement a nationwide sustainable energy system.

Renewable energy is nowadays recognised as a part and parcel of the energy supply. For the past two decades, its consumption is encouraged in all countries of the world, specifically in heavy consuming countries and regions such as the USA, EU, and Asia to promote a sustainable environment (Brodny and Tutak 2020; Nguyen and Kakinaka 2019). Africa is not exempt; because according to Armeanu, Vintilă, and Gherghina (2017), their long use of conventional exhaustible energy resources raised serious environmental concerns that hinder sustainable economic growth. The development of renewable energy can help to minimise environmental impacts, avoid the dependency on fossil fuels, and contribute to economic growth and job creation (Yushchenko et al. 2018; Lee 2019). Maji et al. (2019) in their research for sub-Saharan Africa and West Africa in particular, stated that to achieve sustainable economic growth and social development goals in the near future, cleaner energy sources such as wind, solar, biofuel, and hydropower need to be in place. In addition, Kolb et al. (2020) studies showed that renewable energy sources considerably reduced electricity prices between 2.89 ct/kWh in 2014–8.89 ct/kWh in 2017, leading the German end-consumers cost saving by a total of 40 billion € from 2014 to 2018. Additionally, wind and photovoltaics (PV) contributed significantly to the security of supply, as demand could not have been met by domestic conventional and nuclear generation capacities of up to 424 h in 2018. Togo, like many sub-Saharan African countries that do not produce oil, depends mostly on imports for its electricity supply. This dependence could be extremely reduced if the share of renewable energy is increased as observed in many other studies. For example, according to (Jenniches and Worrell 2019), the brut electricity generation in the German Land Thuringia increased from 2.2 gigawatt-hours (GWh) with a share of renewable energies of 4% in 1991–8.4 GWh in 2014 with a share of renewables of 55%.

Thiam's research also showed how RE facilitated the improvement of the standard of living in a Sahelian developing country of Senegal (Thiam 2011). Based on these examples, developing renewable energy in Togo is not only a necessity to reduce imports for its electricity supply but also to substantially help the country in many angles, including socio-economic development.

Based on the literature, the Togolese national development plan, and discussions with the key energy sector, the government is now conscious of the situation and is taking initiatives to increase

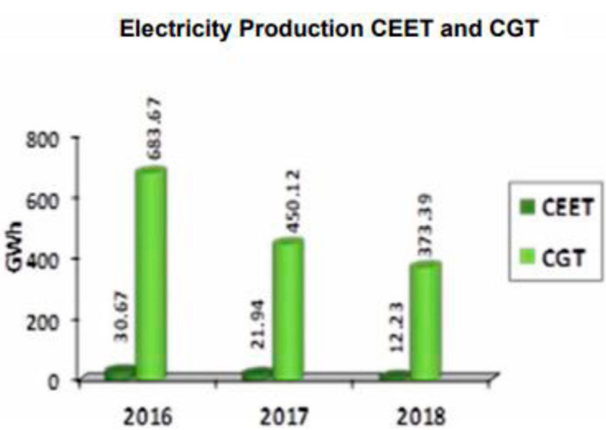

Figure 1. Electricity production CEET and CGT. Source: CEET (2018).

electricity access in Togo and plans to achieve universal access by 2030 (Togo PND 2018; AT2ER 2019). Accordingly, to achieve this, the Togolese government will have to mobilise an average of approximately 83 billion West African CFA franc (Franc Communaute Financière Africaine). This is approximately $142 million per year which will be four times more than the normal average government input in the electrification development per year (AT2ER 2019). Togo's ambition is to deploy more than 300 mini-grids by 2030. To achieve this ambition, it needs an approximate finance of $147 billion FCFA in total – that is over $251 million – to deploy the required mini-grids by 2030.

To reach the set target of 100% electrification rate by 2030, the government of Togo needs to:

- Install 555,000 solar kits
- Install at least 315 mini solar grids
- Connect 960 new localities to the network
- Provide electrification to 400,000 households currently living on the network that are not electrified
- Install at least 108 MW of additional generation on the network

To accomplish these goals, the Togolese government aims to utilise a combination of network expansion and off-grid technologies (mini-grids and solar kits). To reach their target, Togo is focusing on mobilising private sector investments mainly through Public Private Partnerships (PPP) in combination with targeted support mechanisms; for example, allowing people who are most vulnerable to access electricity. Working towards this goal, a few developments have been put in place to increase the electrification rate, allowing an increase from 23% in 2010 to 37% in 2017 nationally as shown in Figure 2, thanks to the extension of the network (Togo Local Electrification Program 2018). However, it is worth noting that the rate of rural electrification is still exceptionally low and has increased from 3% in 2008 to 6% in 2016 (PND 2018).

1.2. Delphi as a method for assessing the development of renewable energy

A widely used approach to study the suitability, opportunities, and transition of renewable energy is the Delphi method. It is a systematic method of gathering opinions from a group of experts through a series of questionnaires, where there is a feedback mechanism through 'rounds' / round questions held while maintaining the anonymity of respondents' responses (experts) (Ishak and Barus 2020). Its use presents numerous advantages among others. Delphi methods can help to identify the driving forces by involving many knowledgeable and skilled participants from multiple backgrounds. It can also help to reliably identify driving forces with the help of large-scale participants associated with the Delphi survey rounds, which makes the selection process more scientific (Chen et al. 2020). This method has been successfully used in many studies. As an example, Pätäri et al. (2016) research, conducted a Delphi study on the importance of investing in energy efficiency, policy interventions, organization and enablers of energy service companies' business, and project outcomes. Their result suggested that customers, especially SMEs unawareness of the energy service companies' business, current financial situation, and high transaction costs with relation to potential savings are among the key factors hindering the Finnish energy service companies' sector development. In addition, Solangi et al. (2019) employed the Delphi method to define and select the most important criteria for the selection of renewable energy (RE) resources namely economic, environmental, technical, and socio-political aspects. Chen et al. (2020) in their paper integrate the Delphi survey into scenario planning, which according to them can help decision makers and researchers to better understand the drivers and factors that influence the development orientation and strategy of renewable energy towards 2030 in China. Their findings showed that the 'breakthrough of renewable energy technologies,' 'growing ecological awareness,' and 'national energy pricing' were the top three key drivers for renewable energy development in China. Furthermore,

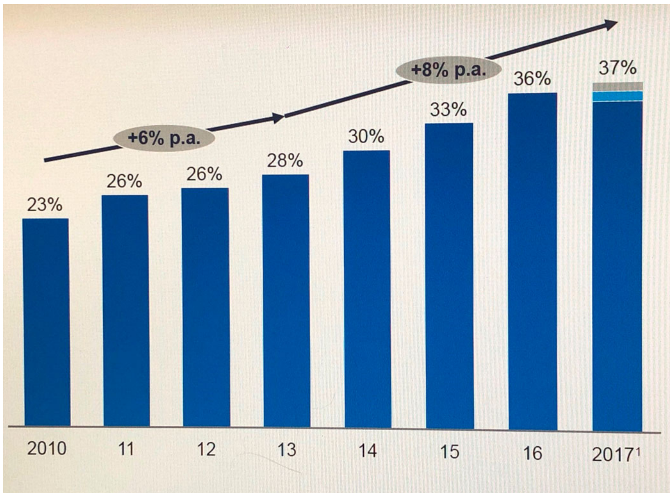

Figure 2. Togo electrification rate in percentage from 2010 to 2017 (Source: Togo Local Electrification Program 2018) *[1] – In 2017, launch of four solar mini-grids (600 kWp) and installation of 2,280 solar kits in 25 villages.

Guerrero-Liquet et al. (2016) identified risk management tools in solar photovoltaic facilities based on the guide to Project Management in the Dominican Republic using the Delphi method. This enables them to not only extract the knowledge from experts, but also to know the causes and effects that help to make the best decision.

More recently, Rikkonen, Tapio, and Rintamäki (2019), focused on the growth opportunities in distributed energy systems by presenting the agricultural, farm-level possibilities of fostering the RE business in Finland. They showed how the Finnish expert community within the agriculture and agri-based small-scale renewable energy production saw the future of RE possibilities in the Finnish national context. They reported that among the national renewable energy and agricultural experts, the most preferred energy sources for increasing RE business on farms were wood, biogas, and solar PV. Elsewhere Jahanshahi et al. (2019) research assessed the economic criteria and their relative importance for the development of the wave and tidal energy technologies based on the experts' judgment. They based their study on a two-round Delphi methodology, to rate the economic criteria influencing the development of wave and tidal renewable energies. They found out that selling the energy produced and tax incentives were identified as the most important factors that can push the development of marine renewable energies.

Therefore, the aim of this paper is to carry out an assessment of the renewable energy development in the energy mix of Togo, highlighting the current energy situation and actions planned for the development to increase energy access. The results of this research could assist policymakers in decisions making on renewable energy technologies with regard to the most suitable sources that improve economic growth and enhance the energy mix to reduce the dependence on fossil fuels, in Togo. Renewable energy, in this context, refers to solar, hydropower, wind, tidal, wave, and geothermal energy. In general, the number of iterations of the Delphi questionnaire can range from two to five, whereby each following questionnaire is developed based on the responses from the previous rounds of the questionnaire. In this research, the work presents and discusses stakeholders' viewpoints based on the three phases of fieldwork undertaken. Particularly, three interview exercises were conducted in Togo with experts in the energy system, academic institutions, policy makers, and financial organizations. The approach used for this study – including the methodological method of the Delphi process used and the expert panel that took part in this study – are presented first. This is followed by a presentation of the study results and main findings of the study, and finally, conclusions are drawn.

2. Methodology

This research is based on a mixed methodological approach which gives room to the use of different views, assumptions, methods, and various types of data collection and analyses. The data collected are based on primary, secondary, and tertiary data. The primary source of data includes interview notes, field notes, and illustrations, which was collected through face-to-face interview, questionnaires, field note, and observations. Secondary data collection is based on the use of journal publications, conference proceedings, national, international, governmental, and non-governmental reports. These are collected through a combination of desktop study, literature review, workshops, and conferences. Tertiary data made use of database resources from archival review.

The Delphi method is used for forecasting to predict and explore the future trends, possibilities, and probabilities of occurrence, and desirability based on the expertise of respondents (Rikkonen, Tapio, and Rintamäki 2019; Banno, Tsujimoto, and Kataoka 2020). This method gives room to review findings and issues of the study in different rounds and to discuss any ambiguity found after the analysis of previous interview data for accuracy. This gives insight to a future view in several rounds (Rikkonen, Tapio, and Rintamäki 2019). A three round Delphi method is used to evaluate the potential of renewable energy technologies and the impact of their development in the energy mix of Togo. These aimed at reviewing the following key points:

- Energy situation in Togo and understanding reasons for high dependence on the international market for Togo's electricity need.
- Reviewing awareness of the renewable energy penetration, in-country skills level, and the potential of different renewable energy sources.
- Finding a potential impact that could help renewable energy development in Togo and how best to move towards self-sufficiency.

The first and second rounds made use of a questionnaire and interviews to collect data and the third round was mainly based on an interview conducted in January 2020, with the purpose of validating answers from previous interviews. The three rounds are corelated. The first round targeted a wide range of participants; most experts in RE of this round participated in the second-round interview. The third-round interview was a sub-set of the second-round interview to validate the data collected from the first and second rounds. The time lapse between the interviews was due to a brief pause in the research and it was deemed necessary to carry out the third round to validate the data; because there have been a few changes in the analysis and result – especially in terms of development, planning, and training.

A semi-structured interview was done during the first round using open-ended questions with 31 key participants of different expertise as shown in Figure 3 and Table 1. This was to get an in-depth understanding of the needs, practices, and problems. These formed the basis for analysis to identify the potential issues and solutions. These were based on understanding the current energy situation to identify views related to the introduction of renewable energy technologies. Questionnaires were sent to participants via email prior to the face-to-face interview meeting. A comparative approach was taken between the urban and rural areas of Togo to understand the current energy situation from both sides and to determine how the lack of energy affects the population. This targeted a wider range of participants including policy makers, academic institutions, financial institutions, non-governmental institutions, and private companies as shown in Figure 3. Participants were selected based on their ability to provide information in their different fields of work. The result and findings are discussed in Sections 4 and 5. The second-round data collection targeted experts with knowledge in renewable energy for feedback on questionnaires which were sent as an online survey (this included participants with technical expertise, research, policy management, and political). These questionnaires were formulated based on the feedback from the first data collection. A total of 17 experts completed the questionnaires as shown in Figure 3 and Table 1.

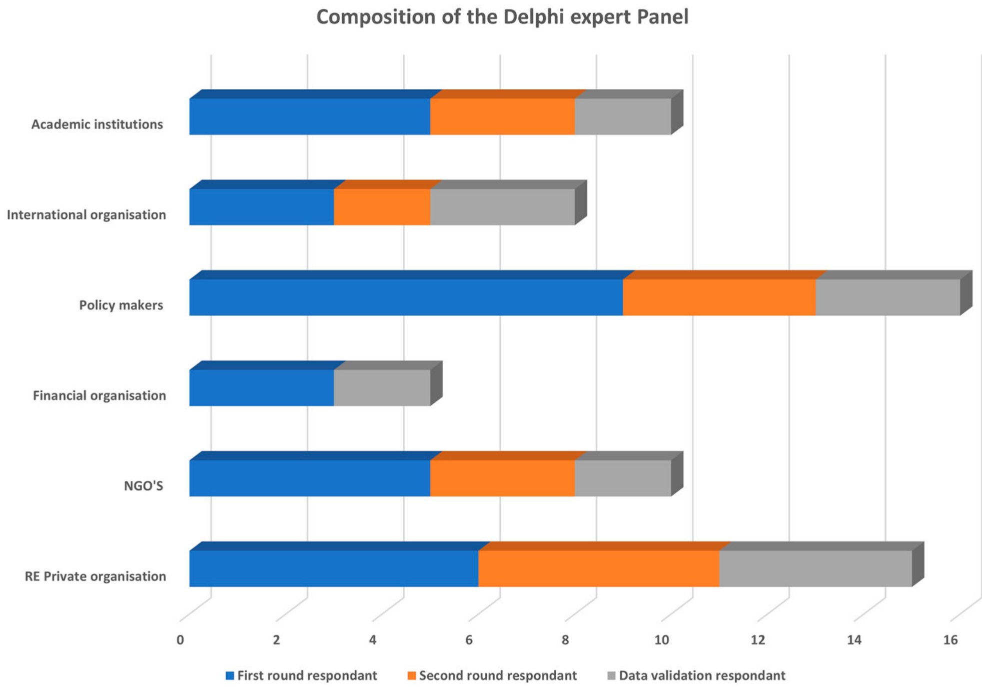

Figure 3. Figure illustrating the composition of the Delphi expert panel.

Questions were refined with the purpose of getting in-depth information from experts and were centered around:

- Discussing the potential issues behind the gaps found after analysis of the first-round interview, finding potential solutions and recommendations for better approaches to move forward.
- Finding out specific details regarding the type of energy used, the power production and installed generating capacity, and what can be done to meet the Togolese government energy vision for 2030.
- Finding out details about the successes and drawbacks of recently implemented development in terms of renewable energy resources, details regarding existing laws that promote the use of renewable energy, the management system, and how best policy makers could address the absence of framework regulations, which was one of the key findings in the second-round interview.
- Finally, questions were asked – if renewable energy should be prioritised, research promoted, and diversification in terms of renewable energy be promoted (Kansongue, Njuguna, and Vertigans 2018).

Table 1. Composition of the Delphi expert panel – numbers refer to the number of panelists per different group.

Expertise	First-round respondent	Second-round respondent	Data validation respondent
RE Private organization	6	5	4
NGO'S	5	3	2
Financial organization	3	0	2
Policy makers	9	4	3
International organization	3	2	3
Academic institutions	5	3	2

The third round was mainly focused on a face-to-face interview with the aim of cross-checking data and validating previous responses related to the recent development based on changes that might have occurred in the past few years. This was also a semi-structured interview that targeted experts with knowledge in renewable energy with technical, research, policy management, and political expertise as shown in Figure 3 and Table 1. A total of 16 experts were interviewed. Open-ended questions were asked, allowing for a discussion with the interviewee to cross check previous round responses. Figure 4 shows the step-by-step methodological approach undertaken by the Delphi process from research problem definition to study report.

The choice of participants included in the study was based on criteria, such as the ability to provide information on the current energy situation, energy technologies use, impact, policies in place, functionalities, current and future plans in renewable energy developments in Togo. Figure 5 shows the profile of the expert panel that took part in this study.

3. Results

3.1. Overview of participants and key points on the types of potential energy for future trends

The interviews and questionnaires in all rounds targeted key stakeholders with knowledge in the energy field. The range of respondents was between the ages of 25–60 years, who lived in their

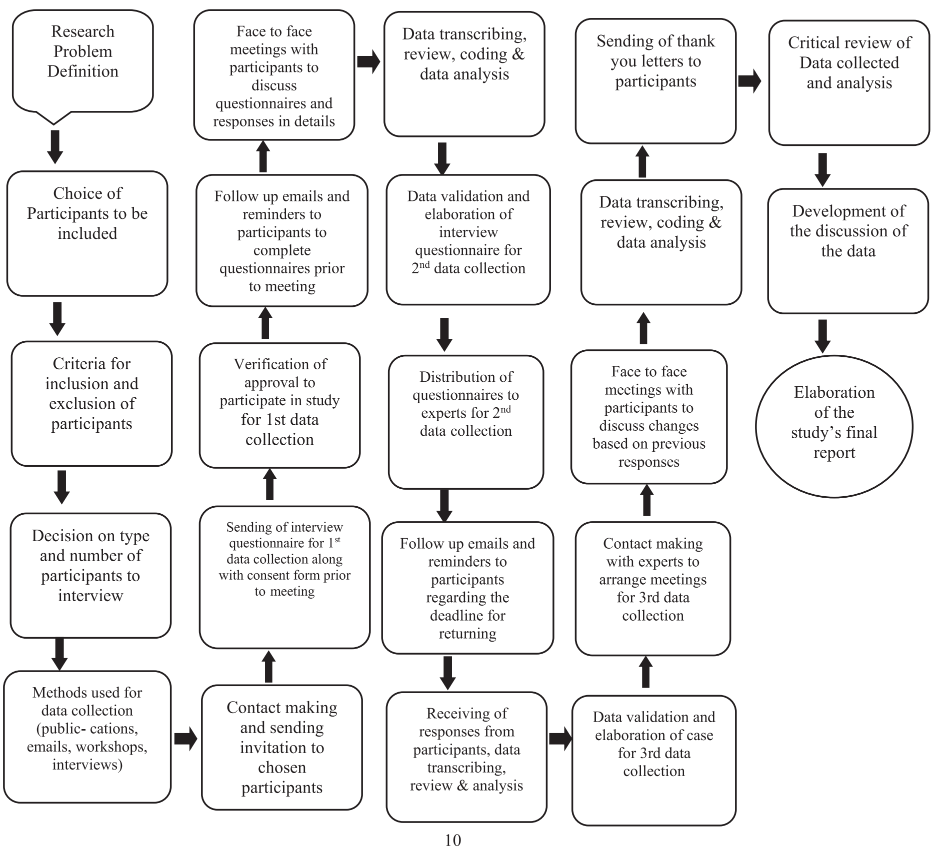

Figure 4. Schematic diagram explaining the methodological approach of the Delphi process from research problem definition to study report.

Figure 5. Schematic diagram profiling the expert panel's current role.

specific community for six years and above. In terms of expertise, 5% of the participants had limited levels of experience in renewable energy; 10% had an intermediate level of expertise; about 45% of the participants had advanced knowledge; and 40% were leading experts in renewable energy. Their expertise ranged from technical, research, policy management, political, and much more, such as head of laboratory/ research centres. The non-expert responses were eliminated, and the analysis focused on the experts' and advanced knowledge participants' responses. Based on the responses, about 70% to 80% believed that there is significant potential in renewable energy, primarily solar and hydropower, respectively. The solar potential is in alignment with meteorological data that shows that solar radiation is high over the years, andrelatively constant as illustrated in Figure 6. Based on this figure, the solar irradiation increases from south to north and reaches a maximum value of 2045 kWh/m^2 per year in the north of the country (Global Solar 2019). The hydropower potential is supported by the fact that there are small rivers that could be exploited for small (less than 10 MW) hydroelectric projects. According to PANER (2015), there is certainly an urgent need to develop small hydropower plants for the supply of electricity to rural areas and remote communities.

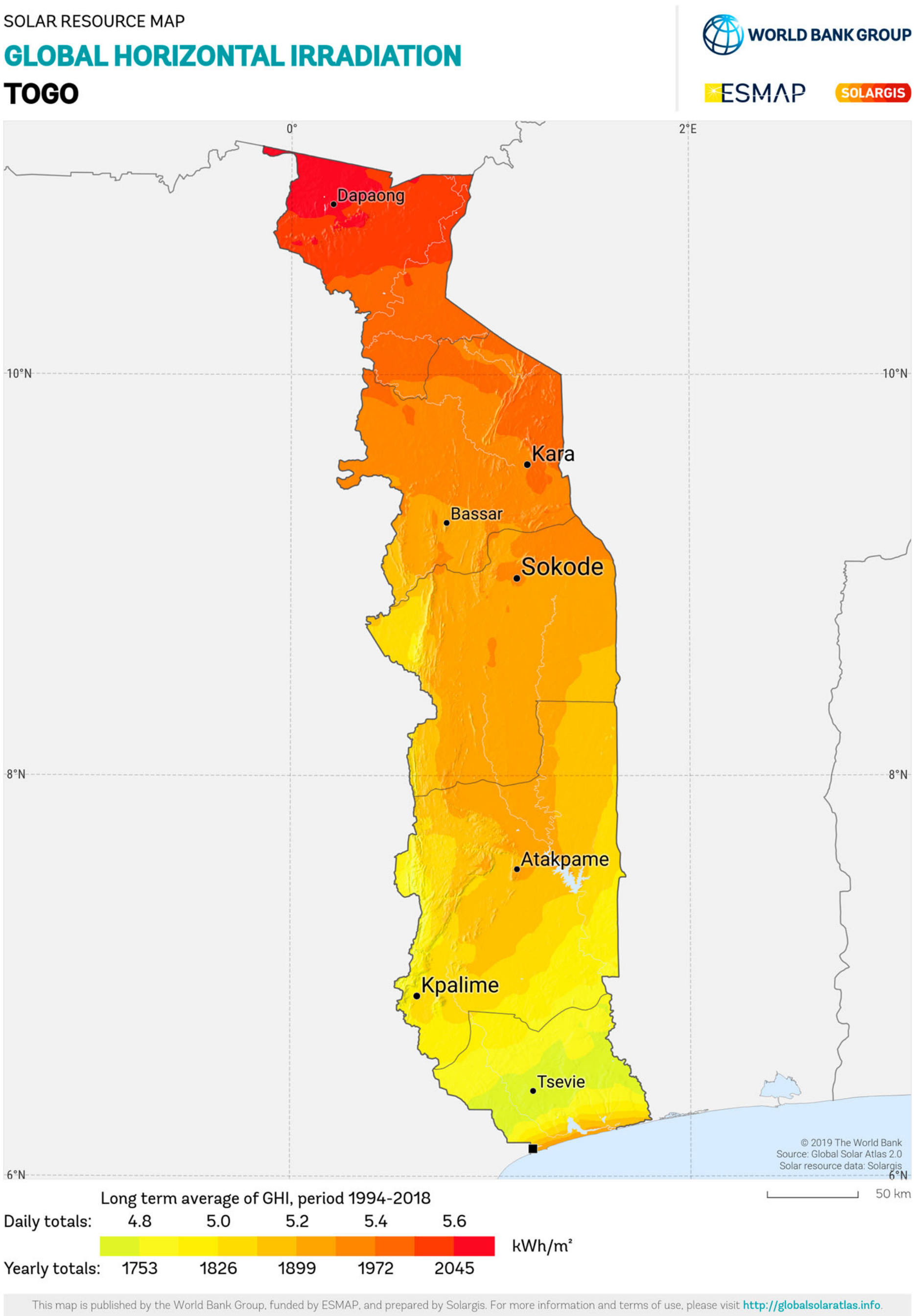

Figure 6. Solar irradiation in Togo (Source: Global Solar 2019).

In comparison to solar energy, wind energy has only been used to pump groundwater; however, an initial exploration has shown that Togolese wind resource is not competitive compared to other sources on the utility scale (PANER 2015). According to Global Wind Atlas, Togo is in an area with very low winds. The wind speed is higher on the coast in the south as shown in Figure 7, and the speed is also higher in mountainous areas.

In addition, the result illustrated that Togo has a widely used approach to study the key resources in biomass energy and petroleum, as well as solar, thermal, onshore wind, offshore wind, geothermal, tidal, and waves available. However, according to expert responses, these will involve significant capital and technical expertise to develop in current challenging Togo's economy. Figure 8 summarises the key views in relation to RE potentials.

Currently, Togo has 230 MW installed generating capacity that produces 1,600 GWh of power annually, of which, 65 MW of Nangbeto hydroelectric power is operated by the Benin Electricity Community (CEB, a jointly operated public entity between Togo and Benin in charge of generation) installation in Lomé. Hydro power of 1.6 MW operated by the Togolese Electricity Company (CEET) is installed in Kpime (Kpalime). A thermal energy of 100 MW operated by Contour Global (CGT), an international power company is installed in Lome, whereas 12 MW of thermal energy is installed in Lome (Sulzer), 11.9 MW of thermal power in Lome B (CTLB), 4 MW of thermal power in Kara, and 1.5 MW of thermal power in Sokode. There are isolated thermal power stations that are not interconnected; the installed power is between 40 and 1280 KVA (CEET 2020).

Currently, Togo relies on biomass energy such as firewood, charcoal, and vegetable waste, which account for about 71% of the energy used, and contributes to deforestation and serious health issues due to firewood pollution. Based on the literature review, Togo relies on petroleum products (26%) and electricity (3%) which are imported, as indicated in Section 1. To reach the 2030 vision set by the government, experts suggested a percentage increase of 202 MW to the current electric power.

3.2. Drawback factors on RE development

Speaking with a broad range of stakeholders to find out their in-depth views in relation to renewable energy development led to the identification of several drawbacks. For example, responses from the expert panel illustrated that some of the challenges faced by the Togolese government relate to determining the generation potential from various renewable energy sources such as hydropower and wind. To emphasise that, one of the responses from the head of a renewable energy research center stated, 'there is a need for real mapping of potential based on different zones to know the type of renewable energy to install'. Other challenges include seeking external funding available to support the establishment of networks and the sustainability of projects via integrated management provided by the mandated operator CEET (Togo PND 2018).

The result also showed that there are few adopted rules and regulations within the energy sector such as standardised Power Purchase Agreements and Power purchase tariffs. In addition, few incentive measures in taxation exist which only favour companies with a public interest and not private organizations. Furthermore, the non-liberalisation of the energy sector does not help investment from private investors to participate. The electricity company of Togo remains the sole entity that can market the electricity generated and there is no competition in electricity markets that will create more competitive markets and reduce the price per unit. Looking at the abundance of renewable energy resources in Togo and the financial constraint faced by the country, the government needs to collaborate a lot more with private organizations to attract more investment in the renewable energy sector. In addition, energy policies with incentives for investment in renewable energy should be developed to allow the increase of renewable energy in the energy mix of Togo.

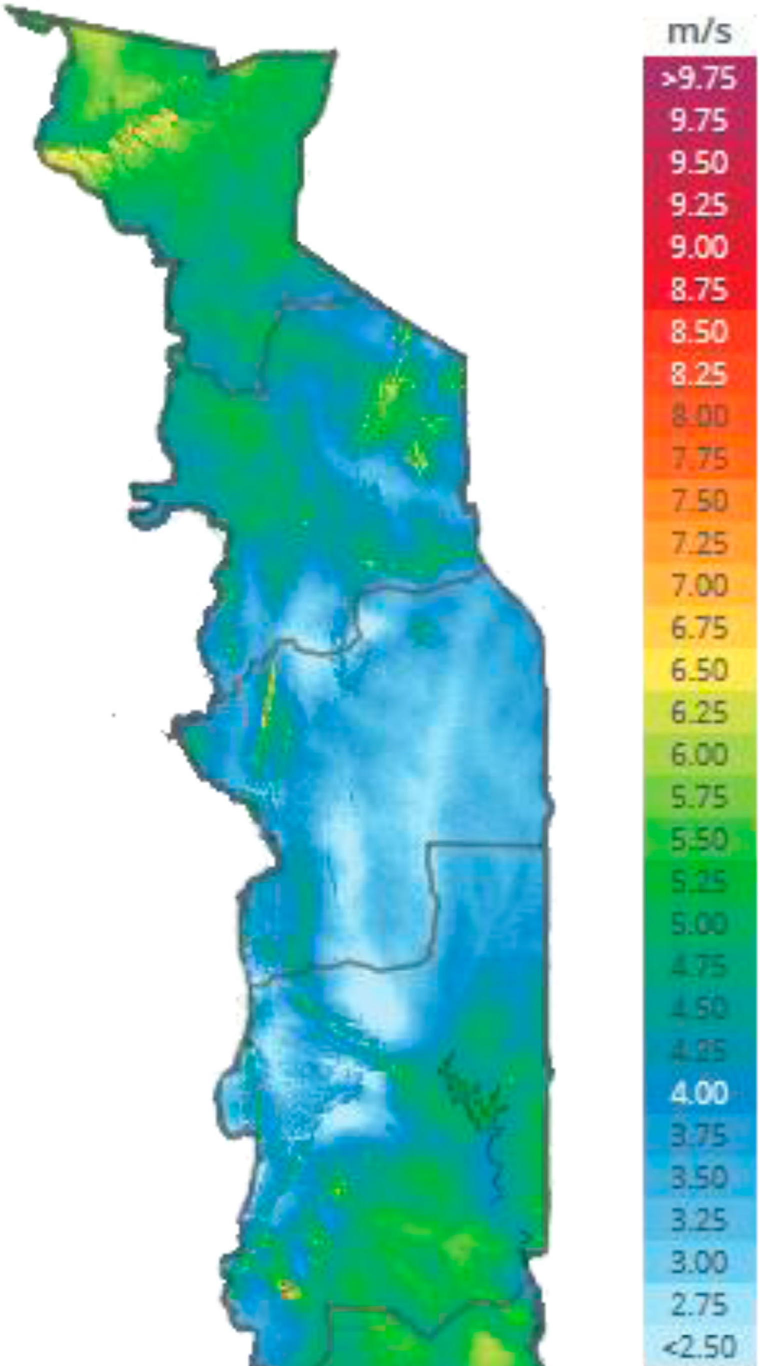

Figure 7. Wind map of Togo (Source: GlobalWind 2019).

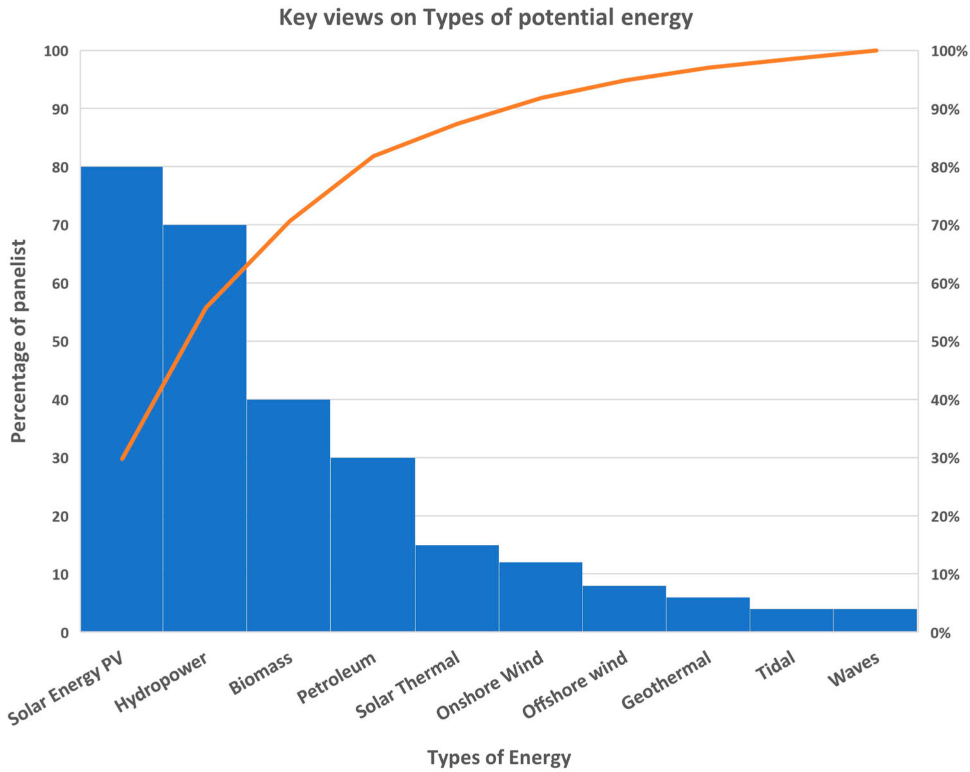

Figure 8. Views in relations to RE potentials for future trends.

3.3. Factors for the promotion of RE development

To find out factors for the promotion of renewable energy, the study focused on gathering key points from different groups of stakeholders (as illustrated in Figure 5) using interview questionnaires. Among these, 'Should renewable energy be prioritised?' was one of the questions to which, 80% of the respondents answered that 'RE offers a good opportunity to provide a reliable access to electricity for the population due to their natural source, while protecting the environment.' Additionally, one respondent mentioned 'renewable energy should be favored due to their inexhaustible source and the fact that they are best placed to facilitate access to energy even in remote areas and preserve the environment.' Besides, one of the responses stated that 'The promotion of renewable energies and the development of conventional (fossil) energies must go hand in hand to guarantee and support the economic development of the country'. This is in line with Acheampong, Dzator, and Savage's (2021) research which stated that increasing the share of renewable energy in the energy portfolio will not only boost economic growth and mitigate CO2 emissions, but will also help sub-Saharan Africa to achieve the Sustainable Energy for All (SEE4ALL) goal as well as the Sustainable Development Goal 7 (SDG7). Despite these arguments, about 20% of participants within the experts' group disagreed with the prioritization of RE that 'renewable energies are mostly intermittent sources, while the demand for electrical energy is continuously on the increase. In addition, they are expensive – given the current technology – and it is impossible to store energy at least to have high powers in line with demand, apart from hydroelectricity.' Moreover, they added, 'the mixing of renewable energies with conventional sources is technically limited given their instability in terms of frequency and voltage. Therefore, it would be dangerous to favor this type of energy.'

Promoting diversification was another discussion point that experts believed is essential because depending on the area, one type of RE might be more suitable and efficient than the other. Besides, they stated that allowing diversification will allow greater access and the reliability of energy and different sources complement each other giving an example of the sun which does not shine at night. They added that diversification will possibly help to overcome the energy shortage. Furthermore, 'diversification is necessary to maximise the use of energy sources available nationally'. Finally, an expert added this 'will have to be done on a case-by-case basis and a prior study will determine the final decision and AT2ER (the Togolese Agency for Rural Electrification and Renewable Energies) is currently working on it'.

Another point for discussion was based on promoting research. To this, all experts supported the argument that 'research needs to be promoted, particularly in Africa, to optimise the system for better performance, create manufacturing plants on site, and to produce materials that are accessible but efficient and adapted to our populations'. They added this is essential because 'it is not certain that all RE technologies can implement climate-adapted products'. Additionally, 'research will make it possible to discover the best formulas for using proven technologies in the field of RE'.

Moreover, suggestions were made for RE to be promoted both by raising awareness due to their many advantages and by encouraging innovation and research as well as staff training for a qualified workforce. They suggested 'a field survey will really guide the search for sustainable solutions in the use of RE'. Besides, they stated that the lack of research is a real development problem, coupled with the lack of funds to support research and development projects. Finally, experts suggested it would be desirable for the state to become more involved in training young students to produce this energy at a lower cost and then to popularise its use to all.

3.4. Recent approaches taken for RE development in Togo to achieve universal electrification

Several approaches have been taken to increase energy access in Togo in the past Quinquennial. For example, to reduce the rural energy deficit, the Togolese government launched a solar electrification project in 2017. This was supported by the AfDB (African Development Bank) for an amount of $975,000 in partnership with a private company called BBOXX. The aim of the project is to bring light to 2 million Togolese (approximately 300,000 households) by 2022. Based on expert's response and literature search, the Togolese government's ambition is to (Togo PND 2018):

- Bring the rate of access to electricity to 60% by 2022 on a national level.
- Reduce the rate of losses on the network from 16.8% to 10% by 2022 and
- Reduce CO_2 emission.

The above ambition can be achieved by strengthening the institutional, political, and legal framework for the energy sector, strengthening the production and distribution capacities of electrical energy, and increasing the storage and distribution capacities for hydrocarbons (Togo PND 2018). Currently, the monopoly of the energy sector does not help, and liberalization is needed to enhance security and the political environment to attract investors. Other universal government plans include:

- Reducing the share of biomass energy (such as firewood, charcoal) consumption in households from 65% to 40% by 2022.
- Increasing the share of renewable energy in the national energy mix by increasing the solar electricity to 50 MWp and that of micro-hydroelectric dams to 64.1 MW (using Titira, Sarakawa, and Kpessi) and
- Adopting energy efficiency standards.

This can be achieved with the abundance of renewable energy resources present in Togo; however, clear goals must be set up by the government to attract more investment in the renewable energy sector and improve energy efficiency standards.

Going forward, as a part of the Togolese government policy to achieve the set ambitious goal, the government plans to develop within the framework of the PND, an energy program that helps to exploit the hydroelectric potential with the construction of hydroelectric dams, such as Tetetou (50 MW), Danyi-Konda (10 MW), Baghan (6 MW), and Landa-Pozanda (4 MW) (Togo PND 2018; TogoFirst 2018). Many rivers exist such as Kpendjal, Ouale, and Sansargou (in Madouri), Oti (in Mango), and Mono (in Kaboli) among others in the country, and full commitment from the government is needed to achieve these development plans.

Another addition will be the planned coal-fired thermal power plant, the international and regional connection program with 2 transmission lines of 330 KV and 4 transmission lines of 161 KV, the construction of a 10 MW solar plant in Mango, and 5 MW in Kara (Togo PND 2018). The coal-fired thermal power plant remains a question mark because Togo does not produce enough coal and the plan is to import this resource to achieve this. Achieving sustainable development is key for a nation to be self-sufficient and this plan, though it could help, will not be the best based on recommendations from discussions with few energy personnel.

Working towards this ambitious plan, the Togolese government has taken some steps ahead that will help in the planning and implementation of the set goals according to the experts' responses. In line with these, recent developments have been put in place on various levels:

- Institutionally, AT2ER ('Agence Togolaise d'électrification rurale et des energies renouvelables') was created in 2016 and started activities in 2017. This is a separate entity within the Ministry of Energy that will specifically take care of renewable energy projects and rural electrification programs.
- On the regulatory level, some renewable energy laws have been put in place to favour private organizations that have the public interest in mind.
- On the organizational level, an electrification strategy has been put in place with the goal to achieve 100% access to electricity by 2030.

In addition, there have been some recent developments such as the construction of four mini solar plants–started in 2017 and finalised in 2019 (see, list in Table 2). The final acceptance of the last three solar mini power plants listed in Table 2 was prepared in 2019 as a part of the regional program for the development of renewable energy and energy efficiency (PRODERE) phase 2 in Togo. However, the Bavou solar mini plant of capacity 150 kWc has been provisionally completed but not commissioned yet.

The current efforts are on the network grid extension to allow power transmissions to target regions of the country. The first solar power plant of 50 MW is being built in Blitta by AMEA Power. This is financed by the Abu Dhabi Development Fund and the West African Development Bank (BOAD). The overall cost of the project is US $35.7 million for the first phase of 30 MW. Several future projects are being planned as well:

Table 2. Construction of four mini solar plants detailing installed capacity in various cities per region.

Regiong	Locality	City	Installed capacity
Plateau	Ogou	Bavou	150 kWc
Central	Blitta	Assoukoko[a]	250 kWc
Kara	Bassar	Koultoum	100 kWc
Savane	South Oti	Takpapiéni	100 kWc

[a]Power plant equipped with three water supply systems.

- Access to electricity – individual solar kit electrification project: The electricity strategy provides for the licensing of six operators for the distribution of kits. Two operators are currently active (BBOXX and SOLEVA). A call for tenders has been launched for additional licenses. Proposals were submitted on 3 December 2019. To date, three companies met the criteria and have been chosen to join BBOXX and SOLEVA for the execution of the CIZO project. These are FENIX INTL, MOON, and SOLERGIE (AT2ER 2020).
- Moon, a French firm yielded by the crowdlending platform Solylend, will provide its Moon Kit which is a solar system that provides lighting and charges USB devices. It comes with a Moonphone, which is a special smartphone through which beneficiaries are to pay back for the kit.
- Solergie, a Belgian firm that partnered with Total in 2018, will roll out its Solergie Box in Togo's rural areas. This is a solar system to which up to eight users can connect.
- Fenix INTL. is a subsidiary of French multinational Engie (since 2017). Based in Uganda, where its main activity is located, it is a pioneer on the home solar systems market in Africa (Togofirst 2020).
- Rehabilitation of 13,000 lampposts: The evaluation report of the invitation to tender issued for the supply of equipment for the maintenance of 2000 solar streetlights was validated by the DNCMP and was awarded to KYA Energy in December 2019. There is no additional information on the progress.
- 10,000 PUDC lampposts: The first phase of installing 2,000 solar streetlights as part of the project to install 10,000 streetlights was completed with the provisionary acceptance of the works made in early December 2019. No current news exists on the progress.

Further, the creation of an entity called Kekeli like Contour Global is at the planning stage for a natural gas plant of 65 MW capacity and harboured by the equipment access delays. Negotiations are ongoing for construction materials needed for commissioning. This will be financed by Eranove, a French-based company.

In terms of training:

- With the help of the URIBIS Foundation, 100 experts have been trained on solar technology and operations in Kpalime, Tsevie, and Anieh cities.
- For the upcoming CIZO project, 3,000 technicians were trained in 2019: (2 weeks of training for each group). There were 600 technicians per region in all the five regions of Togo, making a total of 3000 trained technicians. The training was done by Kya Energy Group located in Agoe – Lome in partnership with the solar energy lab at the University of Lome. The plan is to employ all those trained technicians in the future, once the upcoming project is executed. Also, 50 engineers (av.10 per region) were trained at master's level aimed to oversee the CIZO project in due course.

3.4.1. Renewable energy laws

The summary of the renewable energy laws put in place include the LAW 2018–2018 that relate to the production of electricity from renewable energy sources in Togo, promulgated in 2018. This law provides texts for its application in 4 decrees: orders relating to approval, license, connection to the electricity distribution network, and for the management of waste from electricity production installations, based on renewable energy sources and technical documents; in particular, the network connection specifications and the national plan for the construction of electricity production infrastructures based on renewable energy sources. In 2019, three out of four decrees were issued:

- Decree n 2019–18/PR of 6 February 2019, setting the conditions and procedure for the conclusion and termination of the concession agreement for the production and marketing of electric energy based on renewable energy sources.

- Decree n 2019–2019/PR of 6 February 2019, fixing the power thresholds of the different legal regimes for projects of electricity production based on renewable energy sources.
- Decree n 2019–2021/PR of 13 February 2019, setting the conditions and terms for issuing and withdrawing the license for the production, distribution, and marketing of electrical energy based on renewable energy sources.

Approval orders have also been issued as follows:

- Inter-ministerial decree n 058/MME/MEF/2019 setting the terms and conditions for issuing the approval for the import of materials and equipment to produce electricity from renewable energy sources.
- The inter-ministerial decree n 059/MME/MEF/2019 fixing the costs of examining the application file and the costs of granting approval for the import of materials and equipment to produce electricity from renewable energy sources.
- Decree n 060/MME/CAB/20219 on the creation, attribution, composition, and operation of the approval commission for the benefit of tax and customs exemptions provided for, by the law 2108–2010 of 8 August 2018.

4. Prospects to developing renewable energy

The objective of this study is to evaluate the potential of renewable energy technologies and the impact of their development in the energy mix of Togo. Based on the literature, fieldwork, and interviews, Togo relies mostly on biomass energy, petroleum, and electricity for its energy use (CEET 2018) – despite its potential in RE that could be developed to implement a nationwide sustainable energy system (PANER 2015). As stated in Section 1, most of its energy is imported from the exterior to meet the demand, and approximately 70% of its population still lacks access to energy. The study is based on a three rounds Delphi method to capture in-depth data.

Figure 6 summarises the percentage of experts who voted for the development of different types of RE technology based on the interviews. From all listed renewable energy types, 80% of the participants strongly believe that developing solar energy PV is key to improving the energy situation due to its potential. This is not only based on participants' responses, but also field visits, observations, and literature that emphasised it. For example, Abusief, Caldon, and Turri (2014) stated, solar energy is one of the most promising, non-polluting, free sources of energy. Their study reported the benefit of the high content of the annual solar radiation in the Al Kufra area and implement distributed generation technology using photovoltaic solar energy to improve the security of supply in this area. They concluded that considering the advanced PV technology with decreasing cost and the high availability of solar energy in Al Kufra, it is strongly recommended to implement distributed generation technology using PV and battery energy storage system to store the surplus PV energy produced, to inject it into the grid, or to use it to supply a part of the shed load depending on the system mode.

Participants also argued that compared to the other types of renewable energy, the technology does not require a lot of money to develop like onshore/offshore wind, wave, and tidal energy, even though there is a potential for these as well (example: wind power potential is estimated at 10–12 MW offshore and 3–4 MW onshore). Besides, small-scale solar PV can be installed in remote areas that do not have access to the grid to provide electricity access to remote communities. This is supported by Olatomiwa, Mekhilef, and Ohunakin (2016) study who suggested a system of autonomous, off-grid power generation to be established for rural communities in Nigeria using renewable energy technologies – since improving rural access to electricity through grid extension does not look promising at present due to the associated costs. Furthermore, Siritoglou and Oritis' (2020) study, for instance, made use of tools such as design equations in compliance with IEEE standards for accurately sizing the distributed energy resources of a stand-alone microgrid to meet the critical load demands of military, commercial, industrial, or residential facility when the utility power is not available. This microgrid combines renewable resources such as PV with an energy storage system to increase energy security for facilities with critical loads. This can as well be applied to remote areas to provide the needed electricity using a small-scale solar PV.

About 70% of the participants suggested the development of hydropower energy due to the presence of many rivers in the country. Based on this, the government is planning to increase hydropower capacity through the development of three projects, namely Sarakawa, Tetetou, and Titira.

- At Sarakawa, the government is planning the construction of a 24 MW hydroelectric dam on the Kara River with an annual output of approximately 105 Giga Watts's hours (GWh), construction of an energy evacuation line, and the rural electrification of 29 localities in the project area by extension of the electricity network. The French Development Agency (AFD) and the European Union are committed to developing this project due to the interesting characteristics (technical, economic, and environmental) it present.
- At Tetetou, the government is planning to exploit the hydroelectricity potential using the Mono River to construct a hydroelectric dam of capacity 50 MW with the help of the European Union.
- At Titira, the government is planning the development of a hydroelectric project with a capacity of 24 MW. For this, a joint development agreement was signed in December 2019 between the Ministry of Mines and Energy and GLOBELEQ. This agreement provides for the study of three variants, namely, a hydroelectric plant, a hydroelectric plant coupled with a solar plant, and a solar plant with storage. Discussions are still ongoing.

Currently, Togo relies on biomass for most of its energy supply with more than 60% of its needs filled by wood. According to the response, biomass energy currently plays a big role in the country due to its level of poverty, as most of the indigenous cannot afford other types of energy (Kansongue, Njuguna, and Vertigans 2018). Some rely on cutting trees for their use, destroying the environment. This also comes with a lot of consequences due to pollutions from the use of firewood for cooking, causing health issues, especially in women and children. Participants answered that though this type of energy is harmful, most of the population will keep relying on it for their energy use until the poverty level improves. For example, based on the second data collection, since March 2019, the government has put in place some subsidies, providing a grant of 2,000 CFA per month (approximately \$3.5) over 36 months to each house that owns a solar kit from the Cizo project providers. This is to encourage households to subscribe to solar usage for their energy needs. This offer is conditional on the payment of the monthly household fee. The kits cost: Basic – \$8.23; Basic Plus – \$11.32; Premium – \$19.29. Subscription is quite easy and at least 40% subscribe for the Basic (capacity 50 W), which is mostly used for lighting. However, the big issue comes with the monthly payment because despite the grant, the farmer is left with a bill of approximately \$6 per month to pay, and this is difficult for most farming communities.

Based on our study responses, other types of energy such as solar thermal, offshore wind, onshore wind, geothermal, tidal, and wave all have potential; however. will cost a lot more to develop.

Successes related to the recent installation of solar energy such as the 'PRODERE' project (which consisted of installing solar energy in 22 villages from 2013 to 2016 with the aid of the West African Economic and Monetary Union) (WAEMU) includes lighting purposes, phone charging, powering radio and televisions. In some areas, these are used to help power hospitals for vaccines storage and medications. Other uses include water pumping, lighting schools, markets, and churches. Other solar projects included the construction of four mini solar plants; done from 2017 and finalised in 2019. These are as shown in Table 2, namely Blitta 250 kW at Assoukoko – central region; Bassar – 100 kW at Kountoum in Kozah (Kara); and Takpapieni (Savane) 100 kW; and that of Bavou, 150 kW.

Table 3. Solar Kits distributed per region from October 2019 to April 2020 (Source: SOLEVA quarterly report, 2020).

Region	Clients Home60	Clients Home120+	Clients Home400	Total
Maritime	441	207	73	721
Plateaux	144	75	21	240
Centrale	20	28	12	60
Kara	88	14	5	107
Savana	208	20	29	257
Total	901	344	140	1,385

The solar plant located at Assoukoko is equipped with three water supply systems to help the population with potable water. The remaining three solar plants are mainly for electrification. Also, according to the quarterly activity report of solar kit distributors, SOLEVA distributed from October 2019 to April 2020, an estimate of 1,385 solar kits (Table 3). This is a part of the national plan which provides for the 55,000 kits by 2030 mentioned in Section 1. Everyone can benefit from it, especially in rural areas. The price varies from one operator to another according to the power requested. As mentioned above, the state gives a subsidy program of 2000F CFA per month per household, cushioning the burden on the household. Most of these kits, however, are used for electrifying homes, businesses, and equipment.

With regard to the planned offshore wind project, data gathered shows that this did not progress due to several reasons:

- Potential development for wind energy according to a study report presented in December 2017 during the ROGEP ECREEE workshop is low within the country with an exception to areas located around Lake Togo.
- Delta wind project has not progressed to date due to the selected areas which are subject to wind instability and low capacity. Furthermore, experts mentioned that the wind turbine masts had to be raised to 100 m at least to reach the required speed needed to produce energy. This will require a big investment and its leaders are still looking for technical and financial partners to assist. There have been some rumours as well indicating that the Togolese company in charge of generation (CEB) offered to purchase the kWh at a price that will not ensure the profitability of the project.
- The average wind speed is said to be between 1 and 4 m/s when an average of 6 m/s is required.
- Hearsays of personal interest issues that do not favour policy makers.

When asked if renewable energy should be promoted, 70% of the experts supported the idea mainly for solar energy and hydropower development due to their potential. Some of the arguments they listed included the following:

- They are good for the environment and will help to protect the environment and curve pollution issues and promote better health.
- They are natural sources of energy needed in a fast-developing world because demand is on the rise.
- They can be developed in small scale, especially in remote areas that do not have access to the grid, and can provide reliable access to electricity for the population at an affordable price with time

A total of 30% experts disagreed. Reasons for supporting the non-promotion included:

- They are intermittent sources of energy and will be insufficient to meet the demand that is always on the rise.

- They are expensive; given the current technology and energy storage, they still cause an issue due to the lack of power storage technological equipment.

5. Conclusions

This study presented the view of key stakeholders in relation to renewable energy development (mainly solar and hydropower) in the energy mix of Togo, highlighting the current energy situation and actions planned for the development to increase energy access in Togo. With a three rounds Delphi method, the study captured the view of key stakeholders on the subject matter. It has been concluded that increasing the share of RE, namely solar PV and hydropower, could significantly improve the energy situation in Togo. This could be through the installation and development of small-scale solar plants and hydropower. From the discussions above, a lot of RE development projects are taking place and many others are being planned from now to the next 10 years. The study also found that to date, there are few adopted rules and regulations within the energy sector and few incentive measures in taxation, and these only favour companies with a public interest and not private organizations. Moreover, the non-liberalisation of the energy sector does not help investment from private investors to participate, as the electricity company of Togo remains the sole entity that can market the electricity generated. More than ¾ of the experts' panel also recognised the need to prioritise RE due to their socio-economic and environmental values, while promoting its diversification for better suitability depending on the location, greater access, and reliability of energy. Finally, promoting research was suggested to optimise the system for better performance, create manufacturing plants on site, and to produce materials that are accessible but efficient and adapted to each location. This should be done both by raising awareness due to their many advantages and by incorporating staff training to a qualified workforce for development.

Disclosure statement

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