REPUBLIQUE DU BENIN

MINISTERE DE L'ENERGIE

Feasibility study and action plan for the manufacturing of components for small-scale wind turbines in Benin

Final report

(version in English)

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List of acronyms

ABERME	Agence Béninoise d'électrification rurale et de maîtrise d'énergie
AfDB	African Development Bank
ANADER	Agence Nationale de Développement des Energies Renouvelables
ARE	Autorité de Régulation de l'Electricité
CEB	Communauté Electrique du Bénin
CENER	Centro Nacional de Energías Renovables (National Centre of Renewable Energy, Spain)
CONTRELEC	L'Agence de Contrôle des Installations Electriques Intérieures
CTCN	Climate Technology Centre and Network
DGRE	Direction Générale des Ressources Énergétiques, Ministère de l'Energie
DGEC	Direction Générale de l'Environnement et du Climat, Ministère du Cadre de Vie et du Développement Durable
DTU	Danmarks Tekniske Universitet (Danish University of Technology)
ECOWAS	Economic Community of West African States
ECREEE	ECOWAS Centre for Renewable Energy and Energy Efficiency
EEEOA	Le système d'Échanges d'Énergie Électrique Ouest Africain
EnDev	Energising Development
EPC	Engineering, Procurement and Construction
FCFA	West African CFA franc (XOF), 1 EUR = 656 FCFA, 1 USD = 558 FCFA [57]
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Organisation for International Development)
GoB	Government of Benin
IEC	International Electrotechnical Commission
IRENA	International Renewable Energy Agency
LCOE	Levelised Cost of Electricity
MCC	Millennium Challenge Corporation
ODD	Objectifs de développement durable
SBEE	Société Béninoise d'Energie Electrique
UAC	Université d'Abomey-Calavi (National University of Benin)
UEMOA	Union Economique et Monétaire Ouest-Africaine
UNDP	United Nations Development Programme

Acknowledgements

As part of this study, the researchers have conducted interviews and communicated with over 50 persons from different government agencies, universities, non-governmental organisations and the private sector in Benin and worldwide. We would like to express our gratitude to all those that have cooperated in this study as their input has been very important to the outcome of this report.

Special thanks go to Juste Christel Tankpinou DAMADA, Todéman Flinso ASSAN, Amine Bitayo KAFFO and Raphiou AMINOU who were closely involved in all steps of the study. The researchers also would like to thank the CTCN/UNIDO team for their flexibility and for providing valuable suggestions on how to improve the outcome of this study.

Reader guide

This report presents the final version of the feasibility study and the action plan. A draft report was used as object of discussion for the stakeholder validation workshops on 1 and 2 December 2017 and 19 July 2018. At the end of these meetings, the team of consultants was asked to incorporate the recommendations in the final report.

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Abréviations	Nom complet	Explication
kW, MW, GW	kilowatt, megawatt, gigawatt	Units of power
kWh, MWh, GWh	kilowatt hour, megawatt hour, gigawatt hour	Units of energy
kWp	kilowatt-peak	Unit of maximum power
m/s	metres per second	Unit of speed
#hsh	Number of households	
CO_2-eq	CO_2-equivalent	Unit of global warming potential of a greenhouse gas

Notes from the authors

The information in this report is based on interviews, desk- and literature research and feedback from stakeholders during the intermediary meeting in Cotonou. Finding recent and reliable data in Benin is challenging. The researchers therefore had to use many different data sources with often different time frames and units. Combining these sources provided new insights but also raised new questions, especially in relation to reliability of the gathered data.

The information in this report is based on quality sources and is accurate at the time of writing (2018). However, the Beninese energy and manufacturing sectors are in continuous development, so organizational capacities, fees and other parameters are subject to change. Therefore, for any entity intending to engage in the set-up of small wind turbine manufacturing in Benin, it would be wise to liaise with relevant experts who can use their insider knowledge and relationships to ensure all necessary steps at that point of time are indeed taken.

Preface Minister of Energy of Benin

Dear compatriots, dear readers,

It is with pleasure and honour that I address you regarding the noble initiative that is the manufacturing of small-scale wind turbines in Benin and their deployment in appropriate rural and peri-urban areas.

Indeed, our population's access to modern and sustainable energy services, the expansion of our industrial fabric, and the promotion of research and innovation are among the major concerns of the **President of the Republic**, His **Excellency Patrice Athanase Guillaume TALON** and of his **Government**, as evidenced by pillar number 2 of the Government Action Plan 2016-2021.

By 2030, Benin must achieve the goals it has set through the Sustainable Energy for All initiative (SE4ALL). This requires the convergence of all actors involved in the energy sector in Benin, in particular those in the renewable energy subsector. The technical and financial support of our partners will once again be welcome.

As you are aware, small wind energy is a form of renewable energy of which the valorisation will contribute to accelerating the electrification of localities that are distant from the conventional electrical energy network. It is also a source of both energy and employment for the benefit of youth.

With this project, Benin is planning to make the West African sub-region a flagship of research and development and public-private partnerships in the small-scale wind turbine sector.

I have no doubt that this initiative will spread to other regions of the world. For this to happen, Benin has to make it a reality by rigorously adhering to the action plan resulting from the thorough reflection of actors in the energy sector, whose competences are without doubt.

I would like to end by thanking the Climate Technology Centre & Network (CTCN) and United Nations Industrial Development Organization (UNIDO) for their support in the realisation of this document.

Dona Jean-Claude HOUSSOU
Minister of Energy of Benin

Preface Climate Technology Centre and Network

The Climate Technology Centre and Network (CTCN), the implementation arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism, promotes the accelerated transfer of technologies for energy-efficient, low-carbon and climate-resilient development. As nations around the world seek to fulfil their development goals in an increasingly sustainable and environmentally sound manner, the CTCN aims to serve as a trusted partner by providing expert policy and technology support. At the request of nationally-selected representatives (National Designated Entities, or NDEs), the Centre harnesses the expertise of its global network of over 400 finance, NGOs, private sector and research institutions, along with CTCN hosts, UN Environment and the United Nations Industrial Development Organisation (UNIDO), to deliver tailored assistance and capacity building in a broad range of sectors including agriculture, energy, transport, water and waste management.

CTCN is particularly glad about the results of the technical assistance **"Feasibility study and action plan for the manufacturing of components for small-scale wind turbines in Benin**" featuring the "Direction Générale de l'Energie" as request proponent and implemented by Partners of for Innovation, a CTCN network member. This study represents a key instrument to open the ground for investors to enter the market in the country and enable the completion of the supply chain to locally produce and manufacture small wind turbines.

This work brings high impact at different levels: on one side it will mitigate GHGs emissions through the promotion of wind energy in rural and peri-urban areas. Furthermore, it contributes decisively towards the private sector engagement, being a key target of the climate convention under the UNFCCC mechanism. In addition, the results of this technical assistance carry the potential to be replicated and scaled-up at regional level through relevant financial mechanisms, both institutional and private in nature.

I would like also to thank the effort of the National Designated Entity (NDE), within the Directorate General for Climate Change, in its capacity of country representative and CTCN focal point, for having selected this valuable request for technical assistance to the CTCN. This is also an opportunity to remind the relevance of the role of countries' NDEs as technology focal point within the Conference of the Parties (COP).

I wish the country good luck for this endeavour targeting the introduction of clean energy and the development and enhancing of local industrial capacity. I am eagerly looking forward to the continuation and concretisation of follow-up actions that could originate from this CTCN technical assistance.

Jukka UOSUKAINEN
CTCN Director

Executive summary

Introduction and energy situation Benin (chapters 1+2)

Across sub-Saharan Africa, coastal and wind-endowed regions are considering the option of harnessing wind power to supply electricity to unelectrified communities. South-Benin is one such region, where small wind turbines have been highlighted as a type of technology with a very significant – but at the same time, greatly underutilized and under-researched – potential for renewable energy-based electrification. It is often unclear what the benefits of small wind power are when applied in a new context, as it is a technology for which the feasibility and desirability can be strongly dependent on local socio-economic circumstances. In this, a key determinant of success is the role that local manufacturing can play; not only to reduce the system costs per kWh, but also to turn wind power generation into a technology that is socially embedded and able to contribute to local employment. In this research, it is assessed how and to what extent locally manufactured small wind turbines (1 – 10 kW) can contribute to the electrification of South-Benin.

Role of small wind turbines in the electrification of South-Benin and setting up such an industry (chapters 3+4)

The first part of the study focuses on providing a calculated estimate of the market potential, based on household power demands in villages that are currently unelectrified. Based on a combination of satellite data and direct wind measurements available in scientific literature, it is assessed that **87 villages in the departments of Atlantique, Mono, Ouémé and Couffo**, with a total of **214.081 inhabitants**, can be provided with electricity from small wind turbines. To do so, **a production capacity of 7,7 GWh per year** will be required, for which 4.424 turbines of a 1,4 kW rated output or 1.157 turbines of a 6 kW rated output will be needed.

The second part of the analysis targets the potential for local manufacturing. It provides an inventory of Beninese private sector companies with the potential to deliver (semi-)manufactured goods, assemble individual components and construct turnkey systems. It is concluded that although the sector's initial steps in the small wind domain will be strongly reliant on import, **many of the required skillsets and materials can potentially be covered by one or more Beninese companies** in the short-to-medium term (2020-2025). For steel parts manufacturing and overall system installation, the local capacity is expected to be sufficient in the short term. Technologically more complex components such as electric generators, inverters and controllers will have to be imported for the first few years, but appropriate training and a few years of experience with local maintenance should allow Beninese engineers to manufacture these locally as well. Raw materials (steel, copper) and polyester composites are expected to be imported even beyond the 2030 horizon, however.

Table 1 below specifies the costs per kWh, total investments and number of jobs (as full-time work months) related to the manufacturing of both turbine types. In addition, table 1 provides an estimate of these three parameters if all non-manufacturing costs and activities are taken into account as well. For the calculation of these figures, it is assumed that there is a market for 4.424 turbines of a 1,4 kW rated output or 1.157 turbines of a 6 kW rated output, generating a total of 7,7 GWh per year.

Table 1: Summary of estimated socio-economic results for total market (4.424 turbines of 1,4 kW or 1.157 of 6 kW)

Turbines	Manufacturing costs per kWh	Manufacturing investment	Manufacturing jobs**	Total costs per kWh*	Total investment*	Total jobs**
Passaat (1,4 kW)	93 FCFA	14.347.415.114 FCFA	145	*279 FCFA*	*43.042.245.343 FCFA*	*723*
Montana (6,0 kW)	55 FCFA	8.432.077.632 FCFA	46	*164 FCFA*	*25.296.232.897 FCFA*	*231*

** Total costs & total investment equal manufacturing costs & manufacturing investment multiplied by a factor 3.*
*** Jobs are expressed in full-time work years (2.064 hours). Total jobs equal manufacturing jobs multiplied by a factor 5.*

Table 2 puts these estimates of total costs in perspective with those of solar PV and diesel generators in off-grid situations in South-Benin, making clear that **small wind turbines are expected to be cheaper than diesel generators and comparably priced or slightly more expensive than solar PV**.

Table 2: Total costs per kWh for off-grid technologies in South-Benin

Off-grid technology	Price range (FCFA)	Comment
Solar PV	197 – 262 per kWh	Based on 2011 data and older [26], likely lower today
Small wind turbines	164 – 279 per kWh	Based on calculations in chapters 3 and 4
Diesel generator	230 – 459 per kWh	Based on [26] but corrected for 2017 diesel prices [27]

Action plan for small wind manufacturing and deployment in Benin (chapter 5)

The final part of this report provides an action plan for the development of a small wind turbine sector in Benin. This action plan is based on the conception that the development of a sector from the ground up requires concerted efforts in which not only industry, but also government, academia and civil society work together to generate momentum. It therefore makes a distinction between four pillars: **sector programming, targeted implementation, coalition building and knowledge development**. On that basis, the action plan proposes a wide but at the same time coherent range of activities and targets that can help to make the Beninese small wind sector a reality. In so doing, four time horizons are distinguished: very short-term (2018-2019), short-term (2020-2021), medium-term (2022-2025) and long-term (beyond 2025).

This action plan is intended to serve as input for a more comprehensive, broad-based roadmap, in which activities and responsibilities are further specified and the planning is more detailed. Studies on appropriate incentivization, the interests of women and youth and the development of monitoring and evaluation components will need to be part of the roadmap development process.

The total investment required for wind-powered household electrification in South-Benin is estimated at between 25 and 43 billion FCFA (as indicated in table 1). The budget for the first phase of sector development (2018-2019) is estimated to be around 1% of this total investment: between 0,25 and 0,43 billion FCFA. The budget for the second phase (2020-2021) is estimated to be around 10% of the total investment: between 2,5 and 4,3 billion FCFA. These numbers are derived from a cost assessment of each of the four pillars individually, carried out on the basis of the project team's experience with other renewable energy sector development programmes in Sub-Saharan Africa.

In the very short term (2018-2019), it is advised to kick-start the sector's development by means of a pilot phase. In close cooperation with the Beninese governmental institutions, the universities and the private sector, it is proposed to install 4-6 turbines. To realise this, actions on all four pillars will be necessary, as indicated in the image below.

DGRE/DGEC:
1. Establish a general roadmap for 2018-2025
2. Organise a pilot phase in cooperation with technical and financial partners

Pilot partnership:
3. Installe 4-6 pilot turbines, in close cooperation with the Beninese governmental institutions, the universities and the private sector

Coalition leaders:
4. Make the technical and financial resources available for the installation of 4-6 pilot turbines

Universities / knowledge partners:
5. Make sure to be actively involved in the preparation and execution of the pilot phase

Actions for the very short term (2018-2019)

For the two years that follow (2020-2021), it is expected that the industry's generation of revenue will mainly come from component assembly, installation and early maintenance. During this phase, the **establishing of (political) awareness and trust**, **building of capacity in the manufacturing sector** and **setting up of (inter)national collaborations targeted at the realization of tangible results** will be key. Through the provision of financial support and technical assistance, **international donors are expected to be paramount** for enabling the Government of Benin to kick-start the small wind sector. Table 3 below describes the actions proposed between 2020 and 2021 for developing a small wind sector in Benin, and connects these with specific stakeholders, budgets and milestones.

Table 3: Short-term action plan (2020-2021) for setting up a small wind sector in Benin

A. **2020-2021: Sector programming**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
A.1 Develop a detailed 2-year roadmap for small wind sector development in Benin, in which time-bound tasks are defined and responsibilities are allocated to stakeholders. This includes studies on appropriate incentivization, the interests of women and youth and the development of monitoring and evaluation components.	DGRE, DGEC	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	Roadmap completed
A.2 Seek cooperation with international donors **to acquire the resources necessary** for developing & implementing the sector development roadmap.	DGRE, DGEC		Signed agreement to cooperate
A.3 Identify and attract international expert organizations to **set up a consortium or joint-venture that can play a pioneering role** in the small wind sector in Benin.	DGRE, DGEC with coalition leaders (see actions C)		Signed commitment

The table continues on the following page

B. **2020-2021: Targeted implementation**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
B.1 Install 100 turbines for household use, and involve village chiefs to determine villagers' willingness to cooperate and **participate in the installation and operation** of the systems.	Consortium responsible for targeted implementation [1]	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	100 turbines installed & 3 or more village chiefs interviewed ; voluntary participation of women, men and youth during installation and exploitation;
B.2 Install 20 turbines for productive use of electricity (telecom, tourism, business, irrigation)	Consortium responsible for targeted implementation		20 turbines installed
B.3 Arrange for the **production of small wind turbines in Benin**, in which high-quality small wind systems are used, the amount of locally generated value is maximized and gender-sensitive actions are researched.	Consortium responsible for targeted implementation		120 turbines ready for energy production
B.4 Facilitate the import of raw materials and components by reducing tariff barriers. Remove other legal barriers and offer other incentives. Inform suppliers and traders of these opportunities without discriminating for gender.	DGRE, DGEC		Reported satisfaction of relevant importers ; percentage of male and female suppliers and traders informed and involved in import

The table continues on the following page

[1] See action A.3

C. **2020-2021: Coalition building**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
C.1 Identify and convene **organizations with an interest in the creation of a small wind sector in Benin**, including industry (manufacturing, construction, import), NGOs (including women's organisations), knowledge institutes and agencies.	Coalition leaders	Between 0,25 billion and 0,43 billion *Estimated as 1% of total investment as budget is only intended for facilitation. Coalition participants pay for their own expenses as they have corporate interest.*	Signed letters of intent, also expressing the incorporation of the gender dimension
C.2 Determine the **mandate and cooperative structure** of the coalition, with an opening for taking into account gender-differentiated interests.	Coalition leaders with the Beninese government		Legal documents signed, also expressing the incorporation of the gender dimension
C.3 Develop a detailed approach for the **creation of nation-wide awareness** of small wind technology, the **alignment of actors** in the small wind industry and the identification of avenues for sector positioning and development.	Coalition leaders with the Beninese government		Strategic plan completed and gender-sensitive

D. **2020-2021: Knowledge development**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
D.1 In cooperation with international knowledge institutes, **establish a centre of technical wind energy expertise** to conduct wind measurements (for selecting prospective sites) and applied research (e.g. turbine optimization, system configuration).	Technological Universities	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	Research strategy formulated
D.2 Make wind energy a **prominent part of education curricula** for engineers and technicians (girls and boys).	Technological Universities, SBEE, ABERME		2 or more universities offering a wind course ; percentage of girls and boys registered for these courses

If these actions are successfully completed in the coming years, it is anticipated that within the horizon of 2022-2025 and beyond, the small wind sector in Benin will become a solid industry with an indispensable contribution to the electrification of the country. For the medium-term (2022-2025), the provisional budget is 25-43 billion FCFA. From 2025 onward, it will become possible to scale-up the sector with 1000-4000 operational turbines. Table 4 below outlines the general directions for the sector in the medium term (2022-2025) and overall prospects for the long term (beyond 2025).

Table 4: Directions and prospects for the small wind sector in Benin

2022-2025: Medium-term directions	
General target	*Specification*
Intermediary evaluation and adjustment of sector programming completed with the inclusion of a gendered perspective	• Evaluate the status of the wind sector from the perspective of gender and the goals formulated in the development roadmap • Determine if and how a change of direction is necessary • SWOT-analysis for the effective integration of gender aspects in the proposed measures • Elaboration of programmes specified in favour of women and girls (if needed)
1000-4000 turbines (1-10 kW) produced and installed	• Industry revenue generation increasingly comes from local manufacturing and detailed assembly • Turbine sizes can be varied depending on local socio-economic circumstances
Wind energy coalition positioned as sector association	• Coalition tasks shift more toward the gathering of sector data, promotion of business excellence and representation of the sector in policy negotiations • Female presence in the coalition rises toward 30% • Youth presence in the coalition rises toward 30%
100 electro-mechanical engineers and technicians (both male and female) experienced with small wind technology	• First engineers and technicians graduate from wind-specialized educations (of which gender-specific data is gathered) • Educate existing SBEE/CEB/ABERME engineers and technicians in cooperation with wind expertise centre (and gather gender-specific data)
Beyond 2025: Long-term prospects	
• Industry revenue generation shifts to operation, maintenance and replacement • Possibilities for larger turbines (50-250 kW and 1-5 MWs) are being investigated • Export of components, systems and knowledge becomes a realistic sector opportunity • Jobs created for men, women and youth • Earnings for men, women and youth involved in the small wind sector	

Conclusion and discussion (chapter 6)

This report has elaborated on the techno-economic potential of small-scale wind turbines in Benin, confirming that it indeed exists with good prospects regarding the viability of this technology. The market potential is sufficiently large for creating a decent volume of products, particularly for the smallest turbines, as the wind speeds are high and reliable enough for generating significant kWhs per year. Also, it is expected that local production can account for more than half of the production value of a turbine, reduce its costs with 9-15% and generate a great many jobs for men, women and youth in the production, installation and service sectors.

In addition, this report has prepared an action plan for the development of the small wind sector in Benin. This plan is based on the conception that developing a sector from the ground up necessitates joint efforts in which not only industry, but also government, universities and civil society work together to generate momentum.

Finally, it should be noted that this report inevitably remains within a necessarily limited scope of research. This study has followed a generally techno-economically and theoretically oriented approach, within going into great detail about matters concerning the competitiveness, socio-political awareness, technology acceptation and aspirations surrounding small-scale wind turbines.

1. Introduction

1.1 Rationale and scope

Following an approach similar to that of other governments in sub-Saharan Africa, the Government of Benin has prioritized the increase of energy availability and access as one of the main routes to poverty eradication. In this, the increased deployment of renewable energy is considered a major focal point, institutionalized by establishing the National Development Agency of Renewable Energies (ANADER) in 2014[2]. Despite the (inter)national action plans and initiatives that have been implemented in past years, the energy sector in Benin remains underdeveloped. While there is a growing demand for electricity in Benin in general, the amount of households connected to the national grid is still low, especially in rural areas. The rural electrification rate increased in recent years, from 3.4% in 2010 up to 6.3% in 2015 [1]. The number of rural villages with access to electricity has also seen an increase – from 12.7% in 2010 to 29.3% in 2015 –, also caused by an increase in decentralized power generation. Mini-grids and standalone solutions are considered "*the most suitable option for providing electricity to rural populations*" by the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), stating in its Rural Electrification program that it strives to implement around "*60,000 mini-grids between 2014 and 2020 for a total capacity of 3,600 MW in order to serve 71.4M people for a total investment of €13.2 billion across six years*" [2].

Access to energy plays an important role in the development process. The lack of access to energy for lighting, heating, cooking or other productive uses limits the development of women and men and societies in general. However, men and women experience this 'energy poverty' differently, in terms of gender relations and the distribution of roles and tasks between men and women within a society [37]. The gender aspects of energy poverty within the ECOWAS area limit the opportunities for building the capacity of women and men to implement actions for regional integration and socio-economic development [55].

For households that lack a (reliable) grid connection, decentralized renewable energy generation can thus offer a promising solution. In addition to solar and hydro resources, studies have shown that Benin has a good technical potential for small wind power generation in its coastal areas. Still, deployment of the technology has not yet taken off. Multiple barriers have been identified, a major one being the cost of the turbines. By setting up a local industry that uses a combination of locally sourced and quality imported materials and components to produce these turbines, small wind technology may become more cost-competitive, easier to maintain, and better positioned for social and political commitment due to the increased generation of local employment opportunities. Within this context, the main goal of this study is to:

> ***Identify key barriers to and opportunities for a local manufacturing industry of small wind turbines and the creation of a market with potential for growth.***

In this setting, the scope of the study is focussed on:

- small-scale wind turbines for off-grid power generation with a rated output of 1 – 10 kW;
- unelectrified villages in the rural and peri-urban areas of Benin with favourable wind speeds;
- the importance of integrating the gender dimension and taking into account of youth in the interventions;
- a time horizon of 2020 to 2030.

[2] At the end of 2017, the Government of Benin announced that ANADER will be replaced by '*l'Unité Chargée de la Politique de Développement des Energies Renouvelables*' (UC/PDER).

1.2 Report outline and methodology

This report is based on a comprehensive review of (inter)national literature and databases, as well as a set of interviews with public and private stakeholders in the energy and manufacturing sectors (see Annexes I, VI and VII). After providing a general description of the Beninese energy market (chapter 2), the concept of small wind turbines is explored from the most relevant perspectives (chapter 3). On this basis, an informed assessment of the potential market size is provided. In the subsequent chapter (chapter 4), the wind turbine manufacturing process is explored in greater depth by dissecting the technological value chain of wind turbines, assessing the capacity of local industries for production of components, and identifying the socio-economic opportunities that local manufacturing can provide for men, women and youth in the medium-to-long term. Chapter 5 presents an action plan for the development of a small wind sector in Benin, based on the information in the foregoing chapters. The final chapter (chapter 6) summarizes the main conclusions and places them in their wider context. Annex V presents a strategic approach for incorporating the gender dimension into the interventions proposed.

2. Energy situation in Benin

This chapter describes the overall setting in which any development of a small wind turbine sector will take place. It outlines the institutional context of the energy sector, highlights the most relevant statistics related to energy production and consumption, and discusses some of the main efforts related to the implementation of renewable energy projects.

2.1 Institutional context

In the Benin, multiple national and transnational public bodies play a role in the supervision and development of the (renewable) energy sector. The most relevant organizations are shortly introduced below.

- The **Ministry of Energy,** in charge of the management of the energy sector and the subsector of renewable energy in particular. It is responsible for setting the strategic direction of the State's energy policy as well as the supervision of all public bodies that intervene directly in the energy sector apart from the Electricity Regulation Authority.

- The **Gender Focal Unit (GFU),** a unit within the Ministry of Energy that will be created in line with the ECOWAS (CEDEAO in French) Policy for Gender Mainstreaming in Energy Access. Its main mission is to:

- Ensure that gender will be taken into account in the policies, strategies, programs and projects of the Ministry of Energy;
- Oversee the incorporation of the gender dimension during the implementation of projects and actions aimed at improving access to energy for the population (male and female);
- Ensure the integration of "gender-energy" aspects into existing monitoring and evaluation mechanisms;
- Coordinate the implementation of all action plans related to gender aspects

- The **General Directorate of Energy (DGE),** in liaison with other public bodies, proposes the State's energy policy and ensures its implementation, monitoring and evaluation.

- The **Beninese Agency of Rural Electrification and Energy Management (ABERME)** implements the State's policy in the domains of rural electrification and energy management. ABERME is mandated to supervise all electrification efforts in the rural areas of Benin.

- The **Electric Community of Benin (CEB)** assures the import, production and transportation of electricity for Benin and Togo. The electricity sector in both countries is governed by a bilateral agreement signed in 1968, which granted the CEB a monopoly position for producing, transporting, importing and exporting electricity in both countries. This agreement was revised in 2003, to open up the market for independent producers. This version of the agreement is still in force, and the CEB's status as sole buyer is under revision.

- The **Beninese Society of Electric Energy (SBEE)** was initially assigned to assure the distribution and commercialisation of electricity in Benin, but is now also involved in production and transportation. Its activities extend across the entire territory of Benin.

- The **Agency for Control of Interior Electrical Installations (CONTRELEC)** works on the compliance of indoor electrical installations with technical requirements, in order to ensure the safety of people and property.

- The **Electricity Regulation Authority (ARE)** ensures compliance with the laws and regulations governing the electricity subsector, in order to guarantee the continuity and quality of service as well as the proper development of the subsector. The ARE was created in 2009 and placed under the supervision of the President of the Republic. The members of the National Regulatory Council, the decision-making body of the ARE, were appointed by the Council of Ministers at the end of December 2014. The recruitment of the Executive Secretariat, responsible for executing and day-to-day management of the ARE, is under way.

- The **West-African Power Pool (EEEOA)** is a specialized body of ECOWAS, in charge of the regional electricity system. It aims to integrate national electricity grids into a unified regional market through the development of cross-border electricity exchanges. Its overall goal is to ensure optimal and reliable supply of electricity at a cost that is affordable for the population of the Member States.

In addition to the public bodies, there are also a number of NGO's and universities with relevant activities in the energy domain. Multiple NGO's are involved with the stimulation of public awareness on sensible utilization of fuelwood and use of energy saving techniques, and some of them are active with developments specifically related to renewable energy as well. Prominent examples include:

- **OFEDI**, a Beninese organization advocating women-inclusive energy development;

- GERES, an French organization working on energy access in rural areas in Benin;

- Centre Songhaï, a Beninese organization advocating inclusive and decentralized renewable energy generation;

- The **WILDAF-Bénin** network, a capacity building organisation identified by ECREEE for monitoring the implementation of the ECOWAS Policy for Gender Mainstreaming in Energy Access in Benin. It is positioned to work in close collaboration with the Gender Focal Unit in the Ministry of Energy, focusing among other on the second strategy in this Policy: "*Ensure that all energy policies, programmes and initiatives, including large energy infrastructures and investments, are non-discriminatory, gender-inclusive, gender-balanced and directed towards addressing inequalities, particularly energy poverty, differentially affecting men and women in the region.*"

- **SNV,** a Dutch organization implementing among other biogas, solar PV and access to drinking water projects in Benin.

Universities also have their place in the energy sector of Benin, as they are involved in training, research, experimental projects and technical control through their specialized laboratories. This is the case for among other the *Ecole Polytechnique de Abomey Calavi* (EPAC), *Université Africaine de Technologie et de Management* (UATM-GASA formation), the *Université CERCO* and the *Ecole Supérieure des Métiers d'Energie Renouvelable* (ESMER).

2.2 Production and consumption

The energy market in Benin is characterized by a predominant consumption of traditional biomass sources, which includes firewood, charcoal and agricultural residues, as well as petroleum products. In recent years, the share of consumed energy with biomass as the source has increased from 48,2% in 2010 up to 50,6% in 2015, while the share for petroleum products has decreased from 49,4% in 2010 to 46,7% in 2015 [1]. Electricity plays a minor but growing role in Benin's energy consumption (ca. 3%), for the production of which it is largely dependent on imports from Nigeria, Ghana and Ivory Coast (76%), carried out by the CEB. As depicted in figure 1, other sources of electricity include the SBEE's gas-fired power plants (15%) and Yéripao hydroelectric dam (1%), as well as a number of independent power production (IPP) units (often diesel, natural gas or biomass-fired) controlled by private entities (8%). Both the SBEE and IPPs have ramped up their production in recent years, mostly motivated by deficits in CEB's supplies. However, SBEE's distribution network has been suffering from substantial losses, amounting to more than 20% of its total electricity supply [3].

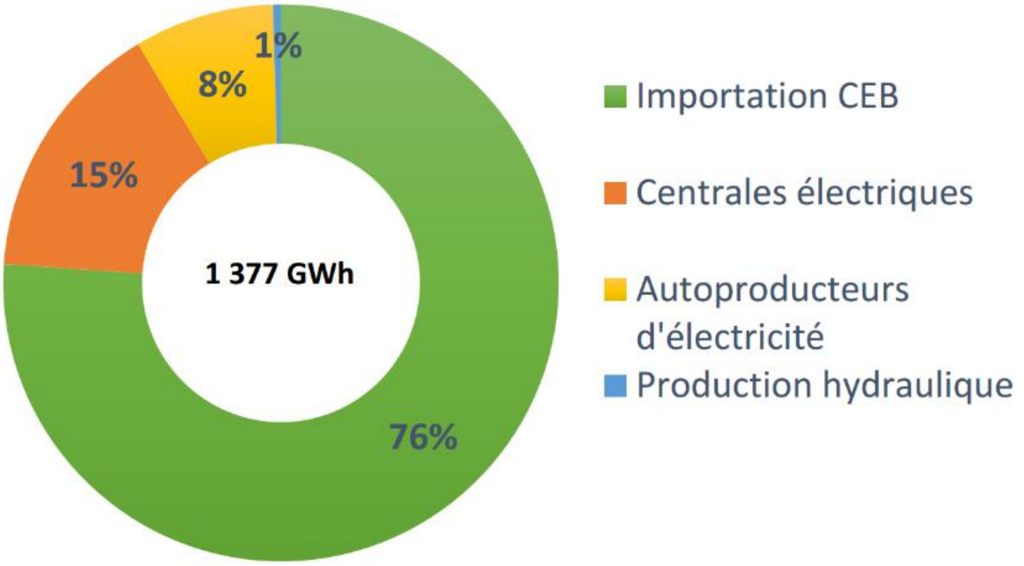


Figure 1: Sources of electricity production in Benin [1]

On the level of households, electricity consumption has seen an annual increase of 2,4% between 2010 and 2015, without taking into account the increased uptake of (pico-solar or battery-powered) LED lighting [1]. Compared to the 2010 situation, the residential sector's electricity demand is expected to almost quadruple by 2030: from 362 GWh to 1416 GWh [3].

At the same time, Benin has a long way to go in narrowing the urban-rural divide. Although in 2015 49.7% of the urban population was connected to the national distribution grid, this holds true for only 6.3% of the residents in rural areas [1]. This is a 3% increase in comparison to 5 years earlier, as can be derived from figure 2. On average, it is estimated that households in rural areas consume around 20 kWh per month, while peri-urban households consume about 30 kWh [4]. In general, these households mainly use electric power for lighting, radio and phone charging.

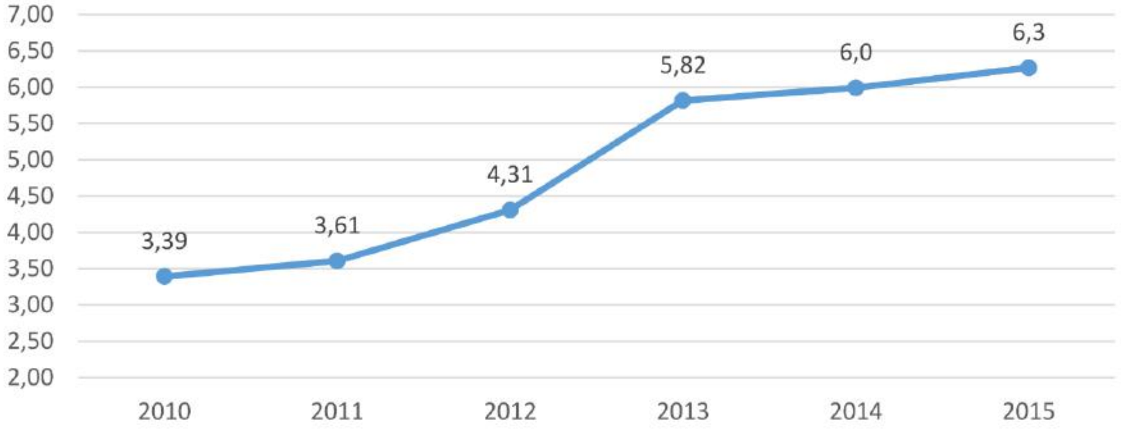


Figure 2: Percentage of residents in rural areas with a connection to the SBEE electricity distribution grid [1]

Disaggregated per department, it becomes clear how stark the contrasts are in terms of their residents' grid connection rates, also in South-Benin. Whereas Ouèmè and Atlantique are slightly above Benin's average of 27.7%, Couffo and Plateau are at the very bottom of Benin's ranks with only 9% (figure 3).

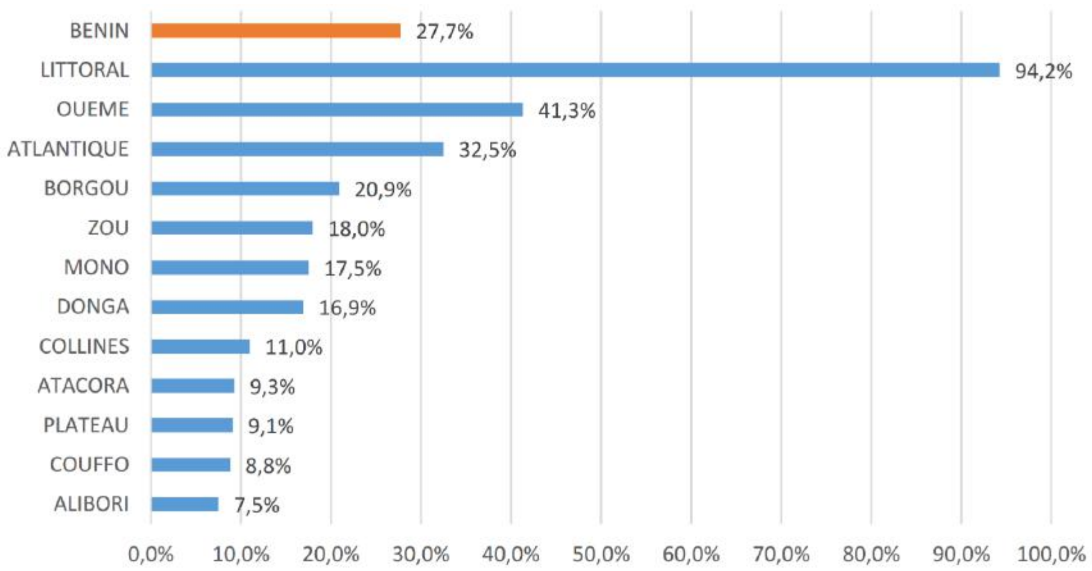


Figure 3: Percentage of residents with a connection to the SBEE electricity distribution grid, disaggregated per department [1]

The cost of electricity creates an imbalance between women and men as economic operators. Due to the poverty of women in comparison to men, women's activities that are essential for the sectors of processing, conservation and commercialisation of food and food products – of which the exploitation is dependent on electric power – are seriously affected. In this case, their low incomes inhibit women from acquiring generators to circumvent this constraint. The impact of the electricity deficit on women's activities has been widely discussed during public consultations. In fact, the women encountered have talked about the harmful effects of the energy deficit on their activities, including damages and rotting affecting restaurant-owners, bar keepers, fresh food traders. As another example, mini-market and eateries undergo frequent and harsh damages due to untimely power cuts. As such, it follows that the lack of control over the supply of electricity in Benin is a major handicap for the development of women's activities, which are concentrated in catering (92,6%) and commerce (78,2%) [38].

Figure 4: Map of Benin, including state borders and selected cities [5]

2.3 Renewable energy technologies and costs

To deal with the issues of insufficient production capacities and slow electrification rates, the Beninese government has, in liaison with broader regional (ECOWAS) and global movements (SE4ALL), spearheaded the development of renewable power generation. Combined with the (financial) forces of international donors such as UEMOA, AfDB, GIZ, MCC and UNDP, this has culminated in the planning and implementation of a range of projects since the 1990s. However, many of these never passed beyond the feasibility study or piloting phases, or remained operational for only a short period of time. In Table 5, some examples are provided of renewable energy projects that have taken place in Benin.

Table 5: Several operational RE projects in Benin, according to [5,6 and 7]

Technology	Year of commissioning	Size	Location	Additional information
Hydro	1996	500 kW	Yéripao	Dam producing 2,5 GWh/year
Biomass	2009	32 kW	Gohomé	Gasifier connected to main grid
Solar PV	2002 - 2010	220 kWp	Multiple	Power stations spread across 24 villages in 10 departments
Solar PV	2008 - 2009	11,4 kWp	Hon & Koussoukpa	308 PV kits installed in both villages, included training
Solar PV	2015	167,1 kWp	Kpokissa, Tchatingou, Tora,, Kabo, Tandou & Oké-Owo (power stations) + Niéhoun & Pentinga (PV kits)	6 power stations and 164 PV kits, part of UEMOA-funded PRODERE program
Solar PV	2016	5064 kWp	Multiple	105 power stations, part of Beninese government-funded PROVES-program

From the feasibility studies, pilots, and full-scale projects carried out, it is clear that Benin has an important unexploited potential in the renewable energy domain. The government of Benin is increasingly aware of this, and is considering investments in new solar PV, biomass and micro-hydro power plants. As becomes clear from the tables in Annex II, projected costs for these plants vary significantly, also depending on the discount rate[3]. At a 10% discount rate, solar PV and biomass projects cost around 131 FCFA/kWh, whereas hydro projects are projected to be in the range of 197 FCFA to 754 FCFA/kWh. At a 2% rate, solar PV costs could drop to 72 FCFA/kWh, while the range for hydro costs decreases to between 85 FCFA and 328 FCFA/kWh [5].

Focusing on the domain of off-grid electric power supply, the most relevant technologies are diesel generators and solar PV-panels. To be competitive with these technologies, it is important to have insight into their overall costs per kWh. However, these depend strongly on a number of factors, which can vary per country, region and village. The main factors are summarized in table 6 below.

Table 6: Main factors affecting overall costs per kWh for solar PV-systems and diesel generators

Solar PV-system (incl. battery)	Diesel-generator
- Solar irradiation - PV array + battery size & price - End-user consumption pattern - Battery discharge depth	- Price of diesel - Cost of diesel transportation

[3] The discount rate is a mechanism used in accounting and cash flow analyses to take into account the time value of money and the risk profile of an investment. In essence, it means that higher uncertainty / risks correspond with higher discount rates.

Detailed geographically specified cost estimates for solar and diesel-generated electricity can be found in [26]. Figure 5 below also graphically depicts these insights for Africa in its entirety, although these are based on data from 2011 or even older. Corrected for 2017 diesel prices in Benin [27], it is estimated that **diesel-fired generators** provide power at **230-459 FCFA per kWh** (levelized cost of electricity, LCOE). The data for **solar PV systems** (which in this study includes lead-acid battery arrays) is more difficult to correct; the study itself indicates **197-262 FCFA per kWh** in South-Benin, but it is likely this figure has been significantly lowered since then. To illustrate: the cost of a PV module – which, should be noted, is not the only factor of importance – has been reduced with around 80%, compared to the values used when figure 5 was generated [28].

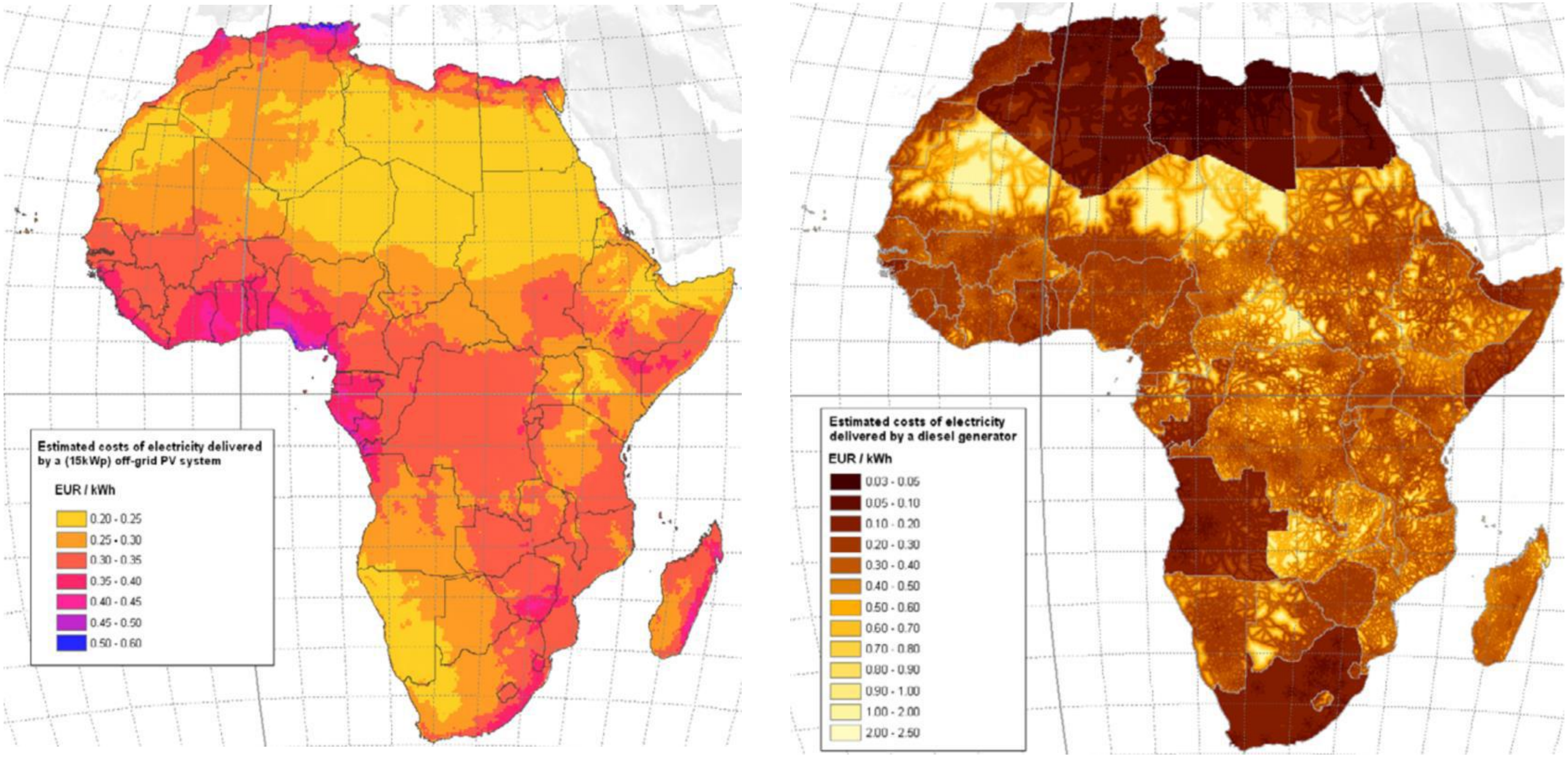


Figure 5: Geographically specified cost estimates (LCOE) for off-grid solar PV (left) and diesel (right) electricity generation systems (1 EUR = 656 FCFA, 1 USD = 558 FCFA)

3. Role of small wind turbines in the electrification of South-Benin

Although hydro, biomass and especially solar PV technologies are playing increasingly important roles in the electrification of Benin, recent studies (some of which quoted in the upcoming section) indicate that there may be potential for wind energy technologies as well. This chapter discusses the main geographic, demographic and technological considerations that need to be taken into account, and follows up on that by making an estimate of the potential small wind turbines have in the electrification of South-Benin. The final section puts these estimates in a wider perspective by looking at the worldwide market and socio-environmental effects associated with small wind turbines.

3.1 Geographic and demographic considerations

As a standalone solution, small wind turbines can generally be relatively reliable and continuous sources of power, depending on local wind profiles. In coastal Benin, wind speeds are relatively high (4,5-5 m/s at 10 meters above ground level) compared to the more inland areas (2,5-4 m/s), as well as relatively constant throughout the day (see table 7 and figure 6 below). In general, it can be said that wind speeds of 4-5m/s are a minimum requirement for the viability of small wind turbines. The overall wind direction is southwest (see Annex III).

Table 7: Monthly wind speed averages and standard deviations (m/s) in Cotonou, adapted from [9]

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Avg.	3,7	4,6	5,1	4,8	4,0	4,3	5,4	5,5	5,1	4,2	3,9	3,6
St.Dev.	1,7	1,8	1,8	1,9	1,9	2,0	1,8	1,7	1,9	1,9	1,7	1,6

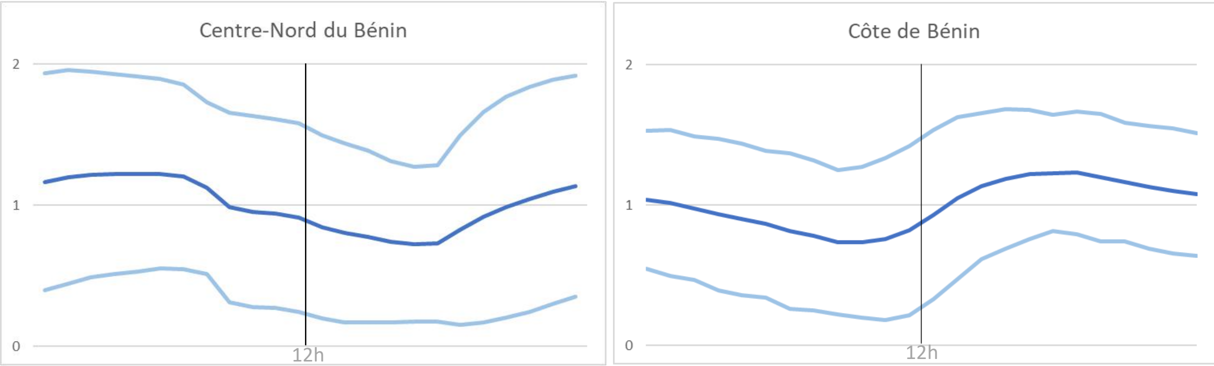


Figure 6: Variation of standard deviation (light blue) and mean (dark blue) of wind speeds throughout the day in central-north Benin and at the coast. Generated and adapted from [10]

Small wind turbines can also function as complements to solar PV in a mini-grid configuration, as during the rainy season (June to September) when PV output is reduced, wind speeds are generally elevated. In principle, this complementarity makes for a smaller required production capacity overall, and thus for a smaller battery capacity or fewer charge-discharge cycles – thereby increasing battery longevity.

In general, to assess the potential of wind turbines, the first measure to consider is about average wind speeds. In a renewable energy potential assessment by the International Renewable Energy Agency (IRENA), it is estimated that 10.361 km^2 of Benin's landmass is potentially suitable for wind energy production [11]. This is however a very rough measure, based on wind speed simulations at 80 meters height. Several databases exist that map wind speeds in more detail and closer to ground level, such as the DTU's Global Wind Atlas [10], ECREEE's ECOWREX GIS viewer [12], and Spanish CENER's wind map of Benin [13]. The CENER map provides wind speeds at 10-12 meters height, making it the most relevant alternative from the perspective of small wind turbines. At the same time though, the ECOWREX viewer is also useful for its information on grid locations and population densities, while the Global Wind Atlas is able to provide details about wind speed distributions and terrain roughness. The latter factor is important for small wind turbines, because it can greatly influence local turbulence and the amount of wind speed decrease closer to the ground. In general, higher roughness equals lower wind speeds and more turbulence. The figures on the following pages demonstrate these features.

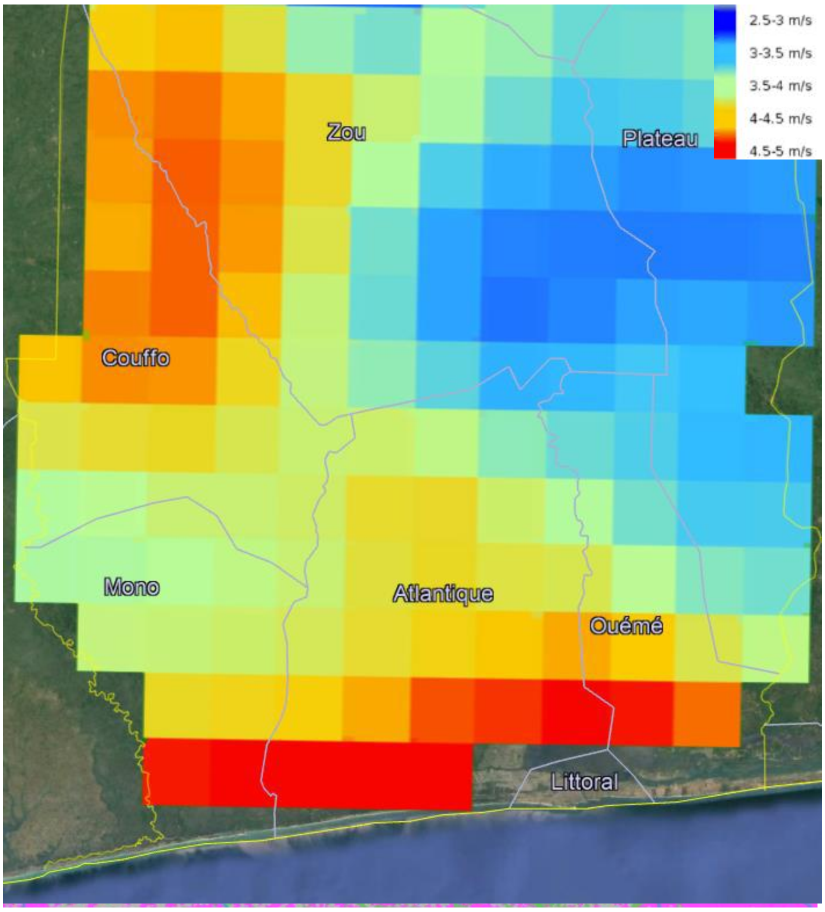


Figure 7: Average wind speeds in South-Benin at 10-12m, taken from [13]

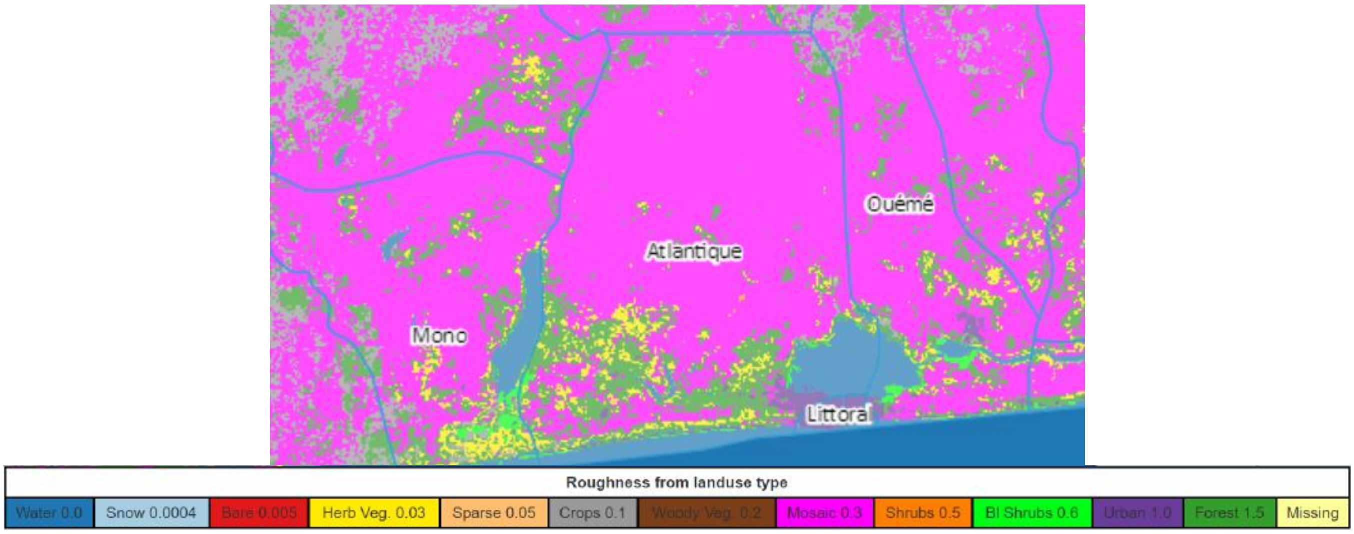


Figure 8: Land roughness in South-Benin, taken from [10]. The further colours are positioned to the right side of the scale, the rougher the terrain will be, indicating potentially increasing wind disturbances as turbine height decreases.

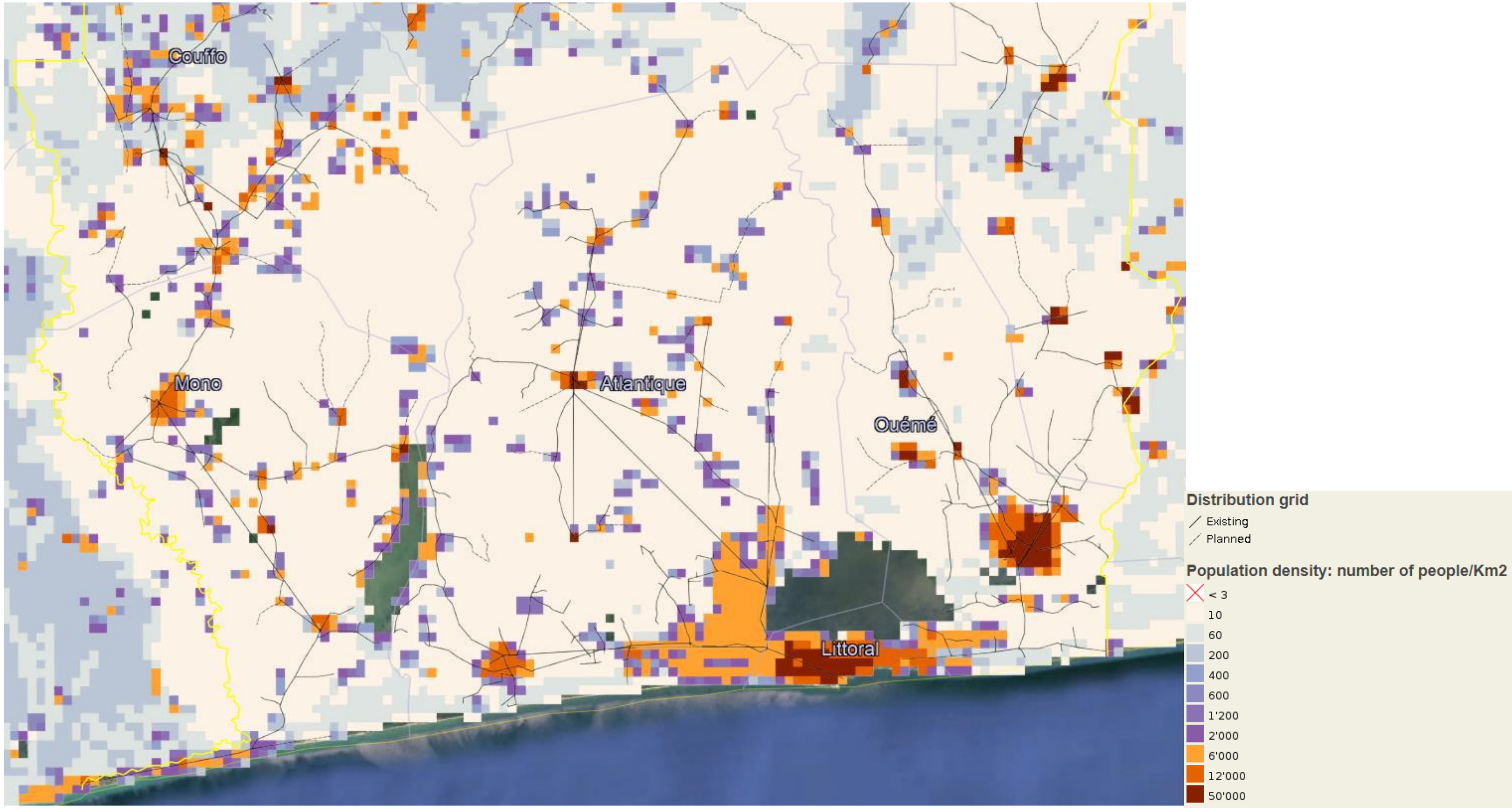


Figure 9: Population density and distribution grid locations in South-Benin, taken from [12]

Figure 7 shows that the coastal areas of Benin have average wind speeds of 4,5-5 m/s at 10m above ground, while the border area between Couffo and Zou is home to winds of 4-4,5 m/s. Based on this first indication, these are the areas in which small wind technology could be viable. More detailed data are available as well: for specific locations across Benin, the Agency for Aerial Navigation Safety in Africa and Madagascar (ASECNA) has measured daily wind speeds for many years. ASECNA's measurements at Cotonou Airport (the most relevant ASECNA-site for this study) have produced very detailed wind data, and served as input for the mathematical simulations of Akpo *et al* [9]. From these sources, it is possible to extract information about wind speed frequency distributions, which serves as valuable input to the calculations of the wind turbines' power output.

Figure 8 hints that certain areas of South-Benin may not be viable for small wind power generation, as these are forested or urban. In practice though, detailed on-the-ground site assessments should be the basis for determining the suitability of any location. Figure 9 shows that the distribution grid is close to most of the populated areas, but in practice the extent to which this grid actually suffices in fulfilling the local population's power demand will be an important determinant of the viability of small wind turbines. Again, this will require more detailed on-the-ground assessments.

In general, a distinction can be made between three types of situations in which small wind turbines can have their use: private ownership, collective ownership near-grid and collective use in remote areas. Below, table 8 outlines the differences between these situations, while the case descriptions of Okoun-sèmè and Adounko in the text box exemplify typical near-grid situations in Benin.

Table 8: Typical situations in which small wind turbines could be applied

Situation	Precondition(s)	Main use of small wind turbine
Privately owned small wind turbine(s)	Owner should have significant (financial) resources available	Complement to or back-up for connection to main grid
Collectively owned small wind turbine(s) – near-grid	- Cooperative neighbourhood - Grid connection expected	First affordable alternative for diesel, then back-up for grid
Collectively owned small wind turbine(s) – remote area	- Cooperative neighbourhood - No grid connection expected	Affordable alternative for diesel generator

Examples of the grid situation in rural and peri-urban areas: Okoun-sèmè and Adounko

The villages of Okoun-sèmè and Adounko are both small villages in rural/peri-urban areas of coastal Benin, without a formal connection to the SBEE grid. Neither of them is expected to be formally connected to this grid in the near future. In these villages, electricity is supplied through decentralized diesel generators and informal wiring to the SBEE grid. These generators were found to consume up to 5-6 litres of fuel per day at 400-450 FCFA per litre, which implies the costs per generator to be in the range of 60.000 – 72.000 FCFA per month. [33]

3.2 Technological considerations

Aside from the decision on the location of wind turbines, it is also important to consider the type of turbine. Wind-electric technology has developed sporadically since 1900, with significant advances in both the United States and Europe made during the war years. The modern revival of wind energy followed the energy crises of the 1970s, and the technology has made steady progress ever since. Across the world, there are currently more than 100 small wind turbine manufacturers active, producing near 300 different models [14]. Of the models under 10 kW rated output, between 10 and 20 are certified according to international IEC standard 61400-2, reflecting sound engineering integrity and quality assurance.

In the domain of residential or remote applications, where simplicity is required, wind turbines have evolved into highly integrated designs with few moving parts. These advanced turbines typically use a rotor that spins about a horizontal axis upwind of the tower. Most of these designs use three slender blades made of composite material (e.g. fiberglass), driving permanent-magnet alternators. However, small wind turbines using synchronous or asynchronous generators with a gear box and disc brakes also exist.

In addition to the more common horizontal axis wind turbines (HAWT), vertical axis wind turbines (VAWT) also have their place in small wind turbine markets, though mostly in Europe and the United States. The advantage of VAWTs is that they are omnidirectional, meaning that they accept the wind from any direction. This simplifies their design and eliminates the problem imposed by gyroscopic forces on the rotor. However, for the case of South-Benin, this advantage is relatively weak because the wind direction is southwest for 90% of the year. In addition, the main disadvantages are that they are not self-starting, more prone to material fatigue, and their general efficiency is around 25% less than that of their horizontal counterparts. Both types are displayed in figure 10.

Figure 10: Horizontal axis wind turbine (left) and vertical axis wind turbine (right)

The safety systems of the horizontal axis wind turbine have a large variety of concepts. One of them makes use of a hinged vane, which turns the wind turbine out of the wind when wind speed reaches maximum speed or power, preventing damage to the turbine. This concept requires no electrical devices or hydraulic system, as it operates on air pressure and gravity forces. Other turbines use variable pitch systems with active or passive pitching. Such a system adjusts the blade pitch to keep the rotor speed within operating limits as the wind speed changes. With a variable pitch system it is very well possible to control the rotor speed, but it is at the same time a complex system to build and therefore more expensive. From the perspective of setting up a local production and maintenance chain, it is advisable to focus on relatively simple designs that use common technologies and materials whenever possible.

For this study, the focus is on wind turbines that make use of certified technologies (IEC 61400-2) and robust materials, so as to ensure good power generation efficiency and system reliability. At the same time, the design should be simple enough to be produced and maintained in the Beninese market as much as possible. For the purpose of making calculations on business cases and market sizes, two different turbine models are used in this study: Fortis Passaat (rated output 1,4 kW) and Fortis Montana (rated output 6,0 kW). As is the case for 90% of the small wind turbines produced worldwide, these models have a horizontal axis, 3-blade design, and are positioned upwind. In addition, they make use of a permanent-magnet generator, similar to 50% of the small wind turbines on the market, and they have been installed and partly manufactured in Africa before (a.o. Mauritania). Therefore, the assumption is made in this study that these turbines are representative for the international market and appropriate for making an informed assessment of small wind viability in Benin.

3.3 Annual production potential and potential market size

To determine the potential market size for small wind turbines in Benin, it is necessary to know how many inhabitants are in need of decentralized electrification. In Table 9 below, an estimate is provided of the number of inhabitants in the communities without grid connections in Atlantique, Mono, Couffo and Ouémé. These communities are located in areas with 4-5 m/s average wind speeds, indicated by orange-to-red colours in figure 7. In addition, the corresponding power demand per community is calculated, assuming 20 kWh consumption per household per month (see section 2.2) and 6-7 people per household.

Table 9: Estimated number of inhabitants and their power demands in windy and unelectrified localities in rural and peri-urban areas in the four southernmost departments

Department	Commune	Number of estimated habitants	Estimated consumption in kWh/month
Atlantique	Kpomassè	5.941	17.823
	Ouidah	3.923	11.769
	Sô-Ava	128.694	386.081
Mono	Grand-popo	11.053	33.159
	Comè	7.358	22.074
	Lokossa	1.354	4.062
Ouémé	Seme-podji	6.048	18.144
	Aguégués	38.097	114.290
Couffo	Aplahoué	10.460	31.380
	Djakotomè	1.154	3.462
Total		214.081	642.243
Total consumption potential per year (GWh)			7,7

Note: Annex IV provides more detail up to the level of villages in the areas

For determining the total size of the potential market, it is necessary to make an informed assessment of the annual power production potential. Based on (inter)national average wind speed maps and wind speed frequency distributions specific to coastal Benin (Cotonou Airport, see [9]), it is possible to calculate the expected amount of kWh generated per year. For both the Fortis Passaat (1,4 kW) and Fortis Montana (6,0 kW) turbines, this data is provided in tables 10 and 11 below. These tables distinguish different average wind speeds and tower heights, while taking into account 30% losses to incorporate the issue of local turbulence. In addition, both tables provide an indication of the amount of households that can be served with these power outputs.

Table 10: Estimated annual output & number of households servable with a Fortis Passaat turbine in South-Benin

Annual output Passaat (kWh) and number of households servable								
	Households servable (#hsh)							
Average wind speed (m/s) at 10m height	*3,5*		*4*		*4,5*		*5*	
	(kWh)	#hsh	(kWh)	#hsh	(kWh)	#hsh	(kWh)	#hsh
Tower height: 12m	750	3,1	1.035	4,3	1.350	5,6	1.688	7,0
18m	918	3,8	1.248	5,2	1.598	6,6	1.973	8,2
24m	1.049	4,4	1.401	5,8	1.799	7,5	2.206	9,2

Table 11: Estimated annual output & number of households servable with Fortis Montana turbine in South-Benin

Annual output Montana (kWh) and number of households servable								
	Households servable (#hsh)							
Average wind speed (m/s) at 10m height	*3,5*		*4*		*4,5*		*5*	
	(kWh)	#hsh	(kWh)	#hsh	(kWh)	#hsh	(kWh)	#hsh
Tower height: 12m	2.524	10,6	3.656	15,2	4.978	20,7	6.427	26,8
18m	3.183	13,3	4.543	18,9	6.046	25,2	7.660	31,9
24m	3.717	15,5	5.235	21,8	6.907	28,8	8.656	36,0

Comparing these tables with ASECNA's data on wind speeds at Cotonou Airport, which show reliable averages of around 4 to 4,5 m/s, it follows that a 1742 kWh/year yield for a Passaat and a 6661 kWh/year yield for a Montana system are to be expected for a 24m high turbine. As can be derived from tables 10 and 11, power production is significantly increased if the turbine is positioned higher off the ground. For 24m high towers and a 7,7 GWh electricity demand per year, **4.424 Passaat turbines** or **1.157 Montana turbines** are required for the electrification of localities in Table 9, based on the conditions at the Cotonou airport. The exact number of turbines will depend on location-specific wind speed averages and frequency distributions, for which on-site measurements are required.

These estimates of total market sizes are conservative, as they only take into account the non-electrified localities and assume a relatively low electricity demand of 20 kWh per household per month. In practice, it is likely that partially-electrified localities could also benefit from wind energy, while the consumption per household is higher in the more (peri-)urban localities. Also, in parallel to household electrification, industrial applications of wind turbines could be viable as well. Examples from previous experiences include the pumping of water for irrigation and cattle drinking water, as well as the powering of telecom sites in hybrid configurations (see the text box below for an illustrative case example), combining wind technology with solar PV and / or diesel generators. Overall, it is clear that the potential market is sufficiently large to be able to sustain an industry around small wind turbines in Benin. In previous comparable projects in sub-Saharan Africa, market sizes of 100-200 turbines have been apt for the creation of a viable service and maintenance network.

Safaricom, Kenya – Wind turbines for telecom operations

Safaricom, the largest cell phone provider in East Africa, extended their service range to the rural areas of Kenya where no utility power is available for their base stations. The normal practice makes use of diesel generators, which require regular attention for fuel resupply and maintenance. To address this issue, Safaricom contracted Winafrique to design and supply pilot wind/diesel hybrid systems at three very remote base stations.

One such system consisted of one 7,5 kW wind turbine (supplied by Bergey), 2 kW solar and 15 kW diesel, while also including an 60 kWh battery bank. Investment costs were a bit over 60.000.000 FCFA. Per year, this system saves about 80% in fuel expenditures, and proves to be a reliable source of power. Due to the success of these pilots, the system will also be applied at six other sites of Safaricom. [32]

3.4 Market potential in a wider perspective

While the estimate of market size is an important figure, any decision to implement wind turbines on a large (in this case regional or national) scale should take a wider context into account, going beyond a focus on costs and wind speeds. This section puts the assessment of market potential in Benin in a wider perspective by providing a succinct overview of the status of the worldwide small wind sector, and also discussing the major social and environmental effects that play a role in the domain of small wind turbines.

Worldwide small wind market figures

On a global scale, the market for small wind turbines is steadily growing, while it is also distinctly concentrated. In 2015, the number of small wind turbines installed worldwide was 990.966, of which 732.000 in China (74%) [17]. In 2015, 43.000 new turbines were installed in China, compared to 1.695 in the United States (the second largest market, 16%) and 277 in the United Kingdom (the third largest market, 3%). Average sizes (rated output in kW) also differ substantially, as an average turbine in China is 0,6 kW, whereas the average in United Kingdom is 5,1 kW. In Africa, the number of turbines installed is much smaller; Morocco, which is the largest market for small wind turbines in Africa, in total had 200 installed turbines by 2015. Table 12 below elaborates on the 2015 key market figures on the worldwide small wind industry.

Table 12: Key figures of the small wind industry worldwide (2015) [17]

Number of small turbines installed per country	**China**	**United States**	**United Kingdom**	**Others**	
Cumulative number of installed turbines (2015)	732.000	160.995	28.917	69.054	*# units*
Cumulative rated output of installed turbines (2015)	415.000	230.400	146.192	157.281	*kW*
Number of new turbines in 2015	43.000	1.695	277	1.028	*# units*
Average rated output per installed turbine	0,6	1,4	5,1	2,3	*kW/unit*

Africa is home to a number of small wind turbine manufacturers, among which Craftskills East Africa in Kenya and Kestrel Wind Turbines, Zonhan, Winglette Wind Machines and Turbex in South-Africa.

Social and environmental considerations

While decision-making about wind energy is generally characterized by a focus on wind resource, costs and end-users, it is important to also consider ways in which the climate, human health (or often, more specifically, quality of life) and local ecosystems could be affected by the installation of wind turbines.

The substitution of non-renewable and often fossil energy sources with renewable alternatives such as wind energy, is an important pathway to achieve significant reductions of greenhouse gas emissions. It should be said that the amount of emission reductions achievable depends very strongly on the type and size of the turbine, as well as the type of source used to produce the energy that is being substituted. Having said that, a meta-study on lifecycles from solar PV and wind energy highlights that small turbines (in this case 5 kW) on average produce 42,7 g CO_2-equivalents per kWh [18], while a different study finds that diesel and coal-fired generators emit between 443 and 1050 g CO_2-eq/kWh [19]. If it is assumed that small wind turbines will substitute 7,7 GWh (estimated market potential in section 3.3) of diesel and coal-generated power with emissions of 746,5 g CO_2-eq/kWh (the mean of 443 and 1050), it can be calculated that **5,42 kton of CO_2-equivalent greenhouse gas emissions can be avoided** through the installation of small wind turbines instead of diesel or coal-fired generators.

Two other factors that are always mentioned in relation to wind turbines are the noise and shadow flicker these turbines produce. Although a lot of research has been done to determine why and when noise becomes a problem for people living in the vicinity of a turbine, most of this pertains to large-scale turbines (100 kW or more), where the impact is much more significant. According to [20], the sound output of a 2 kW turbine is typically close to 50 dBA at a distance of 15 meters – comparable to the sound level of a kitchen refrigerator. Still, the actual impact of this sound level strongly depends on the ambient sound level, as well as individuals' personality and attitude toward wind turbines [21]. A similar reasoning can be applied to the issue of flickering, or the recurring casting of shadows by turbine blades: the impact small wind turbines can have is much more limited than that of a larger turbine, and can generally more easily be avoided through micro-siting. In sum, sound and shadow flickering are relevant issues that need to be taken into account when determining the location of the turbine, but their ultimate impacts will be limited for small wind turbines.

Another issue that could play a role is wildlife mortality, which is often centred around birds and bats. It is clear that the risk of collision depends on the type of avian animals active in the local area, as well as the size of system. Although most research is focused on the U.K. and U.S., these concerns have also played a role in the construction of wind farms in Lesotho and Egypt [22]. Again, however, this risk is less pronounced for small turbine systems. A study in the U.K. found local birds to be unaffected by small systems (<50 kW), while in relation to bats it recommends systems to be sited 20m or more from their habitats [23]. Although interaction with wildlife is another relevant factor to take into account, the impact a small turbine can have is again limited.

Accidents and fatalities pertaining to humans can be another topic to consider. As reported by [24], blade failure, fire and structural failure are the main causes of human-related accidents with wind turbines, most of which affected construction workers. Lighting strikes and poor handling and maintenance are often at the root of these problems [25]. Although lighting-related damage is difficult to prevent or mitigate, handling and maintenance can and should be important matters to address during training of local workers.

Finally, in some countries around the world, the implementation of all wind turbines, including small-scale turbines, are subject to the granting of planning permission. Other countries exempt small-scale wind turbines by defining the conditions that these wind turbines must fulfil.

4. Setting up an industry for small wind turbines in Benin

4.1 Rationale and production basics

Local manufacturing of renewable energy technologies is a very relevant option for sub-Saharan markets. Not only can it help cut the overall costs of the technologies, but it can also create jobs and improve local livelihoods in the process. However, which components can actually be produced locally depends on the types of industries active in the country, as well as their production capacities. For small wind turbines, many components of the system can be produced even without any high-tech industries available.

In essence, the components of the wind turbine that always have good potential for in-country production are the metal components: the tower, frame, tail, tail hinge and housing of the generator. For these parts, production processes are generally limited to cutting, welding and drilling, although corrosion protection can sometimes be more of a challenge. With regard to the electric components, the situation is more complicated. The manufacturing of parts of the generator, as well as the inverter, controller and battery often requires more specialized industry. The same holds true for the blades, which are made of glass fibre-reinforced polyester. Assembly, installation and maintenance on the other hand are generally better suitable for local industries, provided that they have been made familiar with the technologies. Figure 11 below summarizes the main materials and skillsets that are required for the manufacturing, installation and maintenance of small wind turbines.

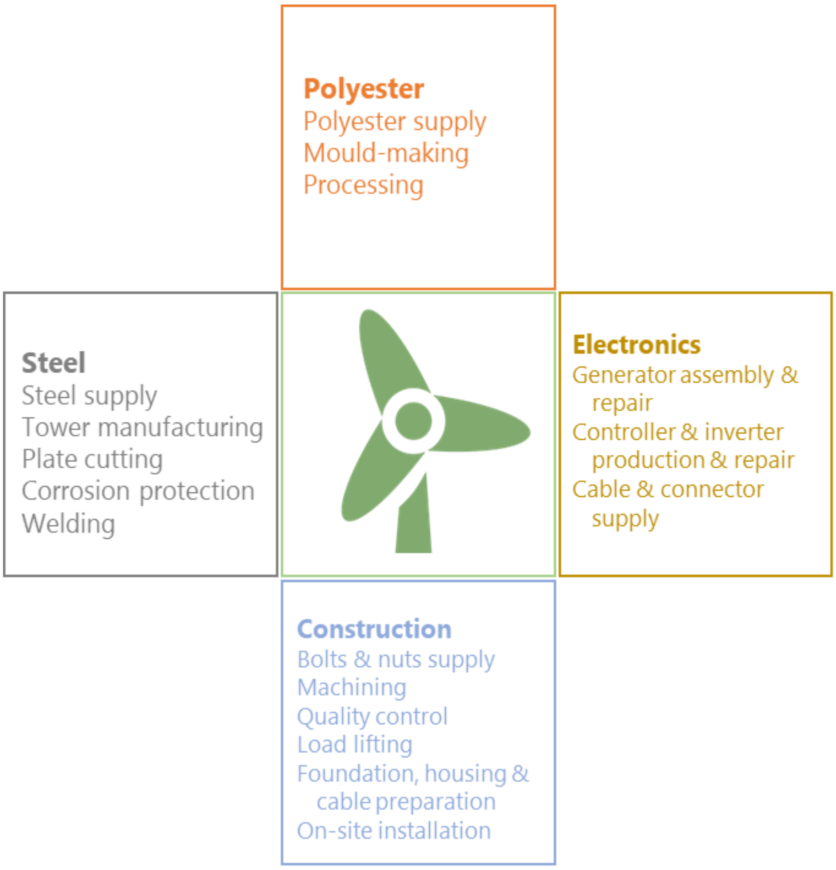


Figure 11: General materials and skillsets required for wind turbine manufacturing, construction and maintenance

4.2 Presence of relevant industry in Benin

To explore the potential for local manufacturing of small wind turbines in greater depth, interviews were conducted with relevant companies, NGO's and universities to determine for each of the materials and skillsets in figure 11 to what extent the capacity is present. Table 13 below summarizes which organizations have been identified as potentially able to manufacture, construct or maintain small wind turbine components. The complete list of organizations interviewed can be found in Annex V, and the questionnaire used in Annex VI.

Table 13: Wind turbine and production capacities identified with each organization (✓✓ = likely sufficient capacity, ✓ = possibly sufficient capacity).

	Relevant organizations							
Wind turbine production & installation capacities required	AJO Sarl	SEEPEG	MDC	Tossou & Fils	ASEMI	Transacier	EMC	2EPS
Steel								
Steel supply (in line with EU/US specifications)					✓	✓✓		
Steel constructions: tower sections of 6m and 500mm diameter / 500kg		✓			✓✓	✓		
Steel plate cutting (5-30mm): laser cutting or flame-arc cutting		✓			✓	✓		
Steel parts corrosion protection: galvanizing, painting, or other		✓			✓	✓	✓	
Welding (qualified)		✓			✓	✓	✓	
Polyester								
Polyester / glass fiber supply								
Polyester / glass fiber-reinforced molds making and processing								
Electronics								
Electric device supply: cables and connectors	✓✓	✓✓		✓✓	✓✓		✓	✓
Electric generator repair workshop and assembly	✓	✓		✓	✓		✓	
Electronic workshop for production and repair of controllers and inverters	✓	✓		✓	✓		✓	
Electronic workshop for cable wiring to control room and end-users	✓✓	✓✓		✓✓	✓✓		✓✓	✓
Installation								
Bolts and nuts supply		✓✓	✓✓		✓✓		✓✓	✓
General machining		✓			✓	✓	✓	✓
Overall quality control		✓✓			✓✓		✓✓	
Heavy load lifting and transporting (> 500 kg)		✓✓			✓✓			
Concrete foundation, housing and cable preparation		✓✓	✓✓		✓✓			
On-site installation with truck and winch		✓✓			✓✓			

As becomes clear from Table 13, the number of organizations able to manufacture wind turbine components is limited. Still, current interview results indicate that most of the required skillsets and materials can potentially be covered by one or more Beninese companies. The clear exception is the manufacturing of polyester blades, for which no suitable company has been identified. Also, for some of the more complex components such as electric generators and controllers, it is expected that although some companies may be able to obtain them, in the near future they will largely rely on imports rather than domestic production. Most of these more complex components can be sourced in Europe (e.g. United Kingdom, Italy, Germany), though on a more detailed level, magnets and some of the raw materials used to produce these components (e.g. steel, copper) are more likely to come from China. On the other hand, the masts can probably be manufactured locally, which means that increasing the height of the turbines is not only very beneficial for expected power outputs (see tables 10 and 11), but also for local employment and revenue generation.

In order to actually prepare the identified companies for wind turbine component production, it is necessary that their employees receive the proper training. For instance, although an electric grid installation company such as AJO Sarl should potentially be able to assemble an electric generator, they do not yet have the experience for producing the windings in the stator and thus need to be trained in it. Previous experiences in India, Egypt and Mongolia, where seasoned experts from Europe or the United States have provided technical trainings to local technicians, show that this generally should not be a problem. In addition, it is worthwhile to note that all interviewed organizations indicate that they believe small wind turbines have good prospects in Benin. Where a new industry is to be set up or stimulated, a common belief in its viability will always be essential.

4.3 Socio-economic results: costs and employment creation

The local production of wind turbines is expected to yield two types of socio-economic benefits in particular: cost reductions and job creations. With regard to the latter, it is necessary to take into account the major constraints to equality of employment in Benin, including gender stereotyping that imposes high gender-differentiated barriers to entry of the labour market. This follows from unequal access to basic education, vocational training, credit, income, real estate, movable property and decision-making processes.

To determine the scope of these two advantages, it is necessary to have a good grasp of turbine costs and the extent to which value can be created locally. For basic Passaat (1,4 kW) and Montana (6,0 kW) systems in the Netherlands, commercial prices are provided in Table 14, including a 20% price reduction that is possible for bulk demands.

Table 14: Commercial turbine prices in the Netherlands (ex. VAT)

Commercial prices of Fortis turbines in the Netherlands (FCFA)	**Passaat 48V**	**Montana 48V**
Pricelist price turbine, including charge controller & dumpload	2.397.680	7.183.200
Pricelist price guyed tower 18m	1.804.656	2.191.696
Pricelist price guyed tower 24m	2.356.352	2.780.128
Combined turbine and tower sales price	4.202.336	9.374.896
With 24m guyed tower	*4.754.032*	*9.963.328*
Net prices minus 20% with 18m guyed tower	3.362.000	7.499.392
Net price minus 20% with 24 m guyed tower	***3.803.488***	***7.970.400***

On top of that, each turbine can be characterized by a relatively simple cost profile, in which costs are connected to individual components. Table 15 specifies the contribution of each main component to the overall system price, indicates how much of this component can be potentially produced locally in the medium term (before 2025), and summarizes the value of this contribution. For these figures, local content consists of labour costs, material costs, production costs, local import costs (of raw materials and semi-finished components) and profit. It does not include potential savings from avoided import taxes and shipping costs.

Table 15: Wind turbine cost shares and local content specified per turbine component

Wind turbine component cost shares			% of component locally producible	Value of local content (FCFA)	
Component	**Passaat**	**Montana**		**Passaat**	**Montana**
Tower (24m)	45,5%	31,4%	100%	1.730.528	2.502.640
Generator	20,8%	21,7%	30-40%	237.472	518.896
Rotorblades & hub	11,8%	12,6%	0%	-	-
Frame	7,8%	5,0%	100%	296.512	398.192
Tail/tailvane	5,8%	3,2%	100%	220.416	255.184
Charge controller	7,3%	25,4%	25%	69.536	505.776
Total local content		*Value of local content (FCFA)*		**2.554.464**	**4.180.688**
		% of overall sales price		**67%**	**52%**

Source: Quantitative assessments made by project team, based on practical experiences and data from Fortis Wind Energy

The results of above calculation show that a significant part of the turbines' value can be created locally. To quantify the actual cost-related benefits that the production in Benin could yield, it is important to capture how local value creation can actually contribute to cost reductions. It is expected that the greatest potential for this lies with the cost of local labour, as daily wages in Benin are generally significantly lower than those in the Netherlands, while other costs (materials, production machinery, etc.) will often differ less. Labour costs in the Netherlands for a worker trained in welding, machining and other skillsets relevant for manufacturing lie at around 32.800 FCFA per hour. While labour costs in Benin for a similarly skilled worker are assumed to be around 2624 FCFA per hour, productivity is estimated to be 66% lower due to a lack of access to sophisticated tools and processes. In Table 16 below, an assessment is provided of the percentage of costs per component that can be attributed to labour, and relates this to the value of local content described in Table 15.

Table 16: Value and share of labour costs in relation to overall costs per component

Component	**% of component costs attributable to labour**		**Value of labour in local content (FCFA)**	
	Passaat	**Montana**	**Passaat**	**Montana**
Tower (24m)	19%	10%	328.800	250.264
Generator	52%	45%	123.485	233.503
Rotorblades & hub	-	-	-	-
Frame	52%	47%	154.186	187.150
Tail/tailvane	50%	50%	110.208	127.592
Charge controller	30%	20%	20.861	101.155

The table continues on the following page

Total value of labour in local content (FCFA)	737.541	899.665
Working hours required in the Netherlands	22,5	27,4
Working hours required in Benin	67,5	82,3
Labour costs in Benin (FCFA)	177.010	215.920
Savings per turbine through local production (FCFA)	560.531	683.745
Savings in % of overall manufacturing cost	15%	9%

Source: Quantitative assessments made by project team, based on practical experiences and data from Fortis Wind Energy

Combining the (socio-)economic assessments in this section with the technical output calculations in section 3.3, it becomes possible to quantify turbine manufacturing costs, total manufacturing investment and employment creation in the manufacturing industry. These numbers correspond with the manufacturing of a (24m) turbine, and exclude costs related to installation, housing, batteries, inverters, depreciation and local infrastructure. These factors have not been taken into account for the calculations, because they depend strongly on the type of system configuration chosen, as well as the applications that are consuming the generated power. To provide a generic estimate of total system costs in a mini-grid configuration, which takes into account batteries, inverters, cables, foundations, housing, local and international transport, depreciation and connection to the end-users, it is expected that **costs per kWh would increase with a factor 3**. This is a conservative estimate, as sources [30] and [31] indicate this factor to be between 1,5 and 2,5. In relation to the number of jobs that would be created in the wind sector outside of manufacturing, which includes project planning, administration, service, on-site installation, electro-mechanic installation and transport, **an increase in jobs of a factor 5 is expected.**

Table 17 below specifies the costs, investments and number of jobs (as full-time work years) related to the manufacturing of both turbine types, while also providing an estimate of these three variables if the abovementioned non-manufacturing costs and activities are taken into account as well. The **manufacturing costs per kWh** are calculated by subtracting the *savings per turbine through local production* (table 16) from the *net price minus 20% with 24 m guyed tower* (table 14), and dividing that number by the turbine's expected annual electricity production (based on wind profiles at Cotonou Airport, see p. 29). The **manufacturing investments** are calculated by subtracting the *savings per turbine through local production* (table 16) from the *net price minus 20% with 24 m guyed tower* (table 14), and dividing that number by the total amount of turbines required to fulfil a yearly 7,7 GWh demand (4.244 Passaat turbines or 1.157 Montana turbines, see p. 29). The **manufacturing jobs** are calculated by multiplying the total amount of turbines required to fulfil a yearly 7,7 GWh demand (4.244 Passaat turbines or 1.157 Montana turbines, see p. 29) with the amount of *working hours required in Benin* per turbine (table 16), and dividing that number by the amount of working hours in a year (assumed to be 2064, equal to 172 per month).

Table 18 compares these estimates of total costs with those of solar PV and diesel generators mentioned in chapter 2, making clear that **small wind turbines are expected to be cheaper than diesel generators and comparable or slightly more expensive than solar PV**.

Table 17: Summary of estimated socio-economic results for total market (4.424 Passaat or 1.157 Montana turbines)

Turbines	Manufacturing costs per kWh	Manufacturing investment	Manufacturing jobs**	Total costs per kWh*	Total investment*	Total jobs**
Passaat (1,4 kW)	93 FCFA	14.347.415.114 FCFA	145	*279 FCFA*	43.042.245.343 FCFA	*723*
Montana (6,0 kW)	55 FCFA	8.432.077.632 FCFA	46	*164 FCFA*	25.296.232.897 FCFA	*231*

** Total costs & total investment equal manufacturing costs & manufacturing investment multiplied by a factor 3.*
*** Jobs are expressed in full-time work years (2064 hours). Total jobs equal manufacturing jobs multiplied by a factor 5.*
Source: Quantitative assessments made by project team, based on practical experiences and data from Fortis Wind Energy

Table 18: Total costs per kWh for off-grid energy technologies in South-Benin

Off-grid technology	Price range (FCFA)	Comment
Solar PV	197 – 262 per kWh	Likely lower as this is based on 2011 data and older [26]
Small wind turbines	164 – 279 per kWh	Based on calculations in chapters 3 and 4
Diesel generator	230 – 459 per kWh	Based on [26] but corrected for 2017 diesel prices [27]

4.4 Sensitivity analysis

To conclude this chapter, a few important notes remain to be made concerning the sensitivity of the quantitative results. As is the case with any (pre-)feasibility study, it is necessary to be realistic about the assumptions that are made, while being transparent about them as well. In general, the socio-economic outputs calculated in this chapter (overall costs per kWh and number of jobs generated) depend on a number of input data, which can turn out to be significantly different in practice. In turn, this difference could have a big impact on the socio-economic outputs. Table 19 below highlights the most important input data, and qualitatively indicates how these correspond with the two main dimensions of sensitivity: uncertainty and impact.

Table 19: Sensitivity analysis for cost and job indicators

Main input data	Data uncertainty	Potential impact on output		Overall sensitivity of output	
		Costs per kWh	No. of jobs	Costs per kWh	No. of jobs
Overall costs of turbine manufacturing	Low	High	Low	Low	Low
Power yield per turbine	Medium	High	Low	Medium	Low
Percentage of local value creation attainable	High	Low	High	Low	High
Daily rates and productivity of labourers	High	Low	High	Low	High
Non-labour costs (material, production, etc.)	High	High	Low	High	Low
Total market size for small wind turbines	High	Low	High	Low	High

Source: Qualitative assessments made by project team

This table shows that the primary risk related to the costs of small wind turbines lies with the actual yield that is going to be realized per turbine. Tables 10 and 11 in chapter 3 detail this data, which already incorporate an element of uncertainty by taking into account 30% losses due to local turbulence. Still, it is vital to conduct detailed measurements on prospective sites to be able to make good assessments of power yield (see chapter 5). Non-labour costs could potentially also affect overall turbine costs, but the values for these were (implicitly) sourced from the Dutch situation, and on the basis of previous experiences in sub-Saharan Africa it is not expected that these costs will turn out to be substantial in the Beninese market.

Concerning the number of jobs that can be created in the manufacturing sector, differences in the data on the amount of local content as well as the labour rates and productivity have the potential to impact the results significantly. To obtain a more detailed grasp of the actual production capabilities and costs in the manufacturing sector in Benin, it is necessary to actively engage representative companies (e.g. those identified in this study) in a public-private dialogue that will be an inherent and important aspect of the establishing of a small wind sector (see chapter 5).

Another factor of importance for the number of jobs is the total market size for small wind turbines. For the calculations in this chapter, this number has solely been based on the socio-technical potential, i.e. the number of people living in unelectrified and windy areas in combination with their household electricity demands (see Annex IV). In practice, it is very likely that this number will not be attainable in the short or medium term, even if turbines employed for productive uses are taken into account (see section 3.3), given that even Africa's most active country in the domain of small wind turbines (Morocco) had only 200 turbines installed by 2015 (see section 3.4). With regard to the number of women's jobs, all will depend on the availability of qualified women and on the project's policy for promoting female leadership in its interventions.

5. Action plan for small wind manufacturing and deployment in Benin

5.1 Theory of change

Working towards a thriving wind turbine manufacturing sector in Benin, it is necessary to follow an approach that sets clear long-term objectives while outlining actions for the short and medium term. In doing so, we suggest to not only develop the techno-economic capacities of the manufacturing industry itself, but also stimulate education and learning processes and build an inclusive advocacy coalition for wind energy in Benin.

In the context of rural electrification, locally manufactured wind turbines are a type of technology that may have a significant impact on local communities, boosting the local economy while increasing the likelihood that knowledge about carrying out (small) maintenance and operation procedures is transferred successfully to the villagers [16]. For it to become a (socially and economically) sustainable development, it is necessary to adopt an approach that evolves over time, adapting to status of the wind energy sector in Benin as it develops.

In doing so, we propose a theory of change that is founded on 4 pillars: sector programming, targeted implementation, coalition building and knowledge development. These pillars have been selected on the basis of the project team's 20+ years of experience in (energy) innovation process design in sub-Saharan Africa, complemented with inspiration from successful industry transformation plans. All 4 pillars should take the gender dimension into account, both transversally and specifically. In the next section, these pillars are used to formulate an action plan for sector development, which is then concretized and summarized in section 5.3.

5.2 Formulating the action plan

The first important step the Beninese government is suggested to take is the development of a multiannual programme or roadmap, in which tasks and responsibilities are attributed to individual stakeholders in a time-bound manner. Clear targets will be needed, to which the industry, society and other stakeholders can resort for guidance. Studies on appropriate incentivization, the interests of women and youth and the development of monitoring and evaluation components will need to be part of the roadmap development process. Sections 5.2 and 5.3 can be seen as precursors to this roadmap. However, during the elaboration of the roadmap, it is critical that the roadmap is subjected to feedback from stakeholders (non-governmental stakeholders included), so as to build widespread support.

Taking into account the relative unfamiliarity with wind energy technology in Benin, it is suggested to kick-start the local market by focusing on the production and implementation of smaller turbine models (< 3 kW) instead of the models on the other end of the small turbine spectrum (5-10 kW or more). This helps to increase product volume, and thereby provides the local industry with more opportunities to cooperate and interact while also generating more revenue. It is important to stress that while the focus on smaller (and thus often less economical) turbines will likely lead to higher costs in the short term, the process of interactive learning that will occur during the start-up phase of the sector is a very important foundation for further development. From this viewpoint, it is expected that (inter)national donor funding will be vital during the sector's first years, in which generating interest and building confidence are paramount. Donors with an established track record regarding the funding of energy projects in Benin include MCC, UN, World Bank, GIZ, DANIDA.

One of the first activities in this roadmap is suggested to be the building of a coalition of industry leaders, knowledge institutes, NGOs and public agencies, in order to generate momentum in the sector. While the Government of Benin will be the main driving force behind the overall programme, a sector-wide coalition will be better positioned to identify and agree on the more specific steps to take, such as the alignment of the value chain or identification of sector opportunities. With regard to the value chain, a more detailed study will define the links in the chain, as well as the actors (female and male) and their respective (potential) roles. On top of that, it is advised to set up a cooperation mechanism (e.g. joint venture) with one or more internationally active and seasoned small wind expert organisations, to help coordinate the development and implementation of pilot systems and make sure these adhere to appropriate quality standards.

For the selection of the first sites, it is advised to focus on productive use, i.e. situations in which the supplied power directly enables the creation of goods and services (e.g. telecom, rural enterprise including those of women and youth). By doing so, small wind technology becomes more likely to generate early interest from organizations that have their own resources available to invest in energy generating technologies. Where household electrification is the primary concern, it is suggested to involve village chiefs to gauge their (villagers') interest to participate in wind pilot projects. This participation could for instance mean that local villagers contribute to turbine operation and maintenance procedures whenever possible. Such involvement should facilitate the education and creation of awareness on the potential use of small wind turbines among local communities. In parallel, local technicians and manufacturers will need to receive technical trainings on manufacturing, assembly and construction, for which the aforementioned international joint-venture (or other type of cooperative setup) could be responsible.

With regard to the number of generators, it is expected that a total of 4-6 turbines can be installed before the end of 2019. This is based on the fact that there are already some organizations in Benin that are familiar with small wind technology and its possibilities, illustrated by for example the presence of two 1 kW turbines at Fidjrosse Beach (see the text box below).

Domestic power supply in Fidjrosse

In a 4-storey family house near Fidjrosse Beach (Cotonou), the house owner installed a rooftop power supply system consisting of 2 wind turbines (1kW each), 10 solar PV-panels (2 kWp in total) and 16 batteries. Together with increased grid support, this system replaced a 30 kVA diesel generator that reportedly consumed 40 litres of fuel per day, of which the value is estimated to be around 480.000 FCFA per month.

Although investment costs were not made available, the owners are very satisfied with the new system, and are planning to add two more wind turbines to it as well. Also, this system is an object of study for private renewable energy company SEEPEG and a group of students from the National University of Benin (UAC). [33]

If the results of the pilot turbines are concluded, the next step is one of replication. It is advised to aim for both household and productive applications, while setting ambitious objectives to spark the interests of the industry. It is therefore proposed to install 100 turbines in villages and 20 for applications of productive use (telecom, tourism, business, irrigation) before the end of 2021.

In addition, it will be necessary to collect more detailed wind data (e.g. seasonal speed variations, daily fluctuations, local turbulence) for prospective localities, and determine the most suitable (mini-grid) system configuration (with or without solar PV). To this end, it is proposed to set up a centre of expertise that is able to carry out and consolidate these measurements, while also being capable of conducting research on technical optimization and (hybrid) system integration of wind technology. Knowledge will be a major driver of sector growth, which is why it is also important to secure one or more wind energy-specialized courses in the curricula of Beninese universities and other (vocational) institutions of education. In this, it will prove to be important to motive both young girls and boys to take an interest in these courses.

In the first years of the small wind sector's development, import will play a large role because there is currently very little experience with component manufacturing (see the text box below). Hence, industrial revenue will likely be generated mainly from general assembly, installation and maintenance, and import of raw materials and components should be stimulated. As a positive image of the technology's productivity and reliability is especially paramount during this phase, the use of quality components will be crucial. As the sector grows and the industry becomes more experienced with the technology, we expect this to shift to more complex manufacturing and at a later stage maintenance and replacement in due time. In parallel, it can be expected that average turbine sizes will start to increase (depending on the demands of the localities), especially when financial support decreases and economic efficiency becomes more important.

As the industry matures, it can be expected that the pace of turbine installation will increase. To obtain an indication of the number of turbines that can be expected to be installed by 2025, it is useful to look to the development of the global small wind sector described in section 3.4, as well as the number of villages and inhabitants in suitable areas described in section 3.3 and Annex IV (87 villages, 214.081 inhabitants). it is estimated that it should be feasible to have 250 turbines installed by 2025. In parallel to this development, the position of the sector coalition will also change. Its activities will focus more on the collecting of industry-wide data, serving as input for discussions and negotiations with policymakers while also providing opportunities for companies to learn from each other. The focus could be on defining research-actions from a gender perspective.

Import of solar equipment in Benin

In the 2008 Finance Act, the government of Benin exempted imports of solar equipment from VAT and customs duties. This law is currently still in force, and is further developed in article 224 of the 2015 Tax Investment Code. However, very few commercial actors have so far benefited from this exemption. The main reasons for this, as stated in survey results, are the lack of awareness of this opportunity or the lack of knowledge regarding the steps to take in order to benefit from the exemption.

It is therefore important to analyse the possibility of putting suppliers and traders in direct contact with the relevant public bodies, to alleviate these issues. If done successfully, such targeted interventions could directly impact domestic prices of equipment and improve solar access to users.

Over time the development of human capacity will progressively bear fruit, as the first wind-specialized engineers graduate and existing engineers (e.g. those working for SBEE, CEB, etc.) are trained. Given that in 2016 at the national university (UAC) alone, around 20 Master students graduated in the domain of renewable energy, it is estimated that a total of 100 engineers specialized in wind energy should be feasible by 2025. The progress of all this will need to be monitored and evaluated as part of the multiannual programme, to make sure that any adjustments to the approach can be made in due time. In the long term, the Beninese wind sector may even look to neighbouring countries for opportunities to export its components, systems or knowledge.

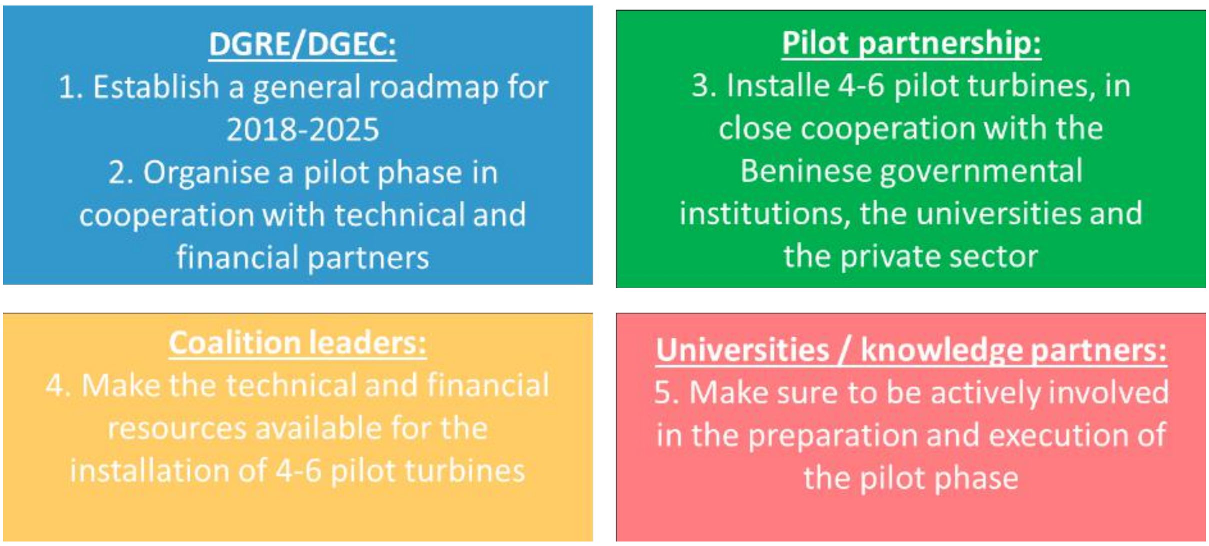
5.3 Concretizing the action plan

With the flow of the proposed action plan described in the foregoing section, the next step is to formulate concrete actions and connect these with specific stakeholders and indicative budgets. In this section, actions are specified for each of the four pillars mentioned before (sector programming, targeted implementation, coalition building and knowledge development) while distinguishing between four time periods: very short-term (2018-2019), short-term (2020-2021), medium-term (2022-2025) and long-term (beyond 2025).

The total investment required for wind-powered household electrification in South-Benin is estimated at between 25 and 43 billion FCFA (as indicated in table 17). The budget for the first phase of sector development (2018-2019) is estimated to be around 1% of this total investment: between 0,25 and 0,43 billion FCFA. The budget for the second phase (2020-2021) is estimated to be around 10% of the total investment: between 2,5 and 4,3 billion FCFA. These numbers are derived from a cost assessment of each of the four pillars individually, carried out on the basis of the project team's experience with other renewable energy sector development programmes in Sub-Saharan Africa.

Very short-term (2018-2019)

In the very short term (2018-2019), it is advised to kick-start the sector's development by means of a pilot phase. In close cooperation with the Beninese governmental institutions, the universities and the private sector, it is proposed to install 4-6 turbines. To realise this, actions on all four pillars will be necessary, as indicated in the image below.



Actions for the very short term (2018-2019)

Short-term (2020-2021)

For the short term (2020-2021), specific actions are proposed for each of the four pillars beow.

A. **2020-2021: Sector programming**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
A.1 Develop a detailed 2-year roadmap for small wind sector development in Benin, in which time-bound tasks are defined and responsibilities are allocated to stakeholders. This includes studies on appropriate incentivization, the interests of women and youth and the development of monitoring and evaluation components.	DGRE, DGEC	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	Roadmap completed
A.2 Seek cooperation with international donors **to acquire the resources necessary** for developing & implementing the sector development roadmap.	DGRE, DGEC		Signed agreement to cooperate
A.3 Identify and attract international expert organizations to **set up a consortium or joint-venture that can play a pioneering role** in the small wind sector in Benin.	DGRE, DGEC with coalition leaders (see actions C)		Signed commitment

Pioneering joint-venture example: Solinc East Africa

Solinc East Africa has seen the light in 2009 as a joint venture between Ubbink B.V., a major Dutch provider of solutions for indoor climate control and energy efficiency, and Kenya-based ABM Limited, a battery manufacturer. Since 2015 the company is majority Kenyan owned.

Solinc set up the first solar module factory in East & Central Africa, where production started at the beginning of 2011. Solinc supplies high quality solar modules of different sizes for home use and solar energy projects, while also, together with their partners, providing engineering solutions for solar system implementations such as solar streetlights. In Kenya, Solinc has achieved market leadership of solar panel distribution, and it aims to achieve the same in Uganda and Tanzania.

B. **2020-2021: Targeted implementation**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
B.1 Install 100 turbines for household use, and involve village chiefs to determine villagers' willingness to cooperate and **participate in the installation and operation** of the systems.	Consortium responsible for targeted implementation [4]	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	100 turbines installed & 3 or more village chiefs interviewed ; voluntary participation of women, men and youth during installation and exploitation;
B.2 Install 20 turbines for productive use of electricity (telecom, tourism, business, irrigation)	Consortium responsible for targeted implementation		20 turbines installed
B.3 Arrange for the **production of small wind turbines in Benin**, in which high-quality small wind systems are used, the amount of locally generated value is maximized and gender-sensitive actions are researched.	Consortium responsible for targeted implementation		120 turbines ready for energy production
B.4 Facilitate the import of raw materials and components by reducing tariff barriers. Remove other legal barriers and offer other incentives. Inform suppliers and traders of these opportunities without discriminating for gender.	DGRE, DGEC		Reported satisfaction of relevant importers ; % of M/F suppliers and traders informed and involved in import

High-quality turbines and local cooperation example: Dongao Island, China

At Dongao Island, 30km from the Chinese coast, a hybrid configuration that included five 10 kW turbines supplies power to 600 local residents and a steadily growing number of tourists (+30% per year). Generating costs are 261 FCFA/kWh, but government subsidies help bring the consumers' price of electricity down to 156 FCFA/kWh.

Crucial for these (in this case public) investments to be made - and thus these cases to succeed - is the reliability of the turbine. Robustness and quality of the system are key for building trust with clients and end-users, making the financial stability and certification of the manufacturer and local reseller a primary concern. In addition, the cooperation with local residents helped to estimate wind resource availability and suitability for installation of the turbines, while also contributing to these residents' interest and confidence in small wind technology.

[4] See action A.3

C. **2020-2021: Coalition building**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
C.1 Identify and convene **organizations with an interest in the creation of a small wind sector in Benin**, including industry (manufacturing, construction, import), NGOs (including women's organisations), knowledge institutes and agencies.	Coalition leaders	Between 0,25 billion and 0,43 billion *Estimated as 1% of total investment as budget is only intended for facilitation. Coalition participants pay for their own expenses as they have corporate interest.*	Signed letters of intent, also expressing the incorporation of the gender dimension
C.2 Determine the **mandate and cooperative structure** of the coalition, with an opening for taking into account gender-differentiated interests.	Coalition leaders with the Beninese government		Legal documents signed, also expressing the incorporation of the gender dimension
C.3 Develop a detailed approach for the **creation of nation-wide awareness** of small wind technology, the **alignment of actors** in the small wind industry and the identification of avenues for sector positioning and development.	Coalition leaders with the Beninese government		Strategic plan completed and gender-sensitive

Wind coalition example: South African Wind Energy Association

The South African Wind Energy Association (SAWEA) is a coalition of a wide range of (inter)national private firms (e.g. EPC contractors, project developers), industry associations (e.g. copper and steel production associations) and knowledge institutes (e.g. universities, research and training centres).

The mission of SAWEA is the removal of obstacles to the implementation of sustainable wind energy activities in Southern Africa. It is engaged with the promotion of industrial excellence, development of energy policy, and provision of information.

Two notable differences between SAWEA and the coalition proposed for Benin are:

- SAWEA does not include representatives from civil society (i.e. NGOs) or government agencies
- SAWEA is less involved with the alignment of industry actors, and more with the provision of sectoral information and policy advocacy.

D. **2020-2021: Knowledge development**			
Action description	*Stakeholder responsible*	*Indicative budget (FCFA)*	*Milestone*
D.1 In cooperation with international knowledge institutes, **establish a centre of technical wind energy expertise** to conduct wind measurements (for selecting prospective sites) and applied research (e.g. turbine optimization, system configuration).	Technological Universities	Between 0,75 billion and 1,29 billion *Estimated as 3% of total investment*	Research strategy formulated
D.2 Make wind energy a **prominent part of education curricula** for engineers and technicians (girls and boys).	Technological Universities, SBEE, ABERME		2 or more universities offering a wind course ; percentage of girls and boys registered for these courses

Knowledge-based sector development example: Kenya Renewable Energy Association (KEREA)

The Kenya Renewable Energy Association (KEREA) is an independent non-profit association dedicated to facilitating the growth and development of renewable energy business in Kenya. One of its main activities is the support of training, capacity building and certification activities in the renewable energy field, and the accreditation of renewable energy product and service providers.

KEREA has a key role in coordinating the development and mainstreaming of a solar PV training curriculum in Kenya. It has been involved with the capacity building of ten technical schools, making them able to offer solar PV training courses. With these trainings completed, graduates from these schools are now able to design, install, maintain, troubleshoot and repair basic solar home systems. In addition, KEREA provides a database of certified solar technicians. Anyone in need of urgent repair, installation, or advice services can dial a phone number, through which they are connected with a nearby technician.

If these actions are successfully completed in the coming years, it is anticipated that within the horizon of 2022-2025 and beyond, the small wind sector in Benin will become a solid industry with an indispensable contribution to the electrification of the country. For the medium-term (2022-2025), the provisional budget is 25-43 billion FCFA. From 2025 onward, it will become possible to scale-up the sector with 1000-4000 operational turbines. On the following page, the general directions for the sector in the medium term (2022-2025) and overall prospects for the long term (beyond 2025) are outlined.

2022-2025: Medium-term directions	
General target	*Specification*
Intermediary evaluation and adjustment of sector programming completed with the inclusion of a gendered perspective	• Evaluate the status of the wind sector from the perspective of gender and the goals formulated in the development roadmap • Determine if and how a change of direction is necessary • SWOT-analysis for the effective integration of gender aspects in the proposed measures • Elaboration of programmes specified in favour of women and girls (if needed)
1000-4000 turbines (1-10 kW) produced and installed	• Industry revenue generation increasingly comes from local manufacturing and detailed assembly • Turbine sizes can be varied depending on local socio-economic circumstances
Wind energy coalition positioned as sector association	• Coalition tasks shift more toward the gathering of sector data, promotion of business excellence and representation of the sector in policy negotiations • Female presence in the coalition rises toward 30% • Youth presence in the coalition rises toward 30%
100 electro-mechanical engineers and technicians (both male and female) experienced with small wind technology	• First engineers and technicians graduate from wind-specialized educations (of which gender-specific data is gathered) • Educate existing SBEE/CEB/ABERME engineers and technicians in cooperation with wind expertise centre (and gather gender-specific data)
Beyond 2025: Long-term prospects	
• Industry revenue generation shifts to operation, maintenance and replacement • Possibilities for larger turbines (50-250 kW and 1-5 MWs) are being investigated • Export of components, systems and knowledge becomes a realistic sector opportunity • Jobs created for men, women and youth • Earnings for men, women and youth involved in the small wind sector	

5.4 Risks and risk management

As is the case with any sector development plan, the proposed actions in this chapter will also bear with them their own distinct risks. To achieve the anticipated outcomes, these risks need to be identified and managed in an appropriate manner. In table 20 below, the main risks associated with the proposed action plan are highlighted and accompanied by a risk management strategy.

Table 20: Risk management framework

Risk	Potential adverse impact	Risk level	Management strategy
Government of Benin is unable to acquire the necessary resources for developing and implementing the sector roadmap as well as the introduction of incentives.	Lack of commitment from stakeholders to be involved.	Medium	Follow a cascaded trajectory: start with the commissioning of preparatory work to define the groundwork for sector development (e.g. stakeholder identification, market study), and use this to build support from international donor organizations specialized in sector programming (e.g. UNDP, World Bank Group) and to initiate discussions within the government to find financial resources to introduce the appropriate incentives.
Stakeholders are unable to agree upon the goals, ambitions or responsibilities for a sector development roadmap.	Inability to formulate concrete actions, leading to a deadlock.	Medium	The approach for coming to a conclusive sector development roadmap starts with the creation of awareness and building of support among stakeholders concerning the rationale of setting up a small wind sector in the first place. Program developers engage in a dialogue with stakeholders to collect their feedback and integrate this into the sector development roadmap. This will incite natural coalition leaders to step up and lead the way.
Stakeholders are unable to incorporate the gender dimension into the roadmap	The interventions favour men and the gap between the two sexes will be further widened	Medium	• Raising awareness of the rationale for gender in this intervention and building capacity of stakeholders on the gender dimension • Involving gender-sensitive organisations as stakeholders • Close collaboration between the GFU of the Ministry of Energy and other gender-sensitive bodies • Stakeholder engagement with gender • Utilization of gender skills
Too few off-takers for small wind turbines can be found in the pilot phase; local communities and rural enterprises lack interest in the technology or doubt its reliability.	Pace of small wind turbine installation is slowed down, inhibiting the sector from building momentum.	Medium	During the development of the roadmap, stakeholder engagement includes prospective end-users as soon as possible (or their representations, such as village chiefs). Relevant case examples from small wind turbine applications abroad can be used to illustrate what the technology could mean in practice for end-users. High-quality components and materials are used for the production of wind turbines, to minimize chances of structural failure.
The cost of manufacturing the small wind turbines turns out to be much higher than anticipated.	Small wind turbines are put at a disadvantage to alternatives such as diesel generators or solar PV, and affordability becomes more limited.	Low	The international cooperative responsible for setting up pilots engages with international manufacturers that balance the quality and costs of components, and could also provide (technical) trainings to enterprises on the Beninese side of the value chain to optimize production processes.

6. Conclusion and discussion

The development of the small wind turbine sector in Benin is one of unfulfilled and under-researched potential. Although it has been known for some time that the coastal region is home to wind speeds suitable for reliable electricity generation, very few turbines have been installed as of yet. This report has elaborated on the techno-economic potential of small wind turbines in Benin, confirming that there are indeed good prospects of viability for this technology. The market potential is sufficiently large to create a decent product volume, especially when choosing smaller turbine types, while wind speeds are high and reliable enough to generate significant kWh's per year. Moreover, it is expected that local production should be able to account for more than half of a wind turbine's production value, reduce manufacturing costs with 9-15%, and generate a great many jobs in manufacturing, installation and services for men, women and youth.

In terms of setting up a local industry, this research has shown that in the short term, the greatest potential lies with component assembly, system installation and maintenance. Fundamental resources such as steel, copper and polyester composites will need to be imported even beyond the 2030 horizon, and it is unlikely that the blades can be produced in Benin after that period either. Technologically complex components such as electric generators, inverters and controllers will have to be imported at least for the first few years of production, but with the appropriate training and a few years of experience with local maintenance, Beninese electro-mechanical engineers should be able to manufacture them locally. With regard to steel parts manufacturing and overall system installation, local capacity is expected to be sufficient in the short term.

In line with the outcomes of the feasibility study, the fifth chapter in this report has elaborated an action plan for the development of a small wind sector in Benin. This action plan is based on the conception that the development of a sector from the ground up requires concerted efforts in which not only industry, but also government, academia and civil society work together to generate momentum. It makes a distinction between actions related to sector programming, targeted implementation, coalition building and knowledge development, and provisionally connects them to responsible stakeholders, budgets and milestones. The action plan proposes a wide but at the same time coherent range of activities and targets that can help to make the Beninese small wind sector a reality for men, women and youth. This action plan is intended to be input for a more comprehensive, broad-based roadmap, in which activities and responsibilities are further specified and the planning is more detailed.

Finally, it should be noted that this report has inevitably been limited to the confines of the research question. This study has followed a generally techno-economic and theoretical approach, without going into great depth on competitiveness, socio-political awareness, acceptance and aspirations with respect to small wind turbines. Follow-up investigations will be necessary to determine in more detail:

a) what are the needs of local women and men related to electric power?
b) what is the local willingness / ability to pay for wind power, disaggregated for women and men?
c) at what price can wind technology be provided to each type of end-user, disaggregated for women and men?
d) what is currently in place to facilitate renewable energy industry development?
e) what has prevented small wind technologies from taking off in Benin so far?

If future research can provide more insight into the answers to these questions, the development of a small wind sector in Benin can be steered into the right direction even more so. In this, emphasis should be placed on research and actions from a gender perspective, so as to avoid the creation of negative effects on women and men throughout this intervention.

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Annex II: Generation costs of envisaged power production projects

[5] Discount rate = 10% (€ 1 = 100 c€ = 656 FCFA)

PROJET THERMIQUES à 7000 heures	CAPACITE (MW)	INVESTISSEMENT (c€/kWh)	COUT FIXE D'EXPLOITATION (c€/kWh)	COUT VARIABLE HORS COMB. (c€/kWh)	COMBUSTIBLE (c€/kWh)	COUT TOTAL (c€/kWh)
CC_150MW	146,70	2,08	0,32	0,15	6,37	8,92
DSL_18MW_FG	16,77	2,55	0,85	0,62	7,78	11,80
DSL_18MW_F	16,77	2,55	0,85	0,62	10,62	14,64
DSL_1MW	0,95	2,14	0,66	0,63	20,56	24,00
Biomasse_5MW	4,75	10,54	3,67	0,00	7,89	22,10
	PRODUCTIBLE					
SOLAIRE PV	**(GWh)**					
Tempegre	40,00	16,17	2,50	0	0	18,67
Bembereke	40,00	16,17	2,50	0	0	18,67
Sakete	13,14	19,69	3,04	0	0	22,73
Kandi	16,24	15,93	2,46	0	0	18,40
Natitingou	16,24	15,93	2,46	0	0	18,40
Zogdobomey	13,58	19,05	2,95	0	0	22,00
Tchaourou	14,89	17,37	2,69	0	0	20,06
MICRO HYDRO	**(GWh)**					
CascadeSosso	2,90	25,11	4,45	0	0	29,56
Gbasse	2,60	25,29	4,50	0	0	29,79
Koutakroukro	0,36	68,54	12,22	0	0	80,76
Chute_Kota	0,18	71,01	12,78	0	0	83,79
Ouabou	0,54	47,05	8,33	0	0	55,38
Kouporgou	0,26	97,71	17,31	0	0	115,02

[5] Discount rate = 2% (€ 1 = 100 c€ = 656 FCFA)

PROJET	PRODUCTIBLE	INVESTISSEMENT (c€/kWh)	COUT FIXE D'EXPLOITATION (c€/kWh)	COUT VARIABLE HORS COMB. (c€/kWh)	COMBUSTIBLE (c€/kWh)	COUT TOTAL (c€/kWh)
SOLAIRE PV	**(GWh)**					
Tempegre	40,00	7,80	2,50	0	0	10,30
Bembereke	40,00	7,80	2,50	0	0	10,30
Sakete	13,14	9,50	3,04	0	0	12,54
Kandi	16,24	7,68	2,46	0	0	10,15
Natitingo	16,24	7,68	2,46	0	0	10,15
Zogdobomey	13,58	9,19	2,95	0	0	12,13
Tchaourou	14,89	8,38	2,69	0	0	11,06
MICRO HYDRO	**(GWh)**					
CascadeSosso	2,90	8,32	4,45	0	0	12,76
Gbasse	2,60	8,37	4,50	0	0	12,87
Koutakroukro	0,36	22,69	12,22	0	0	34,92
Chute_Kota	0,18	23,51	12,78	0	0	36,29
Ouabou	0,54	15,58	8,33	0	0	23,91
Kouporgou	0,26	32,36	17,31	0	0	49,66

Annex III: Wind direction diagram

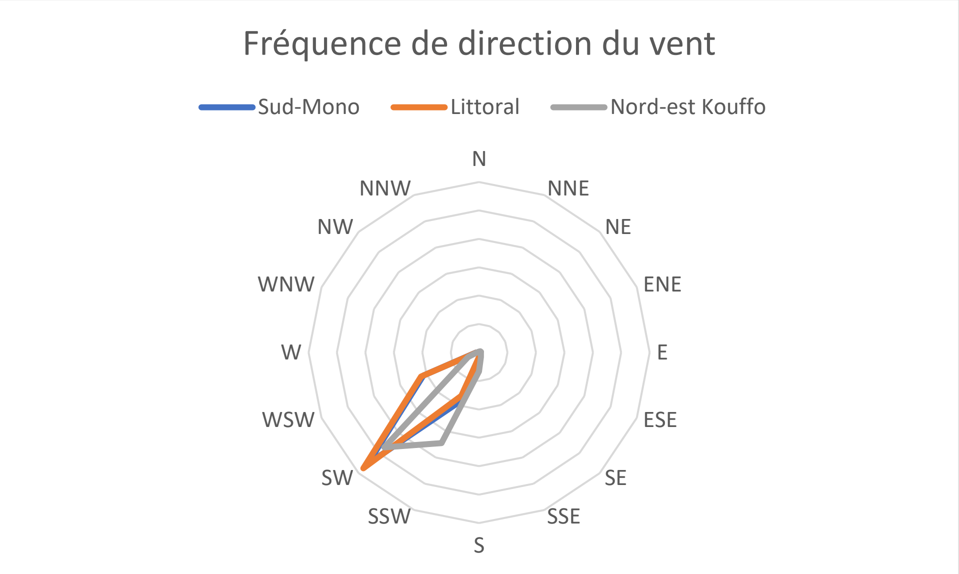

Figure 12: Frequency of wind speed direction in three areas in South-Benin [15]

Annex IV: Estimated number of inhabitants and their power demands in rural and peri-urban areas suitable for wind power in the four southernmost departments

Department	Commune	Arrondissement	Village	Number of estimated habitants	Estimated consumption in kWh/month
Atlantique	Kpomassè	Sègbohouè	Vovio	927	2.781
		Tokpa-domè	Amoukonou	670	2.010
			Gbetozo	1.445	4.335
			Gboho	440	1.320
			Lokogbo I	853	2.559
			Lokogbo II	783	2.349
			Houngbogba	823	2.469
	Ouidah	Avlékété	Adounko	1.251	3.753
			Agouin	793	2.379
			Ahouandji	644	1.932
		Pahou	Kpovié	1.235	3.705
	Sô-Ava	Ahomey-Lokpo	Ahomey-Houmey	3.588	10.764
			Ahomey-Lokpo Centre	4.518	13.553
			Kinto Agué	897	2.691
			Kinto Dokpakpa	2.015	6.045
			Kinto Oudjra	1.489	4.466
			Zoungomey	722	2.165
		Dékanmey	Akpafé	1.268	3.803
			Assakomey	3.562	10.686
			Djèkpé	3.465	10.394
		Ganvié I	Agonmèkomey	2.431	7.293
			Agoundankomey	3.491	10.472
			Kpassikomey	1.385	4.154
			Sokomey	13.260	39.780
			Tohokomey	1.281	3.842
		Ganvié II	Agbingamey	1.463	4.388
			Ahouanmongaho	1.658	4.973
			Dakomey	9.952	29.855
			Dossou Gao	1.157	3.471
			Gounsoégbamey	1.872	5.616
			Guédévié	2.919	8.756
		Houèdo-Aguékon	Domèguédji	4.979	14.937
			Ganviékomey	3.861	11.583
			Gbégbomè	2.282	6.845
			Houèkèkomè	2.282	6.845
			Gbègodo	4.479	13.436
			Gbessou	3.042	9.126

Department	Commune	Arrondissement	Village	Number of estimated habitants	Estimated consumption in kWh/month
			Sokomè	3.848	11.544
		Vekky	Gbétigao	3.445	10.335
			Hlouazoumey	3.744	11.232
			Hounhoué	2.269	6.806
			Kpacomey	3.172	9.516
			Lokpodji	1.073	3.218
			Nonhouéto	2.236	6.708
			Somaï	4.999	14.996
			Tchinancomey	2.464	7.391
			Todo	3.010	9.029
			Vekky Daho	2.503	7.508
			Vekky Dogbodji	2.054	6.162
			Zounhomey	2.490	7.469
		Sô-Ava	Ahomey-Gbékpa	4.095	12.285
			Ahomey-Gblon	3.985	11.954
Mono	Grand-popo	Adjaha	Cotocoli	242	726
			Kpovidji	1.482	4.446
			Todjikoun	1.215	3.645
			Tokpaaizo	1.055	3.165
		Agoué	Agoué II	2.077	6.231
			Ayiguinou	1.421	4.263
			Hilacondji-plage	3.561	10.683
	Comè	Akodeha	Mongnonwi	1.614	4.842
			Agoutomè	2.981	8.943
			Honvè	2.763	8.289
	Lokossa	Houin	Houedaho	1.163	3.489
		Ouèdèmè	Hlodo	191	573
Ouémé	Seme-podji	Aholouyèmè	Goho	1.750	5.250
		Sèmè-podji	Okoun-sèmè	2.321	6.963
		Tohouè	KrakéDaho	1.977	5.931
	Aguégués	Avagbodji	Bem'bé I	2.860	8.580
			Bem'bé II	2.457	7.371
			Djèkpé	3.439	10.316
			Bodjè	774	2.321
			Houinta	5.252	15.756
			Akpadon	3.023	9.068
		Houédomè	Agbodjèdo	917	2.750
		Zoungamè	Aniviékomè	3.250	9.750
			Djigbékomè	2.490	7.469
			Donoukpa	2.204	6.611
			Houndékomè	3.101	9.302
			Kindji	1.950	5.850

Department	**Commune**	**Arrondissement**	**Village**	**Number of estimated habitants**	**Estimated consumption in kWh/month**
			Kintokomè	2.893	8.678
			Sohèkomè	1.424	4.271
			Trankomè	2.067	6.201
Couffo	Aplahoué	Atomè	Agnamè	2.774	8.322
			Hevi	4.384	13.152
		Dekpo	Adandehoué	1.626	4.878
		Lonkly	Lonkly	1.676	5.028
	Djakotomè	Houegamè	Wanou	1.154	3.462
Total				**214.081**	**642.243**

Annex V-1: Gender assessment – Gender and energy in Benin

V.1.1. Understanding of the gender concept

The notion of gender refers to the differences between men and women, girls and boys, in their social relations. Gender describes all socially assigned attributes, the roles and activities related to being a man or a woman, a boy or a girl in a particular society. It is related to the way we are perceived, what is expected of us as a man or a woman, a boy or a girl, according to the organization of society.

It is influenced by race, ethnicity, class, age, caste, religion, economy, education, politics, geographical context etc. It is changeable, dynamic and acquired through socialization. Gender relations are relations of domination or power. These relations vary from one culture and one society to another and from one era to another. As a social construct, these relations are codified, hierarchized, asymmetrical, but also variable in time and space and in accordance with social-cultural background. As social constructs, gender relations can be deconstructed and evolve towards more equality [44].

V.1.2. Analysis of the gender situation in Benin

With a population of 10.008.749 inhabitants, Benin's population is young and predominantly rural and female: 51,2% [41]. Women are the main actors in several sectors of economic activity.

The question of equity and equality between men and women on the one hand and between boys and girls on the other hand is a matter of political concern in Benin. Despite their numerical importance, glaring gaps are observed to the detriment of women and girls in all areas of life (social, economic, cultural, political etc.). After all, the social perceptions and traditional practices rooted in customs, habits and traditions still determine the values and norms, the gender roles and the specific responsibilities of women and men in domestic and extra-domestic activities. The patriarchal social structure gives men a power of domination within social groups and on women in particular. The norms and values give women a lower status than men and affect their participation in certain economic activities. This trend is observed in all departments of Benin. The social context thus remains characterized by very clear disparities between men and women at the level of participation in decision-making processes, access to education, employment, health care, land and credit, and the freedom of choice for marriage. The huge gap between modern legislation and the traditional practices does not allow actual application of the law and the cultural weight remains an enemy difficult to fight. It's common to see that husbands refuse their wives to participate in non-household activities, especially when the activity is conducted on land that he does not control or at a place away from the marital home or the village, or because of the duration of the activity. We also notice the primacy of the husband's activities over those of women. Hence, many women miss the opportunities available to them despite their fervent desire to seize them [35].

Women have very limited access to the main factor of production: the earth (85% of the land owners is men compared to 14,9% women). This lack of access to the land results in unequal access to other productive resources (input, credit, agricultural technical support) and poor performance in output and production volume. Although constituting about 60% of the agricultural workforce, women benefit very little of the different sectors and they are poorly represented in the decision-making structures of farmers' organizations. The proportion of households headed by women is 24,7% in urban environments and 21,9% in rural environments. The gender of the household's head plays an important role in the analysis of the living conditions of the households in Benin. Monetary poverty affects more people living in male-headed households than those headed by women, while non-monetary poverty affects more people living in female-headed households than those headed by men. In fact, the incidence of income poverty at the level of male-headed households was 40,2% compared to 39,7% for households headed by women in 2015. On the other hand, non-monetary poverty affects about 1,3 times the households headed by women than those led by men. The decline in the incidence of poverty observed among women-headed households may be explained by the fact that more and more women are benefiting from opportunities with a direct effect on standard of living such as access to credit (from the Micro-credit program to the poorest (MCPP), that can contribute to the development or diversification of income-generating activities.

There is a slight increase in inequality in general, but this is more pronounced at the level of women between 2011 and 2015. Inequality indices increased regardless of the gender of the head of the household. For households headed by women, the index rose from 0,441 in 2011 to 0,454 in 2015, an increase of 0,013 compared to 0,003 for households headed by men [42].

At the macro level, women remain very poorly represented in national decision-making bodies and also in communal and municipal authorities. The community councils elected in 2002 and 2008 consisted of respectively 3,66% and 4,60% women. There is a decline of economic power between 2011 and 2015, from 0,732 to 0,662, a decrease of 9,6% [43].

The professional inequality between men and women does not seem to have declined much in recent years in both the public and private sector. In 2007, different studies carried out as part of the integration of gender in the private work environment in Benin showed a male preponderance in all sectors of activity, but less in the tertiary sector: (i) among the active population, there are twice as many educated men as educated women; (ii) twice as many men as women in formal private employment; (iii) more than twice as many men as women among the employees in the formal private sector; (iv) 10% more girls than boys among the working children aged 6 to 14; (v) nine times more men than women among business leaders. The share of waged labourers among the active male population (16,8%) is three times higher than that of women (5,0%); 2,8% of Benin women are unemployed, compared to 2,4% of men. Similarly, underemployment affects many more women (65,4%) than men (41,5%) and they have a lower participation rate than men [42]. In addition, 73% of men aged 15-49 are exposed to any media at least once a week compared to 54% of women [45].

According to a study conducted by the National Women's Institute on the participation of girls and women in technical and scientific professions and high schools and public universities in Benin, the percentage of girls in technical and scientific fields is low (less than 20% to 50%). There are fewer than 20% girls in specialities such as building, electrical engineering, mechanics, civil engineering, computer science, animal production etc. In the industrial technical sector, the number of girls is very low with an average attendance rate below 20%. However, these numbers have increased over the years from 11% in 2006 to 37% in 2009-2010. The number of girls is higher at secondary school entities than at university level. The analyses shows that girls are no less talented than boys for the industrial technical sector, because they are even better than boys when they register. Moreover, the biggest successes for girls are registered in university entities (82% to 92%).

In summary, the major constraints to equal employment in Benin are: (i) the overburdening of women in comparison to men, due to the fact that they spend twice as much time on unpaid domestic work, which leads to twice as much female absence at work; (ii) many sectors and industries characterised by gender stereotypes imposing high barriers to entry into the labour market (iii) Strong inequalities of access to initial education, continuing vocational training, credit, income, real estate, movable property, decisions.

Despite this situation, the Global Strategy Paper on Public Service Reforms (SGRFP) adopted in 2013 does not foresee any strategy or action to improve the level of representation of women in public administration. The same goes for strategic documents for stimulating and developing the private sector. The political system operates according to masculine norms and the efforts made to restore the gaps between men and women with regard to the access to decision-making positions and the exercise of responsibility give very limited results. In reality, there is no normative framework outlining clear rules for gender equity in the in the principles of governance and accountability of the country.

In the national charter for the governance of Benin adopted in 2011, gender equality and equity do not occur in the principles or values and even less in the commitments taken by the Benin National Convention. At the level of the different ministries and other structures and institutions of the Republic, gender responsibility is not integrated into systems for planning, monitoring and evaluation. Taking gender into account is left in charge of gender focal units / persons and does not show up in the respective work statements of managers and agents at different levels. The current system of governance therefore does not systematize the breakdown of indicators and produces very little data with regard to indicators for achieving gender equality. Concerns about women's access to decision-making positions, personnel recruitment policy, promotion and appointments practices and employment regulations also receive no special attention at the level of public management bodies. This is also due to the fact that the various frameworks for action and accountability, such as the decrees for establishing, allocating and running public structures, tend to be silent on the objectives and responsibilities with regard to gender mainstreaming. As a result, the various frameworks of action, policies and programs developed by the ministries, as well as the terms of reference of public officials and agents resulting from these decrees do not contain a provision on gender equality. That explains why gender concerns are not systematically reflected in governance systems and the accountability of public institutions. Moreover, there is little incentive for the private sector to create a gender-balanced workforce.

V.1.3. Analysis of the gender situation and energy in ECOWAS and in Benin

Access to energy plays an important role in development processes. Lack of access to energy resources for lighting, heating, cooking or productive activities limits the development of women and men and societies in general. However, men and women experience this "energy poverty" in different ways, depending on gender relations and the distribution of roles and tasks between men and women in a particular society [37]. Gender aspects of energy poverty in the ECOWAS region limit the opportunities for women and men to create capacity for action for regional integration and socio-economic development [55].

Thus, technical solutions and the development projects for energy access will be perceived and received differently by men and women. Women find it more difficult to access the benefits of development interventions, because of existing structural gender inequalities (eg, women's lower literacy rate and education level, less availability to participate, less mobility). The productive activities of men and women are different: the energy needs for productive income-generating activities will therefore also be different for men and women. Decisions to invest in access to energy or energy facilities are usually taken by the head of the household, often the focal point of the stakeholders in development projects too. Women therefore do not always have a voice, at the level of the household or during project meetings. All these elements are not always taken into account in sectoral policies, because it is often assumed that the technical choices are socially neutral. The specific needs of women are therefore not systematically taken into account by sectoral policies [34].

ECOWAS affirms that a specific gender mainstreaming policy on energy access is needed to better meet the needs of all its citizens for modern and sustainable energy services that improve living standard and productivity. That is why it is committed to the advert of accelerated development that is socially just, equitable, economically viable and ecologically sustainable. It also works to contribute to creating a supportive policy environment, in turn supporting the institutional framework and mobilizing resources, with women becoming more actively involved in all aspects of the energy access problem; particularly as energy suppliers, planners, financiers, trainers and customers [37].

This commitment resulted in the validation in June 2017 of the gender mainstreaming policy on access to energy, with the aim of removing existing obstacles to the equal participation of women and men in the expansion of energy access in West Africa. The aim is to use a gender mainstreaming framework to enable energy ministries to achieve their energy access goals in ways that influence the role of women as energy users, as members of the community, business leaders and decision-makers. Therefore, ECOWAS supports member states in achieving their universal goals and ambitions for energy access by integrating gender-inclusive features into climate-resilient energy policies and practices. Strategic objectives include: the institutionalization of gender in energy policies, programs and initiatives, including major infrastructure and investments in the energy sector, increased participation of women in the public sector in the technical fields related to energy and decision-making positions, the possibility for women and men to have equal opportunities to participate and succeed in areas related to energy in the private sector.

In Benin, the high costs of access to electricity create an imbalance between female and male market participants. Because of the poverty of women compared to men, this has serious consequences for the activities of women who are mainly engaged in the processing, conversation and marketing of food and food products, whose exploitation is dependent on electrical energy. In this case, the low income of women inhibits them in acquiring generators to circumvent this constraint. The impact of the electricity shortage on women's activities has been widely discussed during public consultations. Indeed, the women interviewed spoke about the harmful effects of the energy shortages on their activities: damage, rottenness and failures for restaurateurs, liquor store owners, fresh food merchants… For example, mini-markets and restaurants are subject to frequent and severe damage due to untimely power cuts. It follows that the lack of control over the electricity supply in Benin is a major handicap to the development of women's activities, which are concentrated on 92,6% catering and 78,2% commerce [38].

In 2015, it is estimated that only 34,7% of the households are connected to the SBEE electricity grid, with a large inequality between rural and urban areas. In-depth analysis of the situation of gender and social inclusion in the field of energy in Benin has revealed, among other things, different levels of gender inequality, as well as weak support for social issues in Benin's energy sector. It reveals that energy policies and strategies are blind and neutral with regard to gender and social inclusion. According to several studies carried out in the framework of MCA-Bénin II, it appears that the vulnerable people who need to be taken into account by the social inclusion measures in the energy sector include: *(i) people living in rural areas and suburban areas not connected to the electricity grid, and in particular women, (ii) households and people with a very low income (poor people), (iii) households whose heads are not educated (iv), households headed by women, (v) young people, (vi) people with disabilities* [47].

Very unequal power relations between men and women hinder the achievement of the sustainable development goals, in this case SDG 5: **achieving gender equality and empowering all women and girls**. However, Benin has an institutional and strategic framework to promote gender equality and implements many programs and projects aimed at empowering women.

V.1.4. Efforts to promote gender in Benin and limits

The principle of equality between men and women in all areas has been constitutionally recognized since 1977 (Article 124 of the 1977 Constitution) and confirmed by Article 26 of the Constitution of 11 December 1990, which states that: << The states shall ensure equality for the law without discrimination on the basis of origin, race, sex, religion, political opinion or social position. Men and women have equal rights… >> Benin has also adopted international and national conventions and resolutions that prohibit gender discrimination in public policy. To reinforce its commitment, the Beninese state has made great efforts to strengthen the legal arsenal for the promotion of women's rights and to set up an institutional framework for the coordination of the application of gender. This institutional framework was enriched in 2009 by the establishment of the National Institution for the Promotion of Women (INPF).

In its vision of promoting gender, Benin is << **a country where equality and equity promote the participation of men and women in decision-making, access to and control of means of production for sustainable human development** >> by 2025 [51]. The emphasis is on the institutionalization of gender, the improvement of the legal status of women and the strengthening of the socioeconomic capacities of women. For example, Axis III of the Growth Strategy for poverty reduction 2011-2015 aims to reduce gender inequalities and to strengthen social protection. In addition, the creation of decent jobs and the reduction of gender inequalities are prominent in the SCRP 2011-2015. Benin women are very active, present in all sectors of activity and contribute as much as men to the economic development of this country [56].

Similarly, in the Strategic Development Guidelines 2011-2020, the promotion of gender equality and equality has been identified as a strategic development axis. On the strategic axis n ° 7, devoted to the promotion of equality and justice between the sexes, the government indeed commits itself to correct the inequalities in the male / female relations by taking measures ensuring equality and fairness between men and women in access to education, literacy and decision-making structures; by strengthening the institutionalization of gender at all levels and the effective implementation of gender-sensitive national texts and conventions, as well as the engagement of civil society and the awareness of women and men for the promotion of gender; by reducing the monetary poverty of men and women and giving them equal access to and control over resources.

Several initiatives have been taken by rulers to improve the conditions and the status of women, through the poverty reduction programs (microcredit to the poorest), the establishment of a ministry responsible for the employment of young people and women, the progressive subsidization for secondary schooling of girls; the perspective of the establishment of high schools for girls throughout the country.

Unfortunately, all the texts regarding the promotion of women and gender and initiatives do not seem sufficient to change the reality of this country. Even today, women's rights, especially economically, political and socially, are not always respected. Challenges remain to reduce inequality between men and women. It should be noted that PNPG, 2009 and its program and action plan did not explicitly take into account the energy sector. Similarly, the 2009 strategic plan for the development of the energy sector is not gender sensitive. However, the situation has been somewhat corrected in the 2016 government action plan (PAG). Benin, a member of the international community and the United Nations, has acceded to <the Agenda 2030> for the 17 goals of the Millennium Development Goals (SDGs), including SDG 5 in particular.

support for social cohesion by promoting equality and equality between men and women and strengthening family and community barriers, promoting employment, self-employment, communication and improving the information system on the labour market for young people and women. The promotion of the production of parts of wind turbines is therefore part of this dynamic.

Given the predominance of young people and women who are most affected by unemployment and underemployment, the 2016-2021 government program focuses, amongst other things, on training and integration of the youth; carrying out programs to promote the local economy for the empowerment of women; support for social cohesion by promoting gender equality and equity and strengthening the family and community barriers, promoting employment, self-employment, communication and improving the information system on the labour market for young people and women. The promotion of the production of parts of wind turbines is therefore part of this dynamic.

Annex V-2: Gender assessment – Intervention Strategy on gender and wind energy

Gender equality is an important aspect of most SDGs, because availability and access to energy are crucial to enable women and men to meet their daily needs in different socio-economic conditions and contexts.

In the case of this study, the local production of wind turbines is expected to provide in particular two types of socio-economic benefits: cost reductions and job creation, taking into account the main constraints for equal employment in Benin, including gender stereotypes imposing strong barriers to enter the labour market and inequalities in access to education. The intervention strategy will focus on two approaches: the institutionalization of gender in throughout the process and the empowerment of women and girls.

With regard to the institutionalization of gender in promoting small-scale wind turbine manufacturing in Benin, the challenges include: establish the link between wind energy and gender goals, raise awareness among stakeholders and beneficiaries of the relevance of gender mainstreaming, identify practical, productive and strategic gender needs in diagnoses and with beneficiaries (men/women), make a gender-sensitive planning, similarly propose a monitoring-evaluation system from a gender perspective. To achieve this, there is a need to work to minimize resistance at the organizational, programmatic and partnership levels.

In het context of empowering women and girls, it will be a matter of working to compensate for existing discrimination in the past.

Moreover, a number of specific actions (action-research) will be carried out to deepen the analyses and adjust the intervention strategy where necessary.

The assumptions underlying our theory of change are:

- Changing sociocultural norms that discriminate cannot be done effectively without the implementation of stakeholder engagement strategies for gender openness and the empowerment of women and girls in the sector of wind turbines.
- The education and training of women and girls at the professional and higher levels in the same way as men and boys are a guarantee of having a minimum of women / girls as energy technicians and engineers.
- Performance evaluation against gender indications must be integrated in all performance measurements and accountability at the intervention level.
- It will be necessary to obtain the support of the technical and financial partners to mobilize substantial funding to operationalize the gender dimension in interventions.

REPUBLIQUE DU BENIN
MINISTERE DE L'ENERGIE

Strategic action plan for gender and wind energy in Benin

Strategic targets	***Results***	***Indicators***	***Activities to be undertaken***	***Responsible***
A. 2018-2019: Sector Programming				
Make sector programming gender-sensitive	R1. The production of wind energy in a socially integrated technology capable of contributing to local job creation for both men and women is ensured.	Roadmap finalized and gender-sensitive	**A.1** Elaborate a 2-year roadmap for the development of the small scale wind turbine sector in Benin, in which time-bound tasks are defined and responsibilities assigned to stakeholders. • Make an analysis of stakeholders taken into account their openness to gender • Develop a gender vision on the intervention • Set priorities for the institutionalization of gender and the empowerment of women and young girls/boys • Define the indicators and targets disaggregated by gender (male/female, boy/girl) and/or other categories • Conduct a risk analysis related to gender and the empowerment of women/girls and find out if the intervention could have unintended or negative effects on certain social groups. • Anticipate the budget for gender-specific activities or the empowerment of women/girls in relation to the total budget of the intervention. • Select mixed stakeholders of men, women and young girls/boys	DGE
		Cooperation agreement signed taking into account gender aspects	**A.2** Request for the cooperation of international donors to acquire the necessary resources for the development and implementation of the road map. • Share the gender vision with partners and agree on achieving gender-sensitive goals • Negotiate funding for gender-specific activities	DGE
		Signed commitment sensible of gender	**A.3** Identify and attract international expert organizations to set up a consortium or joint-venture that can play a pioneering role in the small wind turbine sector in Benin. • Share the gender vision with the partners and agree on gender-sensitive goals to achieve • Ensure openness in addressing gender equity and women's and girls' empowerment • Negotiate funding for gender-specific activities	Coalition of leaders

Strategic targets	***Results***	***Indicators***	***Activities to be undertaken***	***Responsible***
			B. 2018-2020: Mise en œuvre ciblée	
Make the pilot phase accessible to the beneficiaries/key clients without gender discrimination	The project team integrates the gender dimension into the pilot phase	Turbines installed for the production of energy, gender-specified - Level of understanding of gender and project results by implementing structures - Gender-specific composition of the project management team - Gender skills of the project management team - Number/% of female and male entrepreneurs contacted by the project - Percentage of women and men having purchased wind turbines	**B.1** Implement a pilot phase focused on productive use of electricity (for example: remote telecom sites, rural enterprises), in which high-quality small wind turbines are used. • Make the tools for contracting and personnel management gender-sensitive • Diversify the beneficiaries and key clients of the pilot phase (male/female) • Strengthen the capacity of the management team in utilizing a gender approach • Plan specific research actions with women and men involved in the pilot phase • Monitor the pilot implementation from a gender perspective, using e.g. half-yearly reviews to discuss results, performances and re-adjustments of actions • Set up annual assessment workshops to gain insight into the gender effects produced by the program as a whole	Consortium responsible for the pilot phases
		20 turbines ready for energy production	**B.2** Arrange for the production of small wind turbines	Consortium responsible for the pilot phases
		20 turbines installed and 3 or more village leaders interviewed; Voluntary participation of women, men and young people in the installation and the exploitation of known systems	**B.3** Install 20 turbines for household use and/or production use, and involve village leaders to determine the willingness of villagers to participate in the installation and the operation of the systems.	Consortium responsible for the pilot phases
		Report the satisfaction of the appropriate importers Percentage of suppliers and traders (men and women) informed of opportunities and involved in the import	**B.4** Facilitate the import of raw materials and components by reducing tariff barriers. Remove legal barriers and offer other incentives. Inform suppliers and traders of these opportunities without gender discrimination.	DGE

Strategic targets	***Results***	***Indicators***	***Activities to be undertaken***	***Responsible***
C. 2018-2020: Coalition building				
Build a gender-sensitive coalition	The coalition set up is gender-sensitive	Letters of intent signed Principle agreement for the operationalization of gender	**C.1** Identify and invite organizations interested in the creation of a small wind turbine sector in Benin, including the industry (manufacturing, construction, import) and NGOs including women's organizations, educational institutions and agencies. • Explore other possibilities for potential partners and set up new partnerships to promote and operationalize gender in the intervention • Develop a synergy and a complementarity with gender-promoting organizations to improve the achievement of results of gender and empowerment of women • Develop the gender reflex in all working methods at the organizational, partnership and programmatic level	Coalition of leaders
		Signed legal documents	**C.2** Determine the mandate and cooperation structure of the coalition Elaborate the specifications of the coalition by making gender a criterion for partnership	DGE
		Definitive strategic plan that is sensible to gender	**C.3** Develop a comprehensive approach for creating national awareness of small wind turbine technology, aligning actors in the small wind turbine industry and identifying opportunities for positioning and developing the sector Plan social mobilization for gender mainstreaming in the sector	Coalition of leaders
D. 2018-2020: Knowledge development				
Promote the development and management of knowledge regarding wind technologies, and of gender aspects of wind energy	The level of knowledge in these fields has increased	- Advanced research strategy - Number of gender-sensitive case studies developed - Number of studies on gender mainstreaming in the wind turbine sector - Number of scientific articles on gender and energy published in journals	**D.1** In collaboration with international educational institutions, set up a centre of technical expertise in the field of wind energy for wind measurements (for the selection of potential sites) and applied research (for example : turbine optimization, configuration system) • Develop the research strategy • Identify research topics and offer them to students as part of their internship or dissertation • Undertake activities to promote gender and wind knowledge management, such as research, publications, seminars, meetings etc. • Integrate people with expertise in the realization of studies and various services related to the project.	Technological University
		2 or more universities offer wind turbine courses	**D.2** Make wind energy an important part of the curriculum of engineers and technicians Introduce gender in the curriculum	Technological University; SBEE

Strategic targets	Results	Indicators	Activities to be undertaken
2020-2025: Mid-term guidelines			
Organise the mid-term evaluation and adjustment of the sectoral program	Strengths and weaknesses in terms of gender are identified New challenges in gender are identified The effects of the project on men, women and young girls/boys are known	100 electromechanical engineers and technicians composed of men and women experienced in wind energy technology - The first engineers and technicians (30% women) graduated in specialized wind energy education - Number of men and women trained for SBEE/CEB/existing engineers and technicians in collaboration with the centre of technical wind energy expertise - Number of companies supported in the private sector that have created a gender-balanced workforce - Commercially feasible energy projects initiated and managed by women and men on the basis of wind energy - Number of male and female entrepreneurs who have acquired the technical, financial and other skills necessary to compete as producers and suppliers in the wind energy sector - Level of productivity increase of women and men in their professional activities further to increased use of wind energy - Level of participation of men and women in project activities	Evaluate the status of the wind sector from the perspective of the objectives formulated in the development of the roadmap - Determine if and how a change of direction is necessary Train the first engineers and technicians with a degree in wind energy - Train the other SBEE/CEB/ existing engineers and technicians in cooperation with the centre of technical wind energy expertise Measure the effect/impact of using wind turbines on women and men, young girls and boys
		250 turbines (-10 kW) manufactured and installed - Percentage of manufactured and installed turbines by women and men - Percentage of manufactured and installed turbines for women and men - Level of income generated by the local production industry and detailed assembly based on gender - Turbine sizes according to local socio-economic circumstances an their use by gender	- The generation of revenues in the industry is increasingly coming from local production and detailed assembly - Turbine sizes may vary depending on the local socio-economic conditions • Disaggregated monitoring of turbine manufacturing and installation Indicate which accompanying actions must be carried out to keep production in balance
	The wind energy coalition positioned as an association sector	- Gender composition of the coalition - Percentage of women and men in the management bodies of the coalition - Degree of satisfaction of coalition members - Positioning level of women and men on links in the wind energy sector	The tasks of the coalition are focused more on collecting data from the sector, promoting the excellence of companies and representing the sector in political negotiations. • Ensure a gender balance in the coalition • Facilitate the participation of women and youth in decision-making within the coalition • Develop all the links in the wind energy value chain

Strategic targets	***Results***	***Indicators***	***Activities to be undertaken***
		At the end of 2025: Long-term prospects	
Improve the production capacity of the industry	Capacities of production and marketing are improved	- Larger turbines (1-5 MW) are being installed - Export of components, systems and knowledge becomes a real opportunity for the sector	• Produce larger turbines • Search and diversify markets • Export products • Direct industry revenue generation to operation, maintenance and replacement

Annex VI: Organizations interviewed

Organisations with production capabilities

MDC (member of AISER); **SEEPEG** ; **Le Réveil Tossou et Fils; 2EPS; TRANSACIER; AJO; Groupement ASEMI; EMC.**

Agencies, NGOs, universities and other organisations

NGOs : **Nature Tropicale ; Marine Service Protection ; Centre Songhaï**
Universities : **Institut Université Cerco, Université UATM**
Agencies : **ANADER** (as explained in footnote 2, the Government of Benin announced, at the end of 2017, that ANADER will be replaced by 'l'Unité Chargée de la Politique de Développement des Energies Renouvelables' (UC/PDER).
Other organisations : **IBIG** (member of AISER) ; **ENERDAS** (member of AISER) ; **NGOM Service SARL** (member of AISER) ; **Mini- centrale solaire PV de Kpokissa**

Annex VII: Questionnaire used for survey of Beninese manufacturing capacity

Name, address and contact details

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____

____

____

Organization type

Private ltd. Company / Public ltd. Company / NGO / Government agency / Other: _________

Year of commencement of business

____

Core business

1.1 What are your organization's core present activities?

____

____

____

1.2 What products and services does your organization offer, and at what prices? (enclose brochures, if any)

____

____

____

1.3 Do you have a reference list (with pictures) of the products/services you made/delivered in the last 10 years?

Yes / No (if yes, please add as annex)

1.4 Who are your companies' main clients (or: what type of organizations are your companies' clients)? Can we visit them to see your products in operation?

____

____

____

Workforce

2.1 How many employees does your organization have, and what are their qualifications (e.g. engineers, sales, administrative)?

____

____

____

2.2 How many of your employees are female?

____

____

____

2.3 How many of your employees have experience with the wind energy industry?

____

____

____

Production

3.1 What is your maximal production capacity?

____

____

____

3.2 What has your total sales volume been over the past three years?

____

____

____

3.3 For which of your products do you rely on imports? What is the average price of the imported goods?

____

____

____

3.4 How much storage space do you have available for your products?

____

____

____

3.5 Are you aware of international standards (EU or USA) for your production processes and materials? Is you company able to work in line with these standards?

____

____

____

Stability / outlook

4.1 What projects have you recently undertaken to expand your business?

____

____

____

4.2 What opportunities do you see for further business development in the coming years?

____

____

____

4.3 Do you see a potential role for your own company in the wind turbine manufacturing sector? For which wind turbine components specifically? What potential market size do you expect?

____

____

____

Industry perspective

5.1 What is your opinion on the viability of the wind turbine manufacturing sector in Benin? To what extent can wind turbine components be manufactured locally in the short or long term, and by whom?

____

____

____

5.2 Do you believe that local manufacturing can open up opportunities for increasing the electrification of rural areas in Benin? Do you know any examples of this?

____

____

____

5.3 What are, according to you, the main private and public organizations that (should) play a role in the wind turbine manufacturing industry in Benin?

____

____

____

5.4 What are, according to you, currently the most noteworthy opportunities and barriers for wind turbine manufacturing in Benin (e.g. policies being developed, foreign investors coming in, rural electrification stagnating)?

____

____

____

Other organizations in the value chain

6.1 Do you know of any other organizations in or around the wind turbine manufacturing value chain we should speak to? (e.g. your suppliers, clients, competitors, etc.)

____

____

____

Annex VIII-1: Terms of Reference (ToR)

TERMS OF REFERENCE (TOR)

Feasibility study and development of an action plan for the promotion of manufacturing of components of small power wind turbines in Benin

CTCN request reference number: 2015000071

Requests for Technical Assistance (TA) are being submitted to the CTCN by the National Designated Entity (NDE) of the respective country. The scope of services under these Terms of Reference describes the response to such a request. By mandate, only accepted Members of the CTC Network are eligible to execute the required services to implement the response.

In case you are not a CTCN network member yet, you may bid for implementation of the technical assistance, subject to the condition that you submit your completed application for CTC Network membership before the bid closure and the same is acknowledged by the CTCN. Furthermore, the contract award – should your bid be selected – is conditional to your network membership application having been successfully approved by the Director of CTCN. Should the bidder partner with another institution to deliver the services described in these Terms of Reference, it is expected that the partner institution also joins the CTC Network.

BACKGROUND INFORMATION

The Climate Technology Centre and Network (CTCN) is the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and hosted by the United Nations Environment Programme (UNEP) in collaboration with the United Nations Industrial Development Organization (UNIDO) and supported by 11 partner institutions with expertise in climate technologies. The mission of the CTCN is to promote accelerated deployment and transfer of climate technologies at the request of developing countries for energy-efficient, low-carbon and climate-resilient development.

These requests for Technical Assistance (TA) are being submitted to the CTCN by the National Designated Entity (NDE) of the respective country. The scope of services under these Terms of Reference shall be executed based on a restricted solicitation process where only accepted Members of the CTC Network, are eligible to submit proposals. Should the bidder partner with another institution to deliver a minor part of the services described in these Terms of Reference, it is expected that the partner institution also joins the CTC Network.

The budget range for this contract is USD 77.000.

CONTEXT OF THE ASSIGMENT

Like most sub-Saharan African countries, Benin has low electricity access rates among households with 31 % at national level, 58 % in urban areas and 6.8 % in rural areas (2014 data). The Government of Benin began a rural electrification program in 1993 with the goal of increasing access to electricity for rural populations. This program consisted of installing solar photovoltaic systems in small isolated communities as an alternative to extending the national electric grid. Building on these initial efforts, The Benin Agency for Rural Electrification and Energy Management (ABERME) was created in 2004 to implement a coordinated national rural electrification policy, which has so far supported the development of several rural electrification projects. In June 2013, the National Development Agency of Renewable Energies was established to implement renewable energy and energy efficiency policies, including a 25% renewable energy goal. For Benin to achieve its sustainable development, environmental preservation, greenhouse gas emission reduction, and energy independence goals, the government and other energy institutions must support increased deployment of renewable energy. In addition to solar and hydro resources, studies have shown that Benin also has good small wind resources in its coastal areas that could be a source of power to rural populations in those areas. However, thus far, wind resources remain underutilized in Benin with only a few existing facilities.

In order to accelerate and expand renewable energy based electrification Benin aims to also utilize its wind resources to complement solar, hydro and biomass energy. In spite of the carried out studies that concluded sound potential for small scale wind in coastal areas deployment of the technology has not taken off. Stated as reasons for this were a lack of commitment to plans and strategies, a general lack of interest in wind energy, as well as very limited capacity both within the public and private sector to identify and address current barriers. One known barrier is the cost of small wind technology, which is why investment activities have been limited. To respond to this the request aims at creating a local industry using materials and components that can be sourced locally and therefore easily and cheaply, as well as easy to maintain. The power size of the turbines is expected to be up to 10 kW, however the feasibility study will provide a final indication on the definition of the targeted power size.

OBJECTIVE OF THE CONTRACT

This assistance seeks to advise Benin on the question whether or not kick-starting a local wind manufacturing and deployment market by first analyzing feasibility of local manufacturing of equipment. Then, if the results of the feasibility study are positive, a second phase of the intervention will produce recommendations to Benin as to how to create a manufacturing market as well as how to spur the installation of small wind turbines through capacity building, policies, regulations, programs, and other measures. The anticipated outcome is that Benin stakeholders will be informed about the potentials of local small wind component manufacturing and a market to sell the produced technology to generate renewable energy in rural areas that were previously lacking reliable energy access. Should the technology be deemed feasible stakeholders will furthermore be advised on how to plan a pilot manufacturing plant. In case feasibility cannot be concluded stakeholders will be advised about alternative opportunities to improve access to renewable energy based electricity in rural areas.

Scope and Activities of the Proposed Contracted Services

The Contractor is expected to undertake the following line of activities:

Output 1:
A report of the feasibility study on local manufacturing of small wind technology in Benin. The study will take into account the current state-of-play for a small wind market in Benin including barriers to growth, current and planned regulatory actions and information on human capacity needs, based on an in-country assessment in collaboration with local experts including government, private sector, and other stakeholders; additional online research; and conversations with development partners.

Activity 1.1
Prepare an outline for the feasibility study and identify key stakeholders in collaboration with NDE and proponent

Activity 1.2
Organize and set up conference call to discuss and confirm the outline and scope of the study and identify local experts for subcontracting.

Activity 1.3:
Contract local experts and conduct preparatory research online and through phone calls with development partners and others; make arrangements for in-country meetings

Activity 1.4:
Conduct in-country data collection and stakeholder consultations.

Activity 1.5
Evaluate results from the data collection and consultations and write report

Activity 1.6:
In-country meeting to present and discuss study results; start discussion on next steps and the action plan (see Activity 2.1)

Deliverables under Output 1
Deliverable 1.1: Study outline and list of key stakeholders Deliverable 1.2: Conference call minutes with conclusions; list of local experts Deliverable 1.3: Expert contracts and work plan Deliverable 1.4: Data collection and stakeholders consultation report Deliverable 1.5: Draft summary report for review by the proponent and NDE Deliverable 1.6: Final study report; Draft outline and scope for action plan

Output 2:
If the results of Output 1 are positive and a small wind manufacturing and deployment market is considered feasible: An Action Plan will be developed that will consist of details of small wind industry goals for the 2020 and 2030 timelines, a summary of small wind industry opportunities and pathways to fulfil these opportunities, and a high-level plan for implementation of a pilot manufacturing project. (If the results of Output 2 are negative and a small wind manufacturing and deployment market is considered not feasible: A set of recommendations about alternative opportunities to generate access to and/or produce renewable energy technology locally.)

Activity 2.1:
Identify and invite additional key stakeholders (if necessary), and host an initial stakeholder meeting to determine aim and scope of next steps (in coordination with Activity 1.6)

Activity 2.2:
Develop draft action plan

Activity 2.3:
Incorporate feedback to develop final draft action plan and prepare final meeting to present plan to stakeholders

Deliverables under Output 2
Deliverable 2.1: Action Plan outline and initial recommendations, and stakeholder input on plan requirements. Deliverable 2.2: Advanced draft action plan to be shared with stakeholders for their review. Deliverable 2.3: Meeting report and final action plan.

Throughout all activities the contractor is asked to ensure gender equality both in terms of involvement of women in the activities as well as the outcomes and impacts of the activities. This has to be explicitly reflected in the budget and implementation plan. The contractor will furthermore be asked to regularly report progress to the CTCN and national stakeholders based on previously agreed milestones and to fill a final closure report. These monitoring and evaluation activities should be provisioned in the budget.

GENERAL TIME SCHEDULE AND ACTIVITY/DELIVERY PLAN

The activities under this contract should be completed within a period of six (6) months from signing the contract. The proposed plan for implementation of activities and deliveries:

Activities and Deliverables	Month					
	1	2	3	4	5	6
Activity and deliverable 1.1						
Activity and deliverable 1.2						
Activity and deliverable 1.3						
Activity and deliverable 1.4						
Activity and deliverable 1.5						
Activity and deliverable 1.6						
Activity and deliverable 2.1						
Activity and deliverable 2.2						
Activity and deliverable 2.3						

All draft and final deliveries are subject to approval from the CTCN Climate Technology Manager before these can be concluded.

PERSONNEL IN THE FIELD (PROFESSIONAL EXPERIENCE AND QUALIFICATIONS)

The Contractor is expected to provide the services of a team that should ideally comprise the following competencies:

- Experience with and understanding of the technical components of wind systems, installation and operations requirements, wind resource assessments and key market drivers
- Experience with manufacturing process design, especially in the small wind technology sector
- Understanding and experience with the needs and limitations developing countries are facing in this regard
- Experience with leading technical assistance projects in developing countries, including M&E reporting and budget supervision
- Experience with industrial economics and supply chains and sound understanding of local markets and socio-economic circumstances
- Strong communication and organizational skills

Working experience in Benin and West Africa is preferred for all of the above items. Furthermore, having national Beninese experts as part of the implementation team is required. The CVs of the respective experts assigned to this assignment by the Contractor must be provided.

LANGUAGE REQUIREMENTS

The working language for the purposes of this assessment is French, thus an excellent command of French is required of the proposed personnel. English language will also be required for the engagement with the CTCN. All final deliverables must be submitted in French with selected sections subsequently translated to English by the Contractor.

All delivered documents must be of sufficient enough quality so that no further editing shall be required.

Annex VIII-2: Terms of Reference (ToR) – amendment 1

UNIDO Contract No: 3000049032
Purchase Order No.: 3000057131

United Nations Industrial Development Organization

TERMS OF REFERENCE (TOR)

AMENDMENT I

27 February 2018

Title: Feasibility study and development of an action plan for the promotion of manufacturing of components of small power wind turbines

Country: Benin CTCN request reference number: 2015000071

Requests for Technical Assistance (TA) are being submitted to the CTCN by the National Designated Entity (NDE) of the respective country. The scope of services under these Terms of Reference describes the response to such a request. By mandate, only accepted Members of the CTC Network are eligible to execute the required services to implement the response.

1 BACKGROUND INFORMATION

The background information remains unaffected by this amendment.

2 CONTEXT OF THE ASSIGMENT

Wind power remains an underutilized energy source in Benin, with only a few existing facilities. In order to accelerate and expand renewable energy based electrification Benin aims to also utilize its wind resources to complement solar, hydro and biomass energy. Upon request from the NDE of Benin the CTCN decided to support the country's ambitions and contracted a partner organization to carry out a feasibility study on wind power use and local wind turbine manufacturing, and to develop an action plan for the establishment of a local wind turbine production industry. The implementation of the activities began at the end of June 2017.

3 OBJECTIVE OF THE CONTRACT

During the implementation of the activities outlined in the original Terms of Reference (ToR) to the contract two topics emerged that lie beyond the scope of the ToR, yet are considered valuable complements to the intervention. It has therefore been agreed among the counterparts, the Contractor and the Climate Technology Manager to amend the scope of activities and project budget in order to accommodate for the additional work. The two additional activities are:

(i) taking into account peri-urban areas in addition to the rural areas offered in the ToR and the Contractor's proposal, and

(ii) increasing the number of participants to the stakeholder meetings as well as covering travel and accommodations costs of the participants. In context of the above, this amendment to the original ToR details the additional work and associated costs in order to make the additional funds available to the Contractor.

This amendment is based on the Contractor's draft proposal titled "Work demanded outside the requirements the contract – request for budget modification" and dated 19 October 2017.

[…]

Scope and Activities of the Proposed Contracted Services

The Contractor is expected to undertake the following activities in addition to the activities outlined in the ToR.

Activity 1: Feasibility study of both peri-urban and rural areas

This is an integration to Activity 1.5 of the original ToR whose scope of activities was limited to studying rural areas. However, as a result of the first anemometric analysis carried out, there are indications that potential for small wind turbines shall be significant not only in rural areas in South Benin, but in periurban areas as well. Thus through this activity the Contractor will evaluate the wind energy potential, including peri-urban areas. The Contractor will apply the tools and methods used in the previous part of the study.

[…]

Deliverables Activity 1: A further report section reporting the study on peri-urban areas (to be added into the feasibility study report)

Activity 2: Increasing the number of participants of stakeholder meetings, and covering transport/accommodation costs

This is an amendment to Activity 2.3 in the original ToR. The original ToR includes two stakeholder meetings with 20 participants - the first of two days, the second of one day. The proposal developed by the Contractor budgeted for this amount of participants without including transport and accommodation costs for them. During the implementation it was discussed and agreed among the counterparts, Contractor and the CTCN that the impact of the meetings could be meaningfully increased by doubling the number of participants from 20 to 40, and also inviting participants from rural and peri-urban communities living in the coastal areas. This amendment details the additional funds necessary to cover the costs for up to 40 participants.

[…]

Deliverables Activity 2: Report on workshop with 40 participants

Activity 3: Gender assessment

In line with CTCN standard procedures a gender expert will perform a gender assessment to ensure that the role of women in the local project context is considered and understood. Based on an initial review of Country Gender Profiles, gender roles in households, the workforce and decision making, needs of women, as well as the cultural and legal situation, the expert will collate the relevant information in the feasibility study and formulate gender related actions for the action plan to develop the small wind sector in Benin. These actions will aim to ensure the integration of women and propose targeted gender activities. The expert will furthermore define gender outcomes and indicators for monitoring and evaluation. The gender expert will follow the 3-step approach outlined in the CTCN Gender Mainstreaming Tool for Response Plan Development.

[…]

Deliverables Activity 3: Two-page annex in the final report on gender assessment. Appropriate gender actions embedded in the action plan included in the final report

4 GENERAL TIME SCHEDULE AND ACTIVITY/DELIVERY PLAN

The new contract end date is 31 May 2018.

5 PERSONNEL IN THE FIELD (PROFESSIONAL EXPERIENCE AND QUALIFICATIONS)

The Contractor is expected to provide the following additional competencies:

- •Experience with and understanding of gender issues and the role of women in the local context

Working experience in Benin and West Africa is preferred for all of the above items. Furthermore, having national Beninese experts as part of the implementation team is required. The CVs of the respective experts assigned to this assignment by the Contractor must be provided.

6 LANGUAGE REQUIREMENTS

The language requirements remain unaffected by this amendment.