Renewable Energy Education: Gendered-Design and Innovation in the Context of Small Island Economy

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Abstract

Small island states still rely significantly on imported fossil fuels in spite of their potential for renewable energy, particularly from the sun, wind, biomass and ocean energy. These islands are negligible contributors to global greenhouse gas emissions but they are the most vulnerable to climate change. This paper is based on research conducted in the Republic of Mauritius to evaluate the integration of gender issues in the design and innovation of renewable energy systems for local context, an important issue to be addressed towards renewable energy transition in small island economies. The focus is on the household sector where both gender-considerations and the scope for achieving Sustainable Development Goals through education are significant. A case-study based on the design of a small vertical-axis wind turbine for use in the household sector is looked into with an attempt to integrate gender considerations along with computational simulation conducted on a prototype typical of those implemented in hybrid renewable energy system combining photovoltaic and wind generation, with or without storage.

Keywords: Renewable Energy, Education, Gender, Small Islands, Design, Wind, Behavior, Mauritius

1. Introduction

Use of electricity, including the supply of renewable power, contributes to the Sustainable Development Goals (SDG), namely SDG 7 on Affordable and Clean Energy, SDG 5 on Gender Equality and SDG 13 on Climate Action. As per Fathallah and Pyakurel (2020), the literature reveals a gap in terms of rigorous empirical studies to better understand gendered impacts of energy, thus a need of identifying innovative methods of integrating renewable energy, in particular, in educational programmes such as those for engineering studies. Osunmuyiwa and Ahlborg (2020) discuss the knowledge gaps with reference to gender-sensitive designs towards promoting equal opportunity. They identify the overlapping areas covering electricity, entrepreneurship and gender and highlight the opportunities related to delocalized local energy systems with renewable energy implementation. In the context of small island economies which are most vulnerable to climate change and also are highly dependent on imported fossil fuels, the Republic of Mauritius being an example, consideration of gender issues in the design of sustainable energy systems is an area of explorative research that is of high relevance.

In 2019, in the 'Renewable Energy Roadmap 2030 for the Electricity Sector' developed by the Ministry of Energy and Public Utilities of the Republic of Mauritius, a pathway to achieve 35% of renewable energy in the electricity mix was set for 2025 (MEPU, 2019). In 2021, in the Government Budget Speech 2021-2022, this target has been upscaled to 60% of renewable energy by 2030 (MEPU, 2022). The current figure is 22% for the share of renewable energy in the electricity mix. The total installed capacity is about 700 MW and the annual consumption about 3000 GWh, with 78% being derived from imported coal and fuel oil (SM, 2022). Yet the potential of solar, wind, biomass and ocean energy is significant (MEPU, 2022).

The objective of this research is to determine how the integration of gender issues in the design and innovation of renewable energy systems can promote implementation of renewable energy. The scope relates to small islands, particularly the case of islands of Mauritius (about 2000 km^2) and Rodrigues (about 100 km^2), forming part of the Republic of Mauritius. The focus is on the household sector where the potential of sustainable energy promotion through education is targeted by means of behavioral change as well as renewable technology introduction.

2. Methodology

The energy sector has largely been dominated by men. The participation of women is key to ensure that everyone benefits from and is part of any energy transition. For a successful transition, a change is needed from the past with an inclusive approach. In Mauritius in 1990, women represented 30.4% of the labour force while in 2020, the figure has risen to 39% (SM, 2022); but currently there are no statistics specifically for the energy sector. At the same time, women continue their conventional role within the family as the average time spent on household work and care of family persons per day is 3.6 hours for females compared to 1.8 hours for male. Women-headed households are also significantly on the increase (SM, 2019).

According to IRENA (2019) report on Renewable Energy: A Gender Perspective, women have been usually

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underrepresented in the energy sector. Major designs of renewable energy systems, including wind turbines and solar panels, are generally assumed to be gender-neutral. But this assumption can be challenged as it is more likely that, in fact, gender issues were not even thought of in the design process. This represents a major barrier for women to enter and advance in the energy sector. In order to promote women as an active player in the energy sector, gender-based energy considerations are also important at micro level, for instance in households (Fathallah and Pyakurel, 2020). Information on behaviors, practices, priorities, and constraints in relation to energy must be systematically collected and analysed before integration in design or in policy-making (IRENA, 2019).

In the conclusions of a United Nations Development Programme report for Mauritius, (UNDP Mauritius, 2015) on Gender Assessment, it is stated that there is a need for gender-disaggregated data and indicators to establish a baseline in which to measure improvements and identify areas of focus. This holistic approach to consider the behavioral aspects of agents in relation to energy is the essence to guide the development of gender-based systems –the focus of the present study. Gender matters for the production of energy as well as for the management of renewable energy systems, but there is a lack of empirical studies on how it matters, what the consequences are and what the solutions are. This study focuses on defining tools to collect and analyze gender-disaggregated data in a specific context and investigate how people use, save and think about energy with an objective to identify gendered elements which will become the core components of the educational and innovation process to design renewable energy systems. A case-study for small-scale vertical-axis wind turbines for domestic use with particular reference to a small-island economy like the islands Mauritius and Rodrigues is considered.

Interlinked with the design aspect, this research thus also investigates gender-based energy practices and behaviors. Gender considerations have long been overlooked and omitted as a factor for energy production and consumption. Clancy & Roehr (2003) stated that there is a lack of sex-disaggregated data on domestic energy-related attitudes and practices. Gender-disaggregated data on how people interact with energy seems to be an important piece of the sustainable transitions puzzle. It is evident from available data that men and women have different consumption patterns (Räty & Carlsson-Kanyama, 2010). Dym et al. (2003) noted that technologies specifically employed by women have mostly been designed without considerations for women. This, in any case, does not mean that such technologies should exclusively be designed for women or by women. A proper design approach should consider several parameters, including gender, cultures, religions, disabilities and socio-economic standings, all throughout the design process. Several of these parameters are inter-related. Conceived as such, the design would meet the needs of a wider range of people but it is complex to seek all-around satisfaction. Gender differences, however, need to be considered and analyzed during the project cycle as a matter of ethical principle in view on ensuring inclusiveness and equity.

The first objective of this study, which was to understand gender-based energy behaviors, was accomplished by conducting a two-level survey. Level 1 survey was comparatively more general and was performed across the Republic of Mauritius and included the island of Rodrigues. Level 2 survey, on the other hand, was relatively more detailed and particularly focused on regions where a low response rate was recorded from Level 1 survey. The need for a bottom-up approach engaging the population, in particular household women, was largely satisfied by the conduct of these elaborate surveys in a two-tier approach.

In Mauritius, there is a single grid network provider and there are about 400,000 households connected to the grid. Using the sample size calculator and applying a confidence level of 95% and 5% margin errors, a sample size of 384 is identified for the survey. Questionnaires were designed to target households. Households with one specific gender was not a requirement as gender-disaggregation refers to data. The conventional definition of gender limited to two main genders was retained.

Before starting with the surveys, in-depth focus group discussions were held with representatives of women organizations, and stakeholders. The outcome was used to design the questionnaire with due recognition of the importance and role of women. Reference to the literature and use of proper research methodologies were also important to ensure relevance and statistical significance for the surveys.

The survey questions were devised with clear objectives in English and in Creole to ensure understanding. Creole is spoken widely as it is the national language in the Republic of Mauritius and is very much like French.

2.1 Level 1 survey – July 2021

Level 1 survey contained a total of 20 questions which were split as follows:

- Questions on respondent's demography including family income and level of education. - 9 questions

- Respondents 'Opinion on wind turbines for households'. They were required to advise how important aesthetics of the equipment was for them and did they consider it as a danger. - 7 questions
- Respondents 'Opinion on energy usage'. Last question invited respondents to write their views on the subject. – 4 questions

Survey questionnaires were issued online in view of the pandemic situation. After receiving 121 responses online over 2 weeks, incoming responses slowed down. This could be due to the social context related to the pandemic where such surveys are secondary concerns with several families struck by health, economic and social problems. Some 95 mail solicitations and reminders remained unanswered. Decision was taken to start distributing hard copies of the questionnaires as permitted during the less strict pandemic restrictions later introduced. 300 copies were made. The questionnaires were distributed randomly to people from all walks of life and different districts in Mauritius. The region, location and streets were used as the random component to choose the respondents. The randomness was later checked to tally with the requirements for statistical significance.

A total of 392 responses were secured, including the online ones. It has been assumed that online and direct responses are not any different.

2.2 Level 2 - longer questionnaires addressing specific issues – November 2021

Level 2 survey contained a total of 31 questions which were split as follows:

- Questions on respondent's demography including family income, level of education, electricity bill details and any renewable energy equipment currently in use in their house. - 11 questions
- Respondent's views on renewable energy in households. They were required to advise whether food cooked using solar cookers was of any interest and which equipment in their house they would like to power through renewable energy. - 3 questions
- Respondents views on 'Energy saving culture'. Responses to this section was an eye-opener as it showed a sharp contrast about energy saving attitudes when it concerns a person's home electricity bill as compared to indifference to energy wastage at their work place. – 3 questions
- Questions on daily activities involving electricity at home. The responses have shown that households remain a non-negligible energy consumer even during working hours. – 4 questions
- Opinions on wind turbines for households. – 3 questions
- Opinions on Energy Management. Respondents were required to advise what changes they were ready to make in their lives to reduce their energy consumption. – 4 questions
- Respondents were required to provide their vision of the future of energy. Majority of Respondents were favorable to the introduction of renewable energy in their households provided government subsidy is available. A general optimism for the future of renewable energy was noted but at the same time most respondents considered that the cost of electricity will continue to increase. – 3 questions

Level 2 survey favored regions from where a low response was noted under Level 1 survey. For example, more questionnaires were sent to Black-River region in the west of Mauritius. The reason for this is to ensure that the low response is better understood. In no way, other regions were left out in Level 2 or the statistical significance was compromised.

Level 1 and Level 2 survey received a total of 467 responses. Appendix 1 shows the response details per district over the map of the Island of Mauritius. The Statistics Mauritius, 2020, Digest of Demographic Statistics per district are compared against the survey statistics. In analyzing the data to ensure a suitable representation, the total number of respondents were also compared to actual number of households per district, urban and rural, and age group.

In the course of the surveys, with due respect to confidentiality and non-disclosure requirements, historical data was collected on actual practices, electricity bills and daily activities. It is good to note that the legislation in Mauritius does not allow the utility provider to share consumer information with third parties.

The data analysis concentrated in separating and comparing males and females using statistical methods, testing using a reasonable degree of significance (5%). Statistical analysis included regression (logistic regression) to fully model the behavior of respondents taking into account their characteristics.

3. Findings

Key findings from the survey are as follows:

a) Solar water heaters were the most common type of renewable energy used at household level. From the survey, 56% of respondents stated that they had solar water heaters at home. As per the last Household Budget Survey conducted in 2017 when the total number of households was 368,400, 31.9% of households were equipped with a solar water heater. Five years later, with the increase in the number of households by around 10% and a general increase in average household income, the corresponding figure for households equipped with solar water heaters is expected to have increased. However, this progression may have been negatively impacted by the 2020-2021 pandemic. Upcoming Household surveys by Statistics Mauritius could confirm the tendency.

From this survey, it was interesting to observe the percentages within the various income group respondents who owned solar water heaters (SWH):

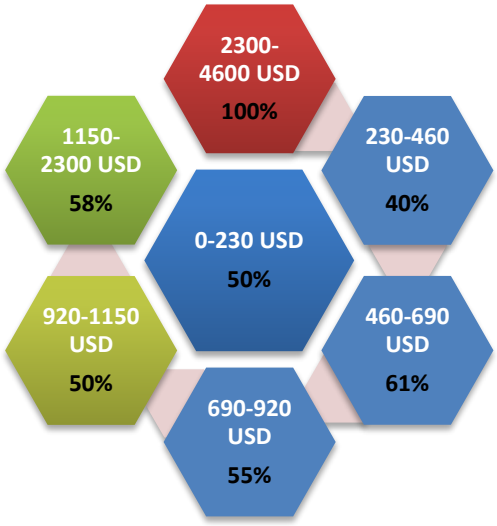

Figure 1 – % within the different income groups owning SWHs (1 MUR=0.023USD)

The percentages remain promising even within the low income groups (0-920USD), thus showing a good interest for solar water heater government subsidies offered for this income group.

59% of respondents who own solar water heaters are University educated.

b) Respondents showed interest in decreasing their electricity bills by introducing renewable energy in their homes. A strong interest of persons below 40 years of age was noted, equally shared by men and women. As to which appliance the respondents considered a priority in using renewable energy, 60% stated that it would be the refrigerator. 42% of respondents choosing refrigerators were women whilst 58% were men.

c) The responses received to the question "What is your opinion on renewable energy for households?" is evaluated below by comparing Mauritius/Rodrigues and women/men.

Mauritius Island

85% of respondents believe that with energy management measures, renewable energy can bring energy autonomy in households. 64% of the persons who hold this belief are below the age of 40. Within this age group, this optimism is held by 62% females and 38% males.

Analyzing further the 62% optimistic female respondents who are below the age of 40, it is noted that the majority (56%) are not married i.e. they are generally still living with their parents.

Looking at all age groups, 51% of the respondents who believe in Energy Management are university educated. Thus positive views about energy management is equally shared by university educated and non-university educated respondents.

From monthly family income perspective, the outcome is as follows:

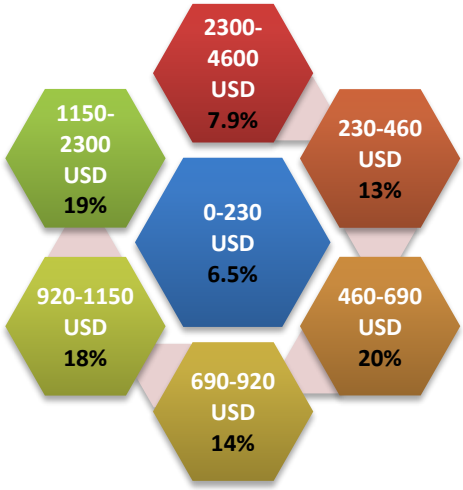

Figure 2 - family income vs. Energy Management

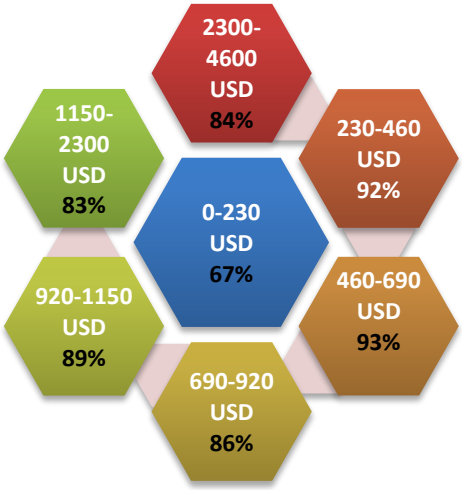

Figure 3 - % within the different income groups believing in EM

The highest optimism is noted within the 460-690 USD income group.

57% of those believing in Energy Management were women and 42% were men, i.e. women were found to be more optimistic than men.

Rodrigues Island

96% of respondents believe that '*With energy management measures, renewable energy could bring energy autonomy in households*'. 57.7% of those believing in the future of Energy Management were women and 42% were men, i.e. women were found to be more optimistic than men.

Thus, general optimism in this matter was more prevalent in Rodrigues (96%) than in Mauritius (85%).

d) Questions 13 and 14 of the questionnaire read as follows:

"13. Do you think these wind turbines could help generate electricity for households?
14. Do you think these wind turbines may pose problems or represent any danger in residential areas, such as on roof-tops?"

From responses received for questions 13 and 14 of the questionnaire, 85% of respondents believed that a vertical axis wind turbine could contribute to the electricity of households and more than 57% considered that wind turbines represented a danger on roof-tops. For those who were positive about having a wind turbine, this opinion was equally shared between males and females.

The findings from the present survey showed that the respondents aged between 41 to 60 years old were 11 times more optimist about such wind turbines than those aged beyond 61 years old. However, the latter age group might be under-represented in the survey. Age group might be a more relevant parameter to consider than gender.

A high share of respondents, 43%, gave importance to the noise level from wind turbines while 25% considered the appearance as important. Figure 4 illustrates the share and breakdown of respondents who were 'Neutral' as to the appearance and noise aspects of small-scale wind turbines. Thus noise was given slightly more importance than appearance.

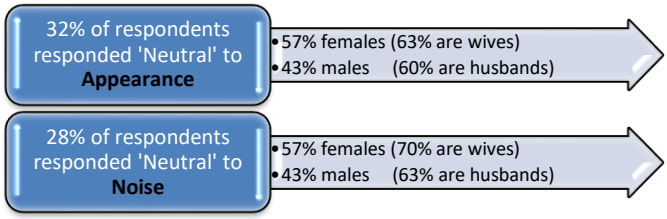

Fig. 4: Share and breakdown of respondents with neutral views on the appearance and noise level of wind turbines

e) The Level 2 questionnaire contained the following series of questions concerning a small vertical axis wind turbine for households. An image with indicative dimensions was provided, questions 22 to 24 of the survey.

Table 1 – Questions 22 to 24 - Wind turbine for households

Question 22 - Would you support wind turbine development for households as a source renewable energy?	
Question 23 - Do you consider your house a good place for installing a small wind turbine on the roof? A vertical axis wind turbine as in the picture below can operate and produce energy under low wind conditions.	
Question 24 - For a small vertical axis wind turbine as in the picture, would you prefer to have it on the roof of your house or on a separate structure? The dimensions are indicative only.	

Figure 5 demonstrates a breakdown of respondents who considered installing a small axis wind turbine at home.

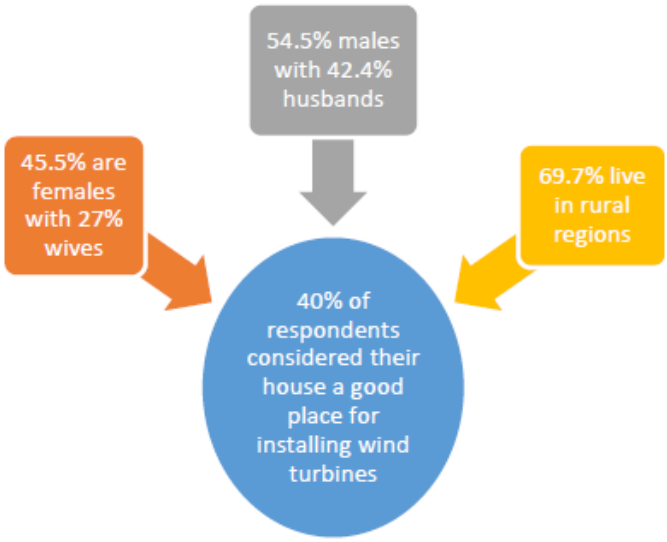

Fig.5: Breakdown of respondents considering installing small wind turbines at home-Question 23

As per Statistics Mauritius Census 2022, 94.8% of houses in Mauritius have a concrete roof. From the same census, it is reported that separate houses dominate. Separate buildings, that is buildings made up of only one housing unit, dominate among residential and partly residential buildings, and comprised around 77.8% of such buildings, compared to 76.7% in 2011. With that perspective, a separate question concerning preference for installation of small axis wind turbine was included.

Figure 6 demonstrates a breakdown of respondents who considered the possibilities proposed for installing the small axis wind turbines.

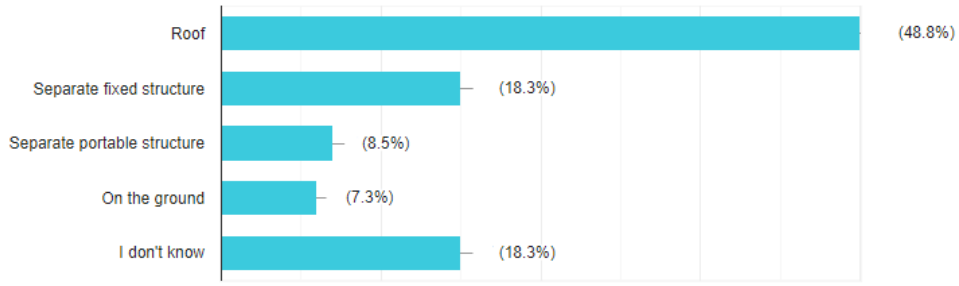

Fig.6: Breakdown of respondents considering installing small wind turbines at home-Question 24

Out of the 49% who opted for the roof, 58% are males and 43% are females. International Energy Agency & Council on Energy, Environment and Water (2019) stated that a lack of safety and security at rooftop solar project sites could discourage women from undertaking work in male-dominated positions. A safe access to the roof may contribute in reversing the above findings.

f) Two worldwide studies carried out by IRENA, International Renewable Energy Agency, were reviewed to identify relevant gender issues:

- IRENA (2019), Renewable Energy: A Gender Perspective. IRENA, Abu Dhabi.
- IRENA (2020), *Wind Energy: A Gender Perspective.* IRENA, Abu Dhabi.

Both studies, have one point in common. 'Perception of gender roles' and 'Cultural and social norms' have been reported by women around the world as an important barrier to the gender equality in the field of renewable energy. It is also stated that because of prevailing views of women's abilities, women continue to have a limited presence in these fields.

In this survey, in spite of 91% of female respondents agree that '*With energy management measures, Renewable energy can bring energy autonomy in households*', only 51% of women respondents were agreeable to cook rice, pulses and other food items using solar cookers.

g) Respondents were required to provide their opinion on the question of whether males or females are more sensitive to energy management in households. The response received are:

Table 2 – Which gender is most sensitive to energy saving?

Responses	Females are more sensitive	Males are more sensitive	Gender does not matter
Total	34.4%	18.1%	44.6%

The majority of respondents have stated that Gender does not matter. For the 55.4% respondents who have responded that gender matters, 79% of females are University educated as compared to only 33% of males who are university educated.

As per Davis (2022), women are more likely to perceive gender inequality than men. It would appear that education at school level in Mauritius is not contributing in bringing gender inequalities to the attention of female students. This may be the result of the fact that at school level, the majority of teachers are females, 79% at primary level and 63% at secondary level (Statistics in Mauritius, A Gender Approach 2018). However, at tertiary level, there are only 41% of female academic staffs (UNESCO Institute for Statistics, uis.unesco.org, Data as of September 2021, https://data.worldbank.org/indicator/SE.TER.TCHR.FE.ZS?locations=MU). This may explain the high contrast in gender inequality consciousness between University educated females and males.

Out of the 48.6% females who have responded that gender does not matter, 46% are wives. And out of the 51.4% males who have responded that gender does not matter, 57% are husbands.

Out of the 34.4% who chose females as being most sensitive to energy saving, only 23% are males. Similarly for the 18.1% who chose males as being most sensitive to energy saving, only 25.4% are females. The percentages choosing the opposite gender are almost same.

Generally studies have qualified females as being more sensitive to energy management in households. As per a research carried out by Isnin et al. (2018) for Institute of Electrical and Electronics Engineers, a strong relationship was established between females and intention for energy conservation behavior. It was concluded that policy makers and government may need to create energy efficiency programs which involve women due to their influence on their households' affair.

This survey is showing a more balanced outcome. Males and females are showing equal sensitivity to energy saving by stating as a majority that gender does not matter. It may be considered that qualifying females as being more sensitive to Energy Saving may be just a perception held by females and not shared by males.

h) The computational modelling of a small-scale vertical axis wind turbine (VAWT) for household use in the local environment in Mauritius was a case-study investigated, with possible hybrid use along with solar photovoltaics, with and without battery storage. The possible integration of gender issues in the design process was looked into. A literature review conducted by Al-Kayiem et al. (2016) described the relevant parameters that need to be considered while designing the Savonius wind turbine which is the preferred type for conditions identified in the local context. It suggested that a two-bladed VAWT performed better that a three-bladed one. The considered Savonius wind turbine had a turbine diameter of 400 mm, a blade diameter of 230 mm and a height of 400 mm (Aymane 2017, Utomo et al, 2018). A two-bladed S-shaped rotor with one stage was considered.

i) Figure 7 shows the variation of angular velocity with time to reach steady state for different wind speeds using Ansys Fluent software. It was therefore deduced that velocities of less than 2 m/s should be avoided to avoid long stabilisation time. The same result is confirmed in Figure 8 showing variation with tip speed ratio.

j) Wind speeds of 3 m/s, or better between 4 and 5 m/s, provide the required conditions for steady operation whilst ensuring efficiency, hence, better cost feasibility. The next plots refer to 5 m/s simulations.

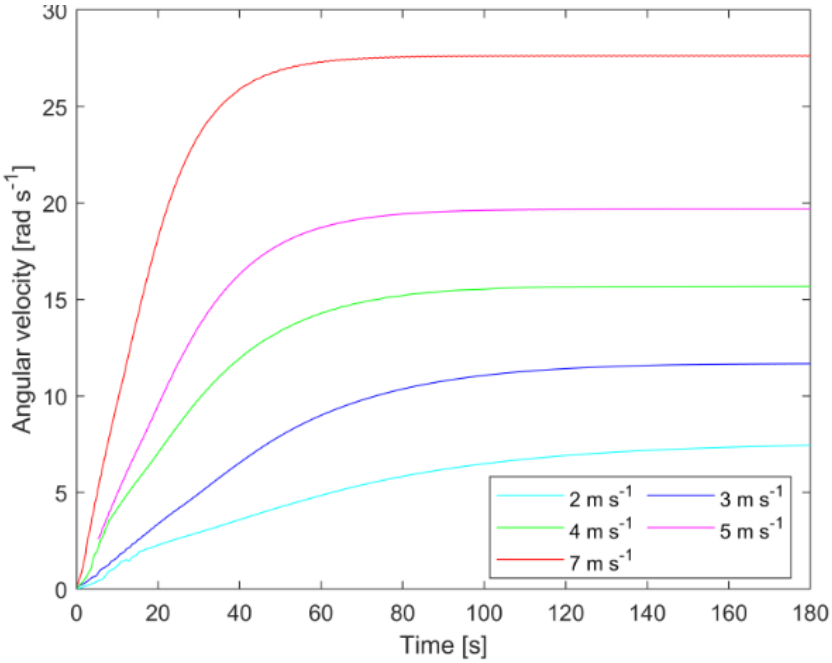

Figure 7. Variation of angular velocity with time for different wind speeds

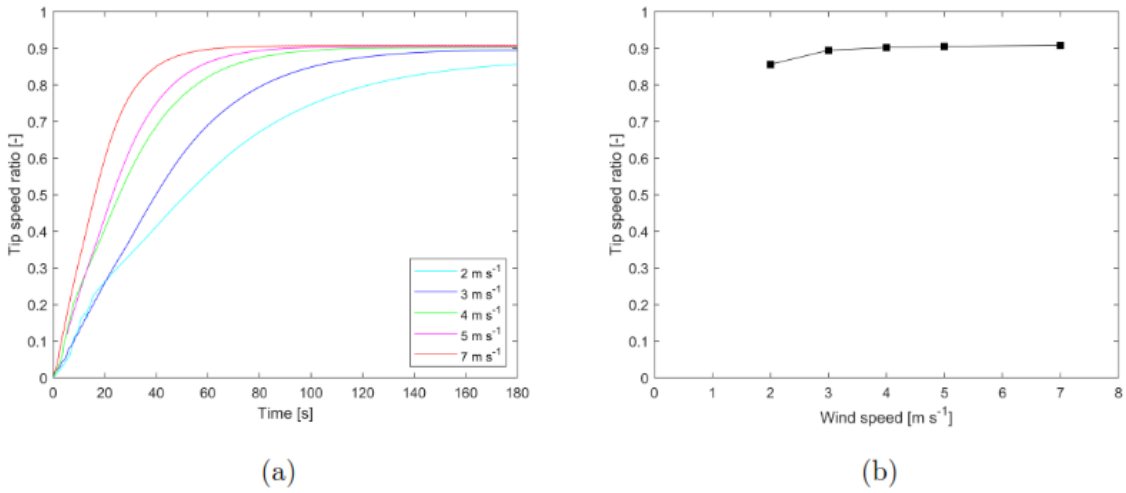

Figure 8. Variation of tip speed with (a) time and (b) wind speed for stable condition.

k) Figure 9 illustrates the turbulence kinetic energy contour plots for the investigated wind turbine at a wind field of 5 m/s at angular positions of (a) 0°, (b) 90°, (c) 225° and (d) 315°. It is evident that the downstream conditions are important to be considered in design. This will need to be further investigated to reconcile with other considerations like space availability, for example if hybrid solar-wind systems are to be implemented (with or without storage).

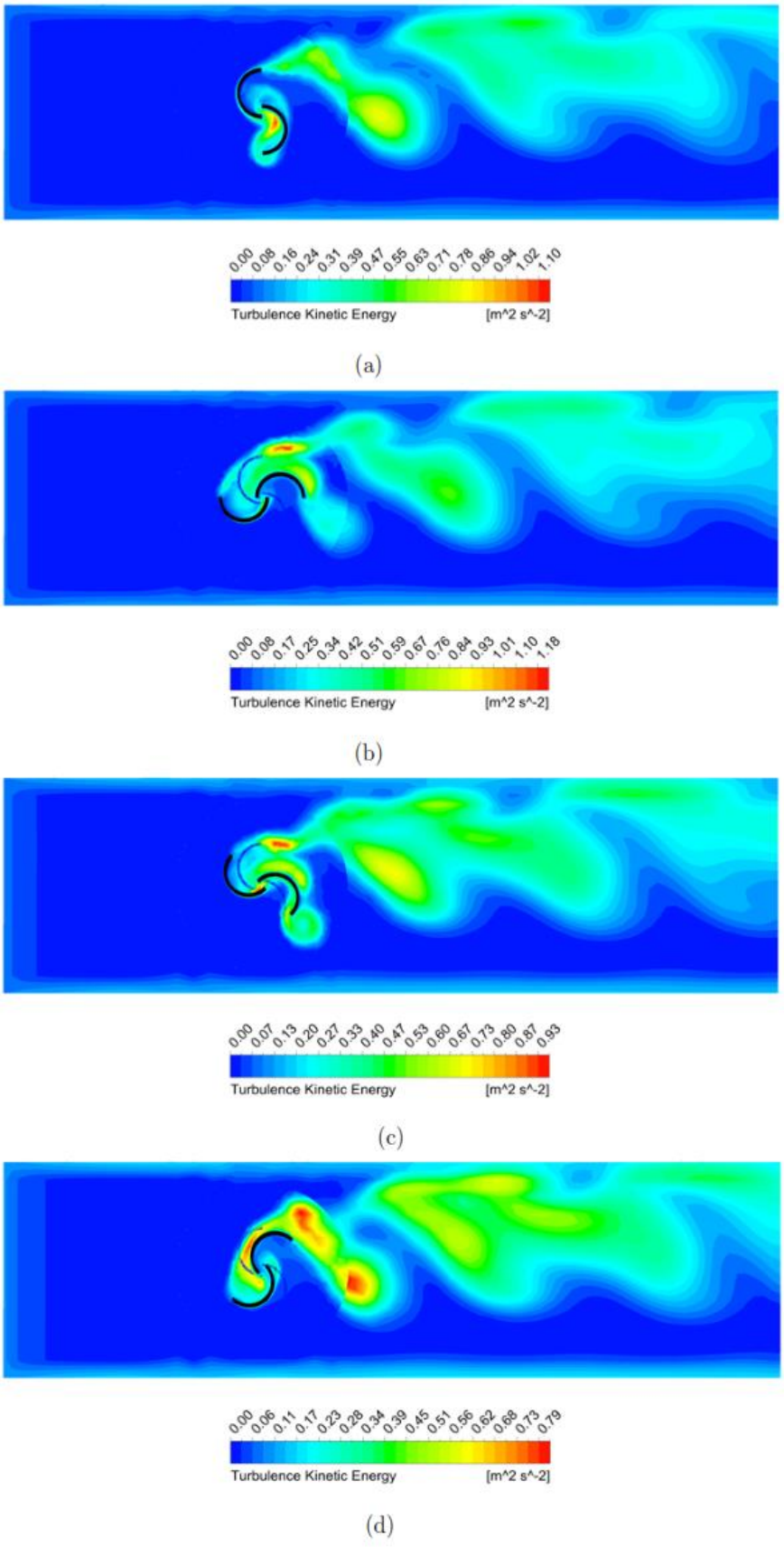

Figure 9. Turbulence kinetic energy contour at angular positions of

(a) 0°, (b) 90°, (c) 225° and (d) 315°.

4. Conclusions

The survey in Mauritius revealed that there is an interest at household level for powering specific household appliances, such as refrigerators, through a small-scale roof-top renewable energy system supported with or without battery. Along with existing deployment of solar water heaters which is progressing rapidly, small vertical axis wind turbines may also be introduced along with possibly solar photovoltaic panels.

The integration of gender considerations with respect to renewable energy systems, particular in the case-study for vertical axis wind turbine of Savonius type, rests upon the need to consider specific safety considerations related to women accessing the facilities. Gender considerations are hard to identify, particularly in relation to design with computational methods. For instance, the problem of noise is not more gender-sensitive for men than for women. Space considerations e.g whether on roof-top or on independent supporting structures, as well as the layout of different renewable and storage technologies are probably important to be addressed from a gender perspective. In comparison to men, women have shown a lower interest for the roof for the deployment of renewable energy systems at home, at least in the case of the survey conducted. The local context and building/housing structure combined with the personality traits of women are therefore two key drivers that designers must consider.

It is promising to note a strong engagement of middle income families.

5. Acknowledgements

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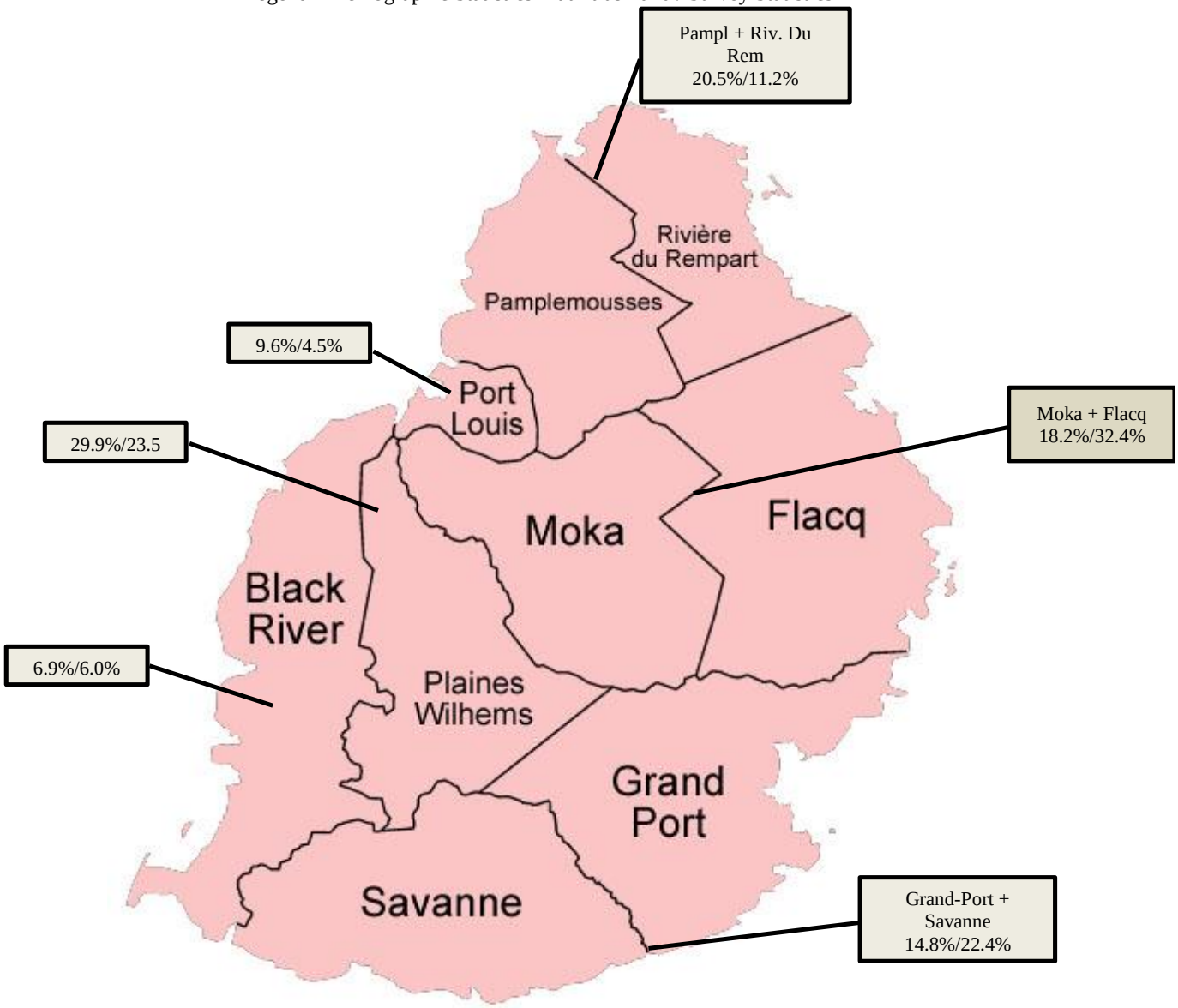
Appendix 1

Comparing Statistics Mauritius, 2020, Digest of Demographic Statistics per district
vs
Demographics of survey conducted

Legend – Demographic Statistics Mauritius 2020 / Survey Statistics



Data mapped on map of Mauritius

In the responses received, Pamplemousses/Riviere du Rempart and Port-Louis have been underrepresented while Moka/Flacq and Grand-Port/Savanne have been overrepresented.