Anders E. Larsen[1], Christian Bang[2], Christian Blücher[2], Mudassir Husaunndee[3], Vishwanath Jhummon[4], Hans Henrik Lindboe[2], Satyajeet Ramchurn[3], Pradeeo Soonarane[5]

MAURITIUS - A SUSTAINABLE ISLAND

- DEVELOPMENT OF FEED-IN-TARIFFS AND INCENTIVE SCHEMES FOR SMALL SCALE DISTRIBUTED GENERATORS IN MAURITIUS

[1] Ea Energy Analyses and Roskilde University, Denmark, phone +45 27 20 02 23,
e-mail: ael@eaea.dk, corresponding author
[2] Ea Energy Analyses, Copenhagen Denmark
[3] United Nations Development Programme, Mauritius
[4] Central Electricity Board, Mauritius
[5] Ministry of Public Utilities, Mauritius

Overview

The Government of Mauritius has a long-term vision of transforming Mauritius into a sustainable Island. One important element towards the achievement of this vision is to increase the country's renewable energy usage and thereby reducing dependence on fossil fuels. Democratisation of energy production is determined to be the way forward. A step in this direction is to devolve upon citizens the ability and motivation to produce electricity via small-scale distributed generation (SSDG), i.e. wind, photovoltaic and hydro installations below 50 kW.

Given that SSDG is more expensive per installed capacity than the existing much larger power plants, subsidies are needed so as to provide incentives to small independent power producers (SIPP), households and firms to invest in SSDG.

The paper presents the context, the theoretical considerations and the proposed incentive schemes to enable electricity production via SSDG.
Furthermore, the paper gives an update on the implementation in Mauritius of the proposed incentives.

Method

This paper (the project) is organized in the steps as shown in table 1 below.

Table 1. Overview of the questions to be answered and methodology adopted

Question to be answered	Adopted Methodology
Which incentive schemes are used in EU countries and developing countries?	Case studies / review of incentive schemes, investment subsidies and feed-in-tariffs (FIT), empirical and theoretical evidence.
What is the cost of the present power production?	Analysis of the cost of the present production cost of the incumbent producer, the Central Electricity Board (CEB).
What is the power production cost of SSDG (wind, photovoltaic and hydro below 50 kW)?	Literature review and interviews about investment cost and expected power production with the three different SSDG- technologies at various sites in Mauritius.
Which incentive scheme could be suggested based on this study?	With an assessment of the necessary subsidy level (i.e. the requested internal rate of return), distributional considerations concerning the localisation of the SSDG across the island, the necessary subsidies (FIT) can be assessed. A model to facilitate the calculations is developed

Supporting technological development

Technological development can be seen in the so-called linear perspective, given in table 2.

Table 2. Technological development in the so-called linear perspective

Phase/activity	Public support/finance
1. Basic research	Basic public funding research
2. Shaping a finding from the basic research, i.e. applied research	Mainly public but also private funding
3. Demonstration of technology	Public investment subsidies
4. Introduction in the market	Feed-in-tariffs/quota systems and perhaps investment subsidies
5. Mature technology that survives under market conditions	Market price for production

Table 2 illustrates a simple model for technological development that is often used as a reference for determining support and finance. However, the model is criticized for the naivety of the linearity. An opposite view based on empirical observations is that the technological development contains numerous loops between all of the 5 phases. The reason for presenting this linear perspective here is that the SSDG technologies in question for Mauritius are neither basic, nor applied research issues; they are rather “mature” technologies that can be improved further. In fact, they are technologies on the borderline between phase 4 and 5. Thus, from the perspective of technological development, the support scheme shall foster steady improvement in the efficiency of the technology.

Simply put: The main goal is to deploy SSDG rather than to develop new technologies.

FIT versus quota systems

The theoretical, and in particular, the empirical literature, advocate the utilisation of Feed-in Tariffs (FIT) as opposed to RPS/RO (Renewable Portfolio Standard / Renewable Obligation). FITs are opted for since they provide the required guarantees to support the market development of renewable energy technologies, specifically for electricity generation. The guarantees cover, amongst other aspects:

- grid access, by obligating utilities to accept the electricity
- price, by determining a tariff rate for each technology that sets a rate which enables profitable operation
- low investment risk, and thereby promoting access to all levels of producers
- equality, as all technologies are to receive a fair price, thus making investments in various SSDG profitable.

FIT-type systems are used in most European countries, as in various Indian states, in Ontario, Canada and in Latin America. Moreover, FIT systems have been proposed for implementation in countries as diverse as Australia, Mongolia and South Africa. The quota system is perhaps the most common alternative, and is used in countries such as the UK where it is known as a Renewable Obligation (RO), in the United states where it is referred to as a Renewable Portfolio Standards (RPS) or Renewable Electricity Standard (RES), and in Japan (also known as RPS). These systems set the amount of RE capacity to be generated, but not the price.

In its simplest version, however, quota systems generally offer a single price regardless of technology, which inevitably leads to the non-consideration of ‘less competitive’ technologies. Alternatively, if a quota system is instead established for each technology, the system will potentially lead to transparency concerns, as well as difficulties in determining the optimum number of players.

The Tendering system is a mechanism in which RE developers bid for power purchase agreements and/or access to a government-administered fund through a competitive bidding process. Regulators specify an amount of capacity or share of total electricity to be achieved, and possibly a maximum price per kWh. Most offshore wind farms have been built through tendering; however it is generally not used for SSDG. The probable reason for this is that tendering works inadequately with small scale installations, and in small and novel markets with only a few poorly informed potential investors.

A challenge with a FIT is to determine the correct tariff to ensure that political goals are achieved without unnecessary profits. If the tariffs are set too low investments will not materialize, and if too high, they can become a financial burden.

Features in Feed-in tariff

Having opted for a FIT, we then need to determine the specific aspects that will dictate how it operates in practice. Table 3 below lists a number of considerations that must be taken into account in this regard.

Table 3. Aspects of a FIT

a)	The amount/size of the FIT (MUR/kWh)
b)	Whether it is applicable only to new (not existing) capacity?
c)	A premium to an electricity market price or a fixed tariff (time of day/year)?
d)	Technology-specific tariffs, stepped tariff for each technology due to advantages of scale? Different level of support according to the sites?
e)	Based on net-metering (SSDG-production minus own consumption) or gross-metering (all the SSDG-production)
f)	Applicable to all consumer types? i.e Domestic, Commercial, Industrial or only Domestic or a quota for each category?
g)	Applicable to Greenfield installations also?
h)	Type of Tariff for Hybrid installations
i)	Purchase obligation
j)	Tariff reduction
k)	Frequency for setting the FIT (typical after 2- 3 years) and minimum period for the guaranteed payments (typical 4 – 25 years).
l)	Actors paying for the FIT, SSDG-surcharge or investment subsidy
m)	Application of Tax on income derived?

In the following section we will briefly comment on the above issues.

a) **The amount/size of the FIT.** The amount/size of the FIT will depend on how big an incentive the government wants to create. The incentive will depend on issues that are only to some extent visible to the government. One example is the concrete financing of the investment. Which conditions for loans can the potential SSDG operators get: e.g. interest rate and loan repayment period? Some SSDG will be installed partly for idealistic and altruistic reasons. Only experience can show if the FITs presented in this report are adequate, and therefore neither too high nor too low.

b) **Applicable only to new (not existing) capacity?** In the case of Mauritius, which has very few (if any) existing installations, the answer is most likely that the FIT could also be applicable to existing installations. If not, it is likely that deployment of new installations will be put on hold while potential investors wait for the new regulation to come into effect.

c) **Premium to an electricity market price or a fixed tariff (time of day/year)?** A FIT organized as a premium to a market price is irrelevant for Mauritius as there is no relevant market price. Instead of linking the FIT to the market price, the fixed FIT could differ according to time-of-day (base-or peak load), year or season (winter or summer). However, the technologies still have little or no possibility to “react” to a time-of-day-tariff. The production from SSDG technologies in question will vary according to the sun, the wind and the precipitation.

d) **Technology and size specific tariffs?** In order to reflect the varying electricity generation cost of the different technologies, technology specific tariff levels could be considered. The tariff levels should be determined in order to support the policy goals of the country. In a first phase, a reasonable interpretation of these goals could be to reach 200 installations within a few years. The tariffs should preferably give incentives to the most cost efficient installations, but should also allow other technologies to be supported for reasons of diversification, demonstration, local learning and cost-reductions. However, from the view of overall efficiency, it is important that the producer profit is highest for the most efficient designs and efficient locations.

   The production costs for each technology vary according to the plant size and local conditions, such as wind yield, solar radiation and water flow. In order to enable the exploitation of numerous sites and SSDG technologies, and at the same time keep the producers’ profits at a moderate level, stepped tariffs could be applied (for each technology).

e) **Based on net-metering or gross-metering?** Whether the payment shall be based on net-metering or gross-metering, is not material if the production is much larger than consumption. However, for small installations with load curves similar to the producer’s own consumption, the question of net-metering versus gross metering is very important. This could, for example, be the case for a small PV-installation, where there will potentially be limited export to the grid. This would result in the FIT being irrelevant, and thereby the intended incentive would no longer exist. It is particularly in such situations that gross-metering should be considered. In addition, in the case of hybrid systems gross measurement might be the only relevant metering in the long run.

f) **Applicable to all consumer types? i.e. Domestic, Commercial, Industrial or only Domestic or a quota for each category?** If the Feed-In Tariff is made open to all categories of customers (domestic, commercial, industrial, etc), it is likely that customers in the commercial and industrial categories will dominate the 200 installations thereby giving little opportunity for the general population to become SIPPs. As such, depending on the government objectives, opening the Feed-In Tariff to all categories of consumers may be contrary to government intentions.

g) **Applicable to Greenfield installations?** In order to promote consumers to produce and use renewable energy and reduce the temptation to produce exclusively for commercial purposes it is proposed that installations with expected production/consumption ratios of more than 3 be considered as Greenfield installations.[1]

h) **Type of Tariff for Hybrid installations.** It is suggested/envisaged that for simplicity and fairness reasons that the tariff for hybrid technologies should be defined by a weighted average based on installed capacity.

i) **Purchase obligation.** The FIT should be supplemented with a purchase obligation or an alternative organization ensuring that the SSDG generator can actually sell the electricity to the grid. A forecast obligation for SSDG generators to the system operator (CEB) can actually facilitate their integration.

j) **Tariff reduction.** A periodic (annual) reduction for new installations can provide incentives for further cost reductions and technology improvements. Ideally, such a reduction should reflect the potential technological learning curve for each technology. Such mechanisms are found in Germany. However, the link between the reduction and the learning curve is debatable, especially if we try to apply it in the context of a small scale novel market such as Mauritius.

k) **Minimum period for the guaranteed payments.** The selected feed-in-tariff needs to be stable over some years, and the tariffs for new installations should be revised every 2-3 years, to adjust for the expected downward trend in costs. All existing installations at the time of adjustment could continue according to their contract from date of approval. FITs should be guaranteed for a relatively long period (i.e., 20 years in Germany and 25 years in Spain).

l) **Actors paying for the FIT.** As far as financing the extra cost of SSDG is concerned, compared to traditional electricity production, the obvious possibilities are the public budget and/or the electricity bill. If the Government chooses to split the financing of the FIT (in the literature the SSDG surcharge) between the CEB and the Government, the split will depend on the avoided costs for the CEB both in the short and long run.

   The government can also decide that all FITs shall be financed by final electricity consumers through an additional charge in their electricity price. The overall evidence from Europe is that the SSDG surcharge (the extra payment for SSDG) is paid via the electricity bill and eventually differentiated for different consumer groups. Compared to the total electricity bill for the consumers, with 200 installations the SSDG-surcharge will be very modest. However, case studies from India and some SIDS point at more state involvement in e.g. subsidy schemes. That being said, many of the design decisions are intrinsically political, e.g. the trade-off between economic efficiency, income distribution and democratization of the energy sector.

m) **Application of Tax on income derived?** As per the Mauritius Revenue Authority (MRA), all incomes, besides a few already listed incomes, are taxable. The income gained by the SIPPs

[1] In such instances one recommendation could be to introduce special tariffs which are fixed at 15% below the ordinary FIT.

from the export of green power to the grid, is taxable as per present Regulations. Allowing this income to continue to be taxable is likely to discourage the population to invest in such SSDGs, as the initial investment itself is known to be quite substantial.[2]

Feed-in tariffs empirical evidence

Several countries have experience with various types of incentives, and feed-in tariffs (FIT) and investment subsidies have been found to be the most important. We have reviewed a broad range of subsidy systems regarding Small-Scale Wind, Photovoltaic and Hydro. Focus in the review was on experiences from Germany, Spain and India. In these countries, FITs are the dominant incentive.

Based on tariff information from more than 20 countries (mainly EU countries), the intervals for FITs related to technology are shown in Table 4.

Table 4. Feed-in tariffs[3]

Feed-in Tariffs Eur/kWh	**Wind**	**Hydro**	**PV**
Minimum	0.06 Slovakia	0.04 Austria	0.08 Estonia
Maximum	0.25 Italy	0.25 Italy	0.63

Source: [1] and [2].

The difference between the maximum and minimum is not only due to the fact that the schemes come from different countries, but mainly because the minimum FIT is typically for larger installations at good sites (e.g. for wind) whereas the max FIT is for small installations at poorer sites e.g. PV at a shady site. Since the size of the installations (SSDG) in Mauritius in this context are very small, the most relevant figures to look at in the table are the maximum figures. The guaranteed period for the FITs is normally between 10 and 25 years.

Subsidies

Technically speaking, the same economic incentive for potential investors can be created with a FIT as with investment subsidies. Without any uncertainty (related to actual SSDG-production) the potential investor will be indifferent between a net-present value over the investor´s time horizon of the yearly profit (FIT minus production cost), and a subsidy of the same size. There are however big differences in relation to the incentives given by a subsidy and a FIT.

It is desirable to give the potential investor:

a) incentives to choose an efficient installation
b) incentives for further improvement of the technology

[2] As such, to promote Green energy in Mauritius, an additional potential recommendation is the undertaking of a review of taxation rules involving taxation of revenue derived from the production of electricity from renewables.
[3] The FIT tariffs in the table are the minimum subsidy given to the SSDG installation - there can be other types of subsidies given together with the FIT.

c) incentives to maintain the investment (e.g. the PV-installation)

If the whole incentive is given via a FIT, the incentive is strong in relation to a), b) and c). This is because the remuneration of the investor is only given via the actual electricity production.

An investment subsidy alone, wither it be a percentage of the investment or a lump sum, will not give the same clear incentives in the right direction; it needs to be followed with quality standards, a quality control structure implying dedicated trained personnel and testing facilities that are very costly for the government, a maximum subsidy per installation, and an obligation to maintain the investment. There is evidence that supports the notion that investments created through an investment subsidy can give inflated purchase prices, are poorly kept and have far too low (in some cases no) production.

On the other hand, a very high FIT combined with net-measurement can also give undesirable and awkward incentives. Since the FIT will be higher than the purchase tariff, there will be a positive but not intended incentive for the SIPP to reduce the consumption of electricity. This could be considered an advantageous side-effect. However, the SSDG-producer would also have incentives to ask for extra meters, thus incurring costs for the CEB.

Taking the necessary investment comfort and possible strategic speculations in improved feed-in-tariffs in later periods into account, the supplementing of the feed-in-tariff with a moderate investment subsidy for installed capacity the first e.g. two years after the introduction of the feed-in-tariff could be considered. Great care should however be taken in relation to transparency and implementation when using subsidies as well as a FIT.

It is debatable whether the subsidy should only be eligible for domestic investors, thereby keeping the focus on the democratization of the grid. On the other hand, this could dramatically reduce the overall achievements and economic efficiency of the program.

Taking into account all of the above factors, we find that the entire, or major portion of, the incentive should be given via the FIT, as this gives more relevant incentives with fewer transactions.

Costs for the Central Electricity Board (CEB)

Based on information from the CEB (the incumbent producer), the total cost and the marginal cost per kWh for the latest three years are presented in table 5.

Table 5. Total cost per kWh and marginal cost per kWh including grid losses of 8.5%

Eur/kWh[4]	2007	2008	2009	Average
Marginal cost per kWh	0.07	0.09	0.06	0.08
Marginal cost thermal per kWh	0.07	0.10	0.07	0.08
Total cost per kWh	0.09	0.12	0.08	0.09
Total cost thermal per kWh	....	0.13	0.09	0.11

The marginal cost for the thermal power plant has been based on oil and other fuel usage and kWh generated for the period. Total cost includes all production costs e.g. labor, materials, administration, depreciation and others.

The marginal cost for all plants and the marginal cost from thermal power plants are both in rounded figures 0.08 EURO/kWh. The average total cost per kWh and the average total cost from thermal power plants are 0.09 EURO/kWh and 0.11 EURO/kWh respectively.

From a socio-economic perspective, to these costs could be added externalities e.g. emission of CO2 and security of supply. This analysis could however move us away from the focus here; since we would have to also discuss the complicated questions of the (marginal) cost of global warming and how much of this is presently internalized.

The purpose here however is to reflect on the rate structure of the CEB, and in particular to establish the avoided cost for the CEB if the CEB instead of producing, buys electricity from SSDGs. Therefore we will not address the social cost (externalities) further.

As for the avoided cost, it is often argued that buying the power from a third party reduces the investment cost for the incumbent producer (CEB). That is so, but if the accounts for CEB are accurate, the depreciation and the financial cost included in the account creates the financial basis for new investments. Therefore we assume that these costs are included in the total cost per kWh in Table 5.

Cost of SSDG

Table 6 shows the anticipated installation costs for SSDG installations in Mauritius. The costs are mainly based on experience from other countries and literature but also on local information and expectations. The micro wind prices are particularly uncertain. The real costs that will be experienced in Mauritius can prove to be lower or higher than shown in the table, depending on the strategies of promoters and local labor costs and skills. Based on experience from other countries the subsidy system itself and local competition between suppliers can affect the price level substantially. It should be noted that reported costs from different countries regarding PV vary substantially, with European prices found at the higher end.

[4] The figures in the table are in different price levels and should in principle be inflated/deflated to e.g. 2009 price level. However, due to uncertainty regarding the inflation factor for these concrete figures this has not been done. This would add an element of uncertainty to the data not needed for the analysis in question (with uncertainty assessing the avoided cost of CEB).

Table 6. Anticipated investment cost of SSDG in Mauritius, EURO/W. The cost model for micro SSDG hydro does not cover the smallest installation with any accuracy

Anticipated installation cost (EURO/W)	**Size in example**	**Wind**	**Hydro**	**PV**
Micro *(approx. 1 kW)*	1 kW	9.1[5]	.	6.5
Mini *(1 - 10 kW)*	5 kW	5.5	6.8	5.5
Small *(10 - 50 kW)*	30 kW	2.5	2.5	5.0

Wind

Via a desktop search, current prices for approximately 50 different wind turbines within the 0.1 kW to 50.0 kW have been identified. These prices were all converted to MUR/kW or MUR/W using the prevailing exchange rate of 44.6 MUR/Euro. Retailers were located in various countries, with the majority coming from the United States and the United Kingdom.

Information regarding what is included in the turbine price (towers, mounting equipment, grid connection hardware, control units, etc) varies greatly from one source to the next, and in many instances is extremely difficult to determine. It is apparent that there is an extremely large range in the prices and likely quality of these turbines. The very cheapest turbine prices are from sources that are questionable at best. There is a definite tendency in that data indicating that the per kW price decreases with the size of the turbine.

Prices per W range from 1-7 Euro, depending on what inputs are included. When looking at turbines that included many of the normally required components (inverter + tower), prices for the smaller turbines ranged from 2-7 Euro/W. In the few instances where it is certain that prices for all components required for grid connection were included, the price was roughly 6.5 Euro/W. All the above prices above are *without* delivery and installation costs.

In arriving at the figures displayed in table 6, delivery and installation costs were added to acquisition costs of roughly 6.5 Euro/W for the micro turbine, 4.5 Euro/W for the mini turbines, and 2.2 Euro/W for the small turbines.

Hydro

In Ogayar and Vidal (2009) there is a very careful analysis of the investment cost of SSHG. They analyse 4 types of turbines: Pelton, Francis, Kaplan and SemiKaplan.

Since the head on Mauritius are probably low there are reasons to focus on turbines optimized for low head. That is the case for the Kaplan (and SemiKaplan) turbine. The Kaplan turbines are widely used throughout the world for electrical power production. For comparison, the lowest head for a Pelton turbine is 100 meters, and for Francis 10 meters.

[5] It should be noted that a secondary analysis of micro, mini, and small wind turbine prices (see Annex II) revealed that total installation costs may be lower than depicted in table 6, particularly for the micro turbines.

Based on a number of previous studies, [3] establish investment cost functions for the different technologies and validate the functions with 22 SSHG-plants in Spain, France, Italy, Belgium, Portugal and Morocco.

The investment cost function for a Kaplan turbine in EUR/kW is:

33236kW (-058338) H (-0,113901)

and for a SemiKaplan:

19498kW (-058338) H (-0,113901).

Since the empirical evidence for very small hydro installations is not well established we have not included a figure in table 6.

PV

PV systems in small sizes is a well proven technology and a relatively standardized product with many suppliers worldwide. Several companies track the market and can deliver well documented information regarding price developments. In this work the pricetracking from www.solarbuzz.com was used as a main source for cost assessment. Solarbuzz has a monthly track of almost 1500 retail prices from 25 manufacturers, and has developed the service since 2001. According to this source the average retail price (for modules only) was around 4,2 EUR/W in Europe and 2,9 EUR/W in USA. The lowest prices were well below 2 EUR/W. In the report the lower prices were given more weight due to the current downwards price trend.

The production in kWh per kW is for wind assumed to be a function of the size of the turbine, thus reflecting the fact that very small windmills (1 kW) are often placed in locations with less wind. With a mean wind speed of 5 m/s a 1 kW turbine can produce app. 900 kWh/year.[6] We do not consider scale dependence for hydro (2214 kWh per kW) and PV (1202 kWh per kW).

Based on the installation cost in table 6 and the assumed production, with a 15 year time horizon, modest operation and maintenance cost and a 7.5 real rate of return we find the production cost as shown in table 7.

Table 7. Production costs for SSDG in Mauritius

Euro/kWh	**Wind**	**Hydro**	**PV**
Micro 1 kW	1.21	…..	0.63
Mini 5 kW	0.53	0.38	0.53
Small 30 kW	0.28	0.15	0.45

[6] It should be noted that numerous studies, including [4], [5] and [6] have all concluded that actual production has been less, sometimes significantly less, than anticipated. This is partly because the turbines have had lower power curves than manufacturers have promised, but the main reason is that wind resources often prove to be much lower than expected [2].

Table 7 shows the resulting calculated production costs of SSDG in Mauritius based on a range of assumptions. The actual production cost of the individual installation will of course vary depending on the quality and efficiency of the facility and O&M costs. Local conditions such as wind speed, flow of river, and shades covering direct sunlight have substantial influence on costs. Other factors are the precise financing (own funds, different types of loans, tax rules, etc.). Particularly the costs of micro and mini wind and of hydro power are quite uncertain and will vary substantially depending on local conditions.

Recommended feed-in-tariff

We suggest selecting feed-in-tariffs that cover the anticipated production costs until a total of 200 installations have been connected, or until a total of 2 MW is installed, whatever comes first over the next 2 years. For the sake of simplicity, we also suggest that only a few tariff levels are selected. We also recommend to not cover all costs for the smallest and thereby least cost-effective installations. If the public want to install such less effective facilities it can be considered reasonable that they cover a part of the cost themselves and/or accept a lower rate of return. When using net metering the actual income to cover the cost is difficult to predict. With net metering the resulting earnings from the SIPP will obviously depend on the production actually sold to the grid. If all the SSDG is consumed by the SIPP the feed in tariff is superfluous. Since the suggested FIT in Mauritius typically is much higher than the purchase price this creates an incentive to reduce the electricity consumption in order to increase earnings. In other words, the bigger the SSDG production the higher tariff you will get. If the feed-in-tariff is lower than the tariff for the SIPP´s own consumption the incentives goes the other way around. The average tariff the SIPP receives decreases when the production exceeds the own consumption.

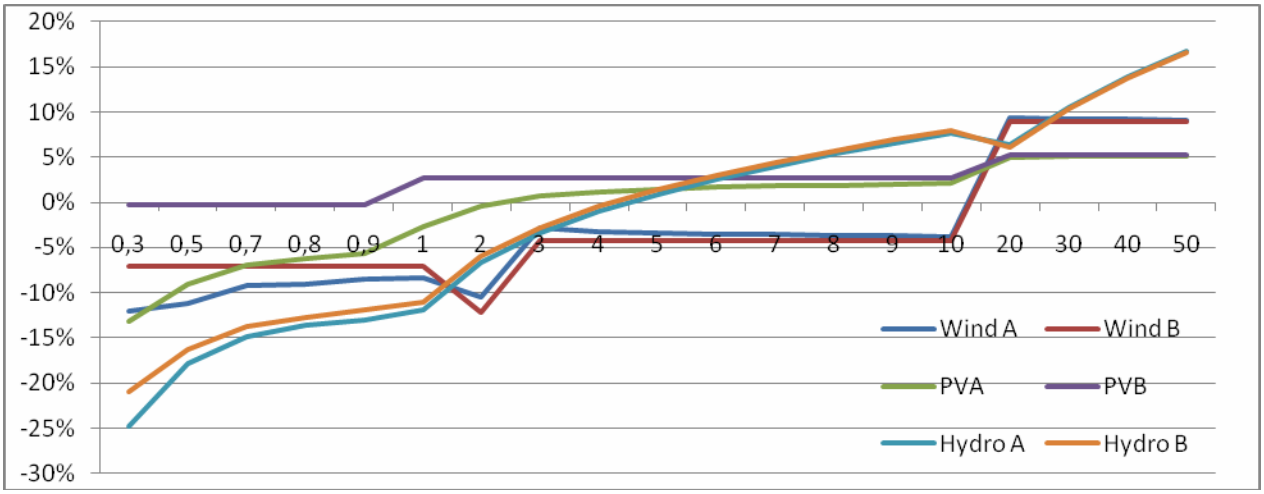
Table 8. Suggested feed-in tariffs to be agreed in contract between SSDG owner and CEB for 15 years

EURO/kWh	**Wind**	**Hydro**	**PV**
Micro 1 kW	0.50	0.38	0.63
Mini 5 kW	0.38	0.38	0.50
Small 30 kW	0.25	0.25	0.38

Source: [2].

With this suggested FIT we have analyzed the resulting IRR taking the available production and cost estimates into account. This is shown in the figure 1.

Fig. 1. The resulting IRR with the FIT suggested in table 8



Source: The Mauritius FIT- Model appendix 1.

Y – axis: Internal Rate of Return (this text will be moved to the figure)
X – axis: size of installation in kW.
A: net metering
B: gross metering

On the whole, we think that the incentives created by the simple FIT-scheme suggested are reasonable. For example, there is only limited economic incentive for very small installations. With gross metering PV comes out with an IRR around 0, whereas the IRR for very small versions of the wind and hydro are negative. There is a reasonable IRR for bigger installations, i.e. over 10 kW. This is defensible since that increases the overall cost efficiency of the program. That being said, other priorities (e.g. incentives for big versus small installations) could lead to other likewise reasonable FITs. Finally it should be mentioned that the investment function for hydro is not well validated for very small installations [3].

The implementation in Mauritius

Regarding the more technical question about gross versus net metering, there has been an agreement in favor of net metering. At the same time there is a consensus that this will give a very modest investment incentive for small SSDG that may result in the implementing of an investment subsidy for the small SSDG.

From a democratization perspective it has been decided that SSDG should be open to all types of consumers (e.g. also commercial and industrial consumers) and not limited to the residential sector as initially planned. There will however be a part of the assumed 2MW installed capacity (between 25 and 50%) that will be dedicated to the residential sector.

Regarding implementation status, the regulations are almost complete. It is expected that they will be published by August of 2010. There are quite a few suppliers/property developers/owners that are awaiting the finalization of the tariffs and are ready to participate in this new market in Mauritius.

From a practical perspective, the CEB (Central Electricity Board) is ready for technical implementation and will have a very close follow-up on actual installations.

Literature

1. Evaluation of different feed-in tariff design options – Best practice paper for the International Feed-In Cooperation 2nd edition, update by October 2008. A research project funded by the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Authors: Arne Klein, Benjamin Pfluger, Anne Held, Mario Ragwitz (Fraunhofer ISI), Gustav Resch, Thomas Faber (EEG).

2. Ea Energy Analyses (2010): Development of Feed-In Tariffs and Incentive Schemes for Small-Scale Distributed Generators in Mauritius. Copenhagen.

3. Ogyar B. and P.G. Vidal (2009): Cost determination of the electro-mechanical equipment of a small hydro power plant. Renewable Energy 34 (2009) 6-13.

4. Lawaetz (2009): Minivindmøllers Elproduktion, Henrik Lawaetz, Risø, Feb. 2009.

5. Mithraratne (2009): Roof-top wind turbines for microgeneration in urban houses in New Zealand, Nalanie Mithraratne, Landcare Reseach, New Zealand, March 2009.

6. Encraft (2009): The Warwick Wind Trails, Encraft 2009.

APPENDIX 1: MAURITIUS FIT-MODEL

This is a sheet designed to describe the revenue stream associated with installing and producing your own power via small scale energy production. Using wind, hydro or PV it calculates the installation cost, maintenance and production steams, and the needed feed-in tariff (FIT) to get a certain IRR. Two difference cases are calculated, netmetering (case A) and export (case B).

Case A Netmetering The only export to the grid is the surplus when the household needs have been covered.

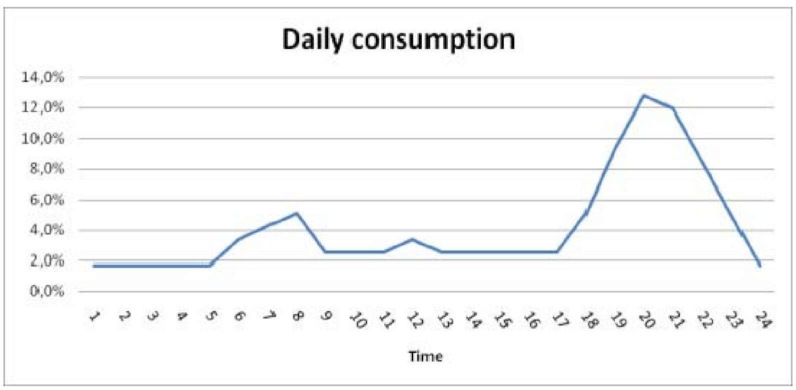
Case B Export Everything that is produced is exported to the grid.

INPUT:

Type **Consumption** (KWh/year)

The average Mauritius household uses 1977 kWh/year. The consumption is equally distributed over 365 days with daily consumption as depicted in the figure below:

Fig. 1. Consumption equally distributed over 365 days



To create a model, choose a **Source** and its **size** (in the green cells)

Consumer		
Consumption	1977,0	KWh/year
	Technology	Size
Source no.1	Hydro	30
Source no.2	PV Wind Hydro	0
Payback period		ars
intrest	0%	
Wanted IRR	15,0%	

Type **wanted FIT** to calculate what FIT is needed to reach this.

Other input: Actual FIT, CEB production costs.

OUTPUT:

The Model will output

- Total Production (per year and month)
  All power produced by installed (PV hydro Windmill)
- Total Export
  Case A
  Case B
- Total consumption
  Household power consumption both pr month and year)
- Total Income
  Case A (incl. steps down on monthly Progressive tariffs due to less import)
  Case B
- Yearly O&M
- Yearly annuity
  With interest of 3% over 15 years.

  IRR
  The interest that is earned over 15 year's period

  FIT for wanted IRR

  Saved CEB production costs

APPENDIX 2

Via a desktop search, current prices for approximately 50 different wind turbines within the 0.1 kW to 50.0 kW have been identified. These prices were all converted to MUR/kW or MUR/W using the prevailing exchange rate of 44.6 MUR/Euro. Retailers were located in various countries, with the majority coming from the United States and the United Kingdom. Information regarding what is included in the turbine price (towers, mounting equipment, grid connection hardware, control units, etc) varies greatly from one source to the next, and in many instances is extremely difficult to determine.

Methodology
Turbine prices were sorted into 5 groups according to turbine size:

- 0.1 – 1.0 kW
- Greater than 1.0 kW – 5.0 kW
- Greater than 5.0 kW – 10.0 kW
- Greater than 10.0 kW – 20.0 kW
- Greater than 20.0 kW – 50.0 kW

For each of the 3 group sizes there were then created sub-categories:

- Turbine only
- Turbine with inverter
- Turbine and inverter including lattice tower
- Turbine and inverter including monopole tower
- Turbine, inverter, and tower, including grid connection equipment

The idea behind this approach was to attempt to isolate what the additional tower and grid connection costs are. Due to lack of clarity in the product description, the placing of turbines into a particular category was not an exact science and involved some guess work.

Results
The results are shown below in two different graphs, the first shows all the turbines priced in MUR/kW. The second graph does the same, but splits the turbines up into the 5 size categories outlined above. Figure 1 clearly shows the tendency for a price increase as more components are added. Figure 2 meanwhile highlights the fact that smaller turbines have a higher per kW price than their larger counterparts.

Both figures highlight the large range in prices. Prices for the 0.1 – 1.0 kW category ranged from 28 – 350 MUR/W, for the 1.0 – 5.0 kW category from 18–300 MUR/W, for the 5.0 – 1.0 kW category from 45 – 100 MUR, and for the final two categories up to 50 kW from 55 to 156 MUR/W.

Another general observation is the rather steady price range for the larger turbines, and much wider range for the smaller turbines. Given the general tendency for prices to drop as the turbine becomes larger, the very small turbines with costs below that of larger turbines is very questionable.

Fig. 1. Specific investment for all turbines

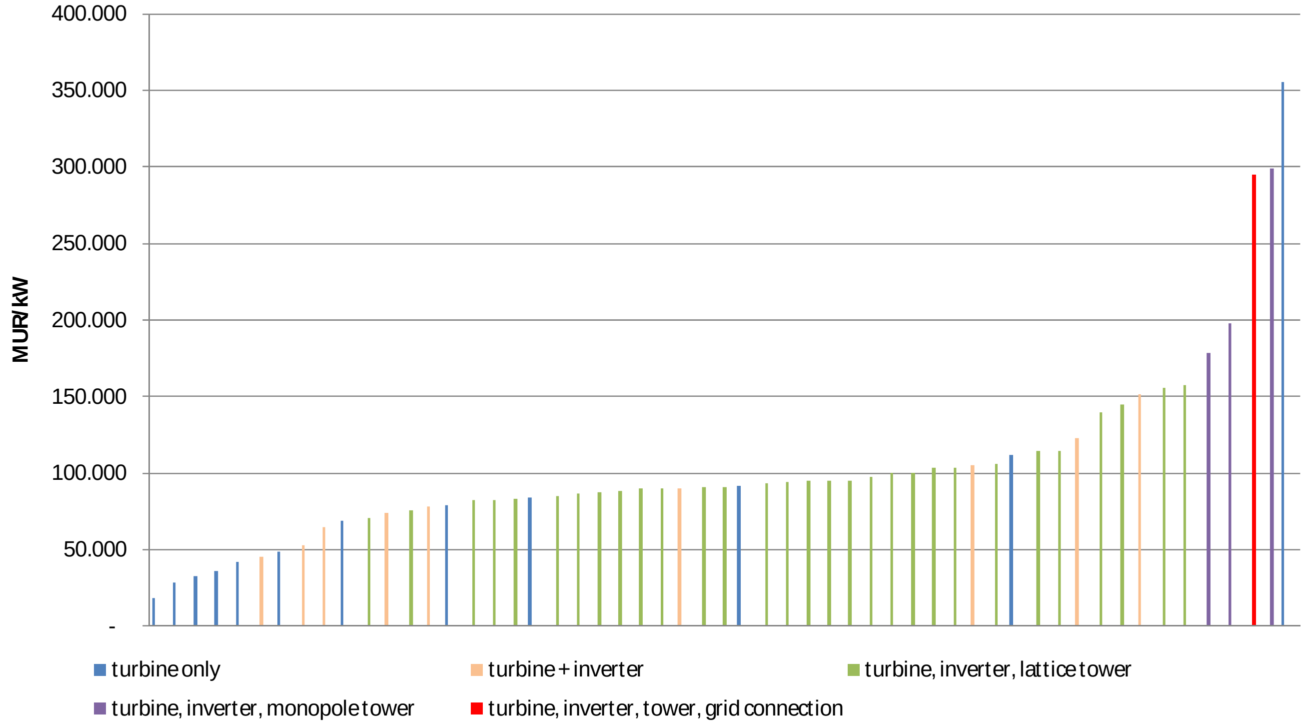
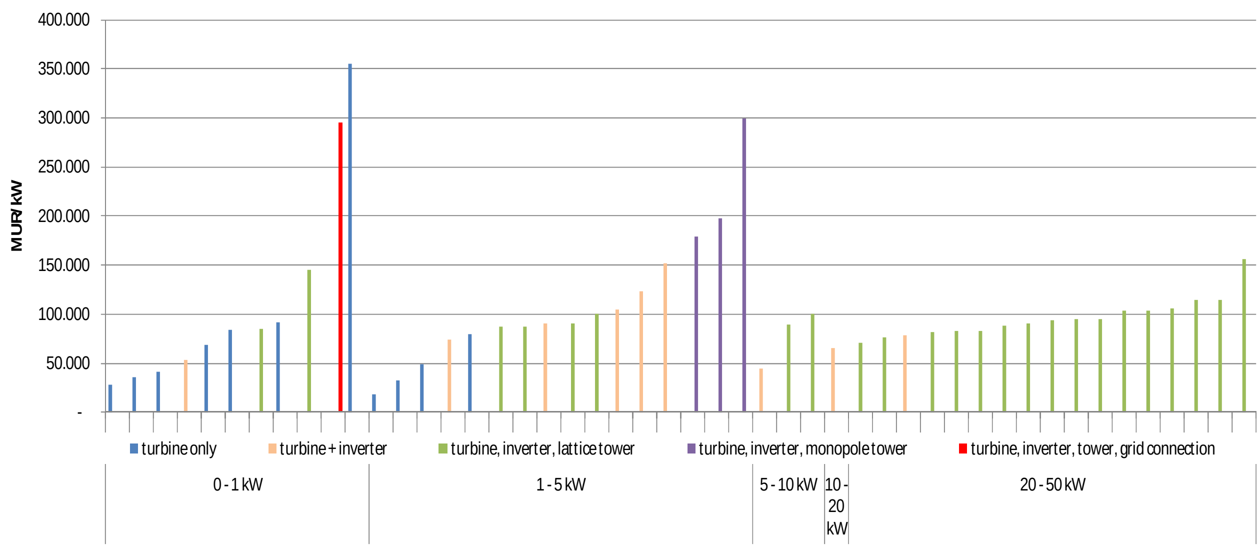


Fig. 2. Specific investment sorted by turbine size



Concerns

Extreme Price Variation: The massive range in prices raises serious doubts about the veracity of the turbine prices at the extreme low-end of the scale. If these are indeed the correct prices, and they are of reasonable quality, it begs the question of how all the other companies can possibly compete in the market.

Turbine Quality: It should be noted that some of the internet retailer sites with the cheapest turbines raised serious doubts about the quality of the product. For example, they explicitly stated that there were no product guarantees and all sales were final. In addition, very few independent product reviews were available, and those that were found were not very positive.

Hidden Costs: With many of the cheaper models it is doubtful that necessary items are included. If for example we take a look at the D400 Wind Generator[7], which is one of the few small turbines that details the price of various components, the price for the 0.4 kW turbine alone is 49,400 MUR, the control unit for grid connection is 25,200 MUR, the mounting bracket is 12,300 MUR, and the grid tie inverter option is 30,700 MUR. Thus on a per Watt basis the turbine costs anywhere from 188 to 295 MUR, depending on what options are included. On to this there are then the added costs of delivery and installation.

Quantity of Sources: While there is a reasonable sample size in terms of the amount of turbines, there are only 7 different retailers utilised. More retailers would raise the statistical strength of the above figures.

Conclusions

After a desktop search it is apparent that there is an extremely large range in the prices and likely quality of the mini turbines. The very cheapest turbine prices are from sources that are questionable at best. There is a definite tendency in that data indicating that the per kW price decreases with the size of the turbine.

Prices per W range from 50 – 350 MUR, depending on what inputs are included. When looking at turbines that included many of the normally required components (inverter + tower), prices for the smaller turbines ranged from 85 –350 MUR/W. In the few instances where it is certain that prices for all components required for grid connection were included, the price was roughly 300 MUR/W. All the above prices above are *without* delivery and installation costs.

In arriving at the figures displayed in table 6, delivery and installation costs were added to acquisition costs of roughly 300 MUR/W for the micro turbine, 200 MUR/W for the mini turbines, and 100 MUR/W for the small turbine.

[7] http://www.energyenv.co.uk/D400WindTurbine.asp