Net-billing for PV to support local economies on Caribbean islands

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Abstract

Very high solar radiation combined with very high conventional power generation costs favor the implementation of photovoltaic on Caribbean islands. To assure the revenues of potential investors and therefore to support the implementation a clear regulatory framework has to be created. Within this work a proper net-billing scheme is developed. Its feed-in tariff adds up to 18.5 US-cent/kWh at Capex of 2,500 USD/kW_p. Once this framework is implemented a huge market potential for local companies will arise. From distributors, over planning offices and installers to the utilities and investors and even local banks, everybody can profit from the increasing implementation of photovoltaic pushed by net-billing in the Caribbean. The market potential for local companies only is estimated to 1.5 billion USD overall by installing 3.0 GW in the Caribbean.

1 Introduction

Most of the Caribbean islands depend highly on fossil fuels, mostly diesel, for power generation [1]. Thus their power generation is very expensive and emits relatively much greenhouse gases. Renewable energies such as wind and solar power can reduce both, costs and emissions [2]. Especially photovoltaic (PV) is easy to install on different scales and solar power generation fits very good to the daily demand profile of most Caribbean islands with a demand peak around noon-time. On most of the Caribbean islands renewable energies reached already grid-parity compared to the diesel power generation (cf. Fig. 5 and [3]). Despite these very good conditions only few PV has been installed yet in the Caribbean area. To attract private investments and to start the implementation of PV from the bottom, net-billing, which means a feed in tariff below the retail price, is a promising market model to overcome the current barriers of implementation (e.g. lack of financing, investors,) [4, 5, 6]. The questions are, how this tool can be implemented and how can local people and businessmen profit from this implementation?

This work is divided into five sectors. After this introduction the simulation tool for the calculation of the net-billing tariff is presented followed by the results of the simulation. Based on these results different business models and opportunities are derived along the value chain for PV. Finally the work ends with a conclusion and suggestions to implement the business models

2 Simulation tool for net-billing tariff

To calculate the levelized cost of electricity of PV and an adequate net-billing tariff to satisfy the needs of a potential investor a model has been developed. This model enables on one hand the calculation of the levelized cost of electricity (LCOE) of PV and on the other hand the determination of a feed-in tariff to cover the LCOE of a potential investor.
The LCOE calculation is explained in Eq. 1, 2, 3 and 4.

$$Gen_{el} = \sum_{i=1}^{n} AnnualGen_n * (1 - DF)^{(n-1)} \qquad \text{Equation 1}$$

$$NPC = \sum_{i=1}^{n,p} \frac{Capex_n * Eq_{ratio} * crf_{eq} + Capex_p * (1 - Eq\_ratio) * crf_{loan} + Opex_n}{(1+i)^{(n-1)}} \qquad \text{Equation 2}$$

$$crf_{eq} = \frac{i_{eq} * (1+i_{eq})^n}{(1+i_{eq})^n - 1} \; ; \; crf_{loan} = \frac{i_{loan} * (1+i_{loan})^p}{(1+i_{loan})^p - 1} \qquad \text{Equation 3}$$

$$LCOE = \frac{Gen_{el}}{NPC} \qquad \text{Equation 4}$$

Explanation of equations:
Gen_{el}: Overall generated electricity; $AnnualGen_n$: Generated electricity per year, depending on the annual solar radiation; DF: Degradation factor; n: Project lifetime;
NPC: Net present costs; $Capex_n$: Capital expenditures PV; Eq_{ratio}: Ratio of equity to loan; $Opex_n$: Annual operation and maintenance expenditures PV; i: Inflation rate; n: Project lifetime; p: Life of loan;
crf_{eq}: Capital recovery factor for equity; i_{eq}: Equity yield rate; n: Project lifetime;
crf_{loan}: Capital recovery factor for loan; i_{loan}: Loan yield rate; p: Life of loan;
LCOE: Levelized cost of electricity

These equations enable to calculate the LCOE of PV under different financial conditions on different places. Unfortunately the feed-in tariff cannot just be set on the same level as the LCOE. Doing this, the investor would lose money based on the different discounted cash flows over the project lifetime. The early capital expenditures – the initial investment in PV – have a higher value than the late revenues of the fed-in electricity due to the compounded interest. To solve this issue, the positive and negative cash flows of each year are discounted and cumulated in the model to find out the minimum feed-in tariff, which makes the investment in PV attractive.
The revenues of the feed-in tariff are calculated according to Eq. 5.

$$Rev_{Feed-in} = \sum_{i=1}^{n} \frac{Gen_{el_n} * FT_n}{(1-i)^{(n-1)}} \qquad \text{Equation 5}$$

Explanation of equations:
$Rev_{Feed-in}$: Overall revenues of fed-in electricity; Gen_{el_n}: Generated electricity per year; FT_n: Feed-in tariff in USD per kWh; i: inflation rate; n: Project lifetime;

As long as the overall revenues are equal or higher than the net present costs of PV, the investor should meet his economic targets. The net present costs reflect already his internal rate of return (i_{eq}) and therefore assure his revenues.

3 Results for net-billing calculation

The calculations have been performed for the island St Vincent with an average global horizontal radiation of approximately 6.0 kWh/m² per day [7]. This leads to an annual power generation of a standard PV system of 1,600 kWh/kW$_p$. In Tab. 1 the main input parameter are shown.

Table 1: Input data for net-billing calculation

Input parameter	Abbr.	Unit / Explanation	Value
Annual PV generation	AnnualGen	kWh/kWp	1,600
Derating factor	DF		0.005
Capital expenditures	Capex	USD/kWp	2,500
Operation and maintenance Expenditures	Opex	percentage of initial costs	0.01
Equity yield rate	i_{eq}		0.15
Loan interest rate	i_{loan}		0.06
Equity ratio	Eq_{ratio}		0.2
Inflation rate	i		0.015
Lifetime project	n	Years	20
Paybacktime loan	p	Years	10
Annuity_equity	crf_{eq}		0.16
Annuity_loan	crf_{loan}		0.14

The calculated LCOE according to the data of Tab. 1 is 0.162 USD/kWh. This is based on a NPC of 4,936 USD/kW$_p$ and a generated amount of PV electricity of 30,525 kWh/kW$_p$. The initial costs are 2,500 USD/kW$_p$ of which 500 USD are self-financed due to the equity ratio of 0.2. The net-billing scheme, which assures, that the PV investor can cover its NPC (including a 15 % equity loan rate), has to provide a feed-in tariff of 0.185 USD/kWh for 20 years.
Fig. 1 and Fig. 2 show sensitivity analyses according to the Capex and the loan interest rate.

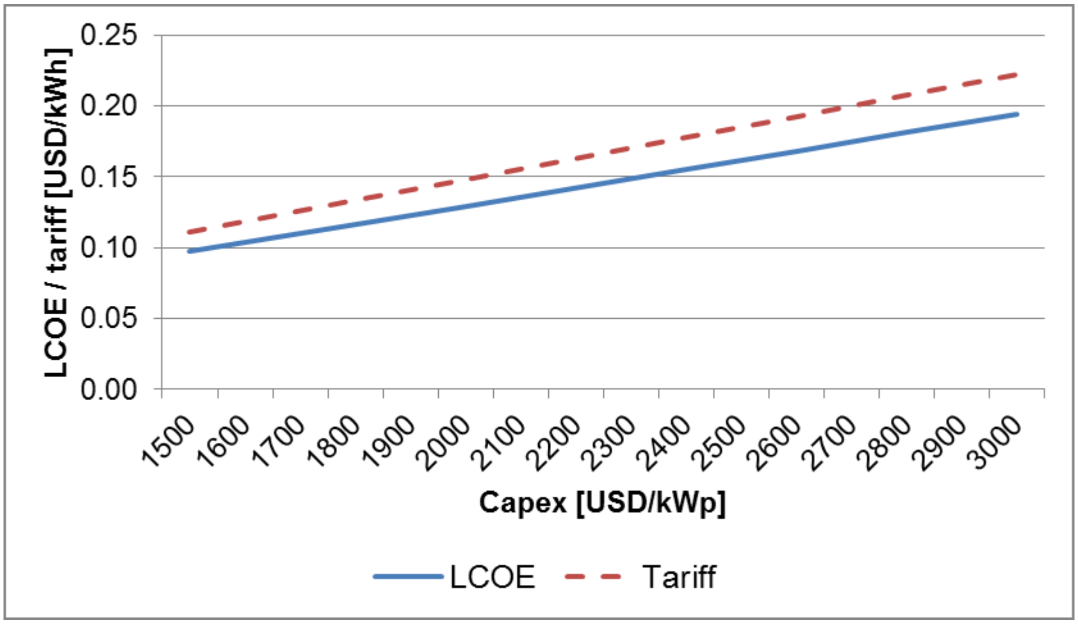

Figure 1: Sensitivity analysis according to different capital expenditures
Input data cf. Tab. 1;

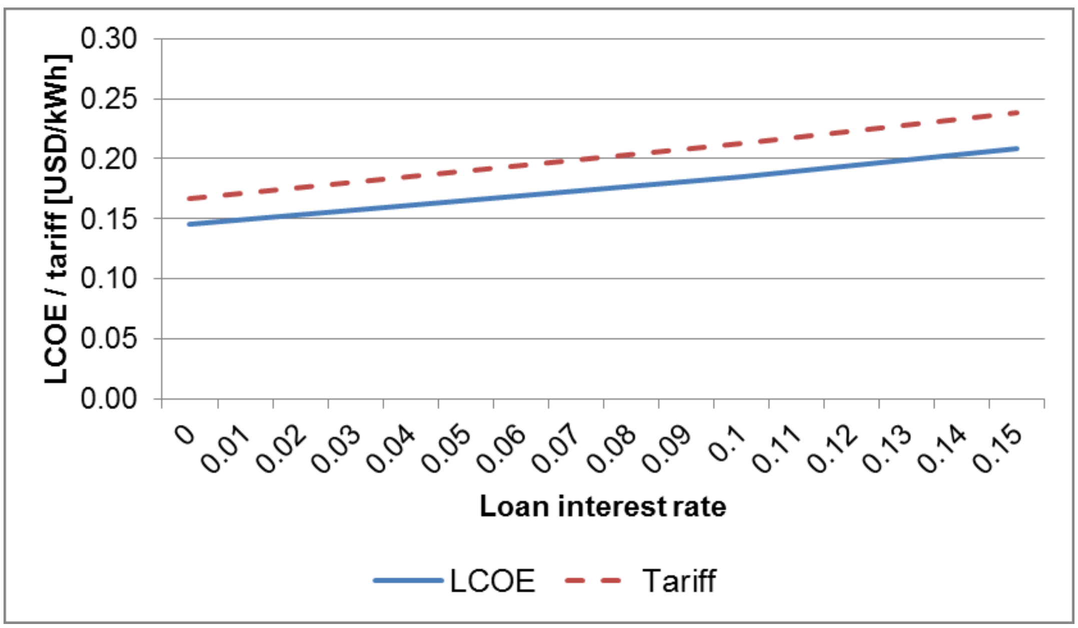

Figure 2: Sensitivity analysis according to different loan interest rates
Input data cf. Tab. 1;

The sensitivity analyses illustrate the influence of the changed input parameters, the Capex and the loan interest rate. Fig. 1 shows clearly the strong influence of the Capex on the LCOE and the tariff. If the Capex double, the LCOE and the tariff double, too. At Capex of 1,500 USD/kW$_p$ the LCOE drops down to 0.10 USD/kWh and the tariff to 0.11 USD/kWh, while the high Capex of 3000 USD/kW$_p$ increase the LCOE to 0.19 USD/kWh and the tariff to 0.22 USD/kWh.

In addition, the decrease of the Capex decreases the difference between the LCOE and the tariff. This is based on the reduced effect of the compounded interest rate. The difference decreases from 0.03 USD/kWh to 0.01 USD/kWh. Hence lower Capex reduce significantly the LCOE and even more the tariff.

The second analysis in Fig. 2 reveals that the loan interest rate has a slighter influence on the LCOE and the tariff than the Capex. From the entire bandwidth of 0 to 15 %, the LCOE and the tariff only change from 0.15 to 0.21 USD/kWh, respectively from 0.17 to 0.24 USD/kWh. The difference between LCOE and tariff changes again based on the same effect as in the first sensitivity analysis. Even though the impact of the loan interest rate is not as strong as the Capex. Fig. 2 clearly shows the effect of special loan rates. In the case of fully subsidized loans with zero percent interest rate, the LCOE could drop down by 0.017 USD/kWh and the tariff by 0.02 USD/kWh compared to the assumed loan rate of six percent.

In the following sections the effects of the net-billing scheme and arising business models for the Caribbean PV market are explained.

4 Business models for PV

The feed-in tariff of the net-billing scheme is an incentive to encourage all stakeholders in the power generation and PV sector to invest into solar power generation. The calculated minimum tariff enables the investor to receive a constant rate of return of 15 percent. In this section, other stakeholders and market participants are identified along the value chain of PV power generation. Their different business models are explained afterwards and estimation for the market potential on the Easter Caribbean islands is given.

4.1 Value chain PV

To understand the different business activities and market actors for solar power generation and their relation they are drawn in Fig. 3.

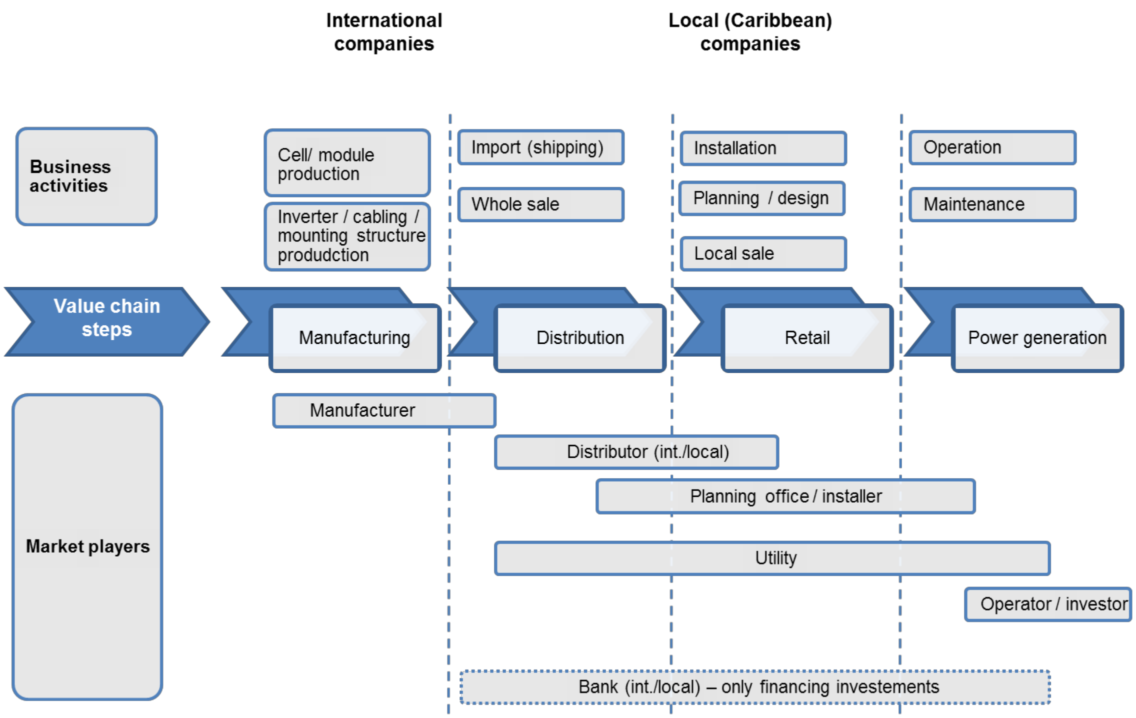

Figure 3: Value chain, market actors and business activities for solar power generation

As shown in Fig. 3 the value chain include these four steps: Manufacturing, distribution, retail and power generation. For each value added step the business activities and market actors are shown. In addition it is indicated if it is an international – non-Caribbean – company (left side) or a Caribbean company (more to the right). Certain actors can cover different value added steps on different levels.

Cell and module as well as inverter, cabling and mounting structure production is only done by international manufacturers, so far no production facilities exist on Caribbean islands. The manufacturer can also act as distributor on the whole sale market.

International and local companies participate in the distribution, means importing (e.g. shipping) and whole sale of the modules and systems. The aforementioned manufacturers, international and local distributors, local planning offices and installer, which buy directly from the manufacturer and local utilities, which can easily import power generating technologies.

The retail market includes the local sale of the PV system, its design and planning and the installation. The local sale can be done by the local distributors, planning offices and utilities. The design, planning and installation are duties of the planning office and installer and the utility.

Power generation is the final step of the value chain. The PV system has to be operated and maintained to guarantee a constant power generation and revenues. The maintenance is mainly done by the technicians of the installers or utilities. The utility can also act as operator and integrate the solar power generation into its main business sector, the conventional power generation sector. To increase competition and to attract private capital the net-billing scheme encourages investors beside the utility to generate solar power. Their main duty is to operate the system and to initially commission it, getting the feed-in tariff as revenue to refinance their investment.

International and local private and public banks perform as additional market actors. They have to support the different actors on the different value added steps with special loans. For the operator or final investor, small loans are necessary to finance small roof-top systems. Retailers and distributors request bigger loans to finance large investments to profit from economies of scale.

4.2 Market entry strategies – barriers and solutions

Several market entry strategies for the aforementioned market actors are explained in respect of barriers and solutions. The special characteristics of the PV markets on Caribbean islands are their small size, good natural conditions and mostly monopolistic power generation sectors [8]. The small size leads to high specific transportation costs and lower economies of scale in terms of import capacities and local installers. The natural conditions with very high solar radiation in combination with an expensive diesel fired current power generation make PV power generation already competitive without special subsidies. This enables theoretically a free competition on the power generation sector, but the mostly monopolistic structure of the power generation sector without regulation slows this competition down.

Tab. 2 explains the entry strategies for the aforementioned actors into the Caribbean PV market. In addition the barriers and the matching solutions and opportunities, based on the strengths of the actors are described.

Table 2: Market actors, their entry strategies in respect of barriers and solutions for PV on Caribbean islands

Market player	Entry strategy	Barriers	Solutions / Opportunities
Manufacturer	- Local dependences - Local marketing - Exclusive contracts with whole sale customers	- Small market size - Core business is production	- Combining different islands to one market - Creating new markets - Extending its value chain
Distributor (int.)	- Local dependences - Local marketing - Exclusive contracts with retail sale customers	- Small market size - No regional experience	- Combining different islands to one market - Creating new markets - Joint-venture with local companies
Distributor (local)	- Exclusive contracts with manufacturers - Extending product portfolio with PV (existing distributors)	- No experience in PV business	- Transferring local know-how and contacts to new PV market
Planning office and installer	- Exclusive contracts with whole sellers - Offering combined solutions (e.g. house building incl. PV)	- No experience in PV - Small market on single islands	- Education of staff - Integrated business (combining with different products (e.g. solar water heater, construction work) and services (e.g. planning, design, financing))
Utility	- Selling PV systems to operators - Generating solar power - Exclusive contracts with whole sellers or manufacturers	- No experience in PV business - Regulation of market power - Small market size on local island	- Education of staff - Experienced retail and consumer service division - Unsold PV systems can be used for own power generation - Very high local customer reception
Operator and investor	- Roof-top PV systems for house owner - Free-standing PV systems for large investors	- Unsecure investment conditions (e.g. net metering or net-billing not fixed over 20 years) - High initial capital costs - Independent power producers have problems to enter the monopolistic market	- Special loans - Secure regulatory framework (fair net-billing scheme; cf. section "3 Results"

4.3 Market potential

The market potential for all Caribbean islands is calculated by multiplying the total installed power plant capacity by 30 %. Until thirty percent total installed capacity it is assumed, that the utility will not face any frequency stabilization problems. To verify this number more detailed calculations have to be performed for each island taking the load profile and current power plant capacity into account. Within this work the estimation of 30 % is enough. The calculated potential in terms of capacity and capital expenditures for each Caribbean island is shown in Fig. 4.

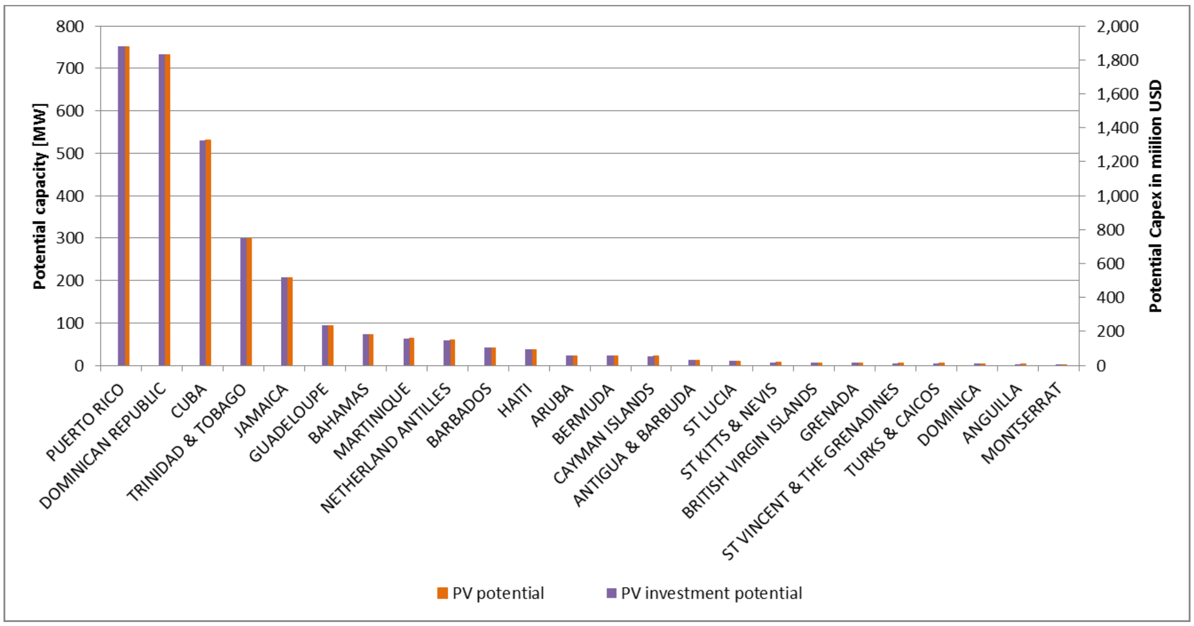

Figure 4: PV capacity and market potential for Caribbean islands

The cumulated market potential adds up to 3.0 GW_p, which requests 7,540 million USD in investments at PV system costs of 2,500 USD/kW_p. The biggest five islands represent 83 % of the market. The smaller Easter Caribbean islands have still a potential of 312 MW_p (780 million USD).

Looking at the value chain, the highest share is covered by the manufacturer of the modules and inverters. Overall it adds up to approximately 80 percent. This business volume creates profit for international companies only, as no Caribbean manufacturer exists. But the lasting 20 % can be local businesses, at least 1.5 billion USD. A large share is the installation, which creates a lot of local craft-jobs [9].

In addition the entire economies can profit from reduced power generation costs by solar power generation. In Fig. 5 the calculated feed-in tariff for Capex of 2,500 USD/kW_p and 1,500 USD/kW_p are shown compared to the regional domestic electricity tariff.

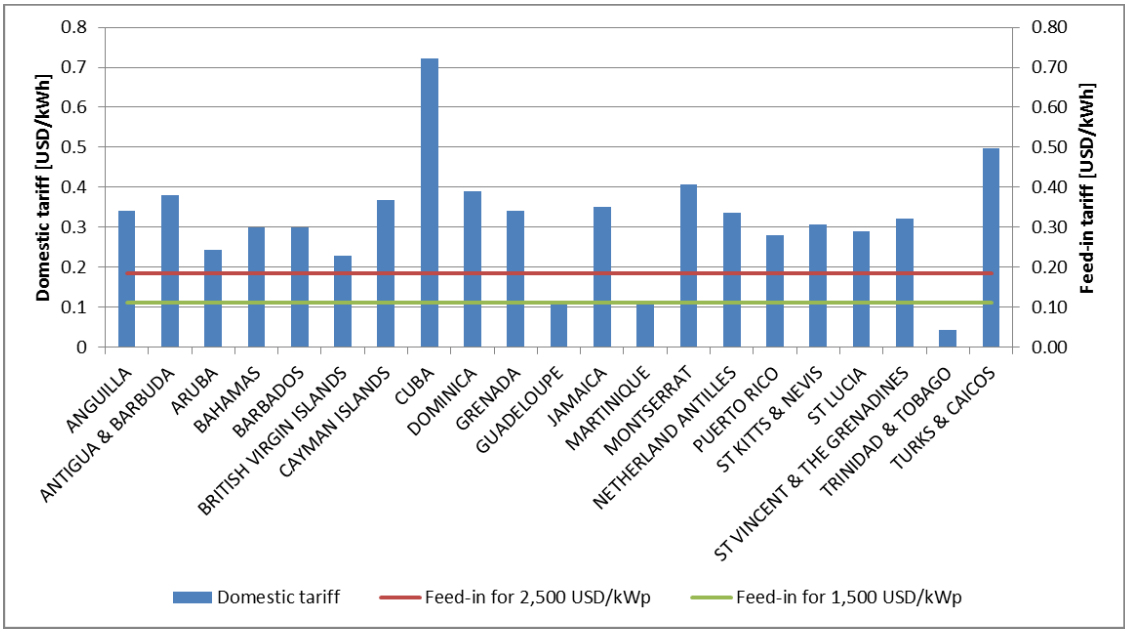

Figure 5: Comparison of domestic tariff with two feed-in tariffs for Caribbean islands. The assumptions of Table 1 have been applied.

The comparison reveals that in most of the islands, the PV electricity is already cheaper than the domestic tariffs. Hence it can help to reduce the electricity costs of the domestic customers. With decreasing Capex of PV the advantages will even get bigger.

The produced PV power will not only decrease the overall power generation cost, it will also decrease the amount of imported fossil fuels. 1 MW_p installed PV capacity can save about 140,000 imperial gallons of diesel per year[1].

5 Conclusion

In summary it can be said that PV power generation can create many business opportunities for local companies on Caribbean islands. There exists a huge market potential as only very few PV has been installed yet compared to the potential.

As soon as secure investment conditions in terms of net-billing schemes have been created on the islands the market is ready to dramatically increase. Financial institutions should be ready to offer special loans, maybe supported by the government. In addition the import taxes for PV should be reduced to lower the investment costs and enable local businesses. These companies will create many local job opportunities for Caribbean people. Special education programs have to be offered to enable the people to gain technological and economic knowledge about PV.

Comparing the development of diesel prices and PV costs worldwide, solar power generation is getting more and more economical. The Caribbean islands with their perfect natural conditions should take the opportunity now to invest into a green economy to step toward a green future.

[1] 1,600 kWh/kWp*year * 1000 kWp leads to 140,000 gallons per year at diesel power plant efficiency of 0.25 and a heat value of diesel of 45 kWh/gallon

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