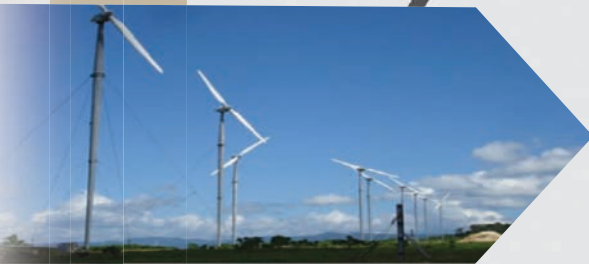


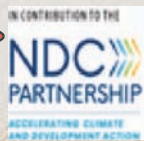


Vanuatu

Nationally Determined Contributions (NDC) Implementation Roadmap



March 2019



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ACRONYMS

BAU	Business as usual
CC	Climate change
CCA	Climate change adaptation
CCU	Climate Change Unit
CIF	Cost Insurance Freight
CO ₂	Carbon dioxide
GGGI	Global Green Growth Institute
GHGs	Green House Gases
GWh	Gigawatt hours
INDC	Intended Nationally Determined Contribution
M&E	Monitoring and Evaluation
MRV	Measurement Reporting and Verification
MW	Megawatt
MWh	Megawatt hours
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NDC-IR	NDC Implementation Roadmap
NERM	National Energy Road Map
NGO	Non-Government Organisation
PV	Photovoltaic
RE	Renewable energy
SHS	Solar Home System
UNDP	United Nations Development Program
UNELCO	Union Electrique du Vanuatu Limited
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar
VUV	Vanuatu Vatu

FOREWORD

It is indeed a great pleasure for me to formally launch Vanuatu's Nationally Determined Contributions (NDC) Implementation Roadmap, a key policy document in achieving our climate change mitigation obligations under the Paris Agreement.

Vanuatu parliament ratified the Paris climate change agreement on 18th June 2016 and submitted our Nationally Determined Contributions (NDCs) and emission reduction targets to the United Nations Framework Convention on Climate Change (UNFCCC). Our NDC mitigation target is transitioning close to 100% renewable energy in the electricity (energy) sector by 2030.

Achieving this target would replace nearly all fossil fuel requirements for electricity generation in the country. The target is consistent with the National Energy Roadmap (NERM), which aims at generating 65% of electricity from renewable energy by 2020. Compared to the business as usual, emissions in the electricity sub-sector will be reduced by almost by 100% and in the energy sector as a whole by 30%. The target is conditional upon appropriate financial and technical support made available.

Further, our National Sustainable Development Plan 2016-2030 (also called as "Vanuatu 2030 - The People's Plan") charts the country's vision and overarching policy framework for achieving a Stable, Sustainable and Prosperous Vanuatu within the next fifteen years, and in doing so sets out the national priorities and context for the implementation of the new global Sustainable Development Goals over the same period. The key goals and policy objectives under the Vanuatu 2030 also include enhanced resilience and adaptive capacity to climate change and natural disasters (adaptation) and Prioritising renewable sources of energy and promote efficient energy use (mitigation).

It's important to note that Vanuatu's NDC hinges on our key national development priorities and relevant policies for respective sectors. These national priorities & policies has very strong linkages to our goals towards sustainable development. I believe that this is a win-win situation, wherein implementing both the mitigation and sustainable development targets under our NDC would assist and support in achieving our national sustainable development policies and priorities.

This NDC Implementation Roadmap aims at providing a pathway for the implementation of specific climate change mitigation actions in Vanuatu which can assist in achieving the target defined in Vanuatu's NDC. This Roadmap is envisaged to:

- Increase awareness among and provide guidance for key stakeholders on the actions necessary to achieve the NDC target.
- Set out a pathway with concrete mitigation actions and interventions leading to emission reductions and transformational change in the electricity supply sector over time.
- Define the regulatory changes required for the implementation of the mitigation actions.
- Lay out the financing strategy for the identified mitigation actions.
- Provide the necessary information for the Monitoring, Reporting and Verification (MRV) system which allows tracking the progress to meeting the NDC targets.

Vanuatu anticipates many impacts from climate change on its society, economy, environment and human health and Vanuatu through the Ministry of Climate Change is actively cooperating with United Nations agencies and international partners to assess these effects and develop appropriate plans through climate change adaptation and mitigation.

We are already experiencing devastating consequences of climate change, and these will become much more severe with temperature increases over 1.5°C. But the science also tells us that it is possible to keep global warming in check if CO2 emissions decline by about 45% from 2010 levels by 2030, and the world has zero net emissions by 2050. The technology is available, especially with renewable energy, but we also must immediately stop new fossil fuel business interests, including fossil fuel products. We are a small island developing nation with absolute levels of CO2 eq emissions very small at under 0.0016% of world emissions. The country is also one of the most vulnerable to the effects of climate change and has much to lose should the worst predictions from increased temperature levels eventuate.

Finally, I wish to reiterate the latest science, released by the UN, which tells us that we are on track for Global warming of over 1.5°C by 2040 if urgent action isn't taken by all countries, businesses, communities and individuals. Vanuatu is committed to support the global combat on climate change and we will do our best to mitigate emissions but would require financial, technical and capacity building support from developed countries to do so.

Honourable Ham Lini
Minister for Climate Change

EXECUTIVE SUMMARY

Vanuatu has submitted its INDC to United Nations Framework Convention on Climate Change (UNFCCC) on 29 September 2015 and the same document was endorsed and submitted as the first Nationally Determined Contribution (NDC) on 21 September 2016. Although being a Small Island State with a small carbon footprint, Vanuatu has committed to a challenging mitigation target in its NDC of transitioning to close to 100% renewable energy in the electricity sector by 2030. Achieving this target would replace nearly all fossil fuel requirements for electricity generation in the country.

This NDC Implementation Roadmap (NDC-IR) aims at providing a pathway for the implementation of specific mitigation actions in Vanuatu. In the business as usual (BAU) electricity demand scenario, an increase in electricity demand from 77.9 GWh in 2017 to 100.7 GWh in 2030 is projected. This is a total increase of 29.4%.

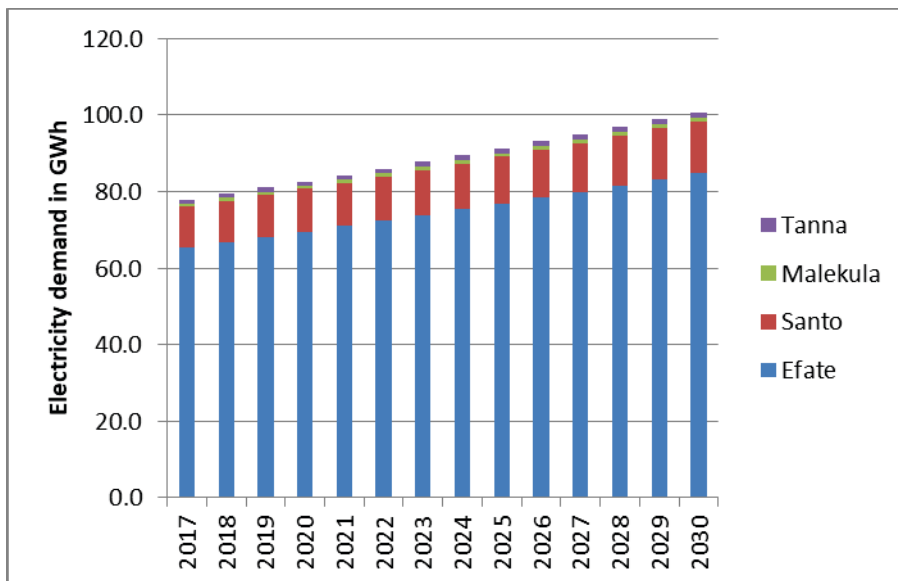


Figure 1: Electricity demand 2017-2030

Vanuatu has been very active in implementing renewable energy projects for electricity generation, including solar PV, wind and coconut oil. The gap analysis takes note of these activities and determines the additional efforts necessary for achieving the target. Assuming a reduction in diesel generation of 15% p.a. from 2019 onwards and with the operation of the Sarakata 1.2 MW hydro power project, the Devil's Point 3.6 MW wind farm and smaller solar PV units at Tagabe, Tanna and Malekula, the gap which needs to be filled with additional renewable energy projects is expected to be 74 GWh in 2030.

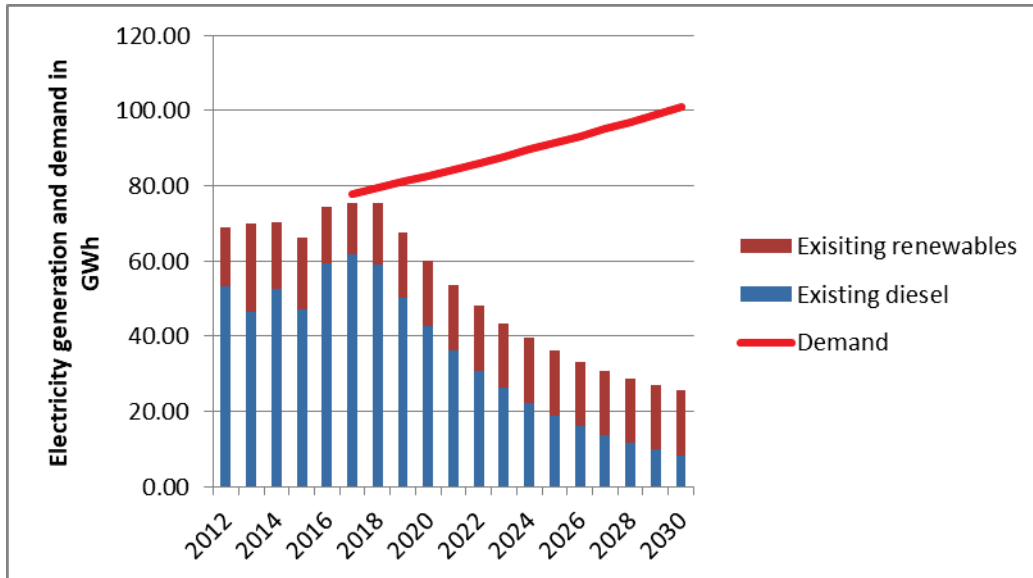


Figure 2: Electricity generation and demand BAU scenario

There are a number of newly implemented renewable energy projects as well as initiatives currently under implementation or preparation, which will have sizeable contributions towards the NDC target:

- Undine 510 kW solar PV plant, commissioned in 2016
- Parliament Building and Meteo complex 767 kW solar PV plants, commissioned in 2016
- Kawene 1.0 MW solar PV plant, put in operation in early 2018
- Brenwe Hydro Power Project
- Sarakata Hydro Power Extension Project
- Vanuatu Rural Electrification Project (VREP) Phase II
- Talise Micro Hydro Power Project

All these projects will reduce the gap to 60 GWh in 2030. To fill the remaining gap, a number of interventions need to be implemented and two different combinations to achieving the NDC target are presented:

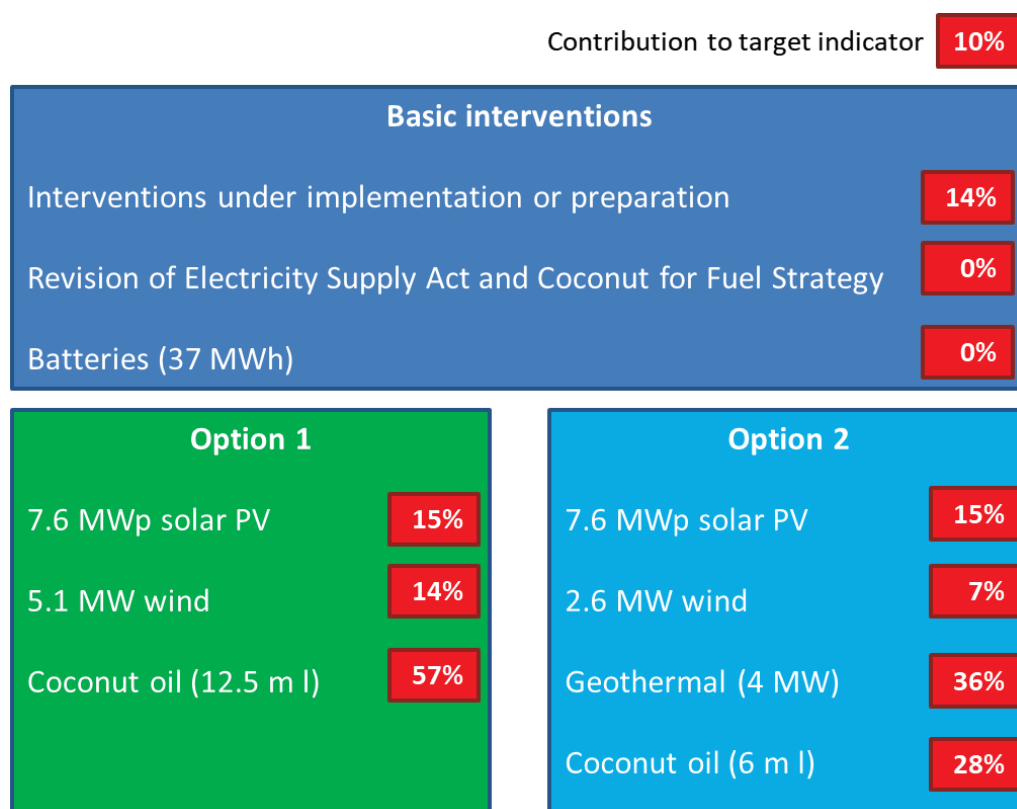


Figure 3: Contributions to target

First of all, there are basic interventions, which are recommended to be implemented in any case:

- Interventions under implementation or preparation: project under implementation such as VREP II or the Talise Hydro Power Project bring good contributions towards the target and should be finalised as planned. Focus should be on implementations under preparation to secure funding and push for implementation.
- Coconut for Fuel Strategy: this is the key element in providing a sizeable contribution to achieving the NDC target and is the first implementation step to be carried out.
- Revision of the Electricity Supply Act: this is a key step for stronger involvement of the private sector and should allow attracting private capital for the investment into renewable energy projects. Batteries: a total of 37 MWh of battery storage capacity are necessary to secure a well-functioning grid, where overproduction can be stored for later consumption.

In addition to these basic interventions, 2 options are suggested for achieving the NDC target.

Option 1 includes the installation of 7.6 MW solar PV and 5.1 MW wind, which together can contribute around 30% to the target. The majority of the contribution towards the target (57%) will come from the use of coconut oil. Total costs of Option 1 are USD 73.3 m (excluding costs for the Sarakata hydro power project as they haven't been determined yet). It is assumed that a pricing arrangement for coconut oil can be found, which is not leading to ongoing operation costs, the costs for carrying out the Coconut for Fuel Strategy are included.

Option 2 includes the installation of 7.6 MW solar PV, which is seen as the renewable energy source with lowest generation costs. The main contribution in Option 2 will come from geothermal (36%), which requires successful drilling and considerable investment for the implementation. The availability of geothermal allows reducing the input of wind energy and it suggested that only half of the additional capacity (2.6 MW) is installed. The remaining gap will be covered by coconut oil and a total of around 6 million litres will be required to achieve the target. Total costs of Option 2 are USD

66.5 m (excluding costs for the Sarakata hydro power and the geothermal project as they haven't been determined yet). It is assumed that a pricing arrangement for coconut oil can be found, which is not leading to ongoing operation costs, the costs for carrying out the Coconut for Fuel Strategy are included.

This NDC Implementation Roadmap is a living document. It will be updated once more information and clarity on various opportunities is available. The MRV system to be installed allows tracking of the process and can give feedback on corrective action necessary for achieving the target.

1 INTRODUCTION

In November 2013 during COP 19, a decision on “Intended Nationally Determined Contributions” (INDCs) was adopted. This decision invited “all Parties to initiate or intensify domestic preparations for their intended nationally determined contributions, without prejudice to the legal nature of the contributions, in the context of adopting a protocol, another legal instrument or an agreed outcome with legal force under the Convention for the period post 2020 applicable to all Parties towards achieving the objective of the Convention as set out in its Article 2 and to communicate them well in advance of the twenty-first session of the Conference of the Parties in a manner that facilitates the clarity, transparency and understanding of the intended contributions, without prejudice to the legal nature of the contributions.” (Dec.1/CP19).

Vanuatu has submitted its INDC to United Nations Framework Convention on Climate Change (UNFCCC) on 29 September 2015 and the same document was endorsed and submitted as the first Nationally Determined Contribution (NDC) on 21 September 2016. Although being a Small Island State with a small carbon footprint, Vanuatu has committed to a challenging mitigation target in its NDC of transitioning to close to 100% renewable energy in the electricity sector by 2030. Achieving this target would replace nearly all fossil fuel requirements for electricity generation in the country.

This NDC Implementation Roadmap (NDC-IR) aims at providing a pathway for the implementation of specific mitigation actions in Vanuatu. All actions listed in the NDC-IR are contributing to the target defined in Vanuatu’s NDC. The document first provides a more detailed look at the NDC and describes how the NDC is embedded in the regulatory environment in Vanuatu. It then determines the business as usual (BAU) electricity demand scenario to understand the expected increases in demand over the period up to 2030.

Vanuatu has been very active in implementing renewable energy projects for electricity generation, including solar PV, wind and coconut oil. The gap analysis takes note of these activities and determines the additional efforts necessary for achieving the target. The various mitigation interventions are then described in detail and potential contributions towards the NDC target are calculated. Finally, two different options of which combinations lead to achieving the NDC target are presented.

2 VANUATU’S NATIONALLY DETERMINED CONTRIBUTION AND IMPLEMENTATION ROADMAP

2.1 VANUATU’S NATIONALLY DETERMINED CONTRIBUTION (NDC)

The Republic of Vanuatu submitted its first Intended Nationally Determined Contribution (INDC) to UNFCCC on 29 September 2015. No further revisions were undertaken and the same document was endorsed and submitted as the first Nationally Determined Contribution (NDC) on 21 September 2016.¹

2.1.1 MITIGATION CONTRIBUTION

¹ The INDC communicated in 2015 and the NDC are identical documents despite the document still being called “Intended Nationally Determined Contribution (INDC)” on the UNFCCC interim NDC Registry.

The NDC is based on the National Energy Road Map (NERM) and the Second National Communication (SNC). The mitigation contribution of Vanuatu is a sector specific target of transitioning to close to 100% renewable energy in the electricity sector by 2030. Achieving this target would replace nearly all fossil fuel requirements for electricity generation in the country. The target is consistent with the NERM, which aims at generating 65% of electricity from renewable energy by 2020. Compared to the business as usual, emissions in the electricity sub-sector will be reduced by almost by 100% and in the energy sector as a whole by 30%. The target is conditional upon appropriate financial and technical support made available.

The NDC lists the following key mitigation interventions to be implemented:

- Doubling of the wind installed capacity to 5.5 MW by 2025
- Installing 10 MW grid connected solar PV by 2025
- Commissioning the proposed first stage 4 MW geothermal plant by 2025
- Adding 10 MW grid-connected solar PV by 2030
- Commissioning the second stage 4 MW geothermal plant by 2030
- Substituting and/or replacement of fossil fuels with coconut oil based electricity generation

These interventions focused on infrastructure investments in the electricity generation sub-sector are supported by various other activities (which are partly overlapping with the interventions mentioned), such as implementation of the NERM, implementation of the Renewable Energy NAMA, Off grid renewable energy projects under Scaling Up Renewable Energy in Low Income Countries Program or energy efficiency measures to be pursued across the board to enable 15% savings in the energy sector.

2.1.2 ADAPTATION PRIORITIES

The adaptation component of the INDC does not seek to set adaptation targets for Vanuatu however it provides an opportunity to reiterate the adaptation priorities as identified and prioritised in key national documents such as the National Adaptation Programme of Action (NAPA) and the National Climate Change and Disaster Risk Reduction Policy.

The NAPA process identified and prioritised adaptation priority needs that were urgent and immediate - those needs for which further delay could increase vulnerability or lead to increased costs at a later stage. The five NAPA priorities include: Agriculture and food security; Sustainable tourism development; Community based marine resource management; Sustainable forest management and Integrated water resource management. The National Climate Change and Disaster Risk Reduction Policy identifies five key adaptation strategic priorities and associated actions to further enhance the national adaptation efforts and build resilience across sectors which include the need for: Climate Change vulnerability and multisector impact assessments; Integrated climate change and disaster risk reduction; Community based adaptation; Loss and damage and Ecosystem based approaches.

2.2 GOAL AND OBJECTIVE OF THE ROADMAP

The Goal of the NDC Implementation Roadmap is to provide a pathway for the implementation of specific mitigation actions in Vanuatu. All actions listed in the NDC-IR are contributing to the target defined in Vanuatu's NDC. As such, the NDC Implementation Roadmap will:

- Increase awareness among and provide guidance for key stakeholders on the actions necessary to achieve the NDC target.
- Set out a pathway with concrete mitigation actions and interventions leading to emission reductions and transformational change in the electricity supply sector over time.

- Define the regulatory changes required for the implementation of the mitigation actions.
- Lay out the financing strategy for the identified mitigation actions.
- Provide the necessary information for the Monitoring, Reporting and Verification (MRV) system which allows tracking the progress to meeting the NDC targets.

The Objective of the NDC Implementation Roadmap is to reach the NDC target of close to 100% renewable energy in the electricity sector by 2030.

2.3 BOUNDARY OF THE ROADMAP

Whereas other documents such as the NERM of 2013 have a focus both on consumers within grid connection areas and “off-grid” households (NERM, 2013), the interventions mentioned in the NDC have a clear focus on the electricity generation sub-sector. The mitigation contribution is defined in the NDC as follows: *“Sectoral commitment focussed on a transition to renewable energy in the electricity generation sub-sector under energy generation.”*

The electricity generation sub-sector is defined as follows:

- Electricity generated in the 4 concession areas (Port Vila, Luganville, Malekula, Tanna)
- Electricity generated in mini- and micro-grids

Consumers, which disconnected from the grid and provide their own electricity (mainly renewables plus diesel) will be included in the calculations for the Roadmap.

Households electrified by Solar Home Systems (SHS) or solar lanterns are not included in the electricity generation sub-sector. Activities on rural electrification with SHS or improvement of energy efficiency are seen as accompanying measures and are therefore not considered in the NDC Implementation Roadmap.

2.4 CONNECTION BETWEEN NERM AND NDC-IR

In parallel to the submission of the INDC and the NDC in 2015 and 2016, the National Energy Roadmap (NERM) got updated in 2016. The NERM reviews current and expected progress against the targets in the NERM of 2013, reflects recent developments and adjusts the NERM’s targets and implementation plan accordingly. The following table gives an overview on the progress against the targets of the 2013 NERM.

Section	Target	NERM baseline ¹	Actual	Projected	
			2015 ²	2020	2030
3.1	Increasing electricity access in and near concession areas ³	59% (2012)	69%	90%	100%
			62%	71%	56%
3.2	Increasing electricity access in off-grid areas ⁴	<10% (2012)	55% ⁵	100%	100%
			9%	61%	55%
3.3	Increasing electricity access by public institutions (on- and off-grid)	48% (2011)	90%	100%	100%
			54%	63%	74%
3.4	Improving diesel generation efficiency	0% (2010)	10%	20%	No target
			2%	5%	
3.5	Reducing the cost of distributing petroleum	Baseline distribution cost unavailable	5% reduction	10% reduction	No target
			Insufficient data	Insufficient data	
3.6	Generating electricity from renewable energy sources	19% (2012)	40%	65%	No target
			29%	40%	

Key





	Target met
	On track to meet target
	Step change required to meet target
	Insufficient data available to make assessment

Figure 4: Current and Expected Progress Against Original NERM Targets

In general, the new version of the NERM includes the following aspects (NERM, 2016):

- Priorities and objectives: Re-frames the NERM priorities to reflect desired outcomes for Vanuatu’s energy sector and to incorporate new areas of emphasis
- Progress: Provides an update on how well Vanuatu is meeting the targets (and what progress might look like by 2020 and 2030)
- Targets: Sets 2030 targets for indicators that previously only had targets for 2015 and 2020, and adds new targets to help catalyse faster progress in particular areas
- Implementation Plan: Refines and adds actions needed to achieve the updated targets and objectives.

Whereas the NERM of 2013 had priorities on access to energy, petroleum supply, affordability, energy security, and climate change, the updated version of the NERM has the following priorities:

- Accessible energy
- Affordable energy
- Secure and reliable energy
- Sustainable energy
- Green growth

The updated NERM also reviews the progress on generating electricity from renewable energy and gives important inputs for the NDC Implementation Roadmap.

The new version of the NERM reflects on the NDC and states that - as existing electricity demand can be met without new generating capacity – *“there is limited scope for large amounts of new renewable capacity (at least not without grant funding) unless demand increases significantly”*. The target set in the NDC is to approach 100% renewable energy in the electricity sub-sector. Even if there is increasing electricity demand, the concession areas currently supplied mainly by diesel will have to switch to renewables to a large extent until 2030 latest in order to achieve that goal. Therefore, the NDC Implementation Roadmap will have to focus on how to increase the share of renewable energies in these concession areas.

It is understood from the NERM that geothermal energy is considered as too expensive and too risky in order to be pursued. Therefore, geothermal energy is not included in the NDC Implementation Roadmap.

Coconut oil is being discussed in the NERM as a replacement for diesel in existing generators. Whereas, this is an important step in increasing the share of renewable energies, an important potential function of coconut oil is missed:

Renewable energies such as solar, wind or hydro have a major disadvantage: they cannot be stored. Whereas hydro power can provide a certain share of base load, the availability of solar and wind is often unpredictable. The higher the share of renewables in a certain system, the more difficult it is to balance supply and demand. The additional challenge in the case of Vanuatu is that all concession areas are isolated grids and balancing of demand and supply has to be achieved in each of the grids.

Storage of electricity from renewable energies can only be done with battery systems, which is costly, especially if longer periods of non-availability of a resource have to be bridged. This is where coconut oil can play an important role. Coconut oil can be stored, can be used in existing diesel generators (with some adaptation work needed, in some cases re-sizing would be necessary, as loads to be covered are lower) and can provide electricity in cases when solar, wind or hydro are not available. What has to be considered when discussing coconut oil is security of supply, availability of land and alternative use in food industry.

Realistically, diesel operated generators will have to play a role as reserve and fall-back position, as covering 100% of electricity demand by renewable energies might be too expensive. This is already reflected in the NDC, where the target is worded as *“to approach 100% renewable energy”*.

The NERM 2016 is currently being updated, the results of the update will be integrated into the final version of the NDC Implementation Roadmap.

3 BUSINESS AS USUAL (BAU) ELECTRICITY DEMAND SCENARIO

Electricity generation has shown a steady increase over the last 5 years. From a total of 69 GWh in 2012, electricity generation in the concession areas (Efate, Santo, Malekula and Tanna) has increased to 77.14 GWh in 2017. This represents an annual increase of 2.3% p.a. Electricity generation in 2015 was lower due to the effects from cyclone Pam, but the drop in 2015 was already compensated in the following year.

In the same time period, the share of renewables was fluctuating between 33.7% in 2013 and 17.7% in 2017. The main reason for these fluctuations and especially the drop in the share of renewables in 2016 and 2017 is due to higher world market prices for copra, which reduced the use of coconut oil in electricity generation (in 2017, no electricity was generated from coconut oil).

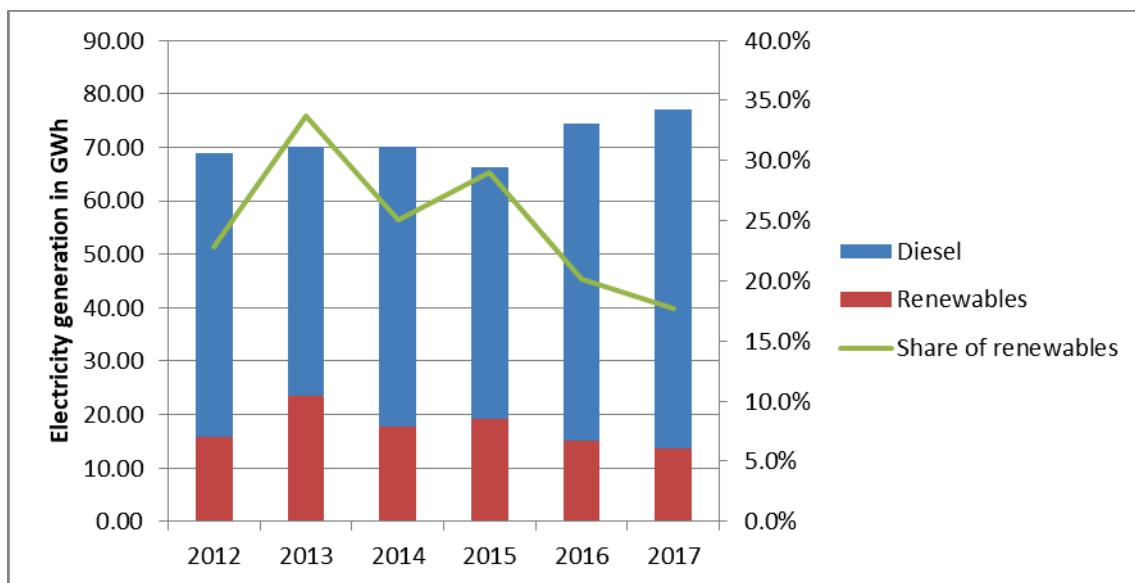


Figure 5: Electricity generation and share of renewables 2012-2017

To project the further development of electricity demand and generation needs, consultations with the two utilities were held. These resulted in the following assumptions:

- UNECLO, concession areas in Efate, Malekula and Tanna: projections of electricity demand are to be seen in relation to GDP development. Experience from historic figures shows that electricity demand increase is about 1.0-1.2% lower than GDP growth. With GDP growth projected at 3.2% for 2018 and 3.0% for 2019², a demand growth of 2% p.a. is seen as realistic.
- VUI, concession area in Santo: increase in electricity demand is estimated at 2% p.a.

The general assumption of a 2% p.a. increase of electricity demand between 2017 and 2030 is consistent with the trend over the last 5 years, which showed an annual increase of 2.3% p.a.

In a study published in 2016, GGGI had projected that electricity consumption will more than double between 2015 and 2030. This was mainly based on the ambitious electrification targets in the NERM, as well as strong growth rates of number of households and consumption in commercial/industrial and private sector. The comparison of electricity demand projected by GGGI for 2017 and 2018 with

² <https://www.adb.org/countries/vanuatu/economy>

actual consumption figures for these years showed that projected demand is around 7% higher than real demand, which confirms that the assumptions used in the GGI study were too high.

The following figure and table show the electricity demand projections from 2017 to 2030. Based on the 2% increase p.a., total electricity demand increases from 77.9 GWh in 2017 to 100.7 GWh in 2030, a total increase of 29.4%.

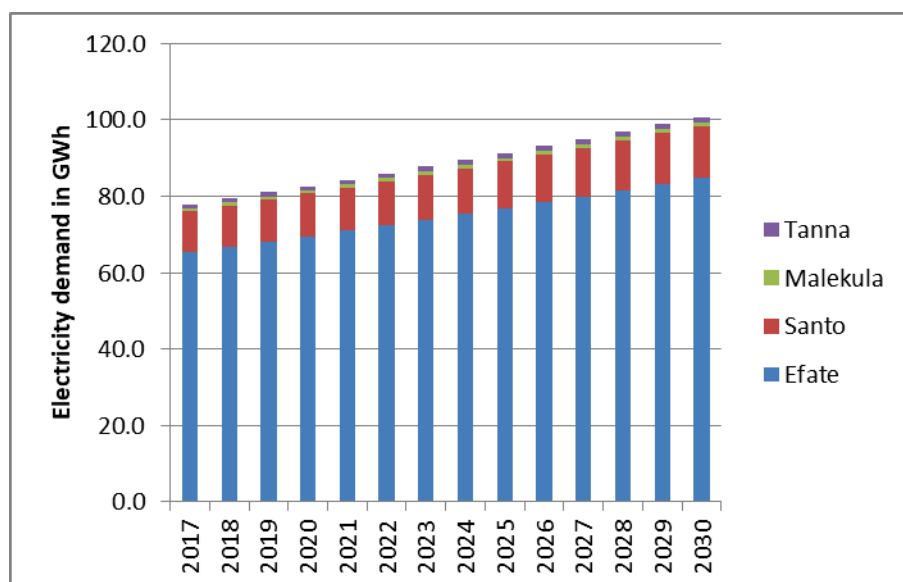


Figure 6: Electricity demand 2017-2030

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Efate	65.6	67.0	68.3	69.7	71.0	72.5	73.9	75.4	76.9	78.4	80.0	81.6	83.2	84.9
Santo	10.5	10.7	10.9	11.1	11.3	11.6	11.8	12.0	12.3	12.5	12.8	13.0	13.3	13.6
Maleku	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.1
Tanna	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3
Total	78.0	79.5	81.1	82.7	84.4	86.1	87.8	89.6	91.4	93.2	95.0	96.9	98.9	100.9

Table 1: Electricity demand projections in GWh 2017-2030

4 GAP ANALYSIS

The objective of this chapter is to identify the gap in electricity demand to be covered by additional renewable energy generation in order to meet the NDC target. The business as usual scenario in chapter 3 projects a sizeable increase in electricity demand in Vanuatu until 2030. From around 77 GWh in 2017, electricity consumption is expected to increase to 100.7 GWh in 2030. This is an annual increase of 2% and a total increase of 29.4%.

In 2016 and 2017, around 80% of the electricity demand was covered by diesel, the remaining 20% were covered by renewable energies. The highest share of renewable energies was in 2013, when 33.7% of electricity was provided by wind, solar PV and coconut oil.

In order to achieve the NDC target of “close to 100% renewable energy in the electricity sector by 2030”, the use of diesel for electricity generation needs to be reduced step-by-step. In 2030, diesel is expected to play a minor role as a back-up and will cover short-term fluctuations in electricity supply

from renewable energy sources (mainly wind and solar). It is agreed among stakeholders that share of a diesel in electricity generation of 5 to 10% is considered to be in line with the NDC target.

For the calculation of the gap between expected demand and generation, diesel generation is reduced by 15% p.a. from 2019 onwards. This results in a share of electricity from diesel of 8.8% in 2030. In reality, diesel generation will have to follow the implementation plan of additional renewable energy capacity and will cover the gap between electricity from renewable energy and total electricity demand.

To calculate the gap, the following information was taken into consideration:

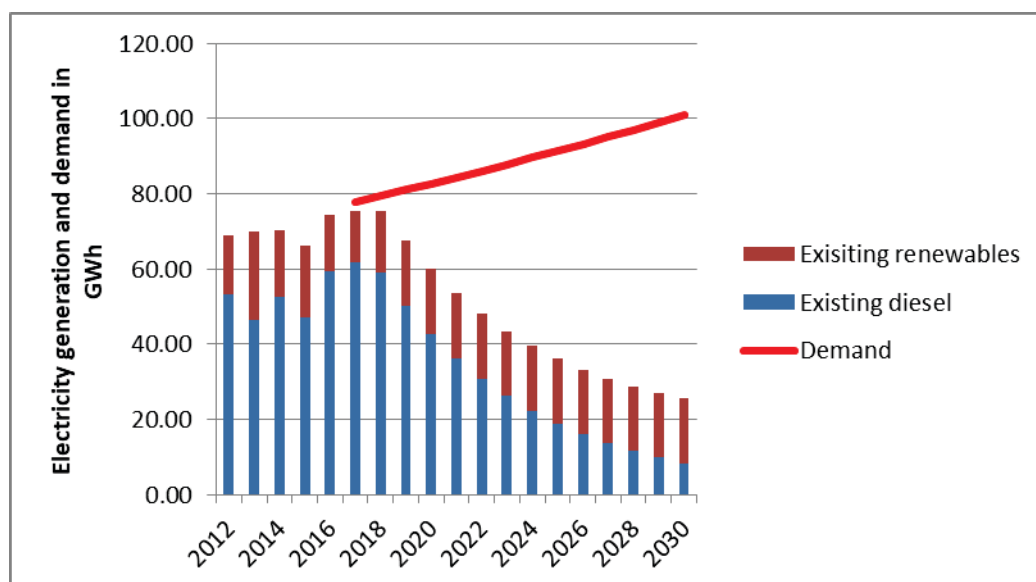
Existing renewable energy capacity: all renewable energy installations in operation by end of December 2015 are included in the existing renewable energy capacity. The major plants are:

- Sarakata 1.2 MW hydro power project
- Devil’s Point 3.6 MW wind farm, commissioned in 2014³
- Solar PV units of 80 kW at Tagabe, 20 kW at Tanna and 20 kW at Malekula⁴

Contribution of coconut oil: the diesel generators operated by UNELCO are capable of using coconut oil as a fuel.

Coconut oil was extensively used in the years 2012-2015 in Efate and Malekula. The shares of coconut oil in total electricity production were close to 50% in Efate and up to 100% in Malekula. Due to changes in world market prices, consumption was reduced dramatically in 2016 and in 2017/2018 no coconut oil was used for electricity generation. For the baseline it is assumed that no coconut oil will be used in the period 2019-2030.

The following figure shows the resulting gap in renewable electricity generation for the period 2019 to 2030. Existing renewables (mainly wind in Efate and hydro power in Santo) provide around 13 GWh per year. Diesel consumption is being reduced gradually until 2030, contributing around 9 GWh per year (8.8% of projected demand in 2030). As a result, there is a gap of 74 GWh in 2030, which needs to be filled with additional renewable energy projects.



³ <https://www.unelco.engie.com/en/commitments/objectives-on-renewable-energy/wind-power>, <http://www.vergnet.com/project/vanuatu-devils-point/>

⁴ <https://www.unelco.engie.com/en/commitments/objectives-on-renewable-energy/solar-power>

Figure 7: Electricity generation and demand BAU scenario

A key technology for the achievement of the NDC target will be coconut oil. Coconut oil can be used (after some adaptation work) in existing diesel generators and plays a major role in balancing the unpredictable generation patterns of wind and solar PV.

UNELCO published the “Vanuatu Electricity Road Map 2015-2030” in 2015, which gives UNELCO’s view on the development of the electricity sector in Vanuatu. In the Road Map, coconut oil plays a major role in supplying electricity and UNELCO projects that more than 50% of their electricity generation can be based on coconut oil in 2030. The following graph shows the projected electricity generation by fuel type between 2012 and 2030.

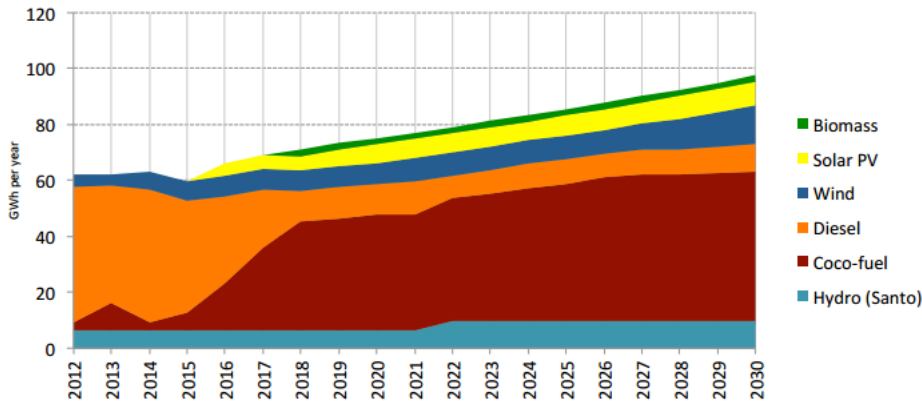


Figure 8: UNELCO electricity generation by fuel type 2012-2030

5 PLANNED RENEWABLE ENERGY PROJECTS

The updated NERM of 2016 included in Appendix B: Implementation Plan a long list of investments and actions that could help meeting the NERM targets. The planned activities were grouped into the following categories:

- Investments and Donor Programmes
- Policies, laws and regulations
- Analysis and studies
- Capacity building and institutional development
- Other

Out of these categories, the first category (Investments and Donor Programmes) is relevant as it includes investments into the supply sector of Vanuatu electricity system. This category basically covers the following types of investments:

- Renewable energy
- Rural electrification
- Energy efficiency
- Grid extension

The first 2 categories are relevant for the NDC Implementation Roadmap, as they are mentioned in the NDC (energy efficiency and grid extension are not targeted in the NDC). The following table lists all activities under these categories and gives an update on the status of implementation.

Investment/ action	Main outcome(s) it contributes to	Priority	Cost ⁵	Lead responsibility	Status	Timing	Update
Investments and Donor Programmes							
Undine Bay Solar PV System (510kW)	Access, sustainability, green growth	Immediate	US\$1.1m	UNELCO	Construction completed; ready to launch	2016	Completed and operational
Demonstration Rural Biofuel Project (Ambae, Vanua Lava)	Access, sustainability, green growth	Immediate	US\$2.2m	EU	In progress	2012-2016	Systems installed and will be operational after proper meter and household wiring are in place
Kawene 1.5MW Grid-connected Solar Facility, Efate (Energy Facility 2)	Sustainability	Immediate	US\$4.3m	EU, UNELCO, GoV	In progress	2016	System installed and commissioned in early 2018 and currently operational
Loltong Hydro Project, North Pentecost	Access, sustainability, green growth	Immediate	US\$0.02m	Governments of New Zealand, Australia, and Vanuatu	In progress	2016	System installed, operating but frequently experiencing stability issues
Talise Hydro Project, Maewo (Phase 2—installing distribution lines)	Access, sustainability, green growth	Immediate	US\$0.7m to US\$1.0m	IUCN, Governments of Austria, Italy, and Vanuatu	In progress	2016-2017	Phase 2 completed at end of July 2018 involving installation of transmission lines to all villages of Talise, Nasawa and Narovorova, and installation of distribution lines with 1-2 public facilities connected. Currently, in search for additional funding for the 3 rd phase for household connections.
Whitesands Solar PV Micro-grid, Tanna	Access, sustainability, green growth	Highest			Proposed		Delayed & No progress

⁵ Costs of investments in many cases represent only the upfront costs, with ongoing O&M costs extra. Some items may overlap with others (in particular, the National Green Energy Fund's budget could potentially cover other initiatives listed in this table).

Investment/ action	Main outcome(s) it contributes to	Priority	Cost ⁵	Lead responsibility	Status	Timing	Update
Efate Grid Connected Solar PV Project (1MW)	Sustainability	Highest	US\$5.6m	UNELCO	Proposed	2016-2018	Already installed at Undine Bay, North Efate.
Vanuatu Rural Electricity Project (VREP) Phase 2	Access, sustainability, green growth	Highest	TBD	TBD	Proposed	TBD	Project approved - \$14.17m and currently in implementation stage. Anticipate completion in June 2022.
Sarakata Hydro Power Extension Project (600kW), Santo	Access, sustainability, green growth	Highest	US\$4.25m	GoV, VUI/Santo concessionaire	Proposed	2018-2021	In progress of finalising funding and design.
Brenwe Hydro Power Project (< 1.2MW), Malekula	Access, sustainability, green growth	Highest	US\$5.6m to US\$6.45m	SREP, ADB and GoV	Proposed	2018-2021	Project approved and implementation commencing in 2019. Anticipate completion by 2021.
NAMA Intervention (5 solar PV micro-grids)	Access, sustainability, green growth	High	US\$2.1m	Austrian Government	In progress	2019	Funding approved, priority given to Wintua, Malekula as grid site.
Takara Geothermal Power Plant (4+4MW) preparatory study & investment	Access, sustainability, green growth	Medium	US\$108m	Geodynamics	Proposed	TBD	Not much progress except NZ MFAT have procure company to support GoV in revalidating the geothermal.
Rural biogas project	Access, sustainability, green growth	Medium	TBD	GIZ	Proposed	TBD	No update yet

6 PROPOSED MITIGATION INTERVENTIONS

To achieve the NDC target of close to 100% renewable energy in the electricity sector by 2030, new capacities to generate electricity from renewable energies need to be added to the electricity system in Vanuatu. A gap of around 70 GWh needs to be closed, which means that current electricity generation from renewables needs to be increased by a factor of 4.

To cover this gap, the NDC lists the following options:

- Doubling of the wind installed capacity to 5.5 MW by 2025
- Installing 10 MW grid connected solar PV by 2025
- Commissioning the proposed first stage 4 MW Geothermal plant by 2025
- Adding 10 MW grid connected solar PV by 2030
- Commissioning the second stage 4 MW Geothermal plant by 2030
- Substituting and/or replacement of fossil fuels with coconut oil based electricity generation

If all wind, solar and geothermal projects are implemented, these will potentially generate 87.5 GWh of electricity.⁶ The geothermal project (both phases) is contributing two thirds to that generation.

This chapter 6 is suggesting interventions required for achieving the NDC target of transitioning to close to 100% renewable energy in the electricity sector by 2030. The various interventions are grouped into three categories:

- Interventions already implemented: this includes interventions which were implemented between the signature of the Paris Accord (December 2015) to date. Interventions covered here are operating and are already contributing to the NDC target and are generating GHG emission reductions.
- Interventions under implementation or preparation: includes interventions which are currently under implementation or are in the preparation phase. Construction has already started if interventions are under implementation. If interventions are in preparation phase, financing has been secured or is in an advanced stage of preparation.
- Additional interventions necessary to achieve NDC target: covers additional interventions necessary to achieve the NDC target.

6.1 INTERVENTIONS ALREADY IMPLEMENTED

The Government of Vanuatu has been active for years to increase the share of renewable energies in the country. Since the signature of the Paris Accord in December 2015, a number of renewable energy projects have been implemented, which are seen as first contributions to the NDC target.

Newly implemented renewable energy projects: all renewable energy installations in operation by end of December 2017 are included in the existing renewable energy capacity. The major plants are:

- Undine 510 kW solar PV plant, commissioned in 2016
- Parliament Building and Meteo complex 767 kW solar PV plants, commissioned in 2016⁷
- Kawene solar PV plant: the Kawene 1 MW solar PV plant was put in operation in early 2018, there is only generation data for a few months available. According to UNELCO, the Kawene plant is performing as the other solar PV units.

⁶ Assuming the following full load hours: solar 1,300 / wind 2,000 / geothermal 7,000

⁷ <https://doe.gov.vu/uploads/pub/FINAL%20AR%20-%202016%20-%20Format1.pdf>

As all these projects were implemented after the signature of the Paris Accord (December 2015), they are seen as first contributions to the NDC target. The following table summarizes the key information on these projects.

	Undine solar PV plant	Parliament Building and Meteo complex solar PV plants	Kawene solar PV plant
Technology	Solar PV	Solar PV	Solar PV
Size	510 kW	767 kW	1.0 MW
Location	Undine Bay, Efate	Port Vila, Efate	Devil's Point, Efate
Year of commissioning	2016	2016	2018
Expected annual electricity generation ⁸	714 MWh	1,074 MWh	1,400 MWh
Operator	UNELCO	UNELCO	UNELCO

Table 2: Key information on newly implemented renewable energy projects

Based on these implemented projects, a total of 3.2 GWh of electricity generated is added in each year. This reduces the gap in 2030 to 70 GWh.

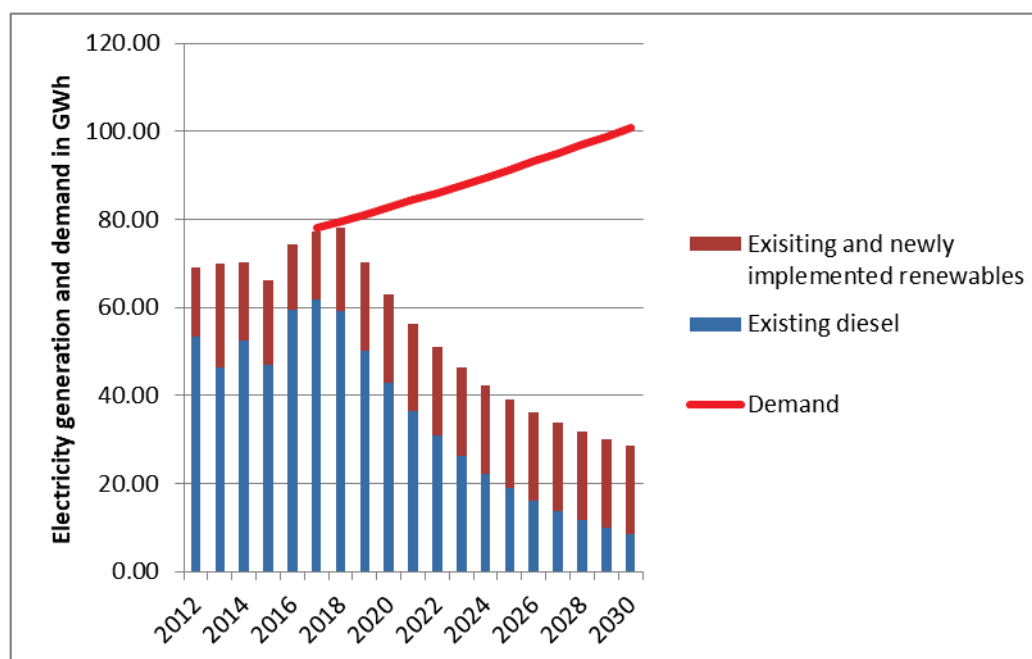


Figure 9: Electricity generation and demand BAU scenario plus newly implemented projects

6.2 INTERVENTIONS UNDER IMPLEMENTATION OR PREPARATION

Due to the activities of the Government of Vanuatu, a number of interventions have been initiated, which are currently under implementation or under preparation for implementation. These

⁸ Assuming 1,400 hours of operation per year.

initiatives are important steps towards increasing the share of renewable energies and contributing to the NDC target.

The following initiatives are currently under implementation or preparation:

- Brenwe Hydro Power Project
- Sarakata Hydro Power Extension Project
- Vanuatu Rural Electrification Project (VREP) Phase II
- Talise Micro Hydro Power Project

The following chapters describe these projects in detail.

6.2.1 BRENWE HYDRO POWER PROJECT

The Brenwe Hydro Power project is a 400kW run-of-river hydro power plant on the island of Malekula, located about 5 km north-west of Unmet village. The project has a head of 100m and a design flow of 0.66m³/s. An approximately 23 km long 20 kV transmission line will be constructed from the powerhouse to Lakatoro where it will connect to UNELCO's existing grid. Project is currently under preparation and will be supported through the Vanuatu Energy Access Project (VEAP). Completion is expected in 2022.

Project will be operated by whoever runs the concession in the area. The concession boundary has been extended to cover the Brenwe area. UNELCO, who recently signed an extension of the concession agreement from 2020 to 2030 will be responsible to manage, provide service and maintain from the completion to 2030.

The project is expected to generate 1,398 MWh of electricity per year (based on BRANTV ProDoc).

Funding secured is secured and the project will be fully financed through and ADB loan and contributions from the Government of Vanuatu.

Summary	
Electricity generated:	1.4 GWh
First year of operation:	2023
Financing:	Secured. ADB Loan plus GoV

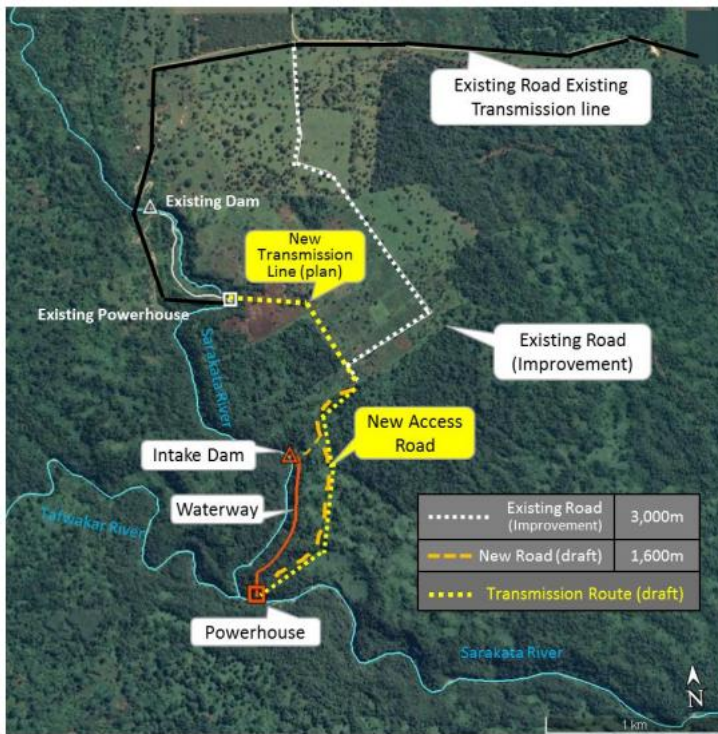
6.2.2 SARA KATA HYDRO POWER EXTENSION PROJECT

More than 70% of electricity demand in the Santo power grid is currently supplied by the Sarakata River hydroelectric power plant (2 x 300kW units installed in 1994/1995, 1 x 600kW unit installed in 2009), the remaining demand is covered by diesel and a small solar PV unit. Due to the increase in demand over recent years daytime peak load reached 1.9 MW in 2016. The expected additional demand of 2% p.a. will increase both peak load and demand further.

The Government of Japan has started investigations on expanding the existing plant by another 800 kW. The aim is to construct a new small hydroelectric power plant in the downstream of the existing Sarakata river hydroelectric power plant in order to supply electricity to the grid. The Project also might include provision of technical facilitation regarding proper operation and maintenance of a small

hydroelectric power plant and sound management and administration, for keeping sustainable operation and maintenance of the facilities.

The following graph shows the planned improvements.



The planned output at 800 kW installed capacity is 5.5 GWh per year. Work on the preparatory survey will be done throughout 2019 and the final report is expected in December 2019. The intention then is to apply for funding at the Japanese Grant for Projects. Under this grant scheme, the Government of Japan is covering the majority of the investment costs with the Government of Vanuatu contributing by providing land, access to electricity grid, etc. Taking into account one year preparation and two years construction, it is expected that the project can be online earliest in 2023.

Summary	
Electricity generated:	5.5 GWh
First year of operation:	2023
Financing:	Funding through Japanese Grant for Projects envisaged, contribution from Government of Vanuatu

6.2.3 VANUATU RURAL ELECTRIFICATION PROJECT (VREP) PHASE II

Work on the Vanuatu Rural Electrification Project (VREP) was started in 2014. Phase I (VREP I) focused on the electrification of off-grid households, aid posts and community halls. VREP Phase II was started in 2017 and covers the implementation of the following components until June 2022:

- Provision of Solar Home Systems and Micro Grids systems in rural areas of Vanuatu: SHS and micro grids will be available to rural households and public institutions. This component will

target approximately 37 public institutions and 8,400 rural households, which equates to approximately 42,000 people.

- Construction of Mini Grids systems in rural areas of Vanuatu: This component will support electricity service provision to approximately 550 rural households, which equates to around 2,750 people, and public institutions and businesses.
- Technical Assistance and Project Management

VREP II will finance around 4.5 MW installed capacity of solar PV with battery backup, generating around 2.7 GWh annually of solar based power. The project has received approval and implementation has started. It is expected that the installations of SHS and micro grids is finalised by 2022, therefore 2023 will be the first year of full operation of these systems.

Mini grids will be operated and maintained by local service providers and procured through competitive tender by the Government of Vanuatu.

Funding secured and USD 6.8 million for design, supply, installation and commissioning of two mini grid systems is provided through the International Development Association and the Pacific Regional Infrastructure Facility (PRIF) and Strategic Climate Fund (SCF) through The International Bank for Reconstruction and Development and International Development Association.

Summary	
Electricity generated:	2.7 GWh
First year of operation:	2023
Financing:	Secured. IDB and Trust Funds

6.2.4 TALISE MICRO HYDRO POWER PROJECT

The Talise Hydro Power project is a 75kW run-of-river hydro power plant on the island of Maewo. The project has a head of 94m and a design flow of 0.12m³/s. As of December 2013, 90% of the generation has been completed however the transmission line and the mini-grid are yet to be constructed. The transmission will connect the villages of Talise, Narovorovo and Nasawa.

Project is currently under preparation and will be supported through the BRANTV Project. It is expected that the project will be operational latest 2022.

The project will generate 262 MWh of electricity per year (based on BRANTV ProDoc). Supply in mini-grid will be 100% based on renewable energy.

Funding secured and the project will be fully financed through the BRANTV project.

Summary	
Electricity generated:	0.3 GWh
First year of operation:	2022
Financing:	Secured. BRANTV Project.

6.2.5 CONTRIBUTION TO NDC TARGET

Based on these additional projects, which are under implementation or preparation, a total of 9.9 GWh of electricity generated is added per year after each of the projects is in full operation. This reduces the gap in 2030 to 60 GWh.

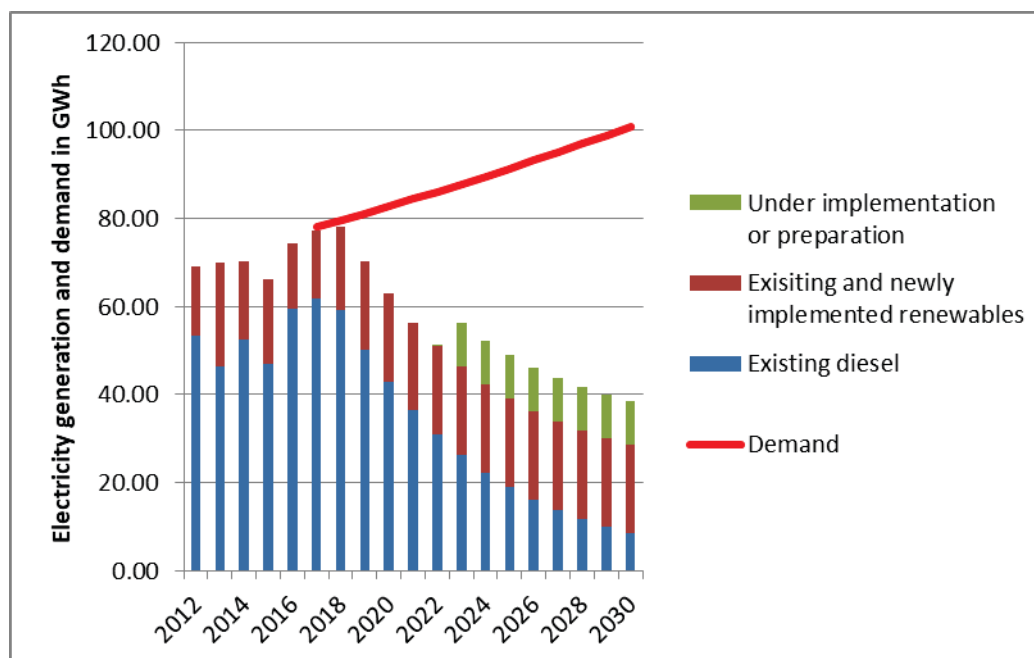


Figure 10: Electricity generation and demand BAU scenario plus projects under implementation or preparation

6.3 ADDITIONAL INTERVENTIONS NECESSARY TO ACHIEVE NDC TARGET

Based on the BAU projections and the projects listed in sections 6.1 and 6.2, a total of 62 GWh of additional generation needs to be provided by 2030 to achieve the NDC target of close to 100% renewable energy in the electricity sector by 2030. This means that the output of existing renewable installations and installations currently under implementation or preparation need to be almost tripled.

With the planned implementation of the Sarakata Hydro Power Extension Project on Santo, more than 90% of the electricity generation will come from renewable energy sources. The situation is similar on Malekula, where the Brenwe project will provide a valuable contribution and the existing diesel generators are able to use coconut oil.

The major gap of renewable energy generation is in Efate, where in 2017 90% of electricity was generated from diesel. The share of diesel generation is Tanna is even higher (more than 96%), but the share of Tanna in the entire electricity consumption of Vanuatu is only around 1.5%.

The following interventions have the capability to provide sizeable contributions to closing the gap:

- Solar PV
- Wind
- Coconut oil
- Geothermal

6.3.1 LEVELIZED GENERATION COSTS

Before analysing the potential contributions of the different technologies, an estimate of the levelized costs was prepared based on available data and information. Levelized costs are an appropriate means to compare the cost of electricity generation from different energy sources by taking into consideration both investment and operation costs.

The majority of data has been provided by UNELCO and is based on their experience with renewable energies as well as information and data from the “Efate Energy Road Map 2018-2030”.

The following data and assumptions have been used for the calculations:

- Solar PV: costs are based on the Efate Energy Road Map, which includes cost estimates for investment and operation costs for 7.4 MWpeak of solar PV added to the grid.
 - Investment costs of USD 1.68 million per MWpeak
 - Operation costs of USD 61,000 per MWpeak and year
 - Lifetime of technology: 15 years
- Wind: costs are based on the Efate Energy Road Map, which includes cost estimates for investment and operation costs for 5.1 MW of wind added to the grid.
 - Investment costs of USD 2.64 million per MWpeak
 - Operation costs of USD 134,000 per MWpeak and year
 - Lifetime of technology: 15 years
- Cost of coconut oil: cost of one litre was quoted by UNELCO between 70 and 80 Vatu/litre. An average of 75 Vatu/litre is assumed.
- Cost of diesel: cost of diesel was highly volatile over the last years. Minimum costs per litre are assumed at 76 Vatu, maximum costs at 128 Vatu (based on data received from Customs Office).
- Batteries: both for solar PV and wind additional costs for batteries are calculated on top of technology costs for solar PV and wind. Battery size is based on UNELCO estimates, costs are based on cost quoted in chapter 6.3.6.
- Efficiency of electricity generation in diesel motors: 0.259 litres of diesel per kWh electricity generated
- Heat rates of coconut oil: 88% of heat rate of diesel (which translates into 0.294 litres of coconut oil per kWh electricity generated)
- Interest rate for investments: 5%
- Exchange rate Vatu-USD: 110

The following figure compares the levelized generation costs for solar, wind and coconut oil with minimum and maximum costs for electricity based on diesel. Geothermal was not included in the comparison due to lack of data.

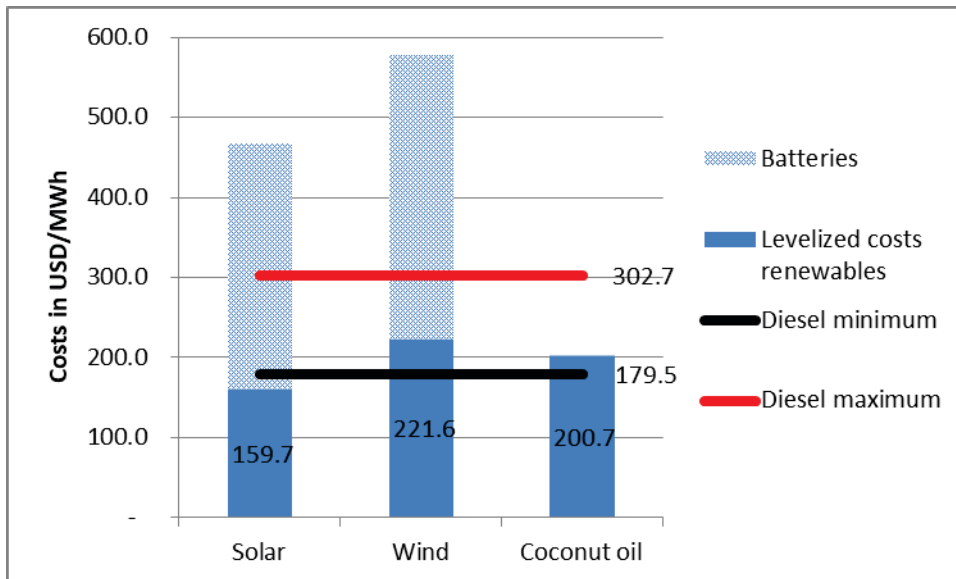


Figure 11: Levelized costs

The following conclusions can be drawn from the analysis:

- The costs for solar PV and wind include both investment and operation costs. Although considerable investments are required for solar PV and wind, levelized costs are well below maximum costs for diesel, which only includes fuel costs and no investment or operation costs. Levelized costs for solar PV are even below minimum diesel costs in the period 2013-2017. Levelized costs for solar PV are considerably lower than costs for wind. This is interesting for various reasons:
 - The generation profile of solar PV is well compatible with the demand profile in the Efate grid, with peak electricity demand around noon – at times when solar PV usually provides highest output. A more detailed analysis can be found in chapter 6.3.2.
 - Investment costs for solar PV projects have come down considerably during the last years, mainly due to lower costs for PV modules. It is expected that this trend continues. In combination with experience from the implementation of solar PV projects, it will be possible to further reduce investment costs, so the levelized costs indicated can be seen as a conservative upper limit.
- When additional costs for batteries are taken into account for solar PV and wind, generation costs are considerably above the price range for diesel generation.
- Due to the requirements for wind projects (cyclone proof, dismantable installations, limitation in size), sizeable reductions in investment costs are not expected. Therefore, the competitive advantage of solar PV with further reduction in investment costs will further increase.
- The analysis of levelized costs does not take into account the question of whether electricity generated can be used immediately to satisfy demand or needs to be stored in batteries to be consumed at a later point in time. This is discussed in the following chapters.

6.3.2 SOLAR PV

Contribution of solar PV

It is agreed among all stakeholders that solar PV will play a major role in providing electricity from renewable energies in Vanuatu in general and can provide sizeable contributions on Efate. Based on the solar radiation and confirmed by results of already operating plants, between 1,350 and 1,400 full-load hours can be expected. As described in detail in previous chapter, a total of 2.4 MWpeak has been installed so far. These solar PV units generate around 3.3 GWh per year and currently contribute to around 4% of annual electricity demand on Efate.

The positive experience with the operation of solar PV units in combination with a continuous downward trend in installation costs calls for further expansion of the capacity of installed solar PV on Efate. In the Efate Energy Road Map 2018-2030 UNELCO proposes an increase of 7.4 MWp, which would give a total installed capacity of 9.8 MWp by 2030. For the NDC Implementation Roadmap it is suggested that a capacity of 7.6 MWp is added, giving a total installed capacity of 10 MWp.

To be able to analyse the impacts of a capacity addition of 7.6 MWp to the grid in Efate, load profiles provided by UNELCO were used. On the day of minimum load (30 September 2017), the lowest demand was slightly below 4 MW, whereas peak was at 7 MW. On the day of maximum load (17 March 2017), demand was between 6.1 MW and 11.7 MW. The lowest demand on 30 September was between 3 am and 5 am, which is not relevant for solar PV, the lowest demand during daytime was around 5 MW. As a consequence, solar PV with a capacity of 5 MWp can be operated at any time already at demand levels in 2017 without the need for battery storage.

The following figure compares the various load profiles with the profile of 10 MW installed solar capacity. “Minimum 2017” is the load profile on the day with the lowest average consumption, “Maximum 2017” the profile on the day with the highest average consumption. “Average 2017” is the average of both curves. The load profile “Average 2030” is the average load profile of 2017 multiplied by the expected increase in demand (29% between 2017 and 2030).

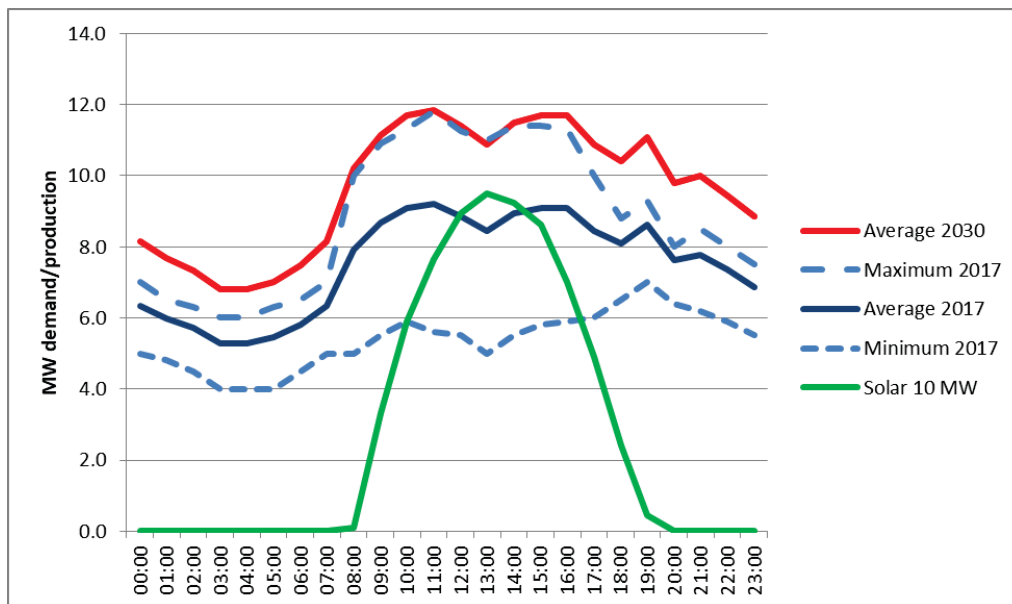


Figure 12: Load profiles 2017 and 2030

As can be seen from the figure, the solar PV supply curve never crosses the average demand curve for 2030, which shows that for most of the day-time there will be no necessity to store excess supply from solar PV. During some days of the year, there is a possibility of oversupply when generation is at

a maximum and demand has a dip around 1 or 2pm in the afternoon. As a consequence, there is no need to have battery storage for the operation of 10 MWp solar PV capacity on Efate.

Implementation

As for the land required, 1 MW of solar PV requires around 15,000 m² or 1.5 hectare. Hence, the additional capacity of 7.6 MW has a land requirement of 11.4 hectare.

For the implementation schedule, the following needs to be considered:

- To be able to use all electricity generated by the 10 MW solar capacity, demand in the Efate grid needs to increase. It is expected that annual demand increase is 2.0%, adding to a total increase of 29% between 2017 and 2030. As a consequence, implementation of solar PV should be phased to allow demand and peak demand during the day to increase.
- A decision needs to be taken on how the expansion of solar PV is implemented. Up to now, all larger solar PV and wind projects were financed by donor funds with utilities in Vanuatu operating the facilities. Due to a lack of the required legal framework, no Independent Power Producers (IPPs) are currently active. If the current way of implementing renewable energy projects is continued, a step-by-step approach in implementation is preferred. This would allow sufficient time to collect funds and give contractors and utilities a stable work load to increase capacity over a number of years.
- If IPPs should play a bigger role and the required legal framework is existing, it will be necessary to bundle implementation and create bigger lots. Then, implementation will either have to take place towards 2030 to wait for an increase in demand or battery storage capacity needs to be added simultaneously to make sure the generated electricity can be used.

For now, it is assumed that the schedule for adding new solar capacity is as follows (years indicate first year of full generation):

- 2022: 1.5 MW
- 2023: 1.5 MW, total of 3.0 MW
- 2024: 1.5 MW, total of 4.5 MW
- 2025: 1.5 MW, total of 6.0 MW
- 2026: 1.6 MW, total of 7.6 MW

In total, the new solar PV capacity will generate 10.6 GWh of electricity per year, thus reducing the gap in 2030 to 50 GWh.

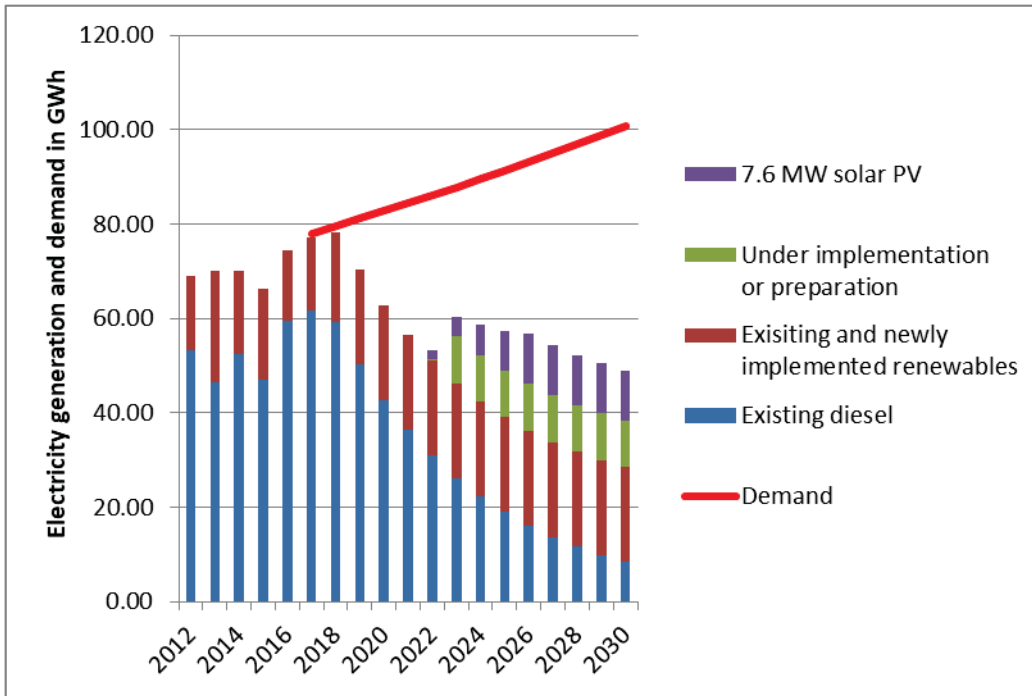


Figure 13: Electricity generation including 7.6 MW solar PV

Investment costs

In the Energy Road Map for Efate provided by UNELCO, total investment costs for 7.4 MWp are estimated at 1,370 million Vatu (around USD 12.45 million). This translates to USD 1.68 million per MW peak.

Based on the feasibility study prepared for the mini grid on Malekula, the following costs for 1 MWp installed capacity are estimated:

Module	USD 570,000
Inverter	USD 220,000
Hardware BOS - Structural/Electrical	USD 400,000
Labor	USD 150,000
Sum	USD 1,340,000

Table 3: Solar PV basic investment costs

What needs to be added to these costs are construction permits fee, interconnection, testing, and commissioning costs, which are dependent on how many separate locations are necessary to achieve a total installed capacity of 7.6 MW. Also, costs for an EPC contractor need to be added in case the solar PV capacity is not operated by UNELCO.

Component	Costs
Installation cost per 1 MWp	USD 1.34 million
Installation cost for 7.6 MWp	USD 10.18 million
Fees and EPC – 15%	USD 1.53 million
Total	USD 11.71 million

6.3.3 WIND

Contribution of wind energy

Wind power has been used in Vanuatu for generating electricity since 2007, when a first wind turbine was erected at Devil’s Point. 10 additional turbines were erected in 2008, followed by 2 additional turbines in 2014. All turbines have a 32 m rotor diameter, a hub height of 55 m and an installed capacity of 200 kW, bringing the total installed capacity to 3.6 MW. A specific feature of the installed wind turbines is the ability to dismantle the blades in case of hurricanes to avoid damage. Due to this special feature, the wind park took no damage of cyclone Pam, which hit Vanuatu in 2015.

The main disadvantage of wind energy compared to solar PV is the unpredictability of the resource. Whereas solar follows a daily pattern which is very much in line with the demand pattern (for details see chapter 6.3.2), it is difficult to predict the availability of wind. As of now, 3.6 MW of wind energy are installed on Efate. The load profiles provided by UNELCO for Efate (see Figure 14 below) show that on the day of maximum demand (17 March 2017) the installed wind capacity could have contributed around 30% to peak demand and around 60% to off-peak demand. On the day of minimum demand (30 September 2017) the 3.6 MW wind could have contributed more than 50% to peak demand. The potential contribution to off-peak demand was 90%.

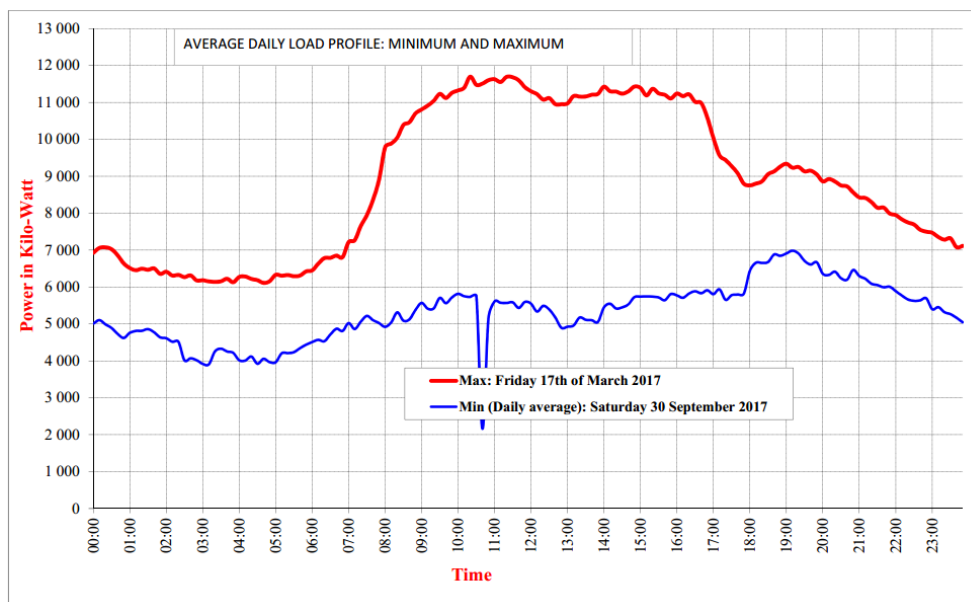


Figure 14: Average Daily Load Profile: Minimum and Maximum – Efate grid

Based on these figures, it is obvious that the operation of wind energy and further increase of the capacity is only possible with sufficient battery storage capacity. Batteries will have the task to store electricity when generation of electricity from solar PV and wind is higher than demand in the grid. More details on batteries are given in chapter 6.3.6.

UNELCO’s Efate Energy Road Map sees an important role for wind energy due to the resource availability and the technical maturity. It is proposed that 5.1 MW of additional capacity are added, generating a total of 9.5 GWh per year.

Implementation

As analysed in the beginning of this chapter, the expansion of the existing wind capacity needs to be synchronised with the introduction of batteries for storage of surplus electricity. As described in chapter 6.3.6, battery storage will be implemented in 2 stages, with a first battery storage system implemented in 2022 and a second in 2025. As a result, the additional wind capacity can be added in 2025.

With this addition (and taking into account the addition of solar PV capacity as described in chapter 6.3.2), the gap in 2030 will be reduced to around 40 GWh.

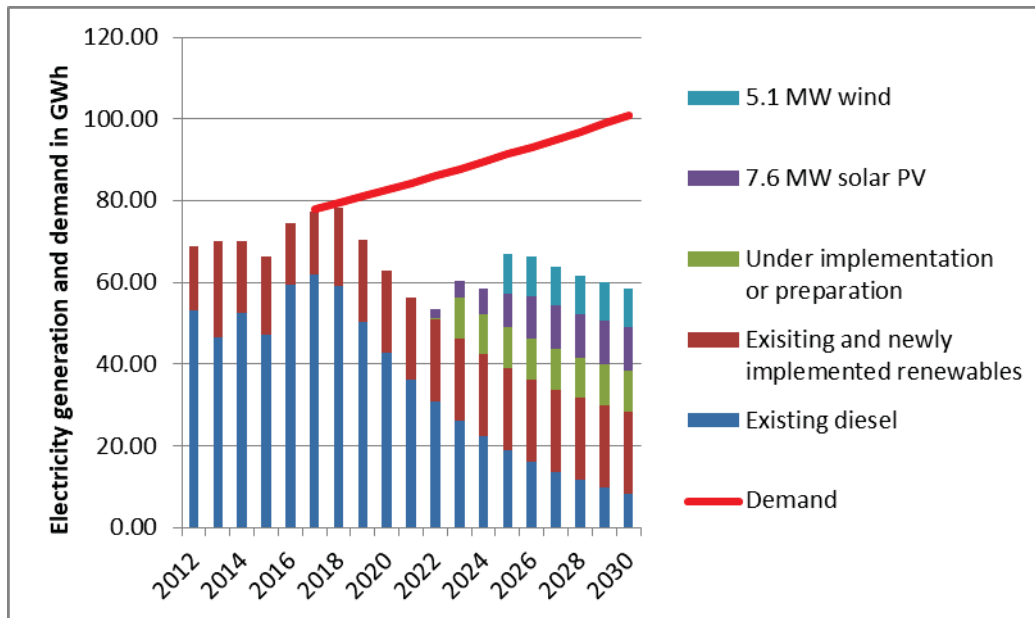


Figure 15: Electricity generation including 7.6 MW solar PV and 5.1 MW wind

Investment costs

The turbines installed at Devil's Point wind park each have a capacity of 200 kW, a hub height of 55 m and a rotor diameter of 32 m. 10 turbines were installed in 2008, 2 turbines were added in 2014. The rather small size of the turbines is based on the ability to dismantle the rotor in case of upcoming hurricanes to avoid damage to the turbine. As indicated in Figure 16, the international trend is towards turbines with bigger capacities and larger rotor diameters. Nominal power of most turbines was between 2 MW and 4 MW, rotor diameter between 80 m and 140 m.

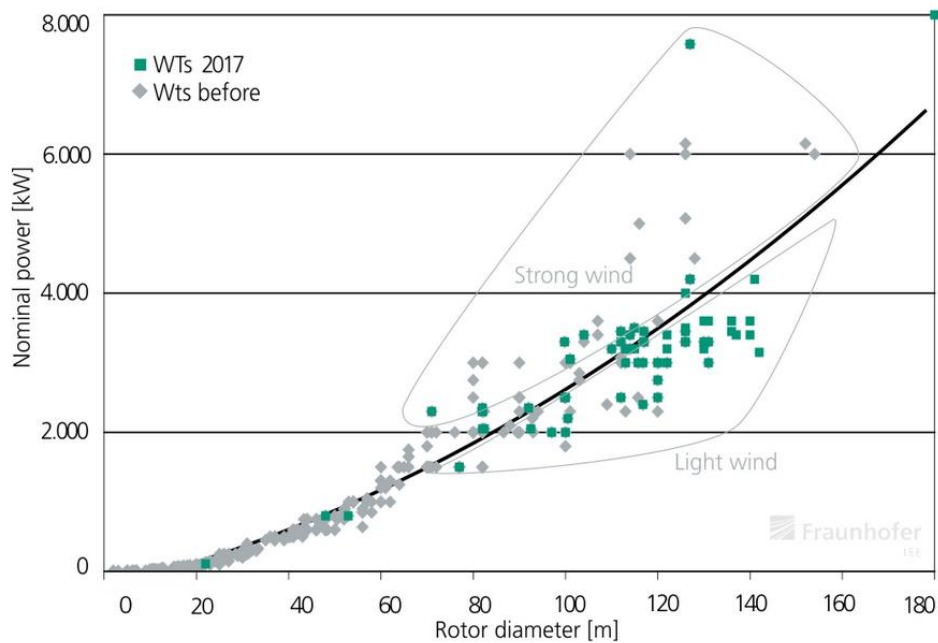


Figure 16: Rated capacity by rotor diameter of different types of wind turbine

Source: Fraunhofer Institute⁹

For the expansion of the existing wind capacity it is advisable to stick to the proven system of dismantlable wind turbines in order to prevent potential damage. As a consequence, it will not be possible to lower investment costs per installed MW, as turbine sizes are limited for this specific application.

In the Energy Road Map for Efate provided by UNELCO, total investment costs for 5.1 MW are estimated at 1,480 million Vatu (around USD 13.45 million). This translates to USD 2.64 million per MW.

6.3.4 COCONUT OIL

Contribution of coconut oil

Coconut oil has played a role in providing electricity from renewable energies in Vanuatu for a number of years. In 2013, slightly more than 3 million litres of coconut oil were used on Efate and Malekula, achieving a share of coconut oil of around 15% in total electricity generation. The diesel generators installed on Malekula and Efate are able to be run based on coconut oil. The following figures show the share of coconut oil in electricity generation and the quantity of coconut oil used between 2011 and 2016. Due to low diesel prices, no coconut oil was used in 2017.

⁹ http://windmonitor.iee.fraunhofer.de/windmonitor_en/3_Onshore/2_technik/4_anlagengroesse/

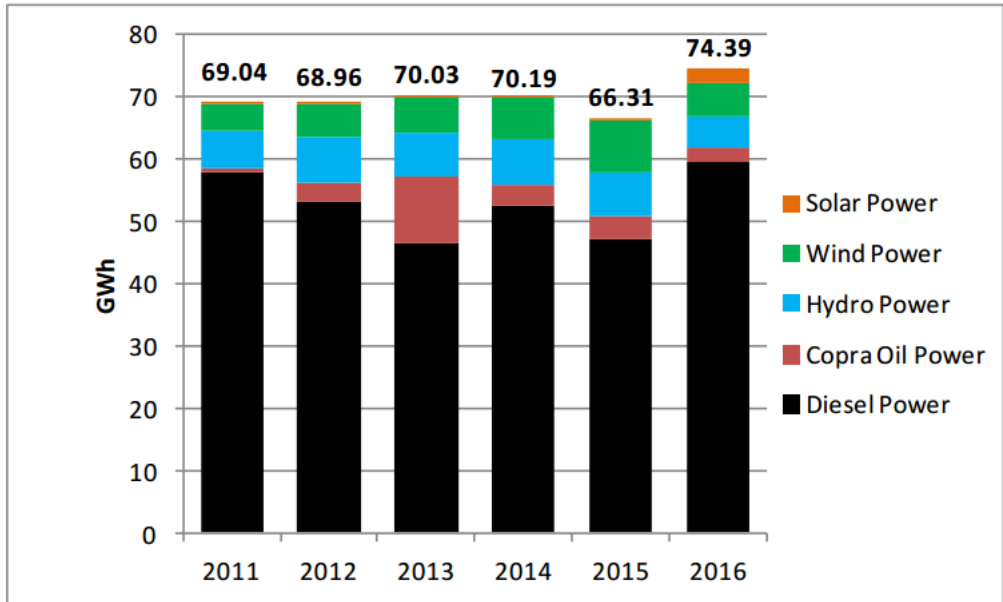


Figure 17: Fuel inputs for electricity generation

Source: URA, Electricity Factsheet 2011-2016

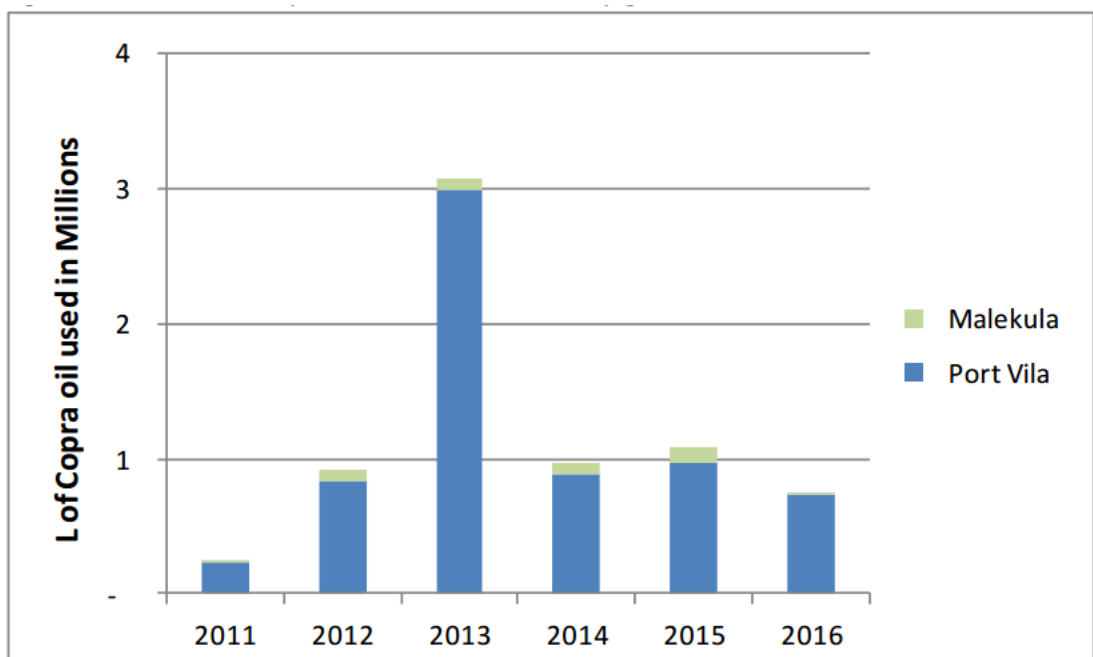


Figure 18: Total litres of copra oil used in electricity generation

Source: URA, Electricity Factsheet 2011-2016

The following figure shows the quantities of copra and coconut oil exported in the period 2008-2013. The low export figure of coconut oil in 2013 coincides with the high use of coconut oil for electricity production.

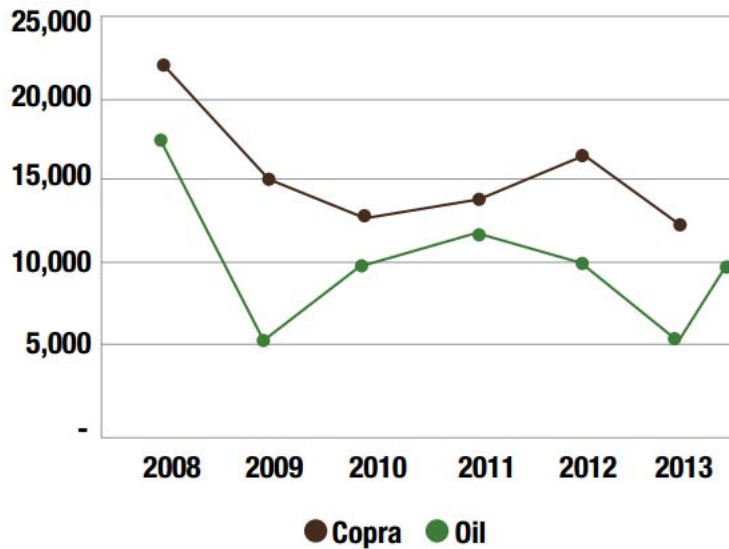


Figure 19: Export of Copra and Coconut Oil

Source: Vanuatu Coconut Strategy 2016-2030. Note: there is no indication in the study on the measurements, it is assumed that figures are tons

The main issues for the use of coconut oil are two factors: the value of copra and coconut oil on the international market and the cost of diesel in Vanuatu. Under the current regulatory framework, utilities are forced to generate electricity on a least cost basis. If imported diesel is cheaper than locally produced coconut oil (the value of which is based on international market prices), utilities are obliged to use diesel for electricity generation.

The following figure compares the price development of coconut oil and diesel between 2010 and 2018. Diesel costs include the statistical import price plus cost components defined in URA's guidance on diesel pricing for electricity services (premium, freight, local charges, excise tax), Coconut oil costs are 90% of world market prices (CIF Rotterdam). In 2013, when electricity generation from coconut oil was at a maximum, coconut oil was considerably cheaper than diesel. In 2016, prices for coconut oil started to increase again, which led to a sharp reduction and finally the stop of generation of electricity from coconut oil.

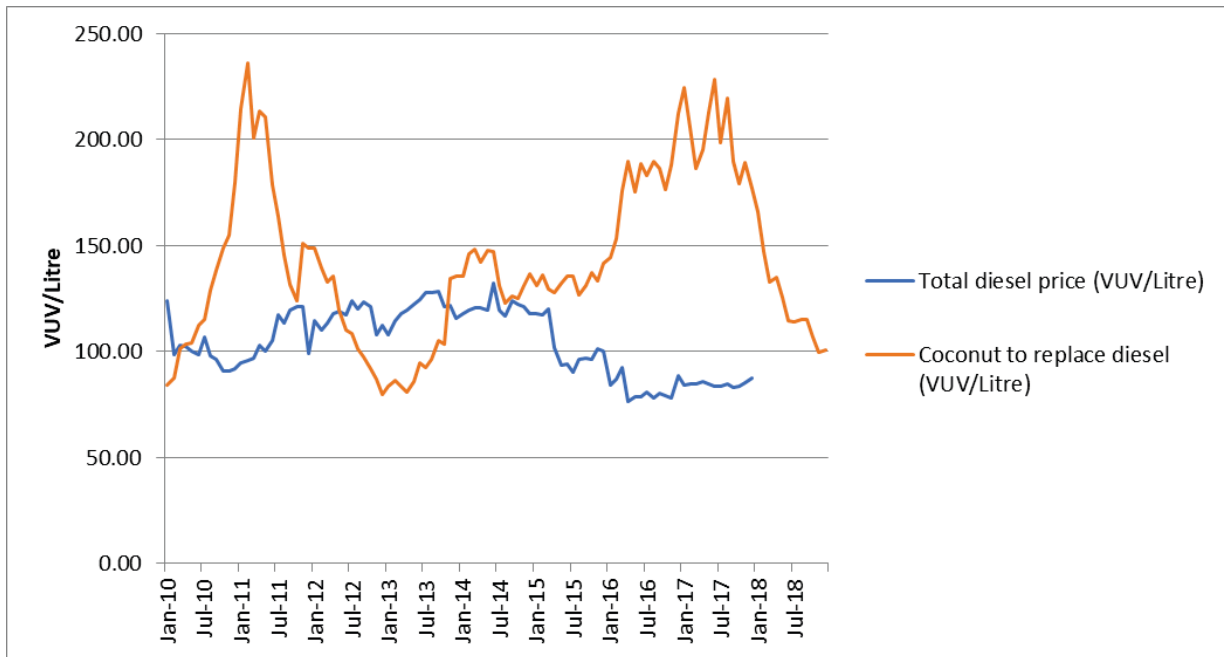


Figure 20: Coconut oil prices 2008-2018 in USD per ton

In 2015, the Government of Vanuatu, led by the Ministry of Agriculture and Rural Development, published the Vanuatu Coconut Strategy 2016-2025. The coconut sector is the most important agricultural sector in the country and is the second largest contributor to foreign exchange earnings after tourism. In 2011, 80% of exports of agricultural products came from the coconut sector, with coconut oil contributing 54% and copra 36%.

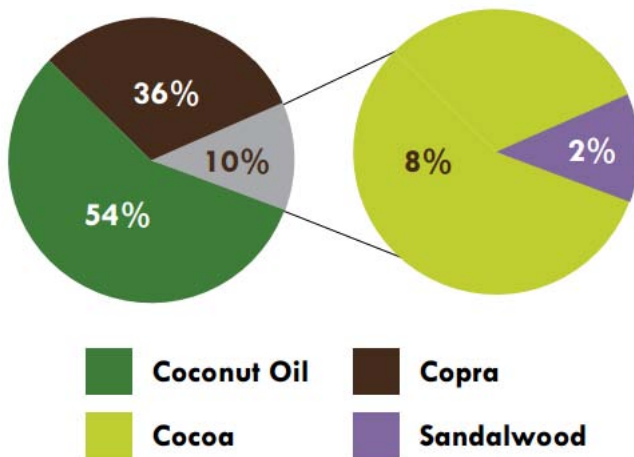


Figure 21: Share of agricultural exports in 2011

The strategy also included a SWOT analysis for coconuts and copra, which is show in the figure below.

Strengths	Weaknesses
<ul style="list-style-type: none"> - Good genetic materials locally available - Favourable climate - Developing market network - Low maintenance plantation management - Fits in well with existing farming systems 	<ul style="list-style-type: none"> - Limited value-added production, reliance on raw commodities exports to foreign markets for processing - Inadequate infrastructure for manufacture and transport - Lack of finance availability for smallholders - Lack of incentives to replant for future supply - Lack of incentives to diversify into other coconut products
Opportunities	Threats
<ul style="list-style-type: none"> - Target higher value buyers with more value added and convenient products - Improve linkages to tourism sector to tap local market for artisanal coconut products - Improve quality and food safety to meet growing world quality standards - Rich value added product possibilities - Add value across entire product line to motivate replanting - Harvest senile palms for flooring and other timber uses - Coconut oil offers health benefits - Organic certification - Private sector investment - Local market of coconut oil not influenced by world coconut oil price - Significantly improve farmers income 	<ul style="list-style-type: none"> - Aging trees, declining supply - Poor tree management promoting pests and disease - Change in government policy - Rising quality standards of markets and competing countries - Land issues - Impacts of climate change and natural disasters

Figure 22: Copra/coconut SWOT analysis

In relation to the use of coconut oil for electricity production, the SWOT analysis includes the following relevant aspects:

- Weaknesses:
 - Reliance on raw commodities exports for foreign markets for processing: by producing coconut oil locally for electricity generation, this weakness is turned into an asset, as facilities are operational
 - Lack of incentives to replant for future supply: to be able to use coconut oil for electricity production on a larger scale, long-term arrangements need to be made between producers and users. This will give an incentive for replanting and at the same time increase confidence in sustainable, long-term supply.
- Threats:
 - Aging trees, declining supply: this is a key issue which needs to be solved. Production will have to increase in order to be able to supply the quantities necessary to achieving the NDC target.
 - Rising quality standards of markets and competing countries: as coconut oil will be used locally and the quality produces is well-fitting for electricity generation, this will not be an issue.

The coconut strategy has the vision that coconut is the top income earner in Vanuatu's agriculture sector by 2026, this should be achieved by pursuing the following objectives:

1. Establish appropriate administrative and regulatory frameworks to manage the coconut sector.
2. Increase farmer access to improved planting materials.
3. Enhance coconut farming through appropriate information and support.
4. Increase production and quality through good agricultural practices.

5. Introduce incentives for private sector engagement in agro-processing and value adding at all levels of the value chain.
6. Enhance trade and marketing of coconut products in the domestic and export market.

All these objectives are relevant to increase the share of coconut oil as a source for electricity generation. The considerable efforts and costs to ship coconut oil internationally will decrease, which is a benefit for the entire sector.

Based on the plan to reduce generation of electricity from diesel by 10% per annum and taking into account the various capacity additions of renewable energy sources mentioned in the previous chapters, there is a considerable gap which needs to be closed with generation of electricity from coconut oil. The gap increases constantly over the years up to a maximum of around 40 GWh required from coconut oil.

Based on the following specific technical parameters, the required volume of coconut oil has been calculated:

- Efficiency electricity generation diesel: 0.259 litres diesel per kWh
- Efficiency coconut oil vs. diesel: 88%

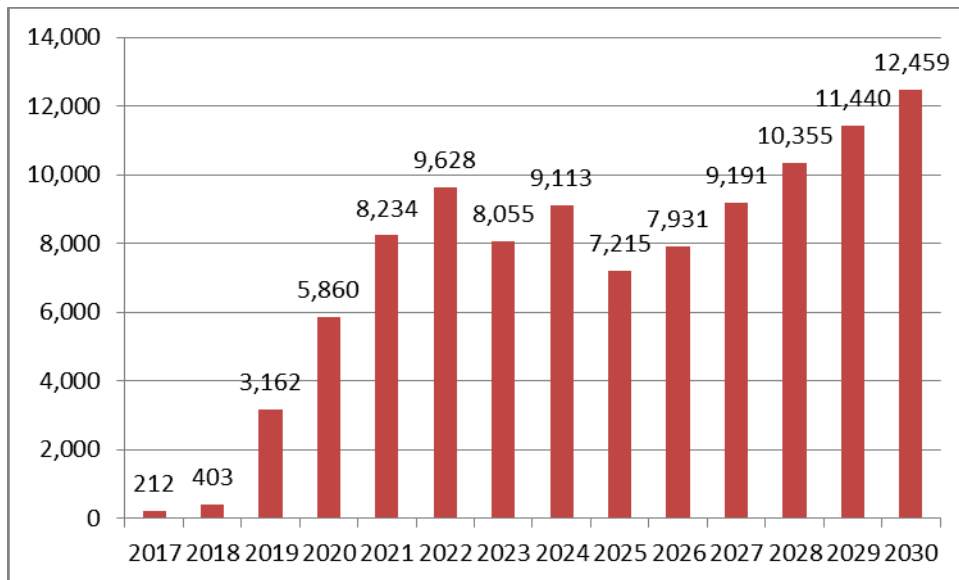


Figure 23: Required quantities of coconut oil in 1000 litres

Demand is increasing steadily to 2024, when more than 9 million liters of coconut oil will be required for electricity generation. As a number of other renewable energy projects will come online in 2025, demand will be reduced in 2025, but then rise further to 12.5 million liters in 2030. With the quantities of coconut oil mentioned in Figure 23 and the contributions of the other renewable energy sources as described in the previous chapters, the NDC target can be achieved.

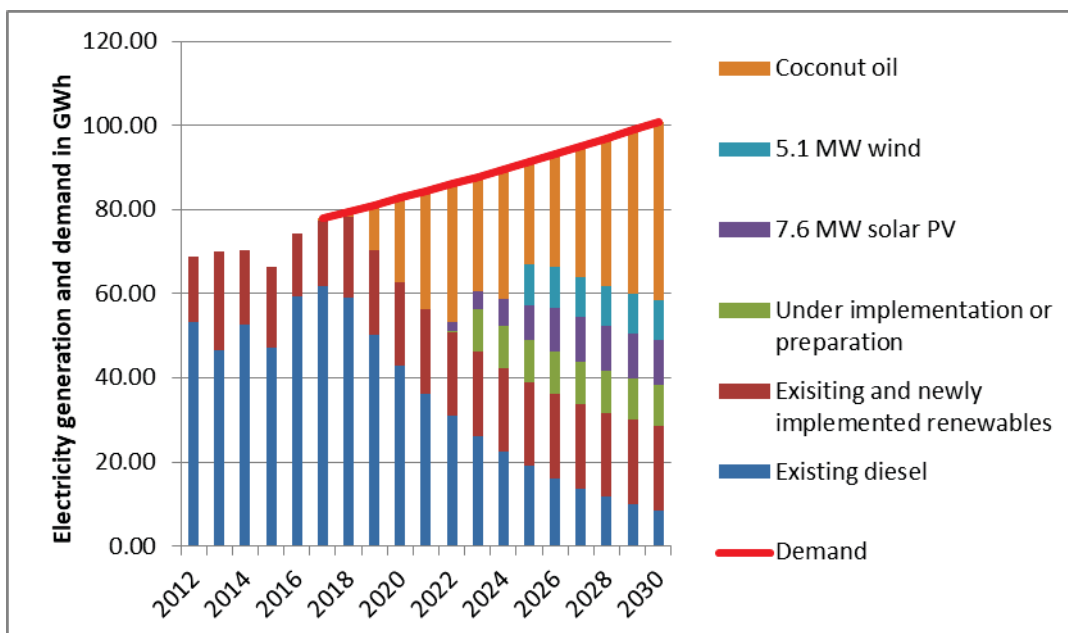


Figure 24: Electricity generation including all renewable energy sources

In the peak year of coconut oil consumption (2013), around 3 million liters were consumed for electricity generation. As seen in Figure 19, total exports of coconut oil were between 5 and 10 million tons between 2009 and 2013. This means that considerable efforts are necessary to secure the local resource for electricity generation.

Coconut oil vs. diesel prices

Despite the numerous benefits of using the local energy source coconut oil for electricity generation, higher costs of coconut oil versus diesel oil were always given as the main argument for the modest and fluctuating contribution of coconut oil in Vanuatu's energy mix. The regulatory framework given by URA binds the electricity price to the price of diesel. Only in periods of time, when coconut oil is cheaper than diesel it is possible to switch.

The key challenge of the current system is that the price of a locally produced energy source is linked both to the international market price of diesel and coconut oil. The linkage to diesel determines that coconut oil can only be used in electricity generation when purchase price of coconut oil is below the price of diesel. Coconut oil market prices also influence the availability of coconut oil for electricity generation, as producers/exports aim at exporting copra/coconut oil in case market prices are favorable. Both factors make it difficult to setup a sustainable delivery mechanism, which guarantees fair and acceptable prices for producers as well as low costs for utilities and finally electricity consumers.

In order to analyze the impact of coconut oil versus diesel prices, 3 different coconut oil pricing models were defined. Based on historic price developments it was analyzed what the impact on total fuel costs for each of the models is. The 3 pricing models were:

- UNELCO flexibility model: coconut oil price is fluctuating over diesel in a bandwidth of +/- 20%.
- Fixed price I: a fixed price for coconut oil of 75 VUV/l is paid. This is based on price indications from UNELCO.

- Fixed price II: a fixed price for coconut oil of 90 VUV/l is paid. This is based on the world market price for copra of VUV 65,000/t mentioned in Copra Subsidy above which no subsidy under the Copra Subsidy Scheme is being paid.

The graph below shows the 3 pricing models in the period 2010 – 2018.

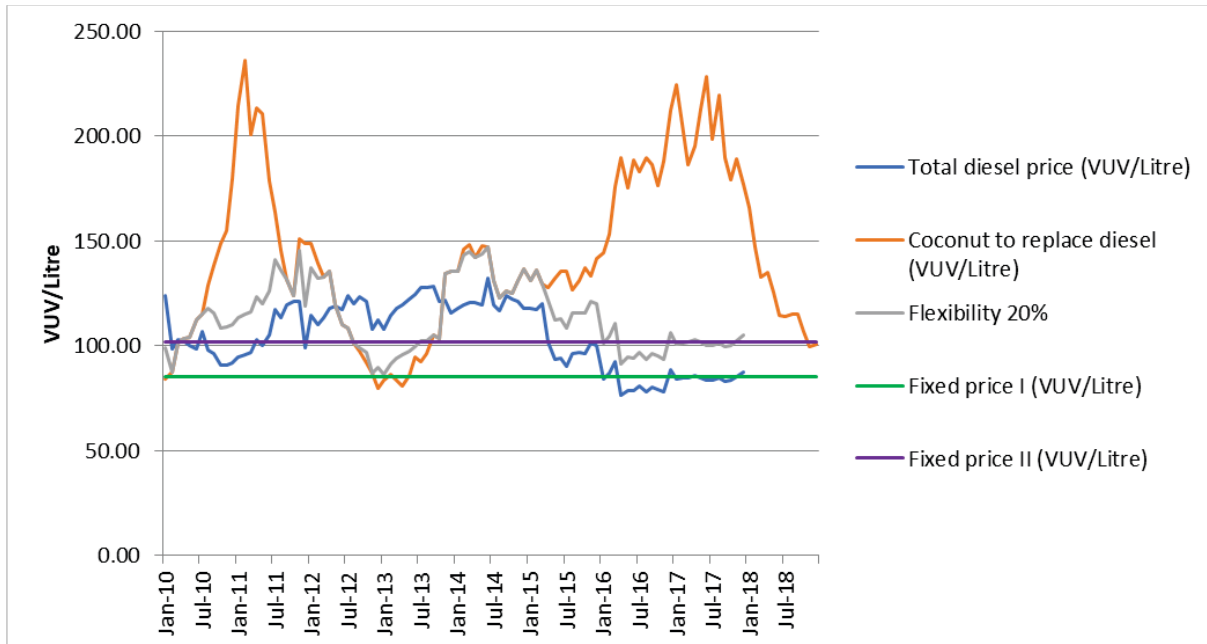


Figure 25: Potential scenarios for coconut oil pricing

For the analysis it was assumed that a total of 700,000 liters of coconut oil per month (8.4 million liters/year) is consumed. This is approximately the average of expected coconut oil consumption in the period 2021-2027. The following conclusions can be drawn from the analysis:

- If the flexibility model would have been applied over the period 2010-2018, electricity costs per kWh would have been on average around 4.5 VUV higher than if only diesel would have been consumed.
- In fixed price model I (price of 75 VUV/litre for coconut oil) electricity costs would have been 0.6 VUV/kWh lower than compared to only using diesel.
- In fixed price model II (price of 90 VUV/litre for coconut oil) electricity costs would have been 2.0 VUV/kWh higher than compared to only using diesel.

Whereas the flexibility model would have led to higher prices of electricity generation, a fixed price between 75 and 90 VUV for coconut oil would have resulted in equivalent costs for electricity generation in the period 2010-2018. It goes without saying that historic price developments give no indication on the development of future world market prices of diesel and coconut oil. However, if the analysis on past costs has shown equivalent costs for coconut oil and diesel, it is justifiable that a fixed coconut oil price is taken as a basis for calculation of electricity costs.

Fixing the price for coconut oil would allow delinking of local production from international market price developments. As local production costs of coconut oil are not being influenced neither by coconut oil nor diesel world market prices, this would be an important step towards building a sustainable, long-term supply oil coconut oil. A fixed price arrangement would allow utilities to sign

long-term (e.g. 10 years) contracts with producers, giving them security of demand and a good basis for ongoing investments (equipment, replanting, etc.).

Coconut for Fuel Strategy

A detailed “Coconut for Fuel Strategy” needs to be elaborated, which needs to include the following components:

- **Securing supply:** the recent decline in production of coconuts needs to be reversed by new plantations. Long-term contracts need to be signed between coconut oil producers and utilities, giving security on both sides on the volumes of coconut oil to be delivered over longer time periods. Current and future production volumes need to be investigated to understand the long-term perspective.
- **Managing production process:** it needs to be assured that sufficient capacity is available to manage the production process from harvesting coconuts to delivering coconut oil to the utility.
- **Evaluating additional benefits:** there are various additional benefits to the growing of coconut trees which need to be evaluated. Examples are:
 - Coconut plantations can be used for additional agricultural purposes, such as kava or grazing of cattle.
 - Copra meal can be used as feedstock for animals, e.g. chicken.
 - A stronger focus on the coconut sector will allow other coconut based projects to grow as well and find their niche markets, such as virgin coconut oil
- **Pricing mechanisms:** need to be developed making sure that both low costs for consumers of electricity and fair income for coconut producers are considered. This can include for example:
 - Fixed prices with inflation adaptation
 - **Pro’s:**
Gives planning security to all partners involved.
Allows long-term investments to increase production of coconuts.
 - **Con’s:**
Doesn’t allow coconut oil producers to benefit from potential increases in market price for coconut oil.
Will require revision of regulatory framework in case diesel price is below agreed fixed price.
 - Variable prices within a certain bandwidth, linked to international diesel and/or coconut prices
 - **Pro’s:**
Coconut oil producers benefit (to a limited extent) from coconut oil market price increases
Electricity consumers benefit (to a limited extent) from decreases of diesel and coconut oil prices
 - **Con’s:**
If coconut oil price is linked to diesel price, fluctuations in diesel price will impact revenue situation of coconut oil producers
Electricity consumers suffer (to a limited extent) from increases of diesel and coconut oil prices
- **Adaptation of the existing regulatory framework** (especially the requirements of URA towards the utilities) to accommodate the agreed pricing mechanism.

Costs of the intervention can only be determined once the pricing mechanism has been agreed upon. Costs will be influenced by the model chosen and the difference between costs of diesel and coconut oil.

The main stakeholders to be involved in the elaboration of the “Coconut for Fuel Strategy” will have to be:

- Ministry of Agriculture and Rural Development: the key role of the Ministry will be to lay the basis for long-term supply of sufficient raw material for the production of coconut oil.
- Ministry of Trade and Finance: will have to focus on a strategy to come up with a financing mechanism to address copra price variations.
- Department of Energy: will have to make sure the strategy is linked with the targets under the NDC.
- Coconut producers: Producers such as Coconut Oil Production Santo Limited (COPSL) will be the partners for the supply of coconut oil to utilities and need to be involved in the decision on contractual arrangements and pricing for delivery of coconut oil.
- Utilities/UNELCO: will be the partners to be involved in the decision on contractual arrangements and pricing for delivery of coconut oil.
- URA: needs to secure that contractual arrangements and pricing are in accordance with current or revised regulation on electricity pricing.

6.3.5 GEOTHERMAL

Vanuatu has been the subject of geothermal prospecting since the 1970's. The biggest potential for use of geothermal energy for electricity generation is seen on Efate where preparatory studies have identified good opportunities at Takara in the Northern part of the island. The plan for the Takara Geothermal Power Plant is to implement the project in 2 stages, each 4 MW installed capacity. The geothermal plant will be able to provide baseload for the Efate grid.

Whereas preparatory studies showed good potential, the biggest risk is in the next step, the exploration drilling. The Government of Vanuatu is receiving funding from New Zealand for the exploration drilling, which is necessary to confirm the technical and commercial viability of the project. It is expected that results are available by 2020.

A first stage of 4 MW would have the possibility to generate between 25 and 30 GWh of electricity per year, thereby contributing between 25% and 30% of total demand in 2030. This would be a considerable contribution to the gap of around 50 GWh. As electricity from geothermal energy would provide a stable baseload, batteries would have to be installed to balance the fluctuations in production of electricity from wind and solar (more details see chapter 6.3.6).

However, as no reliable data both on the resource and commercial aspects are currently available, a decision on a potential contribution can only be taken once robust data and information has been collected. At that point, the levelized costs of generation of various sources need to be compared in order to be able to decide whether geothermal can have a place and what its contribution can be.

6.3.6 BATTERIES

With the further expansion of renewable energy capacities in Vanuatu, especially on Efate, batteries will have to play an important role in maximising the output of each renewable energy source contributing to covering demand. Unlike regular electricity generated in diesel motors, the output of solar and wind cannot be adapted to meet the demand in an electricity grid at any time of the day. Geothermal energy is best operated as a baseload plant, generators operated with coconut oil can be flexible within certain limitations.

The load diagrams below show 2 different scenarios. Scenario 1 (Figure 26) shows the projected load profile in 2030 (based on 2017 figures and expected demand increase) and the supply curve of solar on an average day. Out of the peak load of around 12 MW, solar will be able to cover close to 10 MW. Even with the currently installed wind capacity (3.6 MW), there is a likelihood that electricity needs to be stored in batteries. This likelihood is increasing considerably if the planned capacity of wind expansion (5.1 MW) is installed.

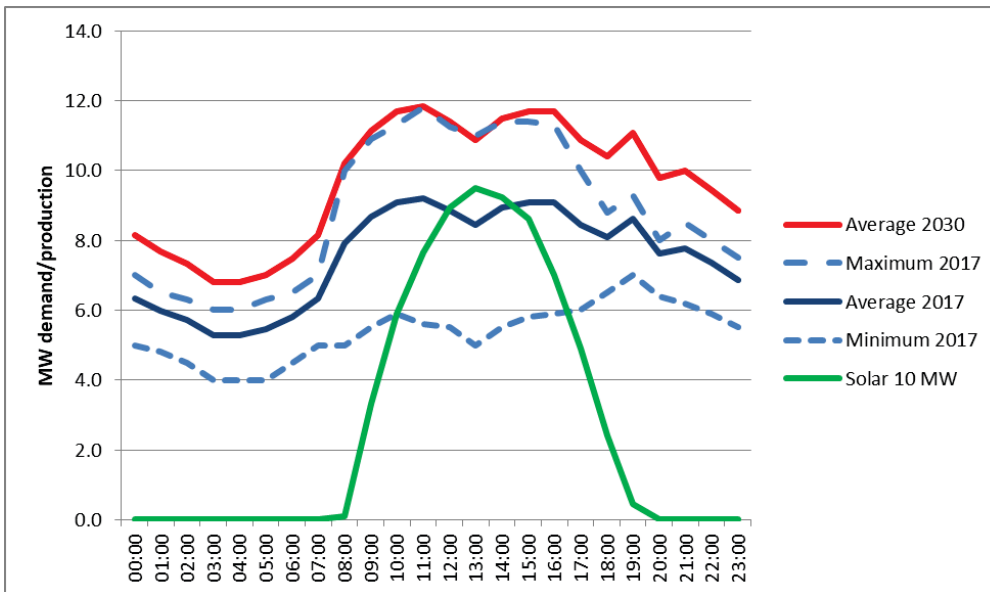


Figure 26: Load profiles 2017 and 2030 – scenario solar only

In the other scenario the first stage of geothermal (4 MW) is implemented and operating at 90% load (3.6 MW) and solar capacity has been increased to a total of 10 MW. In that case – and even without taking into account the currently installed capacity of wind power – supply of renewable energy sources will be higher than demand, leading to the need to store electricity generated during lunchtime to be used during evening and night hours.

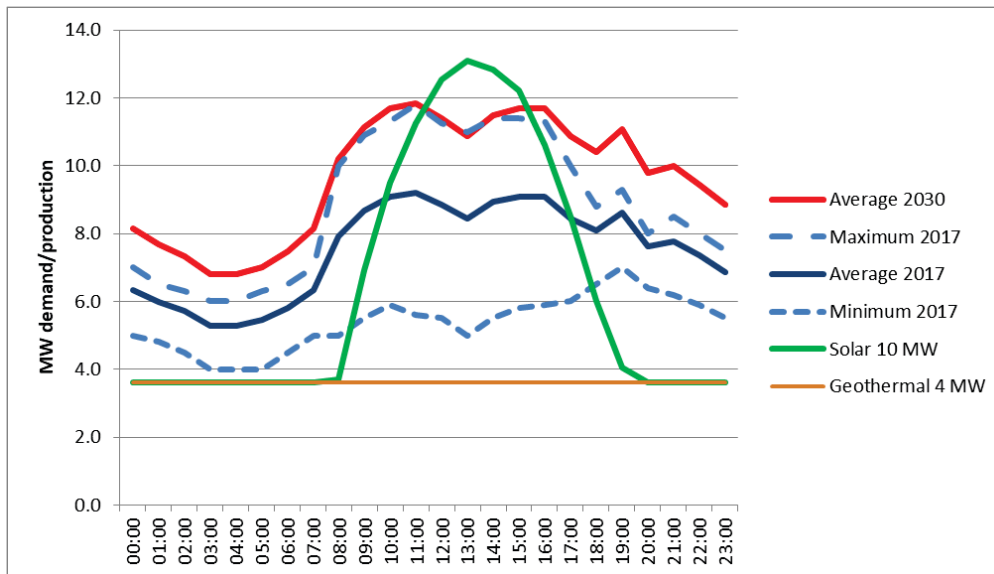


Figure 27: Load profiles 2017 and 2030 – scenario solar and geothermal

As a consequence, batteries will need to be added to the Efate grid in order to be able to achieve the NDC target. Without batteries, diesel generators will have to be in operation to balance demand and the unpredictable supply from solar and wind. Batteries will be designed as a daily storage, where electricity stored will be consumed within 24 hours.

The installation of batteries will be done in 2 stages:

- Stage 1: batteries will be installed with a capacity sufficient to store overhang of production from existing wind, existing solar and solar capacity added until 2023 (3 MW). The estimated size of storage capacity required is a maximum of 15 MWh.
- Stage 2: after decision on the composition of renewable energies required for achieving the NDC target (mainly the decision whether geothermal is an option), the remaining required storage capacity will be calculated. UNELCO estimates that the maximum required capacity is 37 MWh.

Investment costs are estimated by UNELCO at 100 million Vatu per MWh or USD 910,000. This seems to be on the high side, costs of USD 500,000 to 700,000 should be feasible. Based on assumed costs of USD 700,000, investment costs for stage 1 are USD 10.5 million, for stage 2 USD 15.4 million.

It is assumed that grant funding will be required for financing investment into a battery storage system. There is no additional generation of electricity, which could generate revenue for paying back the investments, the batteries only allow to use the installed or to be installed renewable energy capacities.

6.3.7 REVISION OF ELECTRICITY SUPPLY ACT

The current version of the Electricity Supply Act restricts the right to generate electricity in a concession area to the concessionaire. Other persons or companies are only allowed to generate electricity for own purposes. Up to now, either utilities invested in renewable energy plants (mainly smaller sizes) or funding for investment was provided by donors and assets were given to utilities for operation.

This means a de-facto monopoly on generation for concession holders and restricts the participation of other players in electricity generation. Currently, Independent Power Producers (IPPs) are excluded from making investments in concession areas, which limits the opportunities for securing funding for further investments.

The Government of Vanuatu is looking at revising the current Electricity Supply Act in order to allow IPPs to generate electricity and feed it into existing electricity grids. When planning such a revision, a number of points need to be considered when amending the legislation:

- Quantitative limitations: due to the limited size of electricity grids in Vanuatu, the number of additional capacity to be covered by the amendment needs to be clearly limited. It is recommended that the additional capacities to be installed under this NDC Implementation Roadmap are taken as upper limit, while still allowing some flexibility between the sources of renewable energy (e.g. larger increase of solar PV compared to wind).
- Use of electricity: not all of the electricity generated by additional resources can be used directly, as demand will be below the generation of existing and new renewable energy sources. The amendment needs to include provisions for this case in order to balance the needs of consumers (low prices), IPPs (decent return on investment) and concession holders.
- Tariff setting: the amendment needs to propose a way to define the feed-in tariff to be paid for electricity generated and fed into the grid. There are various ways to do this:
 - Setting of a maximum tariff, which is below generation costs of diesel
 - Holding a tender for a certain capacity
 - Running a reverse auctioning for a certain capacity

7 COSTS AND FINANCING

The following table summarizes the estimated investment costs based on the information provided in the chapters in section 6.

Intervention	Investment Costs	Financing status
Brenwe Hydro Power Project + Grid Extension in Santo (Turtle Bay to Port Orly)	USD 15.1 m	Financed (ADB Loan plus GoV)
Sarakata Hydro Power Extension Project	No data available	Funding through Japanese Grant for Projects envisaged, contribution from Government of Vanuatu
Vanuatu Rural Electrification Project (VREP) Phase II	USD 6.8 m	Funding secured, IDB and trust funds
Talise Micro Hydro Power Project	USD 0.7 m	Funding secured, fully financed through the BRANTV project
Solar PV	USD 11.7 m	No funding secured
Wind	USD 13.5 m	No funding secured
Coconut oil	Costs can be determined once price mechanism has been agreed upon	No funding secured

Geothermal	No reliable figures available	No funding secured
Batteries	USD 25.9 m	No funding secured
Revision of Electricity Supply Act and Coconut for Fuel Strategy	USD 0.3 m	No funding secured

Table 4: Investment costs of interventions

Total investment costs add up to USD 76.7 m. This figure does not include costs for geothermal (as there are no reliable figures available at the moment) and coconut oil (as costs can only be determined once price mechanism has been agreed upon).

From the costs listed, the highest share (44.1%) is for batteries. Due to the challenging target of close to 100% of renewable energies for electricity generation by 2030, storage is playing a key role in achieving the target. Batteries will allow storing of electricity generated by solar and wind for later hours when demand is higher than current generation from renewables. The installation of batteries is a key component for achieving the target.

Batteries are not generating additional electricity, they are only storing electricity generated by renewable energy sources for later usage. As a consequence, there is no payback period, batteries are simply necessary for the operation of an electricity system where a high share of generation units cannot be influenced (solar and wind). Securing funding for stage 1 (and later-on for stage 2) of the battery investment has highest priority, as this is the basis for further expansion of renewable energies on Efate.

To prepare for a stronger involvement of private sector player (IPPs), a revision of the existing Electricity Supply Act is necessary. This will allow investors to come in and finance the implementation of renewable energy projects. Due to the limited size of additional capacity required, grant contributions to investments will still be necessary.

8 THE WAY FORWARD

The various interventions described in chapter 6 confirm that the NDC target of close to 100% generation of electricity from renewable energies by 2030 can be achieved by a combination of actions. This chapter now describes different option of how these interventions can be combined.

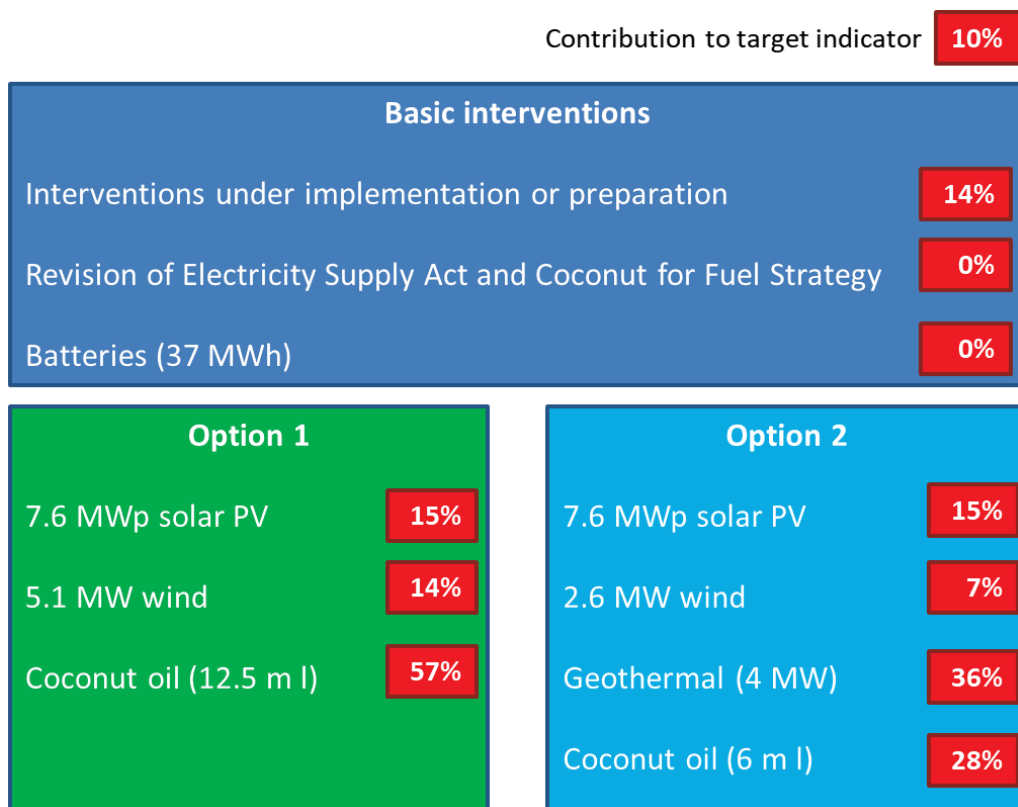


Figure 28: Contributions to target

First of all, there are basic interventions, which are recommended to be implemented in any case:

- Interventions under implementation or preparation: project under implementation such as VREP II or the Talise Hydro Power Project bring good contributions towards the target and should be finalised as planned. Focus should be on implementations under preparation to secure funding and push for implementation.
- Coconut for Fuel Strategy: this is the key element in providing a sizeable contribution to achieving the NDC target and is the first implementation step to be carried out.
- Revision of the Electricity Supply Act: this is a key step for stronger involvement of the private sector and should allow attracting private capital for the investment into renewable energy projects. Batteries: a total of 37 MWh of battery storage capacity are necessary to secure a well-functioning grid, where overproduction can be stored for later consumption.

In addition to these basic interventions, 2 options are suggested for achieving the NDC target.

Option 1 includes the installation of 7.6 MW solar PV and 5.1 MW wind, which together can contribute around 30% to the target. The majority of the contribution towards the target (57%) will come from the use of coconut oil. Total costs of Option 1 are USD 73.3 m (excluding costs for the Sarakata hydro power project as they haven't been determined yet). It is assumed that a pricing arrangement for coconut oil can be found, which is not leading to ongoing operation costs, the costs for carrying out the Coconut for Fuel Strategy are included.

Option 2 includes the installation of 7.6 MW solar PV, which is seen as the renewable energy source with lowest generation costs. The main contribution in Option 2 will come from geothermal (36%), which requires successful drilling and considerable investment for the implementation. The availability of geothermal allows reducing the input of wind energy and it suggested that only half of the additional

capacity (2.6 MW) is installed. The remaining gap will be covered by coconut oil and a total of around 6 million litres will be required to achieve the target. Total costs of Option 2 are USD 66.5 m (excluding costs for the Sarakata hydro power and the geothermal project as they haven't been determined yet). It is assumed that a pricing arrangement for coconut oil can be found, which is not leading to ongoing operation costs, the costs for carrying out the Coconut for Fuel Strategy are included. This NDC Implementation Roadmap is a living document. It will be updated once more information and clarity on various opportunities is available. The MRV system to be installed allows tracking of the process and can give feedback on corrective action necessary for achieving the target.

