A Strategic Approach towards 100% Renewable Energy in Seychelles

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Background: The SIDS energy challenge

Most Small Island Developing States (SIDS) are facing an extreme vulnerability towards the adverse impacts of anthropogenic climate change. Besides the resulting pressure to adapt to changing climatic conditions, including rising sea levels and exposure to storm and other natural hazards, many SIDS have scarce fossil fuel resources for energy production. Hence, many islands are characterized by a strong dependence on imported fuels to meet their energy needs. This often results in relatively high energy supply costs (GIZ, 2014) due to limited or no economies of scale effects, as well complicated and resource-intense transport (Stock, P., 2014).

The remoteness, the high dependence on fossil fuels, and the high expenditures for fuel imports underscore the economic relevance of a transition towards renewable energy (RE) deployment. While the potential for using renewable energies in Seychelles is significant, particularly for solar and wind energy, those resources have only been utilized to a limited extent so far. An increased deployment of renewable energy would benefit the state in the area of climate change mitigation, a decrease in the trade balance deficit, less exposure to volatile fuel prices, a more self-reliant electricity supply, lower imports of fossil fuels, and lower associated environmental risks (IRENA, 2014). Hence, by overcoming the reliance on fossil fuels, and embarking towards an increased use of renewable energies, SIDS can increase both their resilience and economic viability.

This article explores the SIDS energy challenge in the case of Seychelles. After describing the existing energy system of Seychelles, we reflect on the political ambition to increase the share of renewables in the country. In fact, the Government of Seychelles (GoS) is actively exploring opportunities to embark on a 100% renewable energy supply pathway. The article hence discusses the feasibility of such a 100% renewable energy scenario and identifies the potential impacts as well as the main barriers. Since a major barrier is access to sufficient finance, we conclude that a strategic approach for developing a 100% renewable energy scenario must include a robust financing strategy. Finally, the article sketches the proposed elements of such an energy roadmap and financial strategy and is informed by results of preparatory work conducted on behalf of the Ministry of Environment, Energy and Climate Change (MEECC).

The sustainability of the energy system in Seychelles

Seychelles has a population of 97,625 (NBS, 2019), 99% of whom live on the inner islands of Mahé, Praslin and La Digue, with 99% connection to the electricity grid. Electricity consumption has more than doubled from 2000 to 2015 (UNEP, 2016), driven by increasing population, rising wealth and commensurate increase in consumption. Like other SIDS, the country faces extremely high and fluctuating power costs resulting from dependency on mineral oil products for power generation and fuel for transportation. The national electricity grid consists of two separated systems (77 MW in Mahé and of 16 MW in Praslin and La Digue, respectively), both primarily supplied by diesel generators fuelled with light (LFO) and heavy fuel oil (HFO). The share of solar and wind power in the electricity mix is minor, i.e. approximately 2.5% in 2017 (PUC, 2018) with an installed capacity of 6 MW of wind generators and 3.5 MW of solar photovoltaics in 2018 (IRENA, 2019). The fuel costs constitute the major share of the power costs (more than 90% in Seychelles); price fluctuations of crude oil come directly at the expense of both the overall economy as well as the individual end-consumers. In 2014, fuel imports for electricity production amounted to 4% of Seychelles' annual national income (gross domestic product); together with the imports of transport fuels, more than 5% of the national income is used to cover fuel bills (Hohmeyer, 2016).

This poses a major threat to the economic development and stability of Seychelles. Thus, the present electricity system, although supplying power quite reliably, cannot be sustained in the long run without jeopardising Seychelles' future economic development. In addition, the island state's vulnerability to climate change requires necessary investments in relation to adaptation and mitigation. Climate change, compounded by the recent El Niño, has put Seychelles' archipelago and biodiversity systems at higher risk. 17 of the 18 warmest years on record have occurred since year 2000 (NOAA Climate.gov, 2019), resulting in a drastic change in the weather pattern of Seychelles. It has also contributed to rising sea levels and massive bleaching of coral, which is significant for islands in general. For Seychelles in particular, which relies heavily on fishing and tourism, the potential damage could be significant, both economically and socially. On a regional scale, the average economic cost of natural disasters in Seychelles is roughly 1% of the GDP, almost twice as much the average damage cost of sub-Saharan African (SSA) peers (IMF 2017b).

With approximately 0.003% of the world´s GHG emissions in 2011, Seychelles contributes only marginally to the global emissions on an absolute scale (GoS, 2015). However, in particular the energy sector is carbon intensive. About 90% of all domestic CO_2 emissions stem from power generation and the road transportation sector. With respect to power generation, the Public Utilities Corporation (PUC) and auto-producers in the Seychelles emitted approximately 0.28 $MtCO_2/a$ in 2015. Assuming an annual energy production increase of 3% based on historical trends and a grid emission factor of 0.59 tCO_2/MWh, the total baseline emissions would increase to 0.44 $MtCO_2/a$ in 2030, a rise of almost 60% (compare *Figure 1*).

Road transportation caused emissions of additional 0.09 $MtCO_2/a$ in 2015 and is estimated to increase to 0.15 $MtCO_2/a$ in 2030, assuming 3% demand increase (see also Seychelles Energy Commission (SEC) energy data for 2013 and 2015).

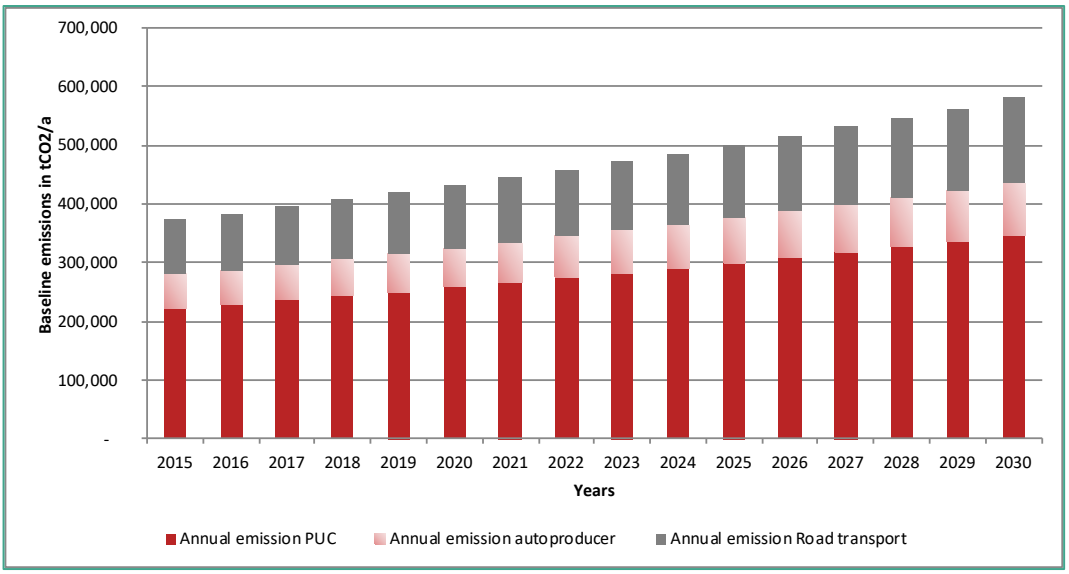

Figure 1: Baseline GHG emissions for the Seychelles (Mahé, Praslin and La Digue) until 2030
Source: Own figure based on MEECC, 2016

This unsustainable situation of the current energy system results in a strong need for an enhancement thus impacting the political target setting process.

Political momentum for renewable energy in Seychelles

In its *National Climate Change Strategy* and *Nationally Determined Contribution* (NDC) Seychelles pledges to reduce its economy-wide absolute GHG emissions by 21.4% in 2025 and 29.0% in 2030 relative to baseline emissions subject to international support (GoS, 2015). The legislated targets of renewable energy consumption are set at 5% by 2020 and 15% by 2030, as outlined in the 2010 Energy Policy (GoS, 2010). Additionally, the Seychelles Sustainable Development Strategy (SSDS) 2012-2020 incorporates national priorities for sustainable development and formulates guiding principles for the energy and transport sector (GoS, 2012). According to the strategy, the "reliance on fossil fuels should be gradually reduced as they are not sustainable sources" and the "energy independence should be increased to reduce economic vulnerability through use of local sources of energy". So far, the "baseline scenario" for energy in Seychelles is of slow, incremental addition of RE production, that will likely meet the modest 5% RE by 2020 but will struggle to meet the 15% by 2030 target without substantial changes to overcome technical, institutional, regulatory and financial barriers. In addition, further diesel generators will be required and installed to meet the increasing demand for electricity foreseen for the next years.

In response to this situation and the economic dependency on fuel imports, the Government of Seychelles embarked on a more ambitious pathway. In 2016, the idea of '100% Renewable Seychelles' gained momentum: A proposal to develop a 100% Renewable Energy Roadmap for Seychelles presented by the Ministry of Environment, Energy and Climate Change (MEECC) was adopted and approved by the Cabinet of Ministers in April 2016 (GoS, 2016). This decision was informed by a first analysis commissioned by MEECC on the potential of the three main granite islands adopting a power supply completely based on renewable power carried out by Europa-Universität Flensburg Center for Sustainable Energy Systems (CSES, see Hohmeyer 2016). Since then, the MEECC with the support of international experts is working on formulating a corresponding strategy to convey the desired energy transition.

To achieve ambitious sustainable energy targets in less than two decades, a comprehensive energy strategy formulated in a roadmap is required (compare e.g. IRENA 2019b). The energy roadmap comprises the adequate energy policies and is supposed to be supplemented with a corresponding financing strategy. This combination will help to overcome the existing barriers for renewable energy uptakes and investments in a shorter timeframe. The roadmap should take into consideration the agenda of important stakeholders in the energy sector, also to increase acceptance.

For formulating and substantiating the energy roadmap it is proposed to structure and label it under one framework, the 'Seychelles' 100% Renewable Energy Strategy' (SeyRES 100). The authors have supported the MEECC and important stakeholders, e.g. SEC or PUC, in defining the needs and identifying the potential support required to implement SeyRES 100 under a comprehensive energy and financial strategy. From December 2017 onwards the MEECC has continuously consulted relevant implementing partners and stakeholders for the development of this energy and financial strategy.

Methodology

The envisaged implementation approach of SeyRES 100 is based on an assessment of needs that is laying the foundation for defining the policy measures, technology requirements, costs and financing, and capacity development needs for the successful implementation. The identified measures are combined and integrated under a comprehensive approach for steering the energy transition towards renewable energies aiming at providing the most appropriate market structure and stable energy prices. In summary, a phased approach of increasing the share of RE over the next two decades is formulated to the key steps of the roadmap, comprising an initial preparation phase, a second diffusion phase for renewable power generation and, eventually, a third phase to integrate the transport sector (see Figure 2).

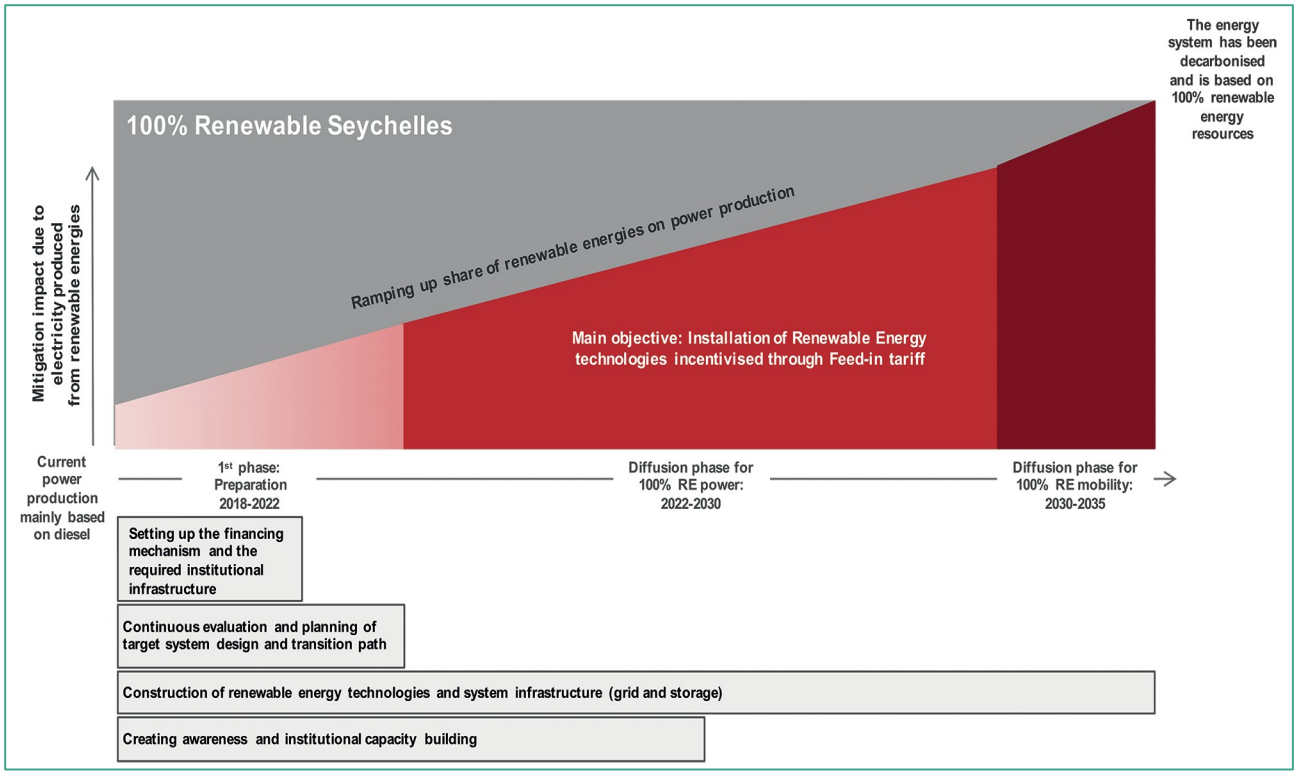

Figure 2: Suggested implementation of the SeyRES 100 until 2035
Source: Wehner et al. (2017)

Key methodological activities for identifying and analysing the relevant roadmap elements comprised of a comprehensive research of available local literature and data, followed by interviews with various relevant stakeholders of the SeyRES 100. This included e.g. the MECCC, the SEC, PUC, the University of Seychelles, Seychelles Institute of Technology, the Seychelles Pension Fund (SPF) and the Société Seychelloise d'Invéstissement (SSI).

Results

The article investigates, in the following section, whether the target under SeyRES 100 is achievable, and highlights the necessary detailed interventions identified and needed to overcome the current prevailing, non-sustainable situation of the energy sector and related barriers.

Is a 100% renewable energy scenario feasible?
Subsequently, we discuss the technical and financial feasibility of a 100% RE scenario for the Seychelles.

Technical feasibility of 100% renewable energy supply
The study 'A 100% Renewable Seychelles' (Hohmeyer, 2016) indicates that a power supply solely from renewable sources is technically feasible. With regards to the three islands, Mahé as the main island enjoys the service of a reliable electricity system, which services

practically every citizen and has very few downtimes. The total annual electricity demand (2015) for Mahé is in the range of 330 GWh/a, and for the interconnected islands (by sub-sea cable) of Praslin and La Digue 43 GWh/a, including system losses. With a maximum load in the range of 53 MW and 8 MW, respectively, the installed capacity of about 77 MW and 16.5 MW allows for a considerable reserve margin (SEC, 2017). All conventional generation units are diesel generators with a wide age span (PUC, 2016).

Based on these assumptions and the figures for annual total electricity demand (including system losses), Mahé island can be supplied with electricity from renewable energy sources every hour of the year under a scenario with 50 MW of installed wind power capacity, 125 MW of installed solar energy (PV) capacity, an assumed liquid biomass volume of 25 GWh/a equivalent to 5,000 t of biodiesel to be used in the existing diesel generators, which will be kept as system backup, and a pump storage hydro plant with a storage volume of 1 GWh (Hohmeyer, 2016). The same has been investigated for the other islands, Praslin and La Digue, with the same general result. Thus, a 100% renewable power supply is technically feasible. However, technical details of a system would need to be further spelled out. For instance, the assessment of the most appropriate project sites and least-cost options have to be identified, using results of (existing and new) RE measurements and corresponding electricity grid simulation for integrating and up-take of the new renewable capacity.

As a high share of solar and wind energy will lead to an electricity production which will at some hours be higher and at other hours considerably lower than the electricity demand, a power supply based solely on renewable energy sources will require substantial volumes of storage. The electricity produced by the storage should be available within a few minutes due to the fast changes in the residual load. The capacity of the power production from the storage needs to be equivalent to the maximum load of the electricity system and the storage volume should be in the order of at least twelve hours of demand. As a result of preliminary analysis of Hohmeyer (2016) for different possible storage options, pump storage hydro systems have been identified to be appropriate and selected for the simulation of a 100% renewable power supply system for Mahé, as this technology offers potentially low storage costs, a relatively high storage efficiency, is available in the right storage size, is technically mature and offers technical advantages for stabilising the electricity system. For the power supply of Mahé the storage needs to have a generation capacity of about 64 MW, a pump capacity of about 128 MW to make the best use of the available overproduction, and a storage volume of about 1 GWh (Hohmeyer, 2016). First quotations for a concept and feasibility study of such a storage are available (Pöyry, 2016).

Economic feasibility of 100% renewable energy supply

Concerning the economic feasibility, Hohmeyer (2016) concluded that a 100% renewable power supply will cost about 2.3 SCR/kWh (2014 value), which is approximately 10% higher than Mahés' current fuel costs for power production of 2.08 SCR/kWh in 2014. The

most expensive element of SeyRES 100 are the incremental costs for technology implementation. Investments of approximately USD 390 million would be needed until 2035. Assuming a local production share of 20% of the investment, technology worth USD 15.6 million would need to be imported annually (2020-2035). Table 1 displays the anticipated investment needs for a supply system of 100% renewable energies for Seychelles.

Table 1: Estimation of investment cost for 100% renewable energy infrastructure
Source: MEECC, 2018

Energy system	Unit	Total	Specific investment cost (USD/kW)	Total investment required (mill. USD)
Solar PV				
- electricity grid only	MW	140	USD 1,725	USD 240
- with e-mobility	MW	188	USD 1,725	USD 325
Wind	MW	56	USD 1,200	USD 67
Total (solar and wind)				
- electricity grid only	**MW**	**196**		**USD 307**
- with e-mobility	**MW**	**244**		**USD 390**
Pump storage				USD 180
Upgrade of low-voltage grid (public utility)				USD 10

Potential impacts of a 100% renewable energy scenario

Potential impacts of the transformation towards 100% renewable energies relate to financial, environmental and social matters. Overall, the energy system will be decarbonised and be based on 100% RE resources. Once this transition of the energy system is achieved, the system can be enlarged to generate sufficient renewable electricity to power all private cars, small trucks and buses, assuming the present fleet is gradually exchanged with electrical vehicles.

Greenhouse gas mitigation impact

In terms of mitigation, the realization of SeyRES 100 would lead to accumulated GHG reductions of 2.8 $MtCO_2$ until 2030 for power generation. Once the transport sector is supplied with the necessary infrastructure and electricity for electric mobility, an aggregated GHG reduction volume of 6 $MtCO_2$ can be achieved until 2035 (power generation and transport). These figures are based on the assumption of an annual energy production increase of 3% (current CO_2 emissions of power generation from PUC and auto-producers). Against the baseline, emission reductions could rapidly ramp up to reach up to 0.53 $MtCO_2$/a in 2030 and 0.68 tCO_2/a in 2035. Additionally, annual emissions from road transportation of approx. 0.09 $MtCO_2$/a in the year 2015 can be added, which are estimated to increase to 0.17 $MtCO_2$/a in 2035. As a result, by 2035, 90% of all domestic GHG emissions in the Seychelles could be completely eliminated.

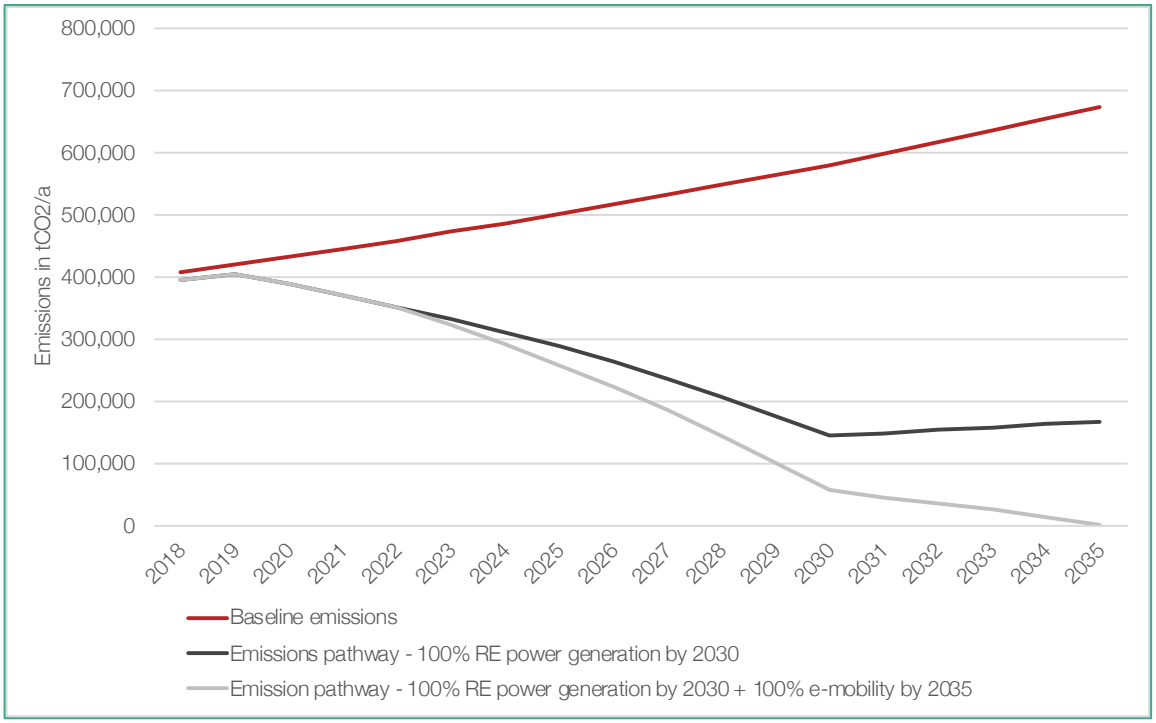

Figure 3: Emission development from power production and road transport under the 100% renewable Seychelles roadmap
Source: Wehner et al., 2017

Economic impact

The enormous dependency on mineral oil products for power generation and fuel for transportation and the high vulnerability to crude oil price volatility have led to high electricity bills for private households and enterprises as well as to a massive drain of hard currency from the Seychelles economy.

As indicated above, a 100% renewable power supply will cost about 2.3 SCR/kWh. Compared to the average electricity rate charged to the customers of 3.85 SCR/kWh (Hohmeyer, 2016), the full system costs of the 100% renewable system amount to about 60% of the average rate charged only. Furthermore, with the 100% renewable energy strategy, Mahé's fuel imports for electricity production can be reduced by about USD 45 million per year. Subtracting the required technology imports worth USD 15.6 million, the average net import reduction amounts to about approximately USD 29 million per year (Wehner et al, 2017), i.e. about 5.5% of the negative trade balance in 2014 (NBS, 2016). Hence, SeyRES 100 could contribute to significantly relieving the national budget, while at the same time achieving the energy sector transformation.

Barriers for 100% renewable energy in the Seychelles

A transformational shift towards an increased share or even 100% of RE has so far not been achieved, due to various technical, regulatory and financial barriers. Overall, the main key roots and barriers that limit the uptake of renewable energies for (domestic) investors comprise:

Political/institutional and regulatory barriers

- Overall, a legal and regulatory, financial, and technical framework is missing – which is now generally targeted by the government.
- The current policy incentivizes electricity consumers to reduce their electricity costs by generating their own electricity using solar photovoltaics (Net-Metering Programme). However, due to grid constraints and limited experience the utility is limiting the up-take of electricity.
- Insufficient experience with private sector and domestic institutional investor investment.
- Lack of engineers and (mechanical) technicians with expertise for building, operating and maintaining renewable energy plants.
- Lack of lecturers and teachers, lab and workshop facilities.
- Lack of skilled and qualified workforce particularly in the public sector due to non-competitive wage levels; people are leaving the sector for private business and/or even the country; students often decide to study abroad instead of in Seychelles.
- Lack of a shared national vision; adequate resources and trained personnel; and the limitations of the existing vocational education and training (VET) culture, pedagogy and training programs (Neves, G., 2016).

Economic, socio-economic and financial barriers

- Limited support to cover up-front costs for renewable energy investments and required transmission and storage infrastructure.
- Lack of financial assessment capability of renewable energy projects at domestic institutional investors and banks: with respect to investors, a lack of experience with RE/energy efficiency (EE) projects hinders the completion of due diligence and investment decisions.
- Internal investment criteria of larger institutional investors such as the SPF or the SSI focus on low-risk investments or investments with state guarantees, which is currently not given in the investment environment of RE.
- General concerns over landscape and local environmental impacts, such as noise of wind turbines and glare from PV systems.
- General acceptance of renewable energy plants and grid extension.

Technological barriers

- Limited experience of the utility with grid integration of different energy sources.
- Limited experiences with increasing shares of renewable energy generation in the energy mix and stable dispatching of electricity.
- Physical grid constraints at the low-voltage network hinder the up-take of electricity especially from solar PV. There are limited incentives for PUC to

undertake required investments, as if they do so they will lose power sales revenues from households/businesses that install PV systems.

- Lack of fundamental information and data on possible renewable energy pathways and potentials at the utility and the regulatory bodies.

Therefore, domestic investments into renewable energies in Seychelles are difficult, if not impossible, to realize at the moment, even though it is a desired aim of the Government. In the following we further elaborate on the potentially most crucial barrier, the financial constraints for investments in renewable energies.

Financial barriers and limitations of public investments

The estimated investment volume of up to USD 390 million will have to be mobilized from private or public sources with domestic or international origin. Currently, Seychelles is still recovering from severe imbalances of payments resulting in a public debt crisis since the year 2008 (GoS, 2008 and 2018), when Seychelles had one of the highest debt ratios worldwide (The Guardian, 2013). At that time, levels of total public debt reached more than 150% of the Gross Domestic Product (GDP). Under three consecutive International Monetary Fund (IMF) programmes, the country conducted prudent macroeconomic policies and implemented structural reforms. Due to the resulting primary fiscal surpluses, paired with strong economic growth driven by the tourism sector, the public-debt-to-GDP ratio has been reduced by almost two thirds since the end of 2008 (GoS, 2018). Those debt management practices that are guided by a 'Debt Management Strategy 2018-2020' and further reforms under the supervision of the IMF are still ongoing. Thus, Seychelles cannot take up further debt finance for public expenditure, nor for parastatal enterprises such as PUC (IMF, 2017a; IMF, 2017b). Thus, there is currently no availability to finance substantial SeyRES 100 investments from the public budget or the balance sheet of state enterprises.

To attract international financial support, measures have been undertaken such as setting up a focused unit on climate funding or engaging in innovative financing solutions (e.g. Blue Bond in cooperation with World Bank). Thus, international support takes up a prominent role as the need to act on climate change collides with the current pathway of the Government to reduce its public debt. However, the access to international financial support, such as bilateral or multilateral climate finance in the context of the United Nations Framework Convention on Climate Change (UNFCCC), is cumbersome and can only provide a limited share of the total investment needs. Thus additional, private finance will be required. In this context, solutions suggested to Seychelles by the IMF include: (1) increasing the efficiency of public investment, such as an effective use of Public Private Partnerships; (2) finding concessional external sources; and (3) creating further fiscal space over the medium-term (e.g. introducing a specific carbon tax, shift resources from other sectors such as social welfare of SOE transfers through reforms) (IMF 2017b).

The energy roadmap: a strategic approach for embarking towards 100% renewable energy in Seychelles

For meeting the targets of SeyRES 100 and addressing the barriers identified above, a variety of activities will have to be undertaken in the context of an energy roadmap. The main objective of the roadmap is to create a suitable policy framework, i.e. institutional, legal and administrative rules and procedures, for providing appropriate and favourable conditions that trigger the 100% renewable energies development pathway, under coordination of the GoS. The interventions also envisage strengthening the individual and institutional capacity thus aiming to trigger additional resources from international climate finance institutions in the mid- to long-term. As shown in Figure 44, the related key elements of the roadmap are clustered along policy/regulatory interventions, capacity development activities, costs and financing and technology.

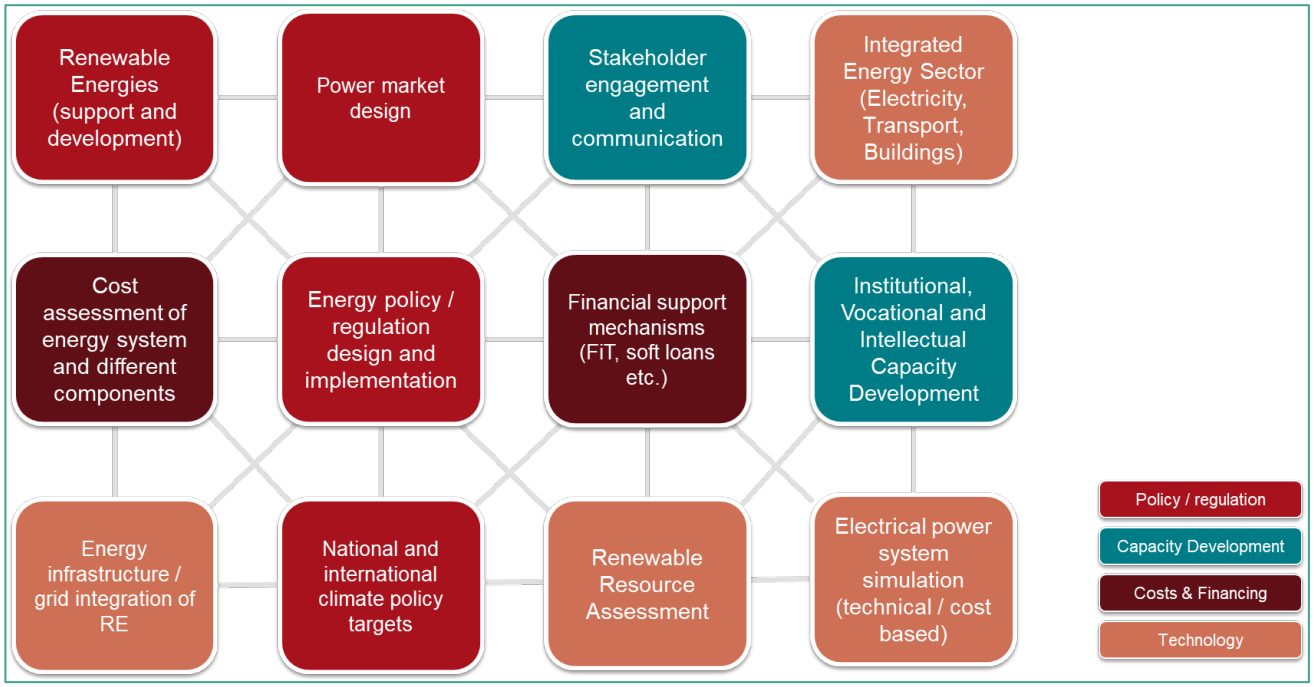

Figure 4: Elements for integrated energy and financial roadmaps
Source: Wehner et al., 2017

In detail, the energy roadmap should lead to the following outcomes:

- ***Making the energy supply system fit for renewable energies.*** Improving the grid capacity and quality is required especially the low-voltage grid (household connection) and in those locations foreseen for larger renewable power-production sites. In the long-term, also the site of the pump storage hydro power plant is relevant. This may include a possible sub-sea cable connecting Mahé, Praslin and La Digue to reduce overall system costs by reducing the need of pump storage to only one plant instead of two as is

presently considered. To support the grid supply security, it is recommended keeping the existing power generation facilities as back-up, as they complement the expansion of renewable power supplies very well.

- ***Implementing a supportive policy framework.*** Setting up the policy framework is key. It will enable and facilitate investments in the new renewable power technologies generated on the island, thereby keeping the income generated from renewable power production in the Seychelles economy. While the roadmap will encourage more local investments, foreign investments would, however, initially also be needed. The possible policy for a financial mechanism (feed-in-tariff and/or power purchase agreements corresponding to the type of RE generator) and regulatory framework (specific ordinances) to guide the smooth development towards the target need to be established (see Hohmeyer, 2017 for a detailed discussion on support mechanisms for REs in the specific SIDS context). Using such a policy for wind and solar power will enable a broad local participation in the investment for generating additional income for Seychellois citizens.
- ***Build-up of sufficient domestic capacities.*** The roadmap comprises a National Capacity Development Strategy on renewable energies and enhanced stakeholder engagement, i.e. to involve citizens in the planning and development of wind and solar energy and to spread the idea as widely as possible and to guarantee the maximum acceptance of the new technologies (i.e. explore the use of a community investment model; youth education). The Capacity Development Strategy will additionally build up a specialized labour force for planning, construction operation and maintenance of the necessary technologies and their full-scale system integration.
- ***Introducing attractive financing options.*** Mobilization of domestic financial resources from institutional and private sector investors is key for the successful country-driven implementation of the SeyRES 100 target. The roadmap activities will support the build up of a long-term sustainable financial system that provides required investments during the transition period. This will build trust of private investors in RE technologies and investments on a large scale. In order to overcome the current limitations for domestic investors, a financial support mechanism could be established. Such a financial facility would provide a secure and attractive legal, economic and technical framework for domestic front-runner investments into renewable energies over the next years. For implementing the initial steps of the energy and financial roadmap that improve the technical, financial and political framework conditions, access and use of international funding is required due to the public budget limitations discussed above.

Conclusion

SeyRES 100 describes a major transformational change for the energy system by aiming at full decarbonization through a supply of 100% renewable energy sources by 2030, and through inclusion of e-mobility by 2035. Such an energy transition would create significant social-economic positive impacts, which will help the country to strengthen its economic sustainability for the future, while eliminating its negative environmental footprint existing at the moment. As the technical and economic analysis demonstrated, 100% renewable energies for Seychelles are theoretically feasible. However, currently existing technical, regulatory and financial barriers hinder the further implementation of SeyRES 100. Besides the lack of an appropriate political framework for enabling the deployment of renewable energies, financial resources for covering the up-front investments and for overcoming the main grid constraints are missing. Domestic public budget resources do not suffice for the implementation of the SeyRES 100, particularly due to the country's public debt situation.

Thus, the transition towards 100% renewable energy power supply requires an individual strategic approach to successfully steer this ambitious transformation. The sketched energy roadmap can support underlying planning and its implementation. It will initially define the necessary policy measures, technology requirements, capacity development necessities, costs and financing needs, and it needs to be reviewed and adapted over time. To successfully attract domestic investors and international support, including climate finance sources, the development of such an energy roadmap has to be complemented by a suitable funding strategy, in order to avoid scattered support and not risk an uncoordinated process between all partners and stakeholders. With appropriate frameworks set, and sufficient international climate finance and domestic capital mobilized, Seychelles has significant potential to harness significant economic, environmental and social benefits from SeyRES 100 in the future.

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