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LONG-TERM STRATEGIES IN SIDS: BLUEPRINTS FOR DECARBONISED AND RESILIENT 1.5°C COMPATIBLE ECONOMIES

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Executive Summary

Long-term strategies[1] provide a space for governments to set out a visionary blueprint for a resilient, decarbonised future that is compatible with limiting warming to 1.5°C. By setting out such a vision, long-term strategies can steer near-term ambition and action and obtain political buy-in for a cross-sectoral transformation of the economy that is aligned with the Paris Agreement's goals.

While these strategies are distinct from the near-term commitments made in countries' Nationally Determined Contributions (NDCs), alignment between the vision contained within a country's long-term strategy and its NDC is crucial, and can improve the efficiency and robustness of near- and long-term target setting. At COP21, Parties were invited to submit their long-term low greenhouse gas emission development strategies (LT-LEDS or LTS) by 2020. As of January 2021, 29 have already done so, including three SIDS.

This briefing outlines why long-term strategies are a fundamental component of national climate policy architecture, and how SIDS can benefit from developing one, both directly in terms of prioritising efforts for achieving the Paris Agreement goals, and indirectly through synergies with other sustainable development and resilience goals. While we focus here on the energy sector – the largest source of emissions for SIDS – an effective LTS should consider all sectors, as well as the interlinkages between them.

Long-term strategy as a means of sectoral transformation in Small Island Developing States

For the majority of Small Island Developing States (SIDS), most emissions come from the energy sector. **In this context, the main lever for reducing emissions will be a phasing out of diesel fuel or residual fuel oil in the power sector and gasoline and diesel in the transport sector.** For electricity generation, this will be made possible through a **future dominance of solar PV and wind, with complementary capacity from geothermal, biomass, hydropower** (which are available in certain SIDS such as Dominica, Samoa or Fiji), and/or wave and ocean technologies.

Many SIDS have already started this transition, with solar PV generation on the rise in a number of islands. However, **transitioning to a power system with high shares of variable renewable energy (VRE) requires long-term planning to develop the infrastructure necessary to support a new electricity mix.** Technologies that are complementary to VRE, such as dispatchable renewables and electricity storage, will be key enablers of a decarbonised system. The financial resources necessary for capital infrastructure investments also need to be in place.

End-use sectors such as transport and buildings will need to decarbonise through electrification and energy efficiency measures.

[1] While commonly named "Long Term Strategies" (LTS), these are defined in the Paris Agreement as ***"long-term low greenhouse gas emission development strategies"*** under Article 4.19 where Parties are invited to "[…] *formulate and communicate* ***long-term low greenhouse gas emission development strategies,*** *mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.*" For simplicity purposes, both of these terms: LT-LEDS and LTS, will be used in this briefing.

In the transport sector, this means **rolling out the necessary infrastructure** (for example, **improved public transport and cycling networks, electric vehicle charging stations**), as well as **implementing policy frameworks for decarbonising the vehicle fleet** (for example, incentivising the uptake of **electric vehicles (EVs)**, and disincentivising the import of internal combustion engine vehicles).

In the building sector, the introduction of **regulations and standards to increase the effectiveness of building envelopes and incorporate natural lighting, the efficiency of appliances (including air conditioners) can reduce future energy consumption.**

Existing buildings will continue to represent the major contribution to energy use, and therefore existing ventilation and air-conditioning systems should be well-maintained and optimised in their operations so as to reduce energy use significantly. New buildings can incorporate envelope designs to reduce energy consumption for cooling, but also to allow greater penetration of daylight, thereby reducing the use of artificial lighting.

A crucial feature of long-term strategies is that they should cover all sectors and allow interactions between sectors to be considered so that visionary thinking and a comprehensive and integrated decarbonisation strategy is put in place.

While the energy sector represents the biggest share of emissions for most SIDS, as it decarbonises, emissions from other sectors such as agriculture, industrial processes and product use, and waste will grow in relative importance. These other sectors also need to be taken into account as part of a long-term strategy.

Benefits and known barriers in the development of LTS

Shift government expenditure and increase energy security:

Most SIDS are characterised by a high dependence on imported fossil-fuels. **Shifting away from fossil fuels will reduce fuel imports and increase SIDS' energy independence, providing direct economic advantages.**

The competitiveness of renewable electricity:

An illustrative scenario developed for the purpose of this briefing shows that overall **an increasing penetration of renewable technologies can lead to significant decreases in the cost of electricity.** The lower cost of decentralised renewable energy systems can also be an important lever to extend electricity to populations without access and in locations where extensions of the centralised grid are cost-prohibitive.

In the transport sector, **ramping up the EV penetration in the fleet can lower the end-user fuel bill as** costs per kilometre for electric vehicles are less than those of gasoline or diesel in nearly all regions and countries. However, this might be jeopardised by a potential increase in imports of low cost, high-emitting cars from markets that have decarbonised their fleets, unless relevant policies are put in place.

Planning for deployment of dispatchable renewables and sector coupling:

Many SIDS have the challenge of not being able to rely on interconnected grids to balance power supply and demand, and **assessing the potential of dispatchable renewables such as hydropower, geothermal, marine power and others, will be a key element in their long-term planning.**

Energy storage capacity combined with smart-grid technologies is an option for complementing variable renewable energy. These will be essential for **providing grid stability** by allowing the storage of excess electricity produced by non-dispatchable sources such as solar or wind, but will also enable the increase of renewable capacity potential and assist the grid operators in matching demand and supply. **Currently, the main storage technologies available include batteries, pumped hydropower (in some selected locations), hydrogen and, where necessary, thermal heat storage.**

Short- and mid-term policy planning through LTS:

Planning a fully decarbonised energy system on the long run highlights the potential and need for fostering a high uptake of renewable energies by 2030, as well as electrifying end use sectors in the mid-term. Renewable energy targets, policies and programmes for the medium term to 2030 will play a key role in the completion of the long-term pathway.

Reaching a 100% renewable energy share in power generation by 2050 will require detailed, but flexible planning for both dispatchable renewable energy and storage technologies in the near- to mid-term. Unless the necessary incentives and policy measures for enabling the deployment of dispatchable renewables, storage and interactive grids are put in place in the near-to-medium term, the deployment of large amounts of variable renewables will not be possible without endangering the stability of the distribution network. On the other hand, simply relying on fossil fuel technologies to support variable renewables **risks being saddled with high-emitting stranded assets.**

In the transport sector, **policies and incentives will need to be implemented to enable the early sales of EVs especially facing the threat of increased imports of discarded internal combustion engine vehicles** from countries that move toward EVs. To reach the goal of a fully electrified fleet of light duty vehicles and buses by 2050, EVs must be 100% of sales by 2040 at the latest, and around 70% of sales by 2030, considering the long lifetime of vehicles.

Planning and ensuring resilient infrastructure:

Long-term planning is intrinsically linked to the planning of resilient infrastructure. This is particularly true for SIDS due to their vulnerability to extreme events and dependence on imports. **Diversifying the power mix towards renewables, especially when spatially distributed, can provide greater resilience** compared to a centralised energy distribution, with potentially faster restoration when damaged.

According to the World Bank, investing in large-scale centralised power plants without taking their future resilience into account would be more costly in the long run than if resilience measures were considered from the outset due to the increasing threat of damages. Poorly planned infrastructure investments could expose a country to higher costs in the future, especially when required to restore damaged infrastructure. **The additional up-front investment needed to make infrastructure more resilient is estimated to be small for low- and middle-income countries, in the order of 3% of expected investments.**

While it is difficult to foresee exactly which technologies and policy levers will be most effective in 2050, a well-designed LTS should outline the priorities of a country's low emissions development toward that horizon, which in turn should guide the selection of policies and measures to get there. Having an LTS in place that has been developed as part of an inclusive process with significant stakeholder buy-in can provide governments with a well-defined direction in which the country wishes to move.

While long-term strategies might be subjected to short-term political change, embedding long-term targets into national law, with a regular review process, will help ensure their longevity and implementation.

When unforeseen events such as the COVID-19 pandemic occur, an LTS can help to shape a country's recovery by providing a vision against which the recovery can be aligned. For example, the priorities laid out in an LTS can focus attention on using recovery packages to facilitate the transition to a decarbonised and resilient economy, rather than on short-sighted fossil fuel developments. In the face of accelerating climate change impacts, it will be important for long-term strategies to be constructed such that they take vulnerability and exposure to these impacts into account and maximise resilience across sectors.

1 Long-term strategies in light of the Paris Agreement and in the context of the SIDS

1.1 Key elements of long-term strategies

As signatories to the Paris Agreement, governments agreed to “strive to formulate and communicate long-term low greenhouse gas emission development strategies” consistent with the long-term goals of the Paris Agreement, including the temperature goal of holding global temperature rise to well below 2°C and pursuing efforts to limit warming to 1.5°C (see the Paris Agreement’s Articles 4.19 and 2.1).

At COP21 in 2015, Parties were invited to submit their mid-century, long-term strategies by 2020 (paragraph 35, decision 1/CP.21). As of January 2021, 29 have already done so, including three SIDS (UNFCCC 2020).

Long-term strategies provide a vision and targets to 2050 that can guide countries’ transitions to a decarbonised, 1.5°C compatible economy. While the submission of a long-term strategy is not legally binding under the Paris Agreement, a LTS can play an important role at the national level in steering near-term action, driving alignment to the Paris Agreement’s goals, and obtaining long-term political buy-in for the necessary system transitions (see table 1 below).

Countries could incorporate long-term targets in their legally-binding national framework to ensure the continuity of the LTS through short-term political changes, and to set up monitoring, reporting and verification mechanisms for its implementation as well as a regular review process (e.g. UK’s Climate Change Act 2008) (Government of the United Kingdom 2008).

Alignment between the vision contained within a country’s long-term strategy and its Nationally Determined Contribution (NDC) is crucial, and can improve the efficiency and robustness of near- and long-term target setting.

Table 1: Key aspect of a LTS.

Features of long-term strategies	
A living document	Countries may choose to incorporate long-term targets into national law. Not legally binding under the Paris Agreement. May become relevant to the Paris Agreement Implementation and Compliance Committee's consideration of issues of a systemic nature.
Provides a long-term vision over a time horizon of 30 years	Not necessarily an implementation plan, but can provide sectoral decarbonisation pathways and strategies, and can be accompanied by an implementation plan.
Should be consistent with / embed the NDC	Steers and informs near-term targets and policies, including NDC updates.
Not tied to a revision cycle, internationally, but regular monitoring (including evaluating, backstopping and reporting) and revisions at the national level against LTS elements would be beneficial	Should cover all the sectors of the economy, and consider interactions between sectors.
Should provide synergies with NDC development, without duplication of effort	Requires strong coordination among ministries, agencies and departments.
Requires a political mandate and buy in	Should be developed in a fully participatory process with stakeholders

Sources : (CAN Europe 2018; Hans et al. 2020; WRI 2019)

Technological decarbonisation of all sectors of the economy will not be the only means to reduce emissions. Behavioural and lifestyle changes (such as dietary changes linked to meat consumption or other foods responsible for high emissions, providing options to allow a shift from private to public transport or other low-emitting means, incentivising circular economies) will also be important; these can be incentivised through better infrastructure and enabling policies.

At the same time, especially with respect to dietary changes, sensitivity to long-standing traditions is necessary – some of which may actually have lower environmental impacts than more recent practices. Such changes take on a particularly important role in long-term planning as the timespan to change behavioural habits could be generational in nature.

This briefing will outline some key reasons why long-term strategies are a fundamental component of national climate policy architecture, and how SIDS can benefit from developing a long-term strategy, both directly in terms of prioritising efforts for achieving the goals of the Paris Agreement, and indirectly through the synergies that arise between long- low greenhouse gas emission development strategies and other sustainable development and resilience goals.

The briefing focuses on the energy sector, including transportation as it contributes disproportionately to SIDS' emissions, small as they are. The energy sector offers a number of low-hanging fruits for reducing emissions, but decarbonisation will require planning for large-scale and systemic changes to infrastructure and markets, making a long-term strategy essential.

This is only a starting point though: a crucial feature of long-term strategies is that they should cover all sectors and allow interactions between sectors to be considered so that visionary thinking and a comprehensive and integrated decarbonisation strategy across all sectors is put in place. Furthermore, and touched on in several times in what follows, there is a recognition that climate change impacts are already occurring and that therefore adaptation measures will be increasingly necessary. Thus, long-term strategies should also include considerations of energy system resilience, and should try to take advantages of potential synergies between adaptation and GHG emissions reduction policies to the extent possible.

1.2 Aligning NDCs and long-term strategies: streamlining resources and embedding processes

While long-term strategies and NDCs differ in their nature and time horizon, they are strongly complementary. Fundamentally, each successive NDC, and the policies and measures used for its implementation, should be aligned with the Paris Agreement's long-term temperature goal.

The five year cycle of communicating successive NDCs that reflect progression and the highest possible ambition (see Paris Agreement, Article 4.3) is designed to see progressively more ambitious emission reduction targets in NDCs that are consistent with 1.5°C pathways, as well as with the corresponding roadmap and long-term goal (e.g. net zero by 2050) contained in a long-term strategy.

Complementarity between long-term strategies and NDCs can be used to streamline and integrate the processes underlying the development of both documents, with the benefit of avoiding inconsistencies while at the same time reducing costs and increasing efficiencies in planning processes. In an ideal case, the LTS should be developed before or jointly with the communication of an updated or new NDC (WRI 2019). The Republic of the Marshall Islands followed this path by releasing both its LTS and its second NDC in 2018, the latter being informed by the former (see box 1).

One example of how the burden on ministries and government agencies responsible for NDC and LTS development could be reduced is through the streamlining of data collection and long-term modelling. Instead of modelling emissions and energy systems to 2025 or 2030, as required for the new/updated NDCs scheduled for submission in 2020, the vision and pathway could be modelled to 2050, with interim targets for the successive NDCs to 2050 then derived from this pathway.

Similarly, stakeholder consultations could consider the LTS and NDC in tandem, increasing efficiency while at the same time allowing stakeholders to better understand the context in which the NDC is being developed. The five-year revision cycles could also become more efficient if a continuity in stakeholders that are already on board with the long-term vision is maintained.

The process of developing a long-term strategy can foster dialogue among stakeholders as to the most prudent pathways forward for each sector. For example, stakeholder engagement can enable discussions that go beyond incremental technological substitutions (EVs for ICEVs; solar panels for diesel generators) and lead to thinking about larger-scale changes (for example, public transportation or ride sharing instead of individual vehicles; interconnected distribution and production of electricity).

Early and detailed thinking about a long-term strategy can also highlight the potential pitfalls or dead ends of some technology choices that may appear promising in the short-term but can make achieving long-term goals more difficult. Focusing on the short-term could, for example, lead to the building up of natural gas import infrastructure at high cost for only marginal GHG emissions reductions gains, only for this infrastructure to become a stranded asset in the medium to longer term.

In the transport sector, given the extended time over which cars are used in SIDS, lack of early policies limiting imports and sales of internal combustion engine vehicles (ICEVs) might lock the country into an emissions-intensive fleet for the next 20 to 30 years; early action coupled with long-term strategic planning is needed to transition to low-emissions technologies vehicles.

Box 1: Case of Republic of the Marshall Islands (RMI)	
In its LTS published in 2018, the RMI included explicit recommendations to be included in the to-be-updated NDC which was published later that same year following the LTS. The NDC included the LTS in its annex (Falduto and Rocha 2020; Republic of the Marshall Islands 2018a, 2018b).	
Recommended in the LTS	Implemented in the NDC
GHGs emissions reduction target to **at least** 45% below 2010 levels by 2030	✓
Revises its GHGs target to **at least** 32% below 2010 levels by 2025	✓
Communicates an indicative target to reduce GHGs emissions by at least 58% below 2010 levels by 2035	✓

Box 2: Case of Fiji
Fiji's Long-Term Strategy explicitly states the intention of using their LTS to inform the next updated NDC. *"The Fiji LEDS builds onto existing mitigation and adaptation actions that are being undertaken by the Fijian government and* ***will inform Fiji's future Nationally Determined Contributions (NDCs)*** *reported to the United Nations Framework Convention on Climate Change (UNFCCC). The strategy* ***will be a key tool, a guiding light, and a fundamental pillar to enhancing and raising ambition in our NDCs."*** (Republic of Fiji 2018)

2 Long-term strategy as a means of developing sectoral transformation pathways in SIDS

2.1 Insights from the IPCC SR1.5

The Special Report on Global Warming of 1.5°C (SR1.5), published by the Intergovernmental Panel on Climate Change (IPCC), provides scientific evidence on the transformations needed at global and sectoral levels to achieve the Paris Agreement's long-term temperature goal (Intergovernmental Panel on Climate Change (IPCC) 2018; Schaeffer et al. 2019). A summary of some of the key messages from that report is given in Table 2 on selected elements particularly relevant for SIDS.

Table 2: Key Messages from the Special Report on 1.5°C and its implications for SIDS Source: (Schaeffer et al. 2019).

IPCC SR1.5 Key messages relevant for the energy sector in SIDS
Large **reductions of fossil fuel use**, in particular: ● Reduce fossil-fuel consumption towards zero by mid-century ● Fully decarbonised primary energy supply by mid-century
Large **demand reductions across all end use sectors by 2030**: ● Increase building energy efficiency such as air conditioning systems and lighting ● Improve public transportation to reduce individual demand

Full decarbonisation of electricity generation by 2050, mainly through: ● Over 50% of electricity from RE by 2030 ● Fossil-fuel phase out in power sector by 2050
Electrification of end-use sectors: ● Ramp up penetration of EVs in public and private transportation to reach full decarbonisation by 2050 ● Deployment of charging infrastructure
Decarbonisation of final energy other than electricity, e.g., for marine transportation: ● Plan replacement of fleet by low-carbon vessels ● Deploy port-infrastructure for charging facilities
Substantial reductions of emissions of non-CO2 greenhouse gases such as methane and nitrous oxide from agriculture, industry and other sectors are needed, as well a phase out of HFCs.

2.2 Decarbonisation pathways in the context of SIDS

For the majority of SIDS, the energy sector is the main contributor to their carbon footprints with shares ranging from around 50% to 95% of their total amount of emissions in 2017 (Gütschow et al. 2019) (see Figure 1). The second most emitting sectors, which vary from country to country, are either agriculture, industry processes and product use (generally caused by the use of air conditioning), or waste.

The energy sector is clearly a priority sector for emissions reductions in the short term, but as its share of emissions decreases, other sectors will take on a greater share of the total in the long run. Decarbonisation options need to be planned as part of the long-term strategy for all sectors, including those that currently have a relatively lower share of emissions.

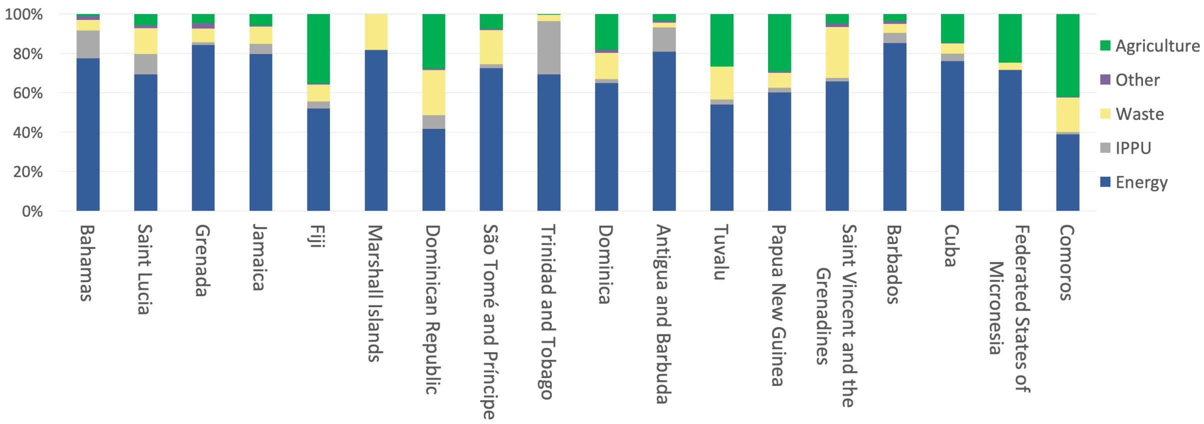


Figure 1: Emissions per sector per country for the year 2017. Energy includes electricity generation, direct use of energy and transportation. IPPU is Industrial Processes and Product Use. Source: (Gütschow et al. 2019).

2.2.1 Energy sector decarbonisation strategies

For the majority of SIDS, the main contributors to energy sector emissions are liquid fuels used extensively in power and transportation (see figure 2 and section 3.5) (Soomauroo, Blechinger, and

Creutzig 2020). The main lever for reducing emissions in the energy sector will be a phasing out of diesel fuel or residual fuel oil in the power sector, as well as diesel and gasoline in the transport sector.

SIDS are nearly all characterised by a high dependency on imported fossil fuels, which comprise the major part of their energy mix and emissions profile although some islands already have a significant share of hydro power (e.g. Dominica, Fiji, Papua New Guinea, Samoa) or solar power (e.g. Kiribati and Tuvalu). Trinidad and Tobago is an exception with a power sector based on domestic natural gas electricity (McIntyre et al. 2016; United Nations 2020). Figure 2 shows installed electricity generation capacity in a selection of SIDS, demonstrating the dominance of fossil fuel generation.

Reducing dependence on fossil fuel imports, while at the same time increasing energy supply, means that the power sector must be decarbonised and end-use sectors electrified, both of which require a long-term outlook.

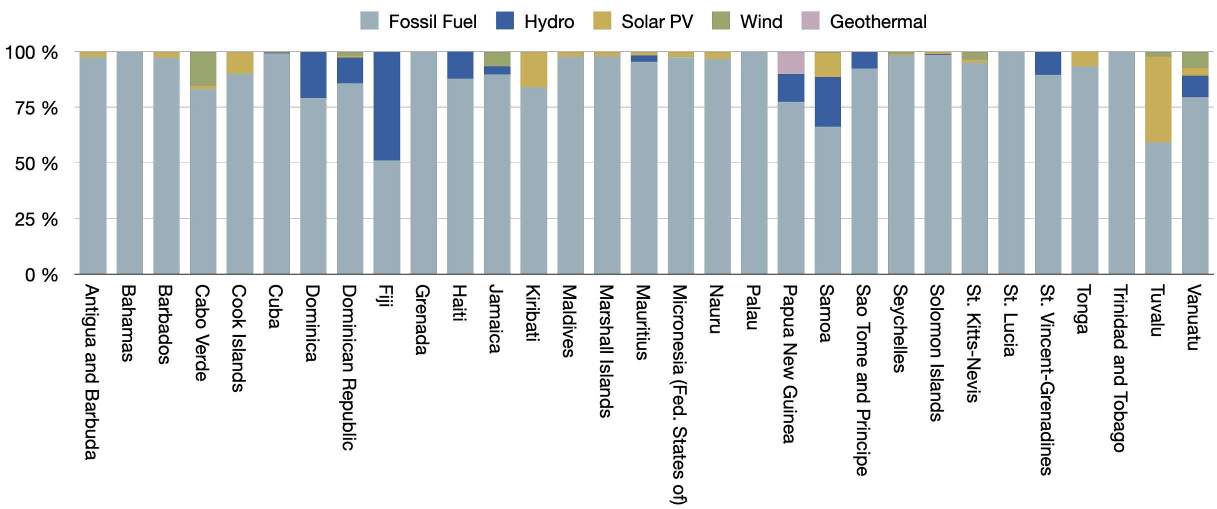


Figure 2: Installed Generation Capacity in selected SIDS in 2017 (in % of total capacity). Source: (McIntyre et al. 2016; United Nations 2020).

Figure 3 represents an illustrative scenario for the decarbonisation of the power sector; here the future dominance of solar PV and wind are demonstrated, with complementary capacity and generation from a dispatchable (i.e., controllable) renewable energy technology such as geothermal, biomass, hydropower (which can be available in certain SIDS such as Dominica, Fiji or Samoa), or wave and ocean technologies. Not shown in Fig. 3 is the role played by battery or other storage.

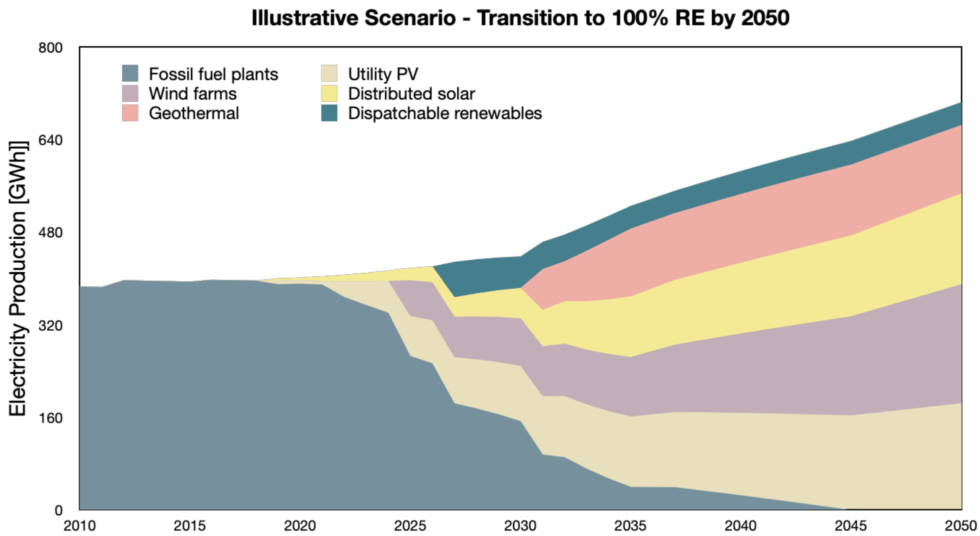


Figure 3: Illustrative electricity output pathway modelled based on overall demand in a SIDS. Own simulation using the LEAP model.

Many SIDS have already started this transition, with solar PV generation on the rise in a number of islands. However, while wind and solar power generation can be deployed rapidly, transitioning to a power system with high shares of variable renewable energy (VRE) production requires long-term planning to develop the infrastructure necessary to support a new electricity mix.

Other than Mauritius, which has a high base in bioenergy, and some countries that can rely partly on hydropower or geothermal, SIDS will have to explore and plan for the development of other dispatchable renewables or energy storage – either at utility-scale or distributed and interconnected to the grid – to reliably meet demand and complement variable renewable (VRE) production.

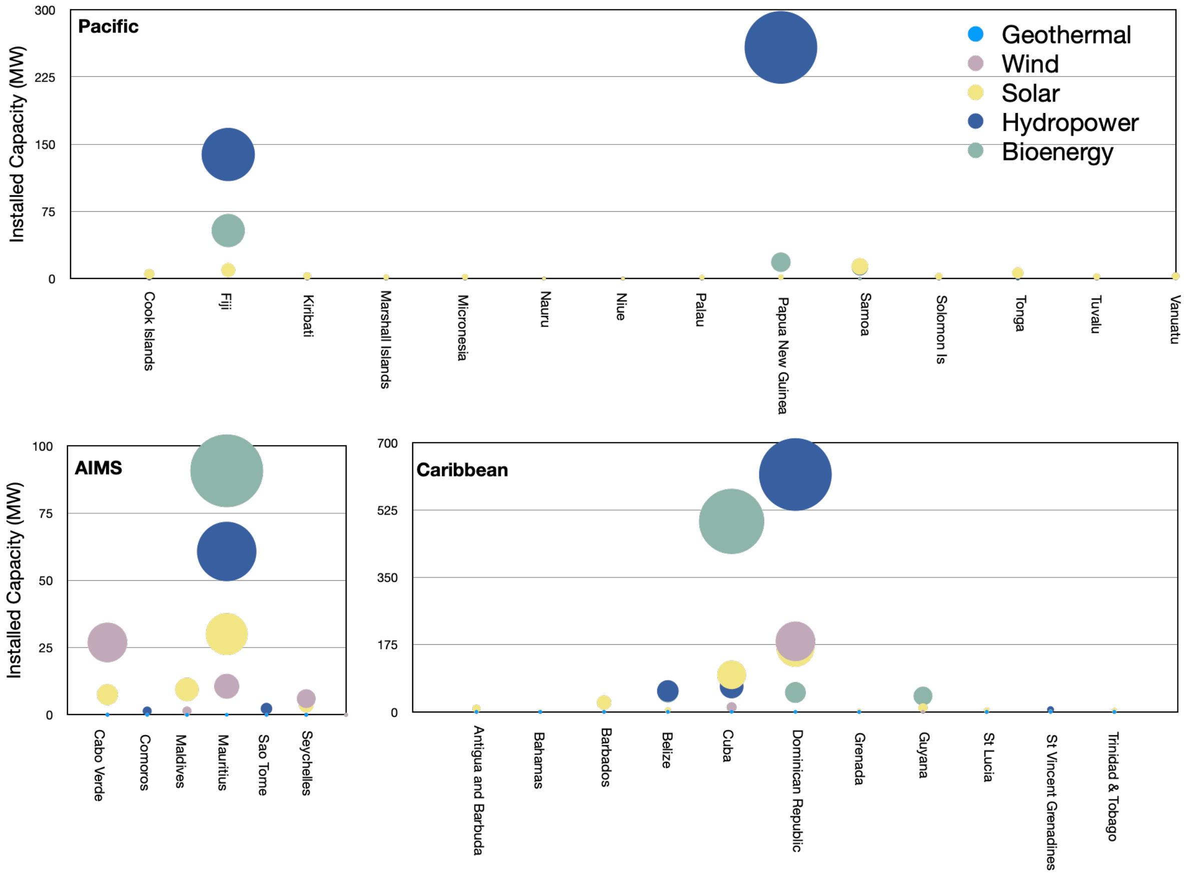


Figure 4: Installed capacity per renewable energy sources in the SIDS from 2013-2018. Source: (IRENA 2020b).

End user sectors such as transport and infrastructure will need to decarbonise through electrification and energy efficiency measures. In the transport sector, this means a rapid shift from internal combustion engine vehicles to electric vehicles (EVs), alongside the development of improved public transport infrastructure. The need for long-term planning in this sector is particularly acute.

Most vehicles in SIDS tend to be older than in wealthier countries, often 20 to 30 years or more, and most imported cars are pre-owned internal combustion engine vehicles, meaning that SIDS' domestic markets are likely to be strongly impacted by external market developments.

For example, in the absence of domestic policies to incentivise EVs and limit imports of ICEVs, the ongoing acceleration of EV uptake abroad could flood the import market with internal combustion engine vehicles, delaying the possibility for SIDS to transition to a low carbon transport sector. Complementarily, cooperation with main exporting countries to implement relevant policies limiting the export of used ICEVs could be an indirect lever for EV uptake in importing countries.

Many SIDS are located in climates that are cooling-dominated, thus removing the need for space heating, one of the major sources of energy consumption in colder climates. Nevertheless, there are still gains that can be made by improving the envelope efficiency of buildings with better insulation (especially during new construction) to reduce cooling loads.

Furthermore, significant reductions in energy consumption can be achieved through better "commissioning" of buildings, that is in careful optimisation of ventilation and air conditioning control systems. Finally, equipment varies greatly in efficiency, and regulations and standards to ensure only highly efficient appliances, including air conditioners, can reduce future energy consumption as part of a long-term emissions reduction strategy.

2.2.2 Beyond the energy sector

The agriculture sector is the second highest emitting sector for some SIDS such as Comoros, the Dominican Republic, the Federal States of Micronesia, Fiji and Tuvalu. Enteric fermentation and manure left on pastures are two main sources of emissions from agriculture. These can be mitigated in the long run through change of diet (if products are consumed domestically) or improved agricultural practices, such as more effective management of soil carbon, efficient fertiliser and nutrient use, and energy efficient machinery (Bacolod, Tabunakawai, and Natasiwai 2020; Republic of Fiji 2018). While the latter options might be implemented in a relatively short period of time, the former is linked to a change of customs and it could take substantial time to see changes in lifestyles.

The waste sector is in many SIDS either the second or third emitting sector. Waste emissions are largely driven by the combustion or decomposition of household waste, and in some cases industrial waste. Given limited space, imports of many goods, including second hand products, and the expense of re-exporting waste, SIDS are particularly prone to challenges with waste disposal.

Links to the energy system can be made by considering solid-waste combustion as a source of energy generation, with waste amounts of roughly 1kg/person/day being typical for the region, translating to approximately 100 MWh of electricity on an island with a population of 100,000 and an efficient collection system – itself a challenge (Espinoza et al. 2010).

A different approach to linking waste to energy is that of landfill gas capture, using a reciprocating engine or turbine to burn captured methane, which are effective ways to mitigate climate change impacts from the waste sectors. Landfill gas capture systems are among the most effective ways to mitigate climate change impacts from the waste sector, not only by reducing emissions but also short-lived climate pollutants. The energy produced can be used to generate electricity or other appliances such as heating and cooking (UNEP 2019).

As example, as part of its energy strategy, Mauritius, which faces an acute scarcity in land availability for landfill, plans to provide 4% from its renewable energy by 2025 from waste accounting on 20MW capacity from a waste-to-energy plant and a 3MW capacity from a gas-to-energy plant (Republic of Mauritius 2009).

In the transport sector, disposal of old vehicles will increasingly become a problem as the number of cars has increased significantly in many SIDS over the past decade, and an accelerated systemic switch to EVs may only serve to exacerbate this problem without comprehensive strategies. Developing a more comprehensive circular economy, encouraging the reuse of materials and incentivising new ways of consuming could help reduce waste emissions in the long-term (Republic of Fiji 2018).

The industrial processes and product use (IPPU) sector is prominent for some SIDS such as Trinidad and Tobago (dominated by the petrochemical industry) and Antigua and Barbuda (historically dominated by refrigeration and air conditioning but recently surpassed by growing construction aggregates (Government of Antigua and Barbuda 2020; Inter-American Development Bank 2015).

In cooling-dominated climates, emissions from refrigeration and air conditioning could be mitigated by, on the one hand, more efficient buildings, but also by raising public awareness on the effect of individual consumption. This could be achieved through, for example, the installation of consumption meters in households combined with more efficient appliances and the use of low-GWP refrigerants (Moie, Papst, and Telesford 2020) in line with implementation of the Kigali Amendment.

Some sectors, such as agriculture and aviation, will need more time to decarbonise because the technologies for doing so are not yet available for deployment and, in the case of agriculture, because the sector is less consolidated and would require a change in practices by both producers and consumers.

Residual emissions from these sectors would need to be balanced through removals in order to reach net zero emissions in greenhouse gases. Removals could be planned for as part of the development of long-term strategies as they would require, land availability and a change in land management practices and/or technological developments, although the latter are less likely to be the right solution for the SIDS.

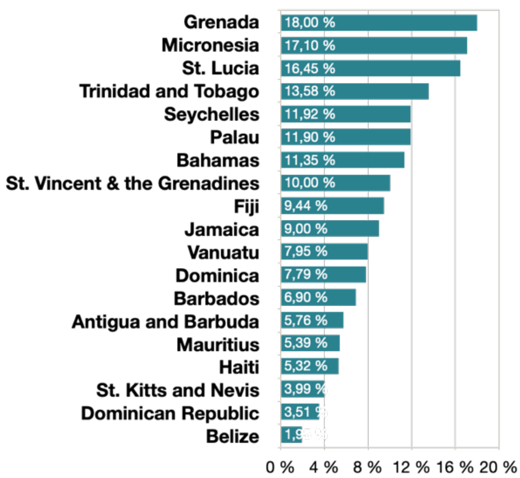
International support and cooperation, including in the case of international aviation and maritime transport, will be crucial for achieving net zero greenhouse gas emissions globally around 2070.

2.3 Shift government expenditure and increase energy security

SIDS are characterised by a high dependence on imported fossil fuels, especially diesel fuel, heavy fuel oil (HFO), gasoline and other oil-based products. In 2010 it was estimated that about 90% of energy for transportation and electricity generation in the Caribbean islands came from oil imports (IRENA 2012).

Shifting away from fossil fuels will reduce fuel imports and thus will contribute to SIDS' energy independence and lower exposure to volatile oil prices. Some SIDS have already or are considering a move toward imported natural gas (a fossil fuel), a trend that may provide short-term benefits, but that exposes governments to competition for natural gas and to fluctuations in gas prices, and result in stranded assets.

Across SIDS, data from the World Bank show that fossil fuel imports represent about 5-10% of GDP. For comparison, the same data source shows that average government expenditures on education in these same countries is 5% of GDP.



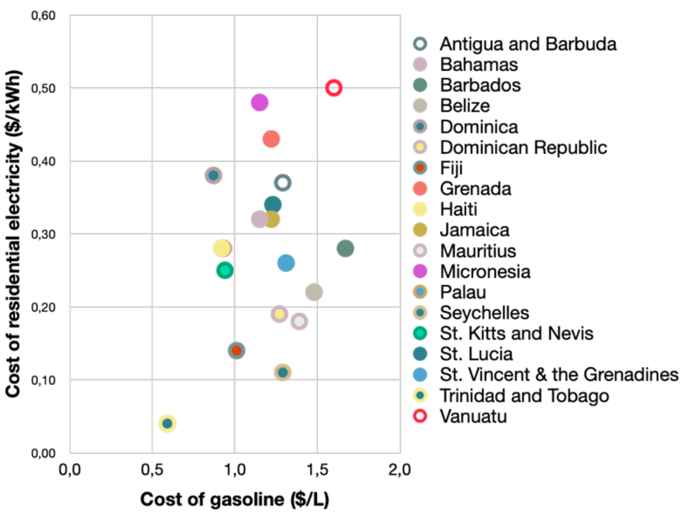


Figure 5: Percentage (%) of GDP spent on fuel imports (left) and cost of electricity versus gasoline (right) for selected SIDS. Source: Readapted from (Gay, Rogers, and Shirley 2018)

Moving away from imported diesel or fuel oil in the power sector has direct economic advantages. In sunny regions, one MW of solar capacity can produce approximately 1.3 to 1.7 GWh of electricity each year (Solargis 2020). Each GWh of solar electricity replaces one GWh of oil-based electricity, for which 250,000 litres of fuel are needed at a representative cost of $0.6/litre. Therefore, each 1MW of solar capacity installed saves, over its 25-year (minimum) lifetime, around US$150,000 each year compared to oil-based electricity. Of course, the infrastructure for solar PV must be paid for, but as discussed in the next section, the balance of costs is very favourable and improving each year.

2.4 The competitiveness of renewable electricity

A remarkable trend over the past decade has been the sharp decrease in costs of renewable energy sources, especially solar PV and wind energy. Solar PV levelised costs of electricity have come down more than 80% since 2010 alone. This is especially relevant in SIDS due to the fact that most are in lower latitudes with abundant sunshine, but often above average wind resources as well.

As seen in Figure 6, the costs of most renewable energy technologies are competitive with fossil fuel costs on a global level. Due to favourable solar and wind resources when compared to the import of expensive fossil fuels, the advantage is clear in most SIDS.

Although up front capital costs for solar and wind are often higher in SIDS than in other regions due to lower levels of experience and higher import costs, as well as smaller scale installations, the relative decrease in costs still holds true for SIDS. Given high costs of current electricity generation in most SIDS, there will in almost all situations be lifecycle cost savings to be realised through the implementation of renewable energy.

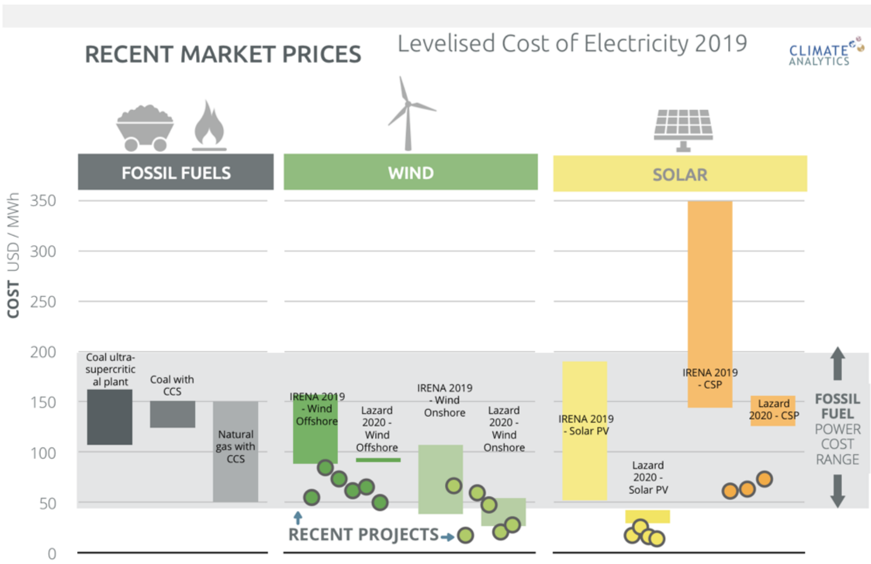


Figure 6: Levelised Cost of Electricity of different generation technologies in 2020. Source: Own elaboration based on Lazard analysis (Lazard 2020) *and IRENA* (IRENA 2020a).

A key aspect of long-term power system planning that is closely tied to both the NDC and the LTS is a need to understand how the overall system will develop, and how the costs from each of the elements of the portfolio of technologies will contribute to the cost of electricity.

For example, it might be that a given technology such as geothermal power or battery storage appears to be expensive on its own, but if that dispatchable technology then allows a much greater percentage of inexpensive solar or wind power to be successfully integrated, then the overall cost of electricity may still be less than fossil fuel alternatives. Some of the options for dispatchable power are shown in Figure 6 and will be discussed further below.

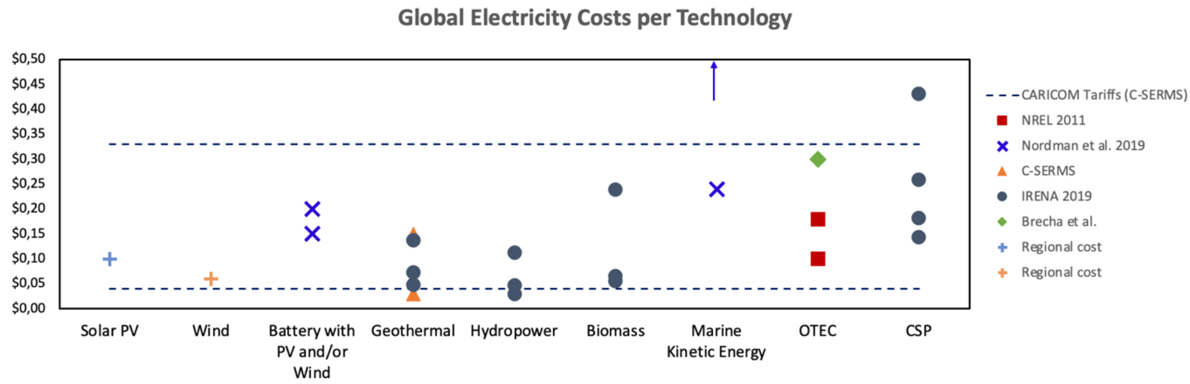


Figure 7: Global cost of electricity as reported in the literature from dispatchable renewable sources. Sources:(Brecha et al. 2021; IRENA 2020a; Nordman et al. 2019; NREL 2010; Ochs 2015)

For those SIDS in which the provision of universal energy access is an issue, the lowered cost of decentralised renewable energy systems can be an important lever to extend electricity to populations hitherto without access and in locations where extensions of a centralised grid are cost prohibitive.

An illustrative scenario based on representative data for a SIDS with a peak capacity of about 60MW and total generation of 400 GWh/year is shown in Figure 8, where each data point is a given combination of solar, wind, battery storage, hydrogen, dispatchable fossil fuel and renewable generators; in other words, a given power mix. It shows that as the penetration of renewable technologies increases in the power mix, the levelised cost of electricity tends to decrease, even for penetrations of 80%-90% or more (IRENA 2020a).

Renewable based electricity costs are mostly driven by the initial investments and infrastructure, hence capital costs will increase with the uptake of renewable based electricity. However, annual operating costs decrease with the uptake of renewables, which can be explained by the comparatively low costs in operation and maintenance for renewables compared to fossil fuel electricity generation, which requires costly fuel imports (IRENA 2020a). Therefore, the higher the renewable penetration, the lower the share of fossil fuel-based electricity, and the lower the cost of producing electricity.

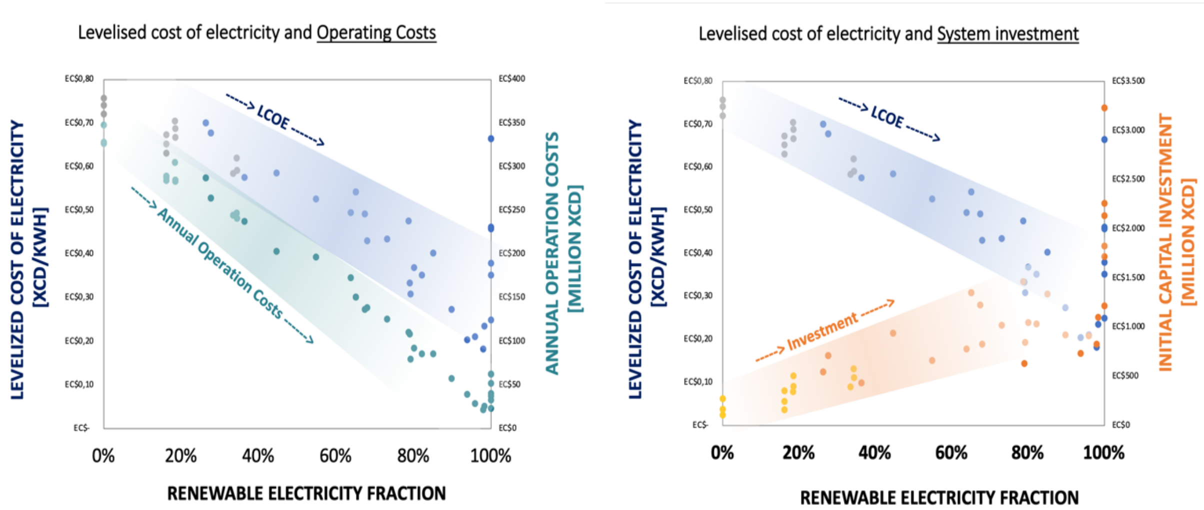


Figure 8: Illustrative system levelised cost of electricity and initial capital investment versus percentage of penetration of renewable electricity in the power mix. Scenario based on a representative SIDS. Own simulation using the HOMER model.

2.5 Planning for technologies to complement wind and solar

To fully shift away from fossil fuels, assessing the potential of dispatchable renewables such as hydropower (where appropriate and consistent with other sustainability goals), geothermal or marine power will be an element in the long-term planning process (IRENA 2020b; Ochs 2015). Table 3 provides a selection of renewable sources relevant in the context of SIDS.

Only a third of SIDS benefit from hydropower resources, which provide a baseload that complements VRE generation. Experience in Europe and in the United States has shown that far higher percentages of variable renewable energy can be reliably supported by the grid than was commonly thought possible twenty years ago.

However, it is equally true that SIDS have the added challenge of not being able to rely on interconnected grids to balance power supply and demand. Therefore, careful mapping of not only solar and wind resources will be necessary, but perhaps more crucially, an evaluation of non-variable (so-called dispatchable) and storage options (see below) will have to be investigated for ensuring both grid stability and finding a cost-optimal solution.

While the competitiveness of solar and wind has been proved already, marine kinetic energy remains a costly source. Although estimates for OTEC are so far mostly speculative, the costs may be in the range of battery storage combined with PV and wind (see Figure 7).

Table 3: Potential Renewable Energy Sources and their relevancy for SIDS. Sources: (Brecha et al.2021; IRENA 2016, 2020b; Nordman et al. 2019; Ochs 2015) Checkmarks indicate that a source is dispatchable; bracketed checkmark indicates conditional dispatchability.

Sector		Dispatchable
Wind	Combined with desalination and pumped storage, can be considered dispatchable.	
Solar PV	Combined with battery storage, solar PV becomes a dispatchable resource.	
Concentrating Solar Power (CSP)	While some CSPs projects exists in the SIDS, it is generally less suited to SIDS due to the land surface it requires.	✓
Hydropower	High upfront costs combined with specific site characteristics requirements such as adequate stream flow have hindered its development across SIDS.	✓
Biomass/Waste	Easily accessible source however a major driver of deforestation and requires a high land availability. Biomass is the main component of Belize, Cuba and Mauritius' renewable energy mixes.	✓
Marine Kinetic Energy	It captures energy from rivers, ocean currents, waves, and tides. It can complement wind and solar energies although it remains variable to a lesser extent than wind and solar. It has however a low potential in the Caribbean due limited tidal channels.	(✓)
Ocean thermal energy conversion (OTEC)	Uses the difference between warm surface water and cold deep ocean water to produce electricity.	✓
Geothermal	Can be used to produce electricity or cooling and heating services, for which it is most commonly used. Although potential has been identified in SIDS, it has been so far to a very limited extend exploited due to technical and costs limitations. Several SIDS have accounted in their energy systems planning the use of geothermal, such as Grenada and Saint Lucia, but have seen challenges in their implementations.	✓

A key technological option for complementing variable renewable energy is that of power storage capacity combined with smart grid technologies (Lazard 2020). Costs of battery storage have also been decreasing rapidly over the past several years to the extent that that solar or wind power coupled with storage is already competitive with fossil fuel generation. That trend is expected to continue.

Battery storage will be essential to providing grid stability by allowing the storage of excess electricity produced by non-dispatchable sources such as solar or wind, but will also increase renewable capacity potential and assist the grid operators in matching demand and supply (Nordman et al. 2019; Ochs 2015). The main storage technologies, which could be considered are batteries combined with PV and/or wind, pumped hydropower and heat thermal storage (Nordman et al. 2019).

2.6 Planning for increased coupling of transportation and power sectors

In the transport sector, ramping up the EV penetration in the fleet will be reflected in lower end user fuel bill. Even now, costs per kilometre for electric vehicles are less than those of gasoline or diesel in nearly all regions and countries.

Literature indicates that fuel consumption costs per 100km could drop from 60% to 70% between petrol and electricity and from 14% to 18% between diesel and electricity for the end user (Table 4 for the cases of Barbados, Fiji and Mauritius) (Soomauroo et al. 2020).

Table 4: Fuel costs for 100km driven by an LDV per type of fuel. Source:(Energy Fiji Limited 2020; Soomauroo et al. 2020).

Country	Unit	Petrol	Diesel	Electricity
Barbados	$ per 100 km	13,36	9,8	4,48
Fiji		8,08	6,02	5,44
Mauritius		11,12	8,61	2,88

A shift to EVs will require an increase in renewable power generation, and charging requirements can initially present challenges to grid operation. However, EVs and their charging infrastructure can offer solutions for power storage and grid services at higher levels of penetration, enabling increased integration of renewables in the power grid and potentially reducing the levelised cost of energy (Gay et al. 2018).

Such services could be significant for SIDS, so any long-term plan for decarbonising the power sector would benefit from research into potential synergies from EV uptake. SIDS will not be immune from the global disposal and recycling issues surrounding EVs, whether from batteries or other materials; planning for disposal is an ongoing challenge, whether for ICEVs or EVs.

2.7 LTS can help drive short- and mid-term policy and planning

Developing a LTS can help countries to identify 1.5ºC consistent near-term targets and strategies, including in NDCs, which are required to be revised every five years. To define how a long-term target could impact shorter-term actions, we use here another illustrative scenario. Results are presented in Figure 9.

To reach a 100% renewable energy share by 2050, the country will need to have implemented by 2030, a share of dispatchable renewables, which would not be necessary in a scenario reaching 50% to 60% of renewable energy by 2050.

Were a country not to implement incentives and policy measures enabling the relative early deployment of dispatchable renewables, it might lock itself into a position where the deployment of variable renewables is no longer possible without endangering the stability of the distribution network, risking being saddled with high-emitting stranded assets.

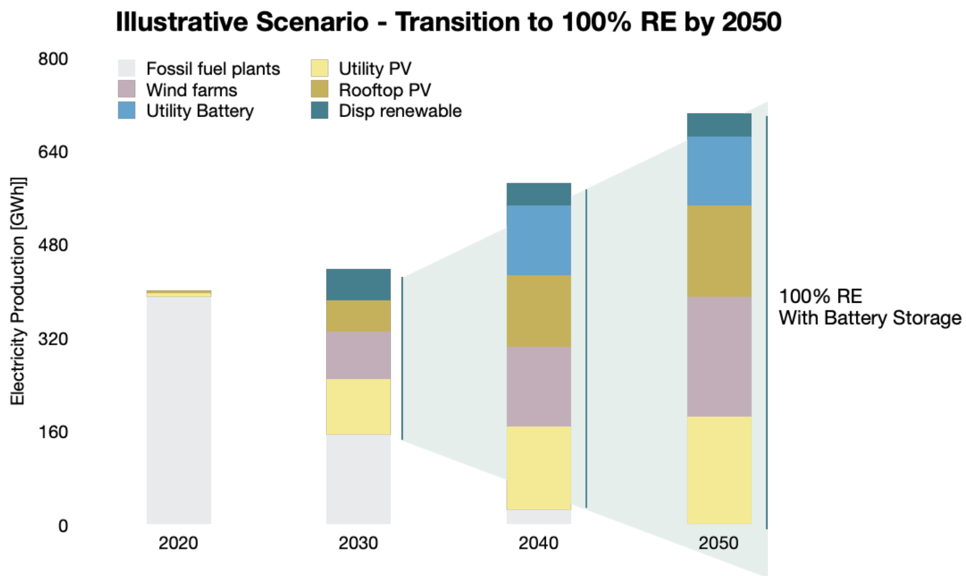


Figure 9: Illustrative scenario based on a fossil fuel phase out in 2050. The model assumes that the transport sector is electrified over time, leading to higher demand for electricity, but a phase out in gasoline and diesel fuel for transportation as well as in the power sector.

The same methodology has been applied to the transport sector, to estimate the impact of long-term goals in the short term by defining a scenario based on an ambitious uptake of renewables (see previous figure) and a high uptake of electric vehicles (EVs) to 2050. We assume here typical lifetimes for vehicles as they exist in SIDS, which are generally kept a long time, around 20-30 years.

As can be seen in Figure 9, to reach a goal of a fully electrified fleet by 2050, 100% of car sales must be EVs by 2040 and already close to 70% by 2030. Policies and incentives will need to be implemented to enable the sales of EVs, especially when facing the waste disposal concerns in islands of existing internal combustion engine vehicles and the potential threat of increased imports of internal combustion engine vehicles offloaded from wealthier countries that have moved toward EVs. With the uptake of EVs, fewer repairs should be expected but capacity building will be needed to 'convert' current knowledge focused on ICEVs repair to EVs.

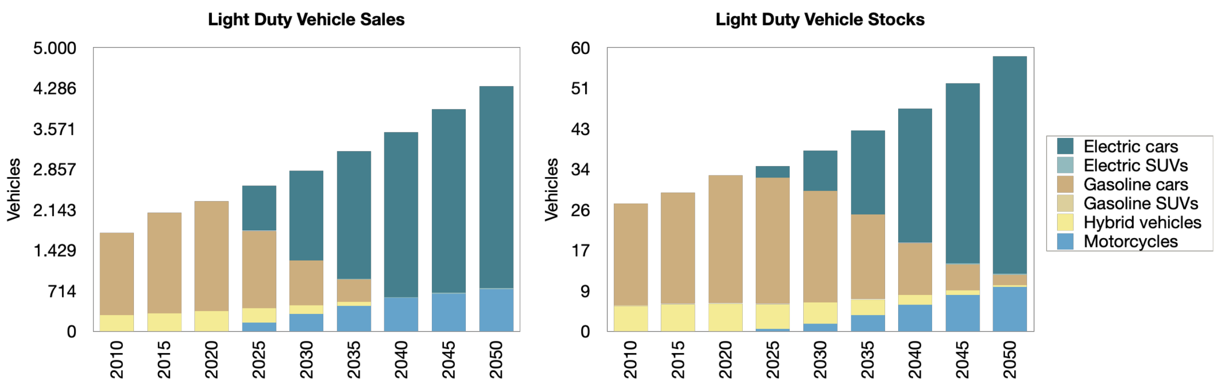


Figure 10: Illustrative EV stocks and sales for Light Duty Vehicles. Own simulation with the LEAP model.

2.8 Avoiding stranded assets caused by short-term planning

The need to decarbonise economies rapidly raises the risk of stranded assets – investments that lose economic value before the anticipated end of their life. Long-term planning can reduce this risk by identifying which types of investments should be avoided in the near-term because they will have no role in a future system. Examples of possible stranded assets in the energy sector include internal combustion engine vehicles and associated infrastructure (e.g. refuelling stations), and fossil fuel power generation infrastructure.

Any future investment in natural gas infrastructure is likely to become a stranded asset. Natural gas is often incorrectly considered as a “bridge” toward decarbonisation. Unfortunately, as a fossil fuel, GHG emissions from natural gas are significant, both during combustion for power generation and also along the production and supply chain.

For SIDS, switching from diesel or fuel oil for power generation to natural gas would require the building up of expensive infrastructure for importing and re-gasifying liquified natural gas from abroad, as well as new generation capacity. All of this represents large up front investments for an energy system that would not be compatible with the Paris Agreement, and that ultimately risks creating stranded assets in a zero-carbon world (IPCC, 2018).

Fundamentally, achieving a long-term goal by 2050 of net zero emissions from the energy sector is incompatible with building an entirely new fossil fuel infrastructure in the 2020s. Fortunately, the falling costs of renewable power generation and storage technologies render natural gas an increasingly unnecessary component in the power system.

2.9 Planning resilient infrastructure

Resilience planning is many-faceted and goes well beyond the immediate needs of meeting GHG emissions reduction targets. Nevertheless, the long-term planning required to decarbonise an economy is intrinsically linked with resilience. For example, in the energy sector the time horizons relevant for planning a power system transformation can range from 5 to 20 years or more (see Table 5), a timeframe over which further significant climate change impacts are to be expected, and which corresponds to the timeframe usually considered in long-term resilience strategies.

Similarly, new housing developments and other large infrastructure projects will not only need to be more efficient in the future (for example, efficient and low carbon cooling systems will be essential in a warming world), but they will also need to be robustly built and well-located to limit damage from extreme events and longer-term impacts such as sea level rise.

Table 5: Key phases in planning power system transition and their time horizons. Time horizons refer to the period of time over that is subject to techno-economic analysis during planning. Note that these time horizons do not consider the need for additional measures related to resilience in the face of natural disasters. Sources: (International Renewable Energy Agency 2017; IRENA 2018).

Power system transition planning phases	Typical time horizon for planning
Long-term generation expansion planning	20-40 years
Geospatial planning for transmission	5-20 years
Dispatch simulation	Weeks to several years
Technical network studies	Up to five years ahead

The linkage between long-term planning, building resilience and addressing loss and damage is particularly the case for SIDS because of their vulnerability to extreme and slow onset events and dependency on energy imports. In the energy sector, diversifying the power mix towards renewables, by its distributed characteristics, could make the system more resilient compared to centralised energy distribution.

Increasing energy efficiency and reducing or shifting demand can also make power systems more flexible in the face of minor outages. Additionally, with renewable based electricity costs mostly driven by capital costs, rather than the fuel costs associated with fossil fuel power generation, a higher share of renewables could make a country's economy more resilient to variations in market prices and fuel imports, provided that there is access to capital (Weir and Kumar 2020). Such considerations can help a country to identify strategies that enhance resilience to accelerating climate change impacts while reducing emissions at the same time.

Two reports published by the World Bank discuss resilience from different points of view, both relevant to discussions of LTSs (Hallegatte et al. 2017; Hallegatte, Rentschler, and Rozenberg 2019). From the institutional to the household level, natural disasters and other events that impact infrastructure result in both monetary damages and in indirect costs such as reduction in productivity. The "Lifelines" report provides many case studies involving health impacts (increases in cholera cases after even a one day water outage) and costs to firms and households of power outages, among other disruptions. In particular, one theme stressed in the report is the disproportionate impact on lower-income groups and in lower-income countries of disruptions, going beyond cumulative or average numbers.

A finding of the "Lifelines" report is that additional investment needed to make infrastructure more resilient is estimated to be small for low- and middle-income countries, in the order of 3% of expected investments. Of course, such an aggregated measure must be examined in more detail for a given resilience measure in a specific context. Expressed another way, there is a benefit-to-cost ratio significantly greater than one for undertaking resilience planning and investments, and that benefit increases even further when the likely impacts of climate change are taken into account.

In addition, it is estimated that delaying investments in measures that build resilience by a decade is also costly because of the large scale of current investments in these countries and the increasing threat of damages.

The "Unbreakable" report attempts to quantify better the disproportionate impacts of natural disasters on the poor by looking beyond the standard measure of dollar or GDP impacts of disruptive events. Essentially, in addition to examining relative hazard exposure and asset vulnerability, the authors "scale" damages in a measure of "socioeconomic resilience" – $1 in losses has a higher impact on "well being" for a poorer person than for a wealthier person. The net result of the study is that losses in well being are significantly higher than asset losses as traditionally measured.

Taken together, the findings of these two reports clearly illustrate the substantial potential economic and social benefits of developing an LTS with resilience built in. At the most general level, having an LTS in place that has been developed as part of an inclusive process with many stakeholders will mean that there is a well-defined direction in which the country wishes to move. Such direction can help to shape recovery when unforeseen events occur, for example, by requiring that recovery packages are used to facilitate the transition to a decarbonised and resilient economy, rather than on short-sighted fossil fuel developments.

The intersection between an LTS, adaptation to climate change, and minimising, averting and addressing loss and damage represents a key challenge for all SIDS. Adaptation strategies and responses to loss and damage will need to be incorporated into long-term planning. Comprehensive risk management, aimed at strengthening the resilience of vulnerable people and communities, can provide a valuable framework for identifying possible responses to loss and damage (see Saint Lucia's

2018-2028 National Adaptation Plan (Government of Saint Lucia 2018) for an example). These responses can then form part of a country's LTS.

2.10 Planning for career training in new developing technologies

New technologies and infrastructure systems will require new job skills and training. Employment in the energy sector is generally not high in many SIDS, but transitioning to infrastructure that runs on renewable energy with far more distributed generation will lead to an increasing number of jobs over at least the next few decades.

While many jobs will be in construction, and therefore temporary, energy transition is not instantaneous. Planning for job training and transitioning a portion of the workforce to new careers is an inherently long-term process. This will be true for the power sector, but also for the transport sector with the switch over time to electric vehicles. It is to be expected that EVs will require less maintenance and also different skills than the repair of ICEVs.

Energy system transformation planning will not automatically mean an increase in jobs in the long-term, but the energy system transformation will certainly give rise to new areas of work, fostered by training to support regionally-based innovation; these are issues for which many countries are beginning to make plans.

Estimates of planning and construction jobs as well as jobs in operation and maintenance for renewable energy systems are uncertain and dependent on the level of experience with the technologies in a given region (Rutovitz, Dominish, and Downes 2015). A rough estimate might be approximately 2-5 person-years per MW of installed capacity (Rutovitz et al. 2015, private communication, solar installer in the Caribbean).

Since even for smaller SIDS estimates of installation needs are in the order of 100MW or more, a significant number of jobs can be created. It should be noted, however, that many of the jobs created during the energy system transformation will be in construction and installation related activities. It appears to be much more uncertain how many permanent jobs will be created.

Conclusion: overcoming challenges and leveraging synergies in LTS development

This briefing, with a focus on the energy sector, including transportation, has outlined the clear economic and social case for the long-term, holistic and economy-wide planning required to produce a long-term strategy. Long-term strategies are a fundamental component of national climate and development policy architecture that can drive sectoral transformations in the short-to-medium term, avoid the creation of stranded assets and lock-in to high-emissions technologies, and incorporate essential resilience planning.

As discussed in section 2, opportunities for synergies between NDC and LTS planning processes can be leveraged to increase the efficiency and effectiveness of these processes, and to enhance stakeholder understanding and buy in. In addition, in helping to set intermediary targets and mid-term actions, LTS development could also form a basis for access to financing for projects.

Long term strategies are critical for the alignment of short and medium-term goals expressed in NDCs and other national targets. However, a lack of resources is often seen as a barrier to developing long-term strategies, with focus instead placed on delivering short-term plans that lack a longer-term perspective. Funding cycles have historically driven many countries including SIDS to adopt a project-based approach, which tends to drive planning at a short-term scale (five to ten years) and to deprioritise long-term planning.

Developing a long-term strategy that is embedded in the whole economy will require a shift away from project-based approaches, with work coordinated across sectors and ministries, and additional capacities will likely be needed to achieve this shift. By its very nature an LTS should be a living, non-partisan document that enshrines continuity across electoral cycles. To ensure its accomplishment, an LTS would need to include key milestones for the short and medium term, such as the setting of renewable energy deployment and EV sales targets, and the putting in place of key enabling policies.

Given their specific geographic situation and vulnerabilities, there is a particular need for SIDS to already start planning their future energy systems and how they will be resilient to climate change impacts. Reaching a 100% renewable power system by mid-century will require careful assessment of the potential for variable and dispatchable renewables potential in the short-term; decarbonising road transport will require policies and incentives to be put in place in the next decade to ensure the take up of EVs begins to ramp up; and realising the possible synergies from planning both of these transitions in tandem will require careful coordination.

Long-term planning can also enable the possible co-benefits associated with such shifts – including job creation, reduced air pollution, energy independence, increased energy access, and resilience to extreme events – to be realised. In general, the Paris Agreement calls for not just climate change mitigation, but also that attention be given to broader measures of sustainable development. From this point of view, there is implicitly a need to avoid making changes in one sector (e.g. energy system transformation) that deprives another sector of necessary resources.

While not the main focus of this briefing, LTSs should also provide a vision for how emissions will be reduced and resilience enhanced in other sectors – industrial products and processes, waste and agriculture. As with the energy sector, synergies within and across these sectors can be leveraged to increase efficiency and enable a deeper reduction in emissions.

While SIDS contribute an extremely small portion of global emissions, they are among the first to suffer disproportionate climate impacts. Developing long-term strategies that are consistent with the Paris Agreement temperature limit in an inclusive stakeholder process would allow SIDS not only to demonstrate leadership in the international community, but also to reap the benefits from having a forward thinking and resilience-focused long-term plan in place to guide their development.

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