The optimal path for greater use of renewable energy in Sri Lanka

WHITE PAPER ON POWER SYSTEM OPTIMISATION

Around the globe, the energy market landscape is in transition, largely due to the rapidly decreasing cost of renewables. Major players are moving towards more flexible and sustainable energy systems with a rapidly increasing share of renewable energy, declining inflexible baseload generation, and a wider application of energy storage technology.

In contrast to this broad global trend, Sri Lanka's current plan for new capacity development is heavily reliant on conventional thermal baseload additions, namely coal and combined cycle gas turbine (CCGT) power plants.

The purpose of this study is to compare Sri Lanka's current development plan, the Long Term Generation Expansion Plan (LTGEP)*, with an alternative for developing the country's power system in a more optimal way that would save costs and reduce emissions significantly.

As our modelling demonstrates, Sri Lanka could better utilise the good conditions for wind and solar power in the country. Flexibility in the form of gas-powered engine power plants – which can be ramped up and down quickly to cope with fluctuating demand – and energy storage in the form of batteries are needed to cope with intermittency. We will also show why investing in thermal baseload today will restrict the country's alternatives in the future, whereas a flexible system will keep the option open to achieve 100% renewable power generation in the future, and indeed put the country on the right path to towards that future.

*https://www.ceb.lk/publication-media/planing-documents/46/en

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I. Market background

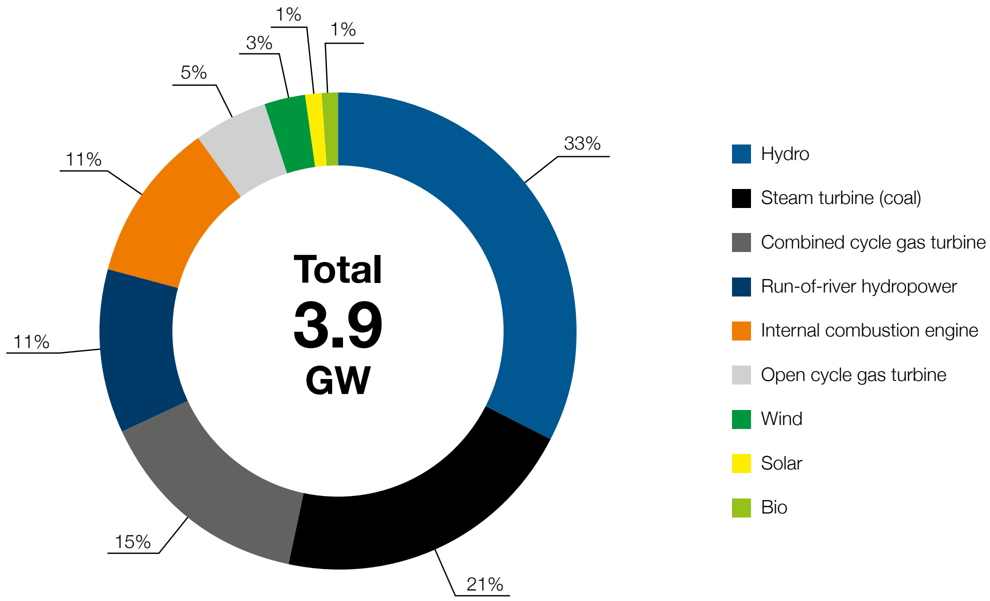
Sri Lanka is facing continuous load growth and and has even occasionally experienced load shedding during dry periods. The night-time peak is soon expected to surpass the morning peak as more appliances are connected to the grid.

The country has a good variety of generation technologies in its portfolio with a large share of both reservoir and run-of-river hydropower. At the moment, only a small amount of wind and solar power is in use in the country.

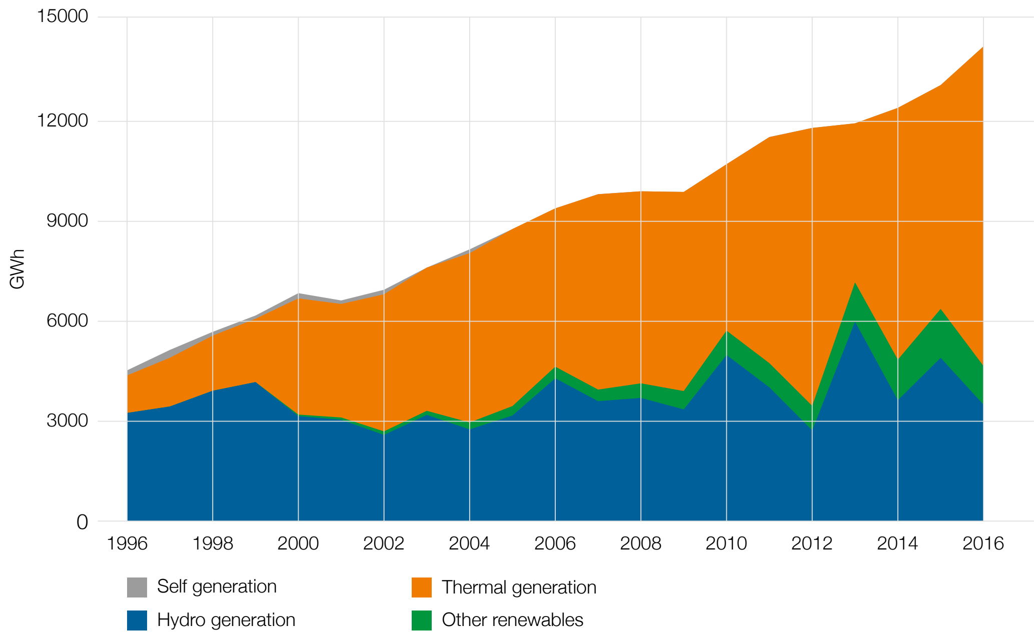
Because Sri Lanka's power generation relies heavily on hydropower, its energy supply is significantly affected by weather conditions. During long periods of high temperatures and low rainfall, hydro resources grow scarce and maintenance of grid stability becomes more challenging. More generation capacity is needed to cover growing electricity demand and economic growth in the country.

Under the country's current development plan, the main additions are 2.7 GW of coal plants and 1.2 GW of combined cycle gas turbines over a planning horizon from 2018-2037.

INSTALLED CAPACITY IN THE CURRENT POWER SYSTEM IN GW AND BY TECHNOLOGY TYPE



ANNUAL POWER GENERATION IN THE SYSTEM IN GWH AND BY TECHNOLOGY TYPE



Source: Ceylon Electricity Board Long Term Generation Expansion Plan

II. Determining the optimal path for Sri Lanka

The objective of this study was to find the optimal path for the Sri Lankan power system going forward to 2037. Although renewables are rapidly becoming cheaper, they are under-represented in the LGTEP. We wanted to study if there was a way to lower costs by incorporating more renewables.

For this study, we compared two key scenarios using PLEXOS® simulation software:

SCENARIOS CONSIDERED

Development-as-planned scenario

This scenario follows the LTGEP, adding 2.7 GW coal and 1.2 GW of CCGTs. Retirements also follow the LTGEP, namely 600 MW of old CCGTs, 400 MW of old engines and 200 MW of old open cycle gas turbines (OCGTs) over the planning horizon. Both additions and retirements are forced to happen according to the LGTEP at certain years. For example, in 2023 300 MW of coal-based power is added. The remaining capacity additions are optimised by PLEXOS.

High renewable scenario

In the high renewable scenario, retirements also follow the LTGEP (600 MW CCGTs, 400 MW engines, and 200 MW OCGTs). However, PLEXOS optimises the new build-capacity from a set of available generation technology options. The optimisation considers the optimal plant sizes, construction timeline and power plant utilisation for maintaining system reliability criteria with the lowest total system generation cost. Engines and battery energy storage are available as options and LNG is available as a fuel.

Installed capacity and planned additions were taken from the LTGEP. Renewables and battery pricing and price learning curves were taken from Bloomberg New Energy Finance, wind and solar profiles were obtained from IPPs and open sources. This study was made as a long-term generation expansion model in PLEXOS. The planning horizon is 2020-2037 and the resolution time of the model is two hours.

ABOUT PLEXOS® ENERGY SIMULATION SOFTWARE

PLEXOS by Energy Exemplar is a proven energy simulation software used by the world's leading system operators, regulators and planners as well as utilities, traders, consultants and manufacturers. Wärtsilä uses PLEXOS globally for power system modelling both in long-term capacity development optimisation and short-term dispatch optimisation. PLEXOS is built to find the most cost optimal solution for each scenario based on the applied constraints.

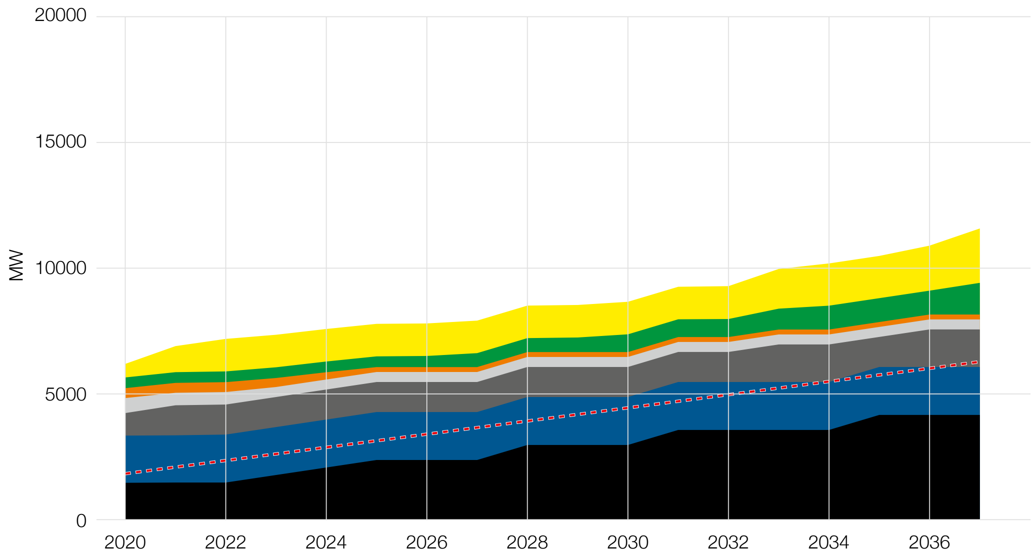
III. The modelling results

CAPACITY DEVELOPMENT OVER THE PLANNING HORIZON

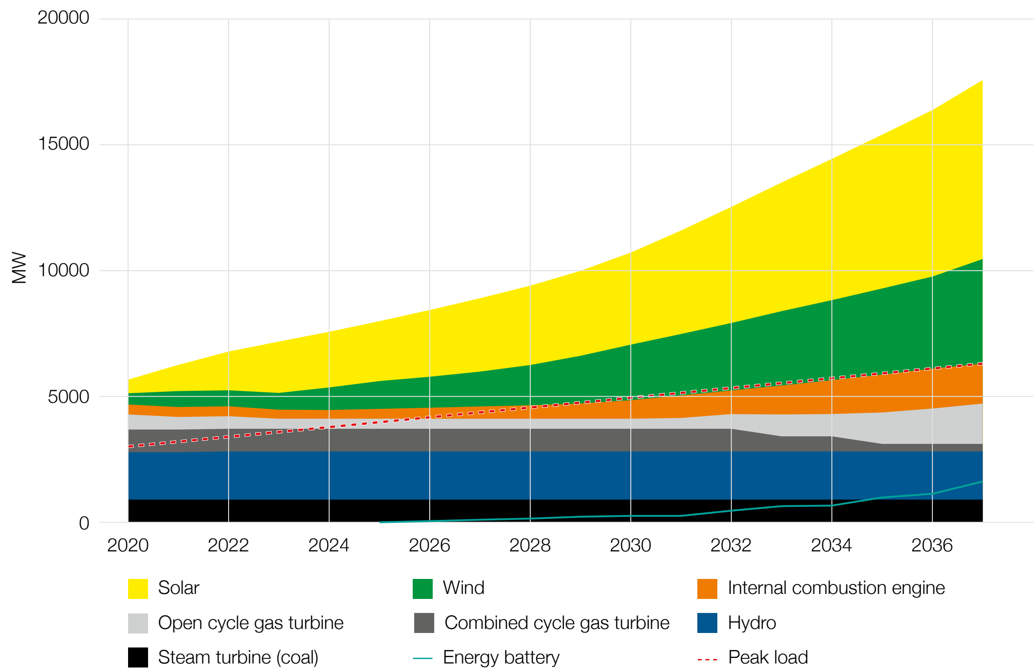
Our modelling with PLEXOS simulation software shows that the LTGEP plan is not the most cost optimal way forward for Sri Lanka. The development-as-planned scenario does not allow for a large amount of renewable energy to enter the system, whereas the high renewable scenario allows solar capacity additions to dominate together with wind capacity – both of which are rapidly decreasing in cost.

In the development-as-planned scenario, thermal capacity additions rely heavily on coal and CCGTs. When a system has a large share of inflexible thermal baseload it is not able to adjust to the fluctuating generation of the renewables, thus inhibiting the adoption of renewable technology. When flexibility is added in form of engines and battery energy storage, large amounts of renewables can be added to the system.

Development as planned



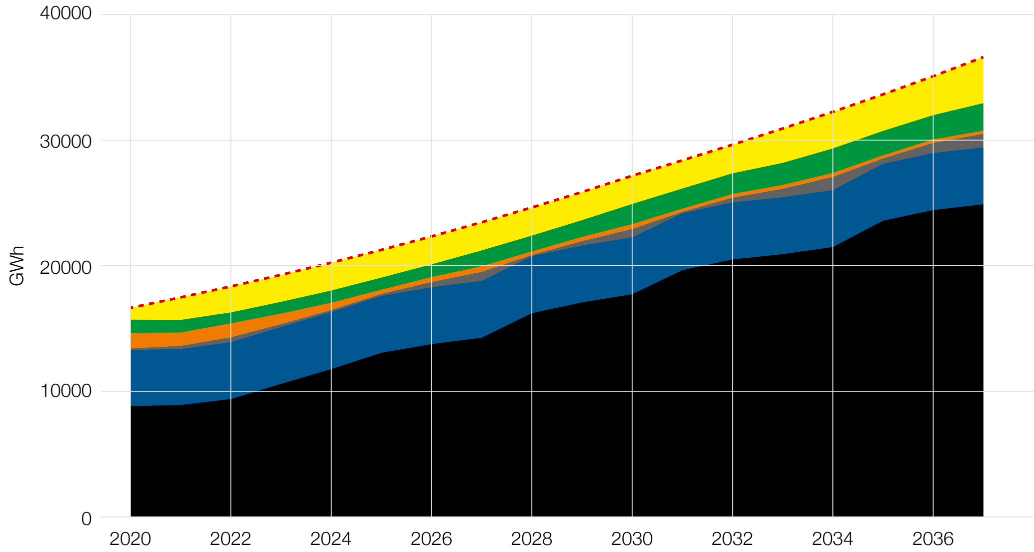
High renewable scenario



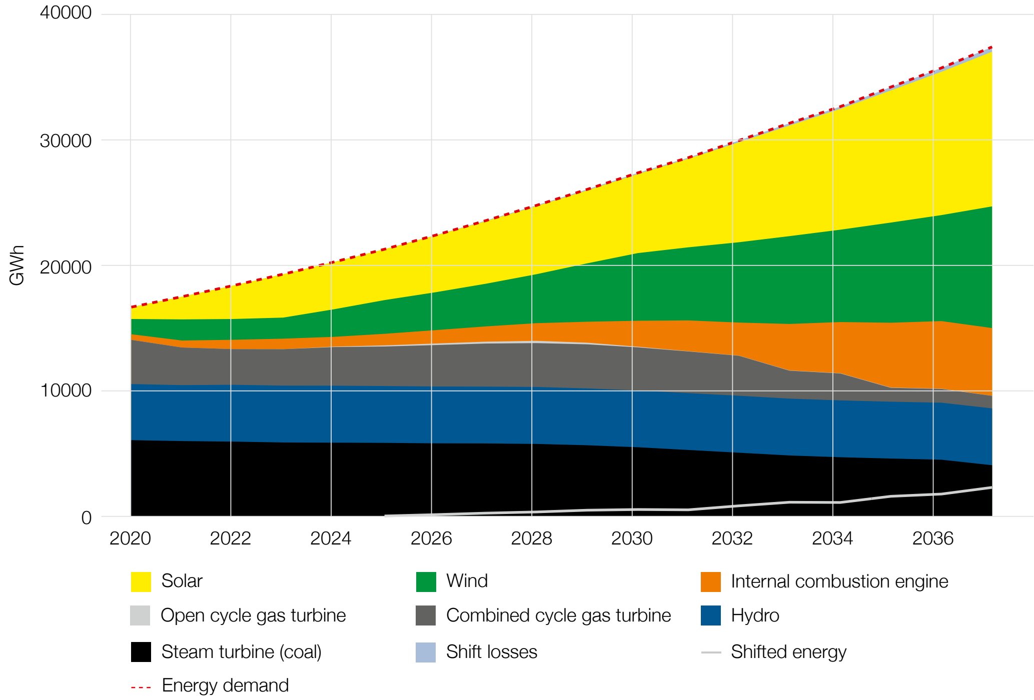
ENERGY MIX OVER THE PLANNING HORIZON

In the development-as-planned scenario, coal makes up the majority of the generated energy. However, when coal is not forced into the mix, the system can be optimised and is more flexible, enabling more renewables to be built in.

Development as planned



High renewable scenario

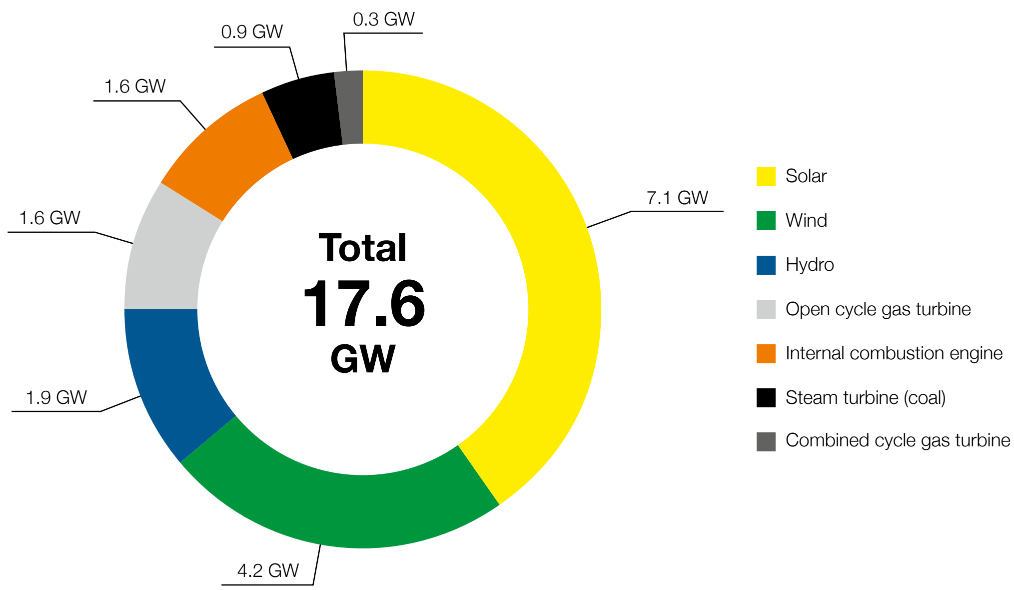


OPTIMAL CAPACITY MIX (HIGH RENEWABLE SCENARIO)

In the high renewable scenario, the good solar and wind conditions in Sri Lanka impact the results for installed capacity in 2037. PLEXOS sees that it is economical to invest in 7 GW of solar and 4 GW of wind over the modelling horizon. There is no need to build more coal capacity due to the availability of low-cost renewables.

Flexibility is provided by 1.4 GW of newly built engine power plant capacity. PLEXOS sees the need to invest in OCGTs to manage a few difficult hours annually but the capacity factor is only a few percentages on an annual basis. No new CCGTs are built in the high renewable scenario and two thirds of the installed base is retired. New-build coal was an option in the model but no new coal is built due to more flexible thermal options and cheap renewables. New-build hydro was not available as an option in either scenario as Sri Lanka's hydro potential is close to fully utilised.

Total installed capacity in high renewable scenario, 2037

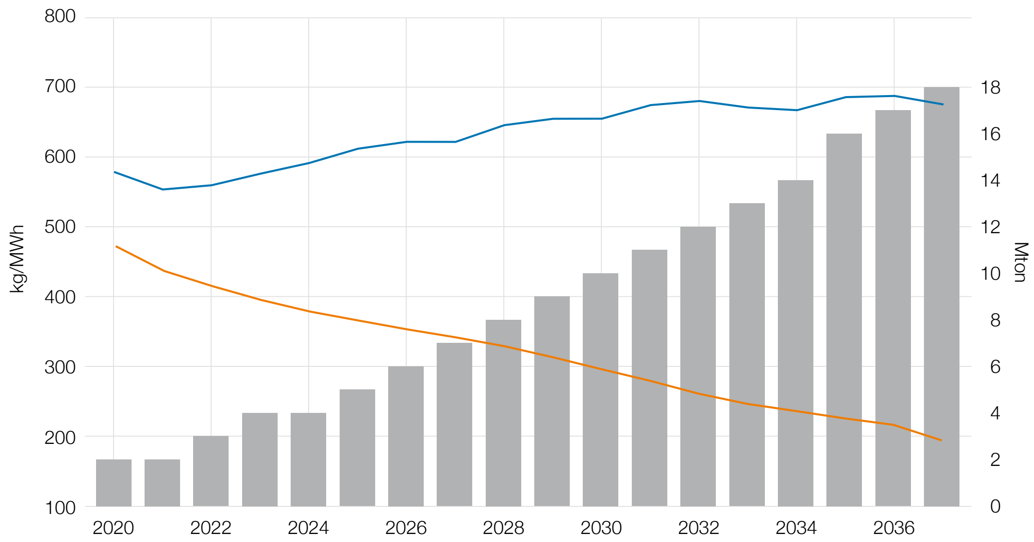


RENEWABLES ADDITIONS OVER THE PLANNING HORIZON

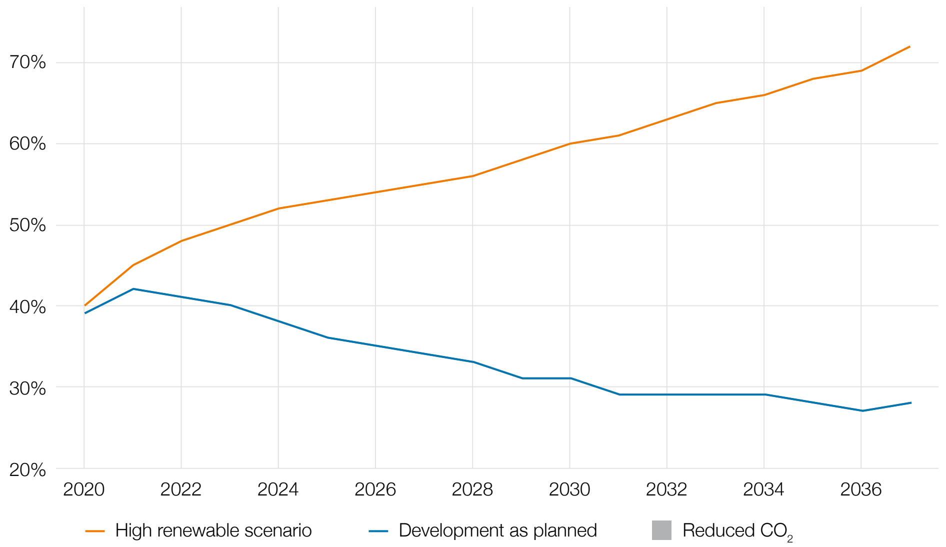
When comparing the emission intensity (kg of CO_2 emitted by produced MWh electricity) of the two scenarios, we can clearly see two different trends. In the development-as-planned scenario, emission intensity increases as more of the energy generated is fuelled by coal. In the high renewable scenario, more electricity is produced by renewables, meaning a decrease in emission intensity. The annual emissions reduction in the high renewable scenario compared to the development-as planned scenario grows every year to reach 18 million tons, averaging out at nine million tons per year.

A total emission intensity reduction of over 70% is achieved in the high renewable scenario when comparing the last year of both scenarios. In the high renewable scenario, over 70% of the electricity generated comes from a renewable source in 2037, while the corresponding figure for the development-as-planned scenario is only 30%.

CO_2 emission intensity



Share of renewable energy



IV. Recommendations and benefits

Where to start?

Sri Lanka has a relatively good capacity mix to start with, meaning investing heavily in solar and wind in the first few years is the best approach.

How much capacity should be based on renewable energy by 2037?

In the high renewable scenario, over 4 GW of solar and over 7 GW of wind could be added to the system over the whole planning horizon compared to about 2 GW of solar and 1 GW of wind in the development-as-planned scenario.

How much flexibility should be added?

Over the whole planning horizon, 3 GW of flexibility should be added to the system to ensure that it can cope with the intermittent generation from renewables, split into 1.4 GW of gas engines and 1.6 GW of battery energy storage.

What's the role of traditional thermal generation capacity?

As more flexibility is introduced to the power system, existing traditional thermal capacity is able to run more optimally. The flexible technologies are able to handle the intermittency of the renewables, letting the traditional thermal capacity run baseload at higher efficiencies and lower costs. However, no new traditional thermal capacity should be added to the system, since every added asset inhibits the adoption of renewables for decades to come.

What is the optimal share of energy based on renewables?

The share of renewable generation will decrease in the base case from around 40% to 30%. In the high renewable scenario, at the end of the planning horizon the share of renewable generation is 70%.

THE BENEFITS

70% RENEWABLE ENERGY

70% REDUCTION IN CO_2 INTENSITY

17% REDUCTION IN SYSTEM EXPANSION COSTS

USD 5 BILLION CUMULATIVE SAVINGS

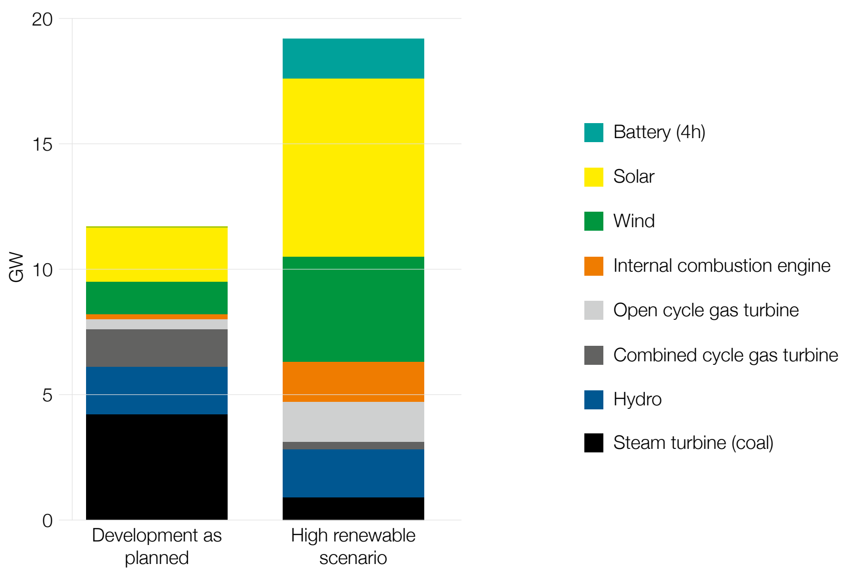
V. Conclusion

This study explored alternatives to Sri Lanka's current power system expansion plans. Since the country has favourable solar and wind conditions, the high renewable system recommended by Plexos fully utilises renewable energy sources. In practice, this means a total of 11 GW of installed capacity for solar and wind, with 1.4 GW of engines and 1.6 GW batteries to provide flexibility.

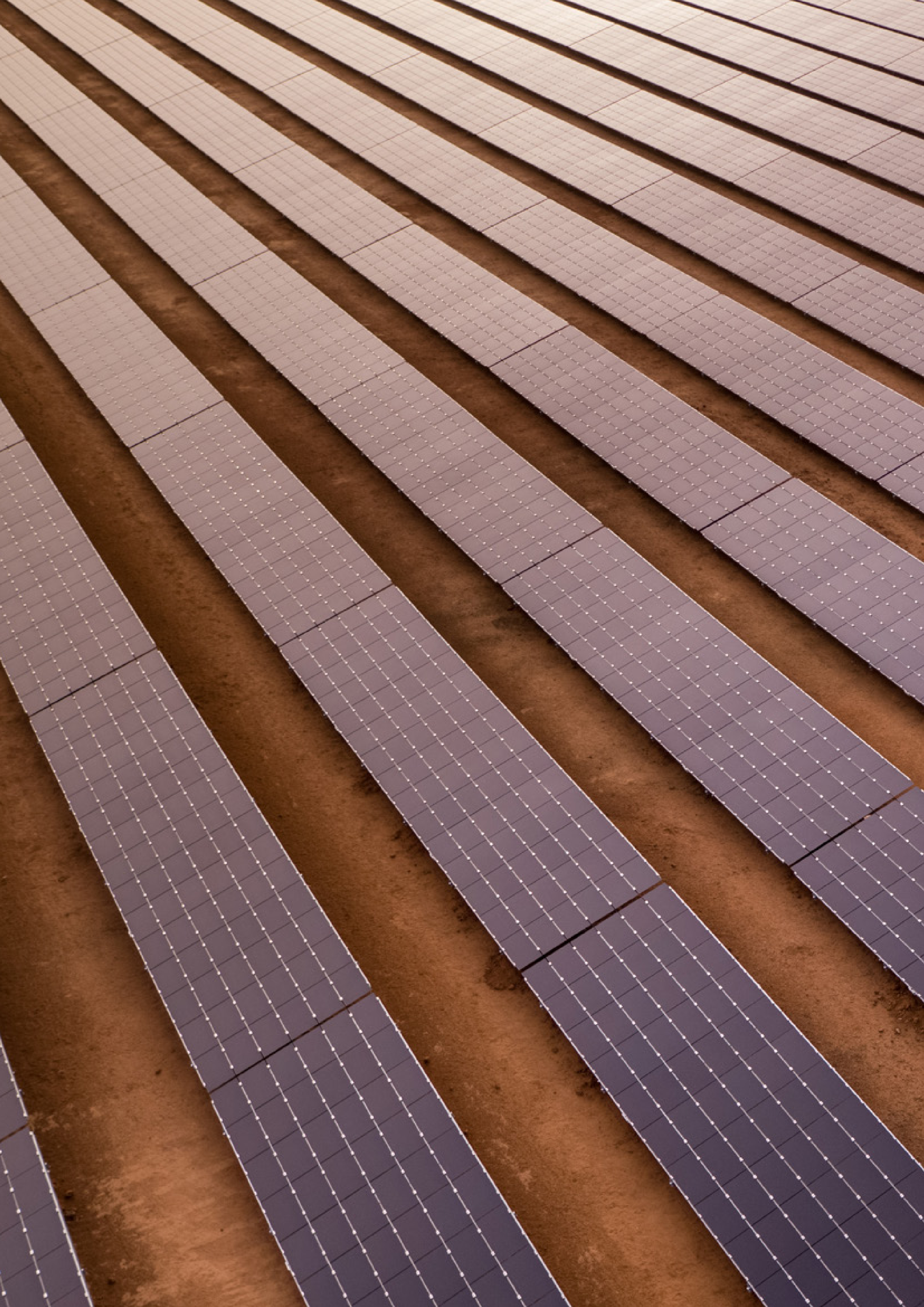
Capacity additions up to 2037 in the high renewable scenario	
Battery (4h)	1.6 GW
Solar	7.1 GW
Wind	4.0 GW
Engine (flexibility)	1.4 GW
OCGT (capacity)	1.2 GW

Choosing the high renewable path means the country should see emission intensity decrease by 70% compared to the current plan, while still having enough capacity to meet growing demand. In addition, system expansion costs will be 17% lower, saving around 883 billion rupees (five billion US dollars) cumulatively over the whole planning horizon.

Total installed capacity by 2037



Despite larger capacity buildout in the high renewable scenario investment cost savings are achieved due to declining renewable prices. Additional savings are achieved from optimised operation which leads to lower fuel and operation costs.



About Wärtsilä Energy Business

Wärtsilä Energy Business is leading the transition towards a 100% renewable energy future. As an energy system integrator, we understand, design, build and serve optimal power systems for future generations. Wärtsilä's solutions provide the needed flexibility to integrate renewables and secure power system reliability. Our offering comprises engine-based flexible power plants – including liquid gas systems – hybrid solar power plants, energy management systems and storage and integration solutions. We support our customers over the lifecycle of their installations with services that enable increased efficiency and guaranteed performance. Wärtsilä has 70 GW of installed power plant capacity in 177 countries around the world.

06.2019 / Tenfour

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