WÄRTSILÄ

The optimal path for greater use of renewable energy in Taiwan

WHITE PAPER ON POWER SYSTEM OPTIMISATION

The global 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 flexible power generation and energy storage technologies.

In Taiwan the government's planned power generation mix for 2025 is 20% renewables, 30% coal and 50% natural gas, with all existing nuclear reactors retired before the end of 2025 as part of the island's "nuclear free homeland" vision. The target is to install 27 GW of renewables, including 20 GW of solar PV and 6.7 GW of wind power by 2025.

In this study we used PLEXOS® energy simulation software to model the optimal investment path for meeting Taiwan's goal of 20% renewable energy by 2025 while ensuring efficiency, reliability and a reduction in costs. The modelling demonstrates that Taiwan can cost-effectively increase the amount of renewables in the system well beyond 20%. Flexibility in the form of gas-powered engine power plants – which can be ramped up and down quickly to cope with fluctuating demand – is needed to cope with the intermittency of renewables. We will also show why investing in traditional thermal baseload today will restrict the country's alternatives in the future, whereas a flexible system will keep the option open to achieve a high renewable power system in the future even faster.

CONTENTS

LEARN MORE:
https://www.wartsila.com/energy

I. Market background

The Taiwanese Ministry of Economic Affairs (MOEA) and the integrated utility Taiwan Power Company (TPC) have planned new installations of coal and combined cycle gas turbines (CCGT) from 2018 to 2025. They will retire all nuclear and oil steam power plants by 2025.

Generator type	Coal	LNG						
	Oil	Nuclear						
					Dalin #5 (500)			
					Tongxiao CC #4 (386)			
					Tongxiao CC #5 (386)			Xinda #3 (550)
		Xiehe #1 (500)			Datan CC #7-GT stop (600)	Xinda #1 (500)	Xiehe #3 (500)	Taichung GT #2 (70)
		Xiehe #2 (500)			Taichung GT #1 (70)	Xinda #2 (500)	Xiehe #4 (500)	Taichung GT #3 (70)
Retirement	NPP1 #1 (636)	NPP1 #2 (636)		NPP2 #1 (985)	Taichung GT #4 (70)	NPP2 #2 (985)	NPP3 #1 (951)	NPP3 #2 (951)
Year	2018	2019	2020	2021	2022	2023	2024	2025
New installation	Dalin New #1 (800)	Dalin New #2 (800)	Tongxiao New CC #3 (893)		Datan CC #8 (1000)	Datan CC #9 (1000)	Taichung CC #1 (1000)	Taichung CC #2 (1000)
	Tongxiao New CC #1 (893)	Linkou New #3 (800)				Xinda New CC #1 (1000)	Datan CC #7 (1000)	Xiehe New CC #1 (1000)
	Datan CC #7 (600)	Tongxiao New CC #2 (893)					Xinda New CC #2 (1000)	New Northern CC (500)

Note: The TPC thermal & nuclear units' retirement and new installation plan between 2018 to 2025 are based on MOEA's report "Review of the energy policy assessment in response to the referendum" on March 4, 2019.

The above table was published on the TPC website (as on March 4, 2019)

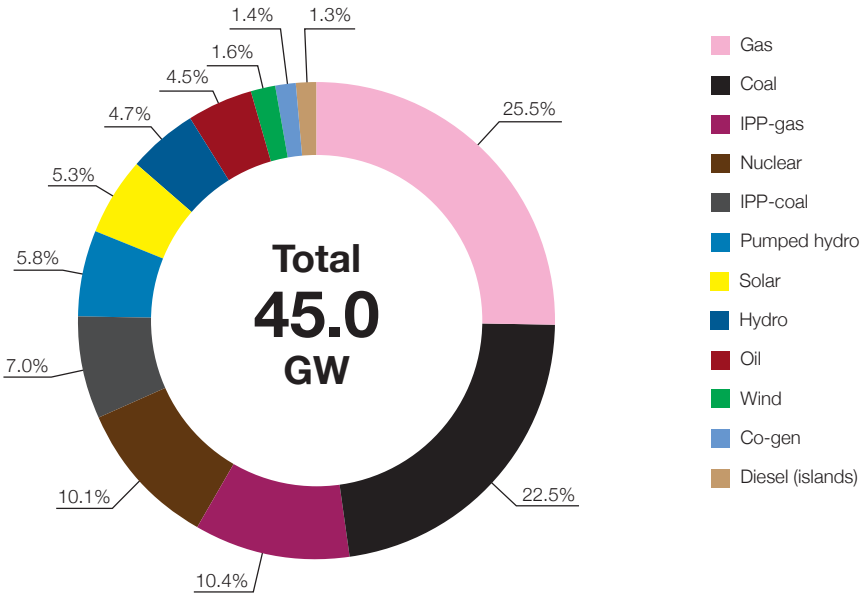
Power demand in Taiwan is expected to grow slowly at around 1-2% per year. The market is in the process of being liberalised to effectively end a 70–year monopoly on the sale of electricity and also to encourage green energy production. TPC will be restructured into two separate operations: one for power generation and the second for electricity transmission, distribution and sale. This means that other power suppliers will be able to sell electricity produced by renewable energy sources directly to consumers, in a change from the previous system in which private companies sold energy to TPC, which charged a transmission handling fee and then distributed it at the price it had set.

As part of the plan to reach 20% renewable energy sources by 2025, a total of 5.5 GW of offshore wind power has been auctioned. There is also a plan to add 1 GW per year of new offshore wind capacity from 2026 to 2030.

INSTALLED CAPACITY

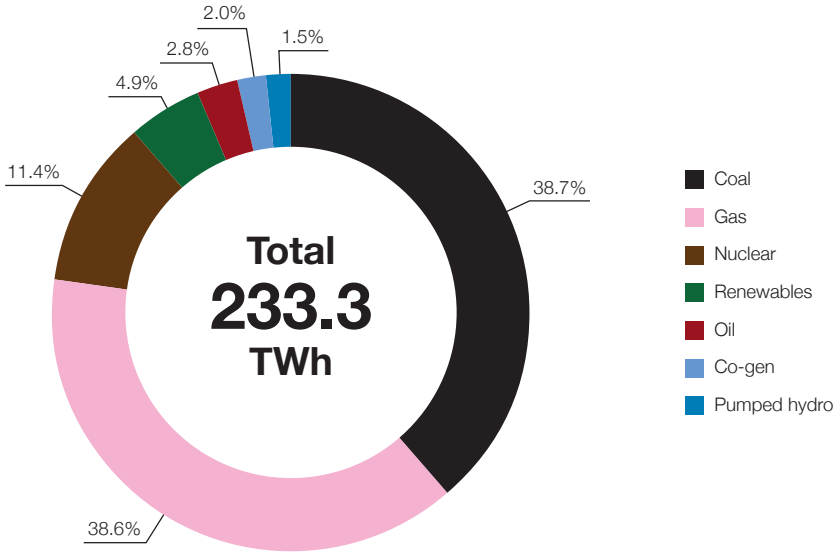
The current installed capacity of TPC, IPPs and renewables under feed-in tariffs is about 45 GW, with coal and gas accounting for the majority of the installed base, and renewables accounting for about 17% of installed capacity and 6% in the generation mix.

Installed capacity in the system, 2018



Source: TPC

Generation mix 2018, TWh



Source: TPC

II. Determining the optimal path for Taiwan

Wärtsilä's analysis, carried out using PLEXOS, focused on the importance of flexible power generation to complement renewables, as the total amount of renewables may be curtailed by inflexible capacity. The goal was also to see if total operational costs and emissions can be reduced while still ensuring high reliability. The PLEXOS modelling is based on the operational cost and capital expenditure of different technologies. Renewable feed-in tariffs and market prices are not considered in this exercise. The system load profile in 2025 was projected based on the actual load profile of 2016.

SCENARIOS CONSIDERED

Scenario 1 (base case) – without flexible generation

New coal plants, CCGTs and renewable energy capacity are added to achieve the target of 20% renewable energy sources, 30% coal and 50% gas.

Scenario 2 – with flexible generation

New coal plants, CCGTs, renewable energy and flexible generation in the form of gas-powered engine power plants and battery storage are added to achieve the target of 20% renewable energy sources, 30% coal and 50% gas.

Scenario 3 – high renewable

MOEA target constraints are removed and PLEXOS optimises the generation mix based on the best available choices and outcomes.

The sources for this study are TPC's 2017 long-term expansion plan, TPC's 2016 power generation data and the MOEA power generation mix target.

This study was made as a long-term generation expansion model in PLEXOS. The planning horizon is 2020-2030 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

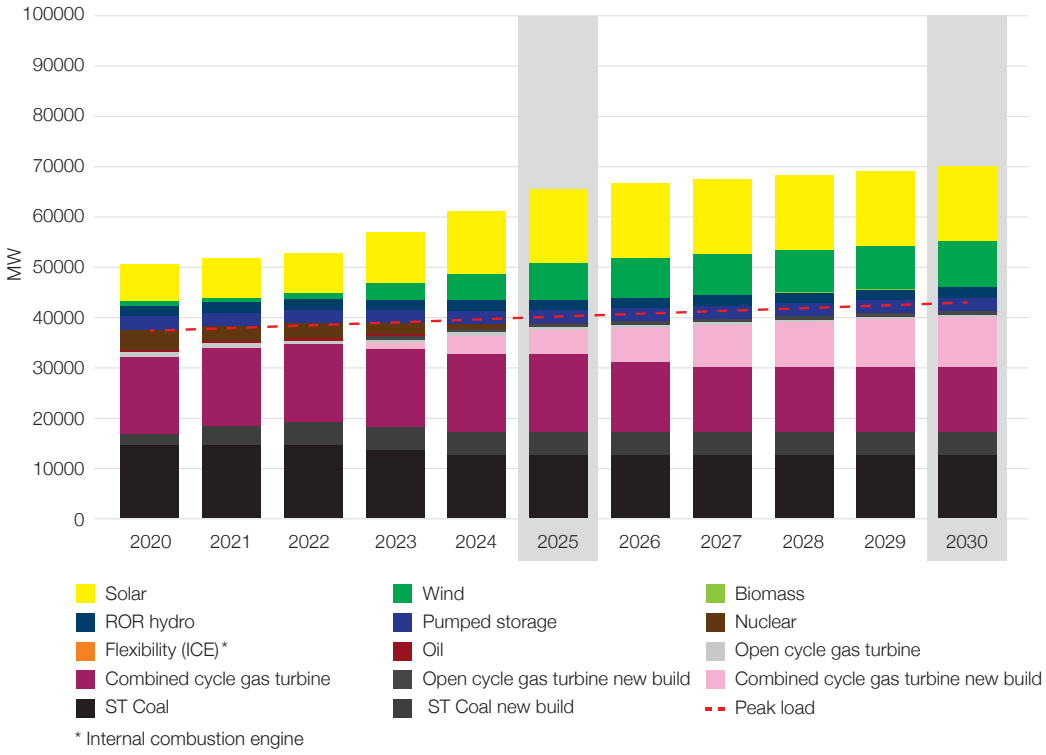
SCENARIO 1 (BASE CASE) – WITHOUT FLEXIBLE GENERATION

In scenario 1, when the system has a large share of conventional thermal baseload, it is not able to adjust to the fluctuating generation of the renewable energy sources, thereby inhibiting the adoption of renewable energy sources. This means that only 11 GW of new solar power can be added to the system by 2025. The modelling results are as follows:

- Coal plants are added until 2022, with only gas plants added thereafter*
- No new solar power plants are added from 2025-2030 because of a lack of flexible power generation
- A minimum reserve margin capacity of 15% is needed, including 30% solar and 20% wind as firm capacity

* The base case scenario is based on the 2017 plan published on the TPC website

System without flexible generation

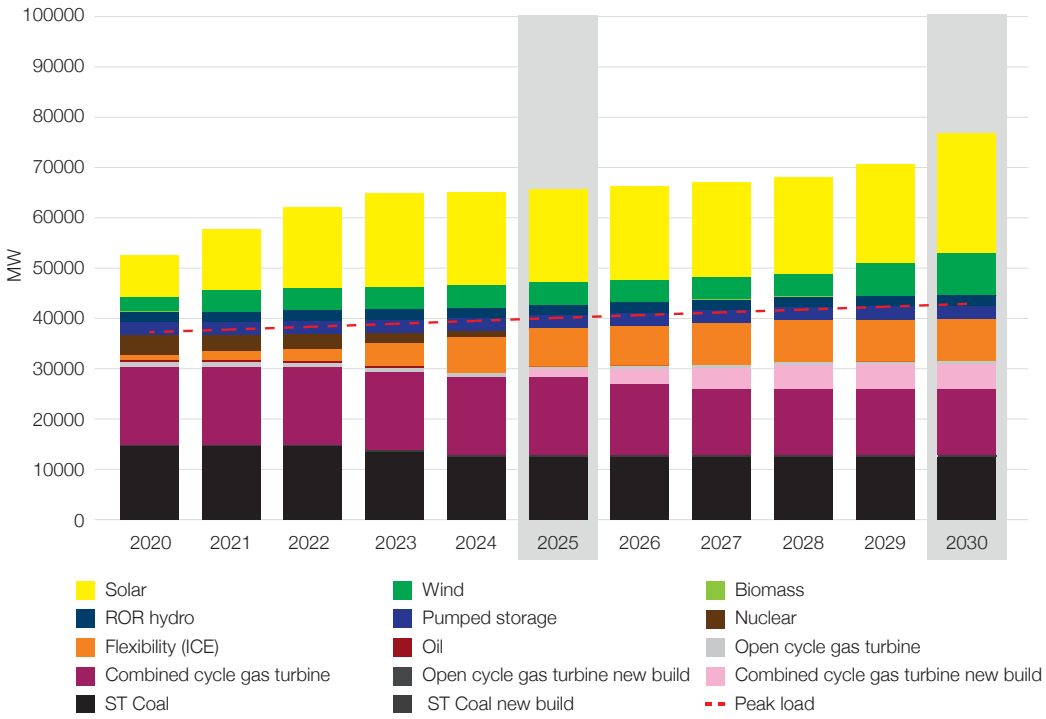


SCENARIO 2 – WITH FLEXIBLE GENERATION

In scenario 2, the target of 20 GW solar can be achieved by adding flexible generation in the form of gas-powered engine power plants and battery energy storage to the grid. The modelling results are as follows:

- No new coal plants are added
- 1.5 GW CCGT and 7.5 GW internal combustion engine (ICE) power plants are added by 2025, increasing to 5.1 GW CCGT and 8.3 GW ICE power plants by 2030
- 4.3 GW wind is added by 2025, with more wind installations from 2026 to 2030

System with flexible generation

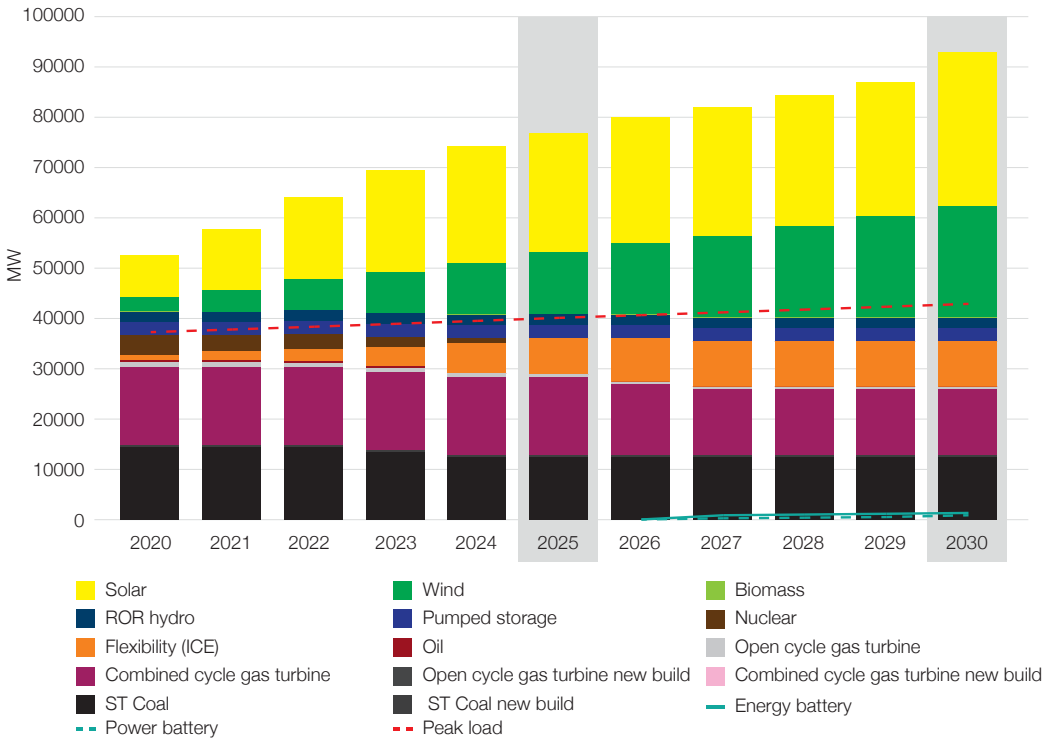


SCENARIO 3 – THE HIGH RENEWABLE OPTION

In scenario 3, the optimal mix is not constrained by the target of 20% renewable energy, 30% coal and 50% gas. There are no constraints such as installation space or grid connections in the model. The modelling results are as follows:

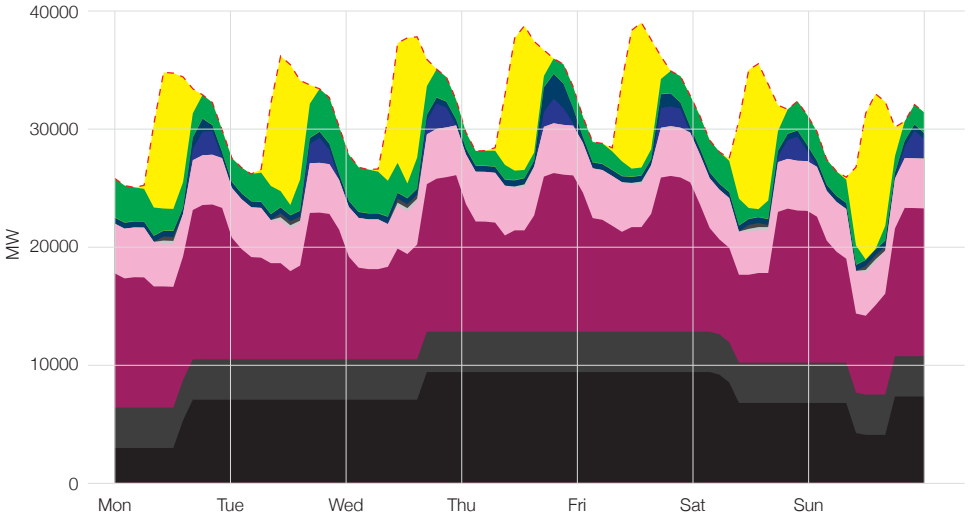
- No new coal plants or CCGTs are built – only new ICE power plants, battery storage and renewable energy are added
- 24 GW of solar energy is added by 2025, rising to a total of 30 GW by 2030, while 22.3 GW of wind power is also added by 2030
  - Batteries are economical after 2027, with 2.1 GW of batteries added between 2027 and 2030

System with high renewables

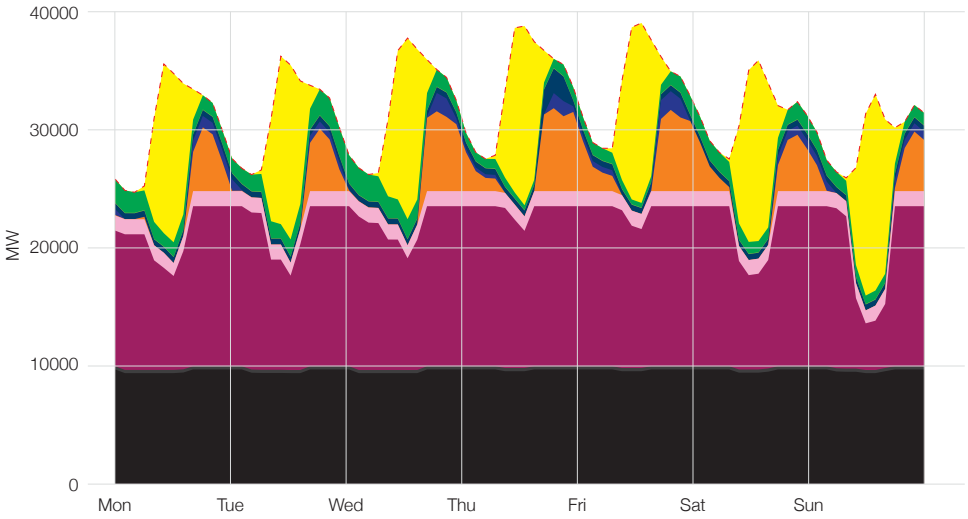


DISPATCH GRAPHS FOR 2025

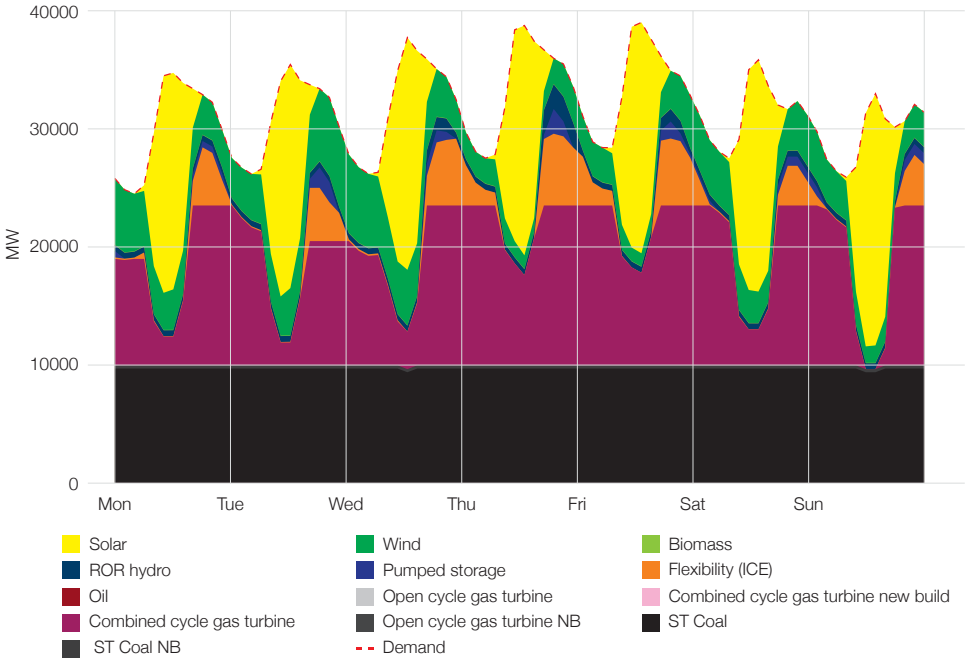
Scenario 1 (base case) – without flexible generation



Scenario 2 – with flexible generation



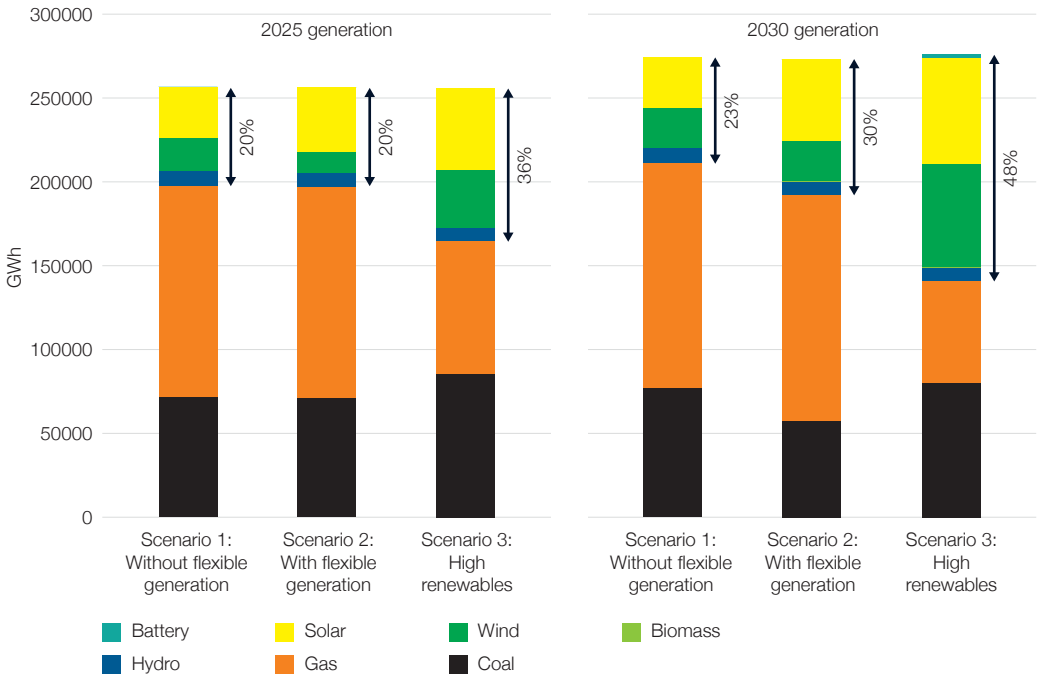
Scenario 3 – the high renewable option



IV. Recommendations and benefits

In order to meet the government's target of 20 GW of solar energy production, flexible capacity in the form of gas-powered engine power plants is needed. However, the 20 GW target for solar energy production is not the most cost-optimal way forward. The share of renewable energy generation can increase from 23% to 36% by 2025, and 48% by 2030, in the high renewable scenario. In this scenario, PLEXOS proposes to only build renewables and flexible ICE power plants, rather than relying on new coal plants and CCGTs.

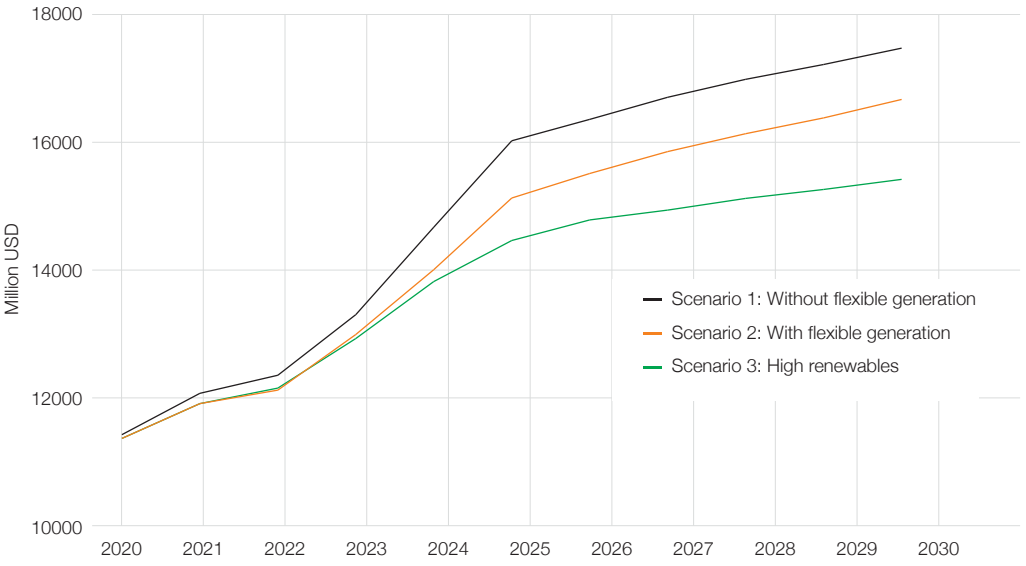
Recommended generation mix by 2025 and 2030



The benefits of adding flexible capacity while keeping the 20/30/50 target are cumulative savings of 6.5 billion USD in total system cost* from 2020-2030. If the fixed targets for generation are removed, cumulative savings from 2020-2030 are 12.5 billion USD in total system costs. This corresponds to a 12% system level saving.

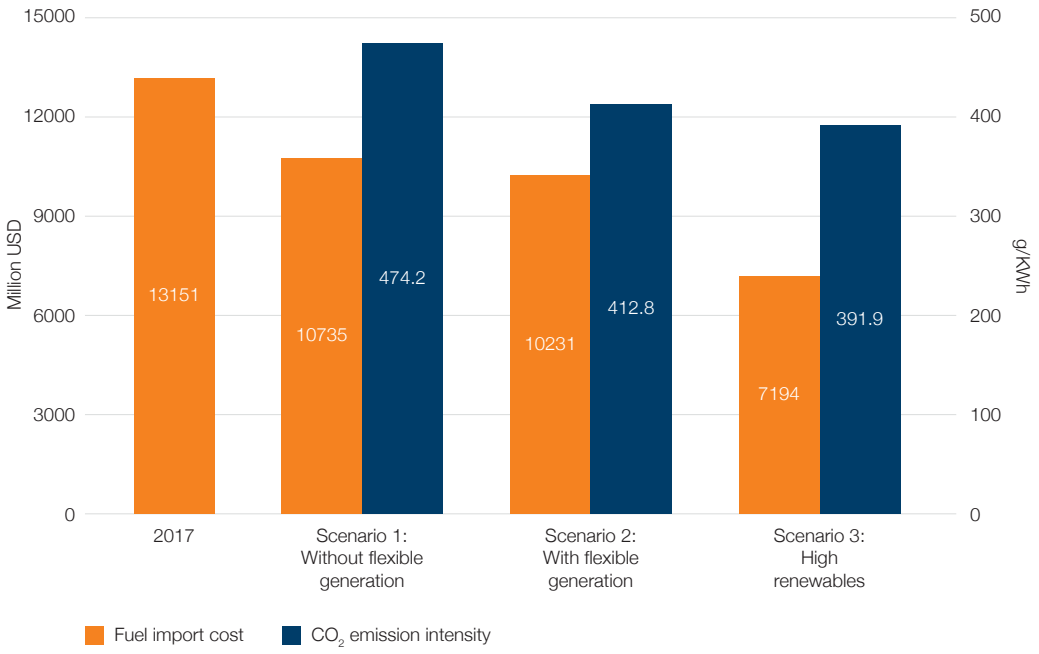
*Total system cost = operational expenditures (OPEX) + fixed operation & maintenance (FOM) + capital expenditures (CAPEX)

System level costs



In addition to the cost savings, there will be a reduction in fuel consumption and CO_2 emissions by 2030. In the high renewable scenario, this amounts to a 33% fuel import savings and a CO_2 emission reduction of 17%.

Fuel (coal & LNG) import cost and CO_2 emission intensity in 2030



THE BENEFITS

17% REDUCTION IN CO_2 INTENSITY

FUEL IMPORT SAVINGS OF 33%

USD 12.5 BILLION SAVINGS IN TOTAL SYSTEM COST

V. Conclusion

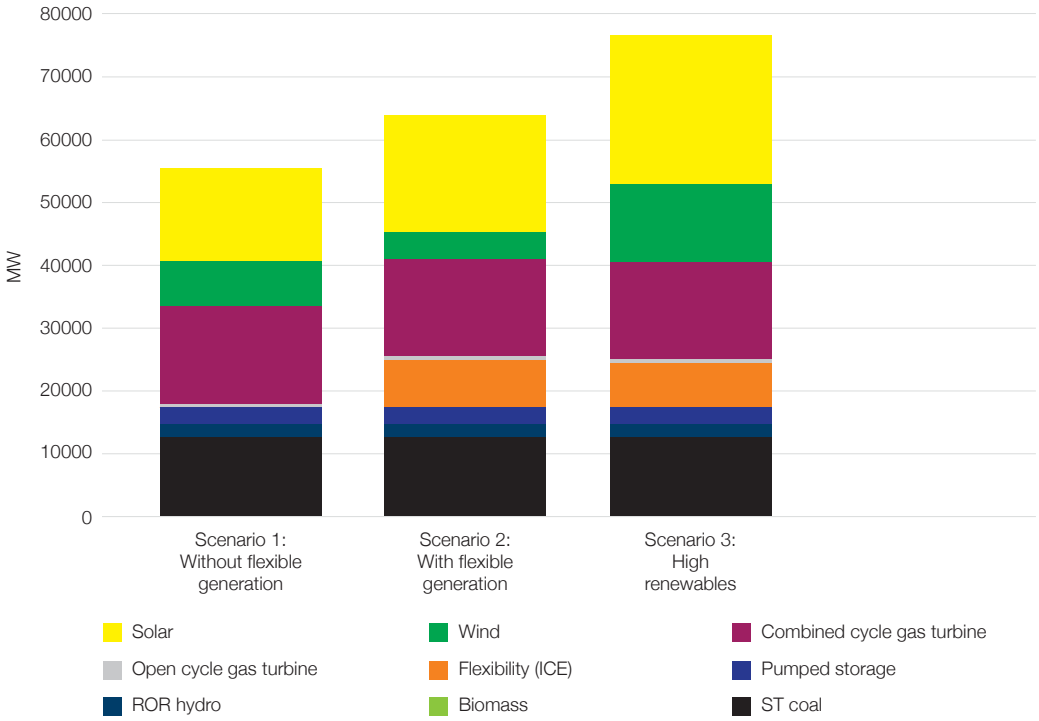
This study explored alternatives to Taiwan's 2017 power system expansion plans. Using rigorous analysis and complex system modelling software, this paper reveals how Taiwan can plan the most flexible, economical and environmentally friendly power system possible.

If there is no flexible power generation added to the grid (the base case), baseload capacity will hinder renewables deployment as the total amount of solar energy that can be added to the grid is limited to 15 GW.

If flexible power generation in the form of gas-powered engine power plants and battery storage is added, the target of 20 GW of solar power can be achieved. This approach also reduces thermal power operational costs when compared to using CCGTs, and no new coal plants are needed.

In the high renewable scenario, Taiwan can further improve its renewable energy generation from 20% to 36% by 2025 and 48% by 2030, with wind and solar power becoming a primary source of electricity.

Installed capacity 2025



	Scenario 1 – without flexible generation (MW)	Scenario 2 – with flexible generation (MW)	Scenario 3 – the high renewable option (MW)
Solar	14920	18501	23755
Wind	7197	4374	12262
Combined cycle gas turbine	20334	16961	15500
Open cycle gas turbine	1220	550	550
Flexibility (ICE)	0	7558	7158
Pumped Storage	2602	2602	2602
ROR Hydro	2089	2089	2089
Biomass	83	83	83
ST Coal	17068	12852	12852
Nuclear	0	0	0
ST Oil	0	0	0

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.

10.2019 / Tenfour

wartsila.com/energy

WÄRTSILÄ