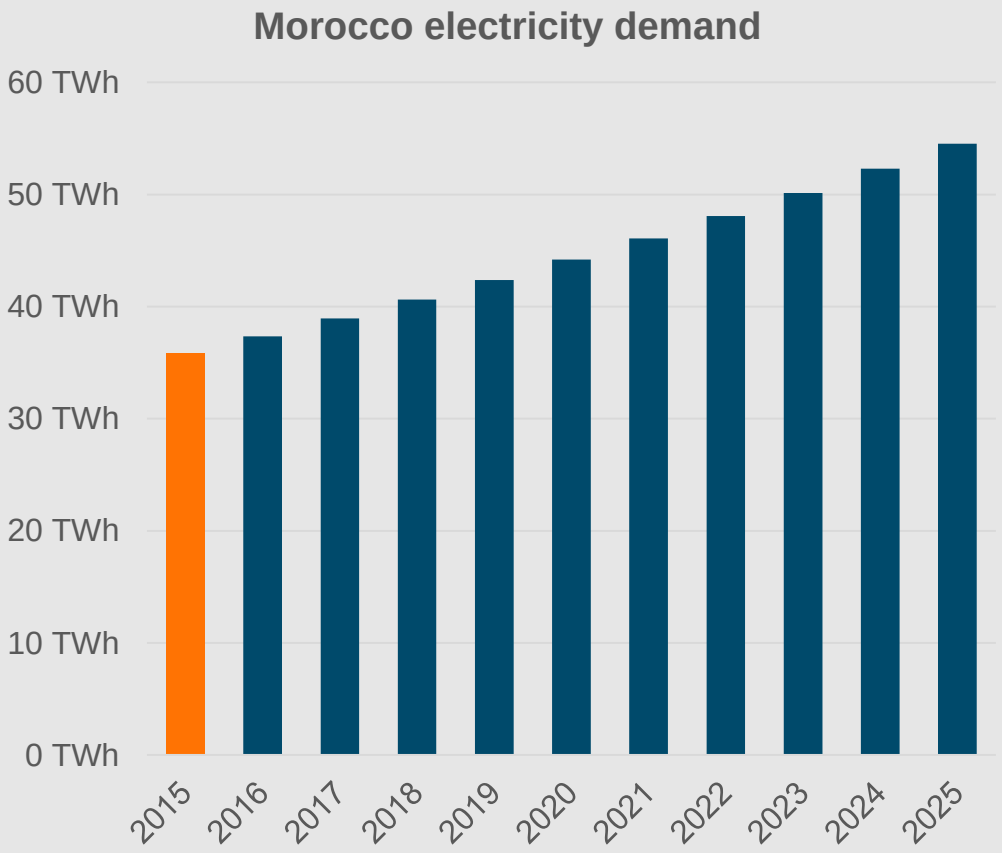
WÄRTSILÄ ENERGY SOLUTIONS

THE NEED FOR FLEXIBLE ENERGY IN MOROCCO

The power demand and peak demand is expected to grow with ~4% annually until 2025



2015

Annual demand	Peak demand
35.8 TWh	5 800 MW

2025

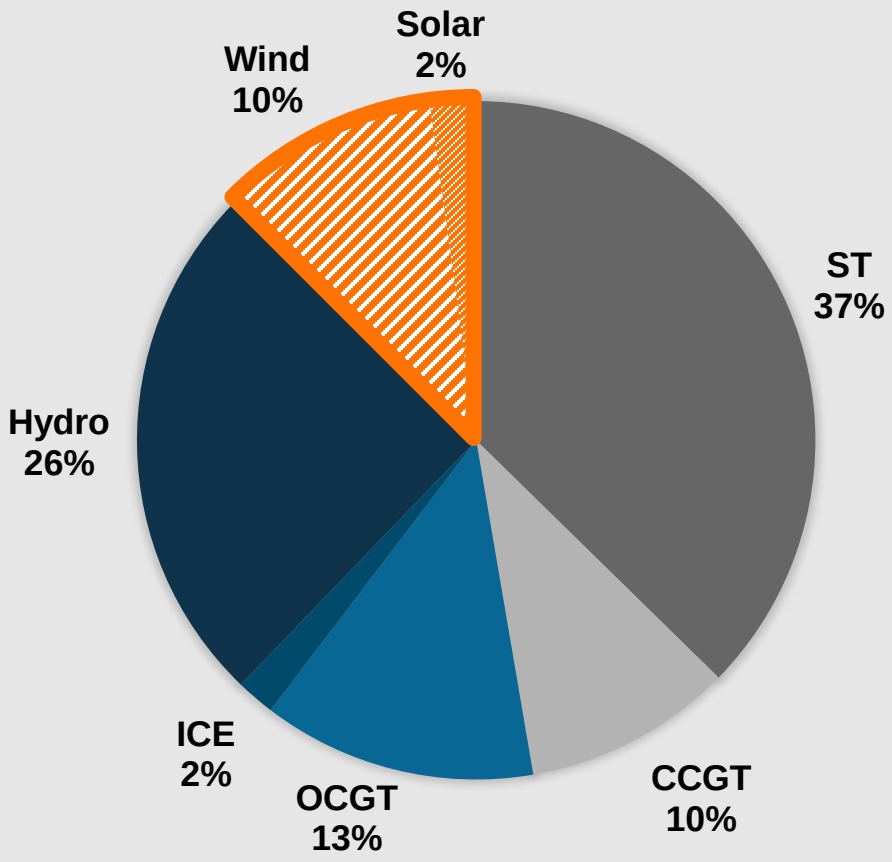
Annual demand	Peak demand
54.5 TWh	8 585 MW

Source: GlobalData, ONEE

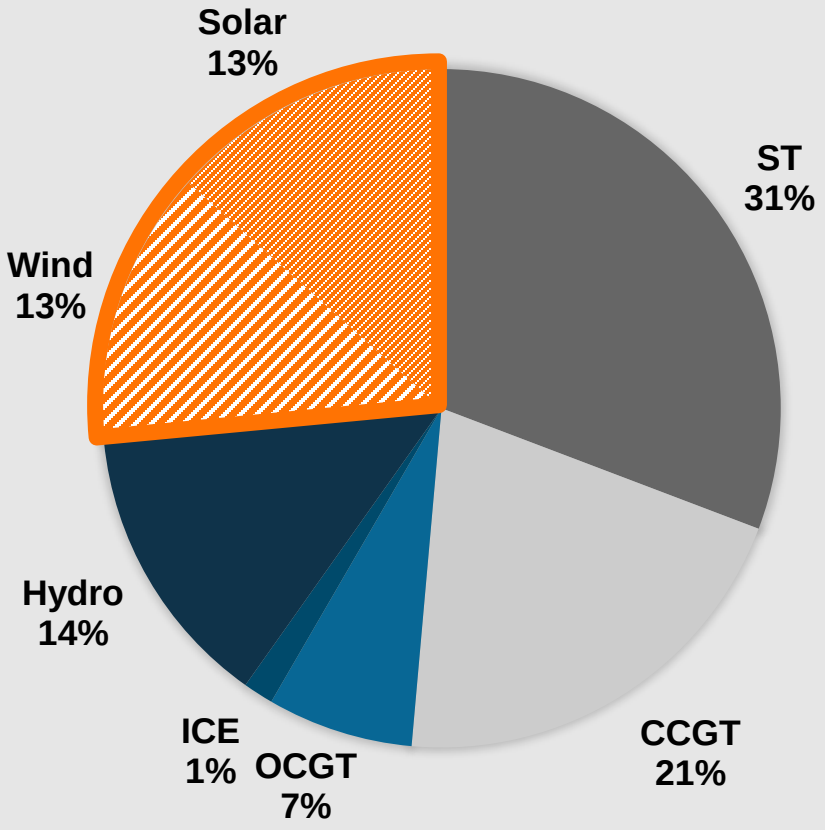
MOROCCO HAS AMBITIOUS TARGETS FOR INCREASING THE SHARE OF INTERMITTENT RENEWABLE ENERGY SOURCES IN THE POWER MIX UNTIL 2025

Forecasted capacity mix until 2025

INSTALLED CAPACITY 2015



INSTALLED CAPACITY 2025



Source: GlobalData, ONEE

SOLAR

- Morocco is an excellent location for solar power
- The aim is to add about 2 GW solar power during the upcoming 5 – 10 years
- The technology will be a mix of CSP and PV plants

WIND

- The “Moroccan 2 000 MW wind program” until 2020
- 8 large-scale projects of which several are already online and under construction

LNG

- LNG terminal in Jorf Lasfar with a capacity of 2 million tons of LNG annually
- Pipeline between Jorf Lasfar and Tangier, approx. 400 km
- Conversion of OCGT’s and CCGT’s to LNG operation
- 2 400 MW new gas-fired thermal capacity

SCENARIO 2025

With increasing amounts of intermittent and unpredictable renewable energy sources, flexibility is needed in the system.

BASE CASE

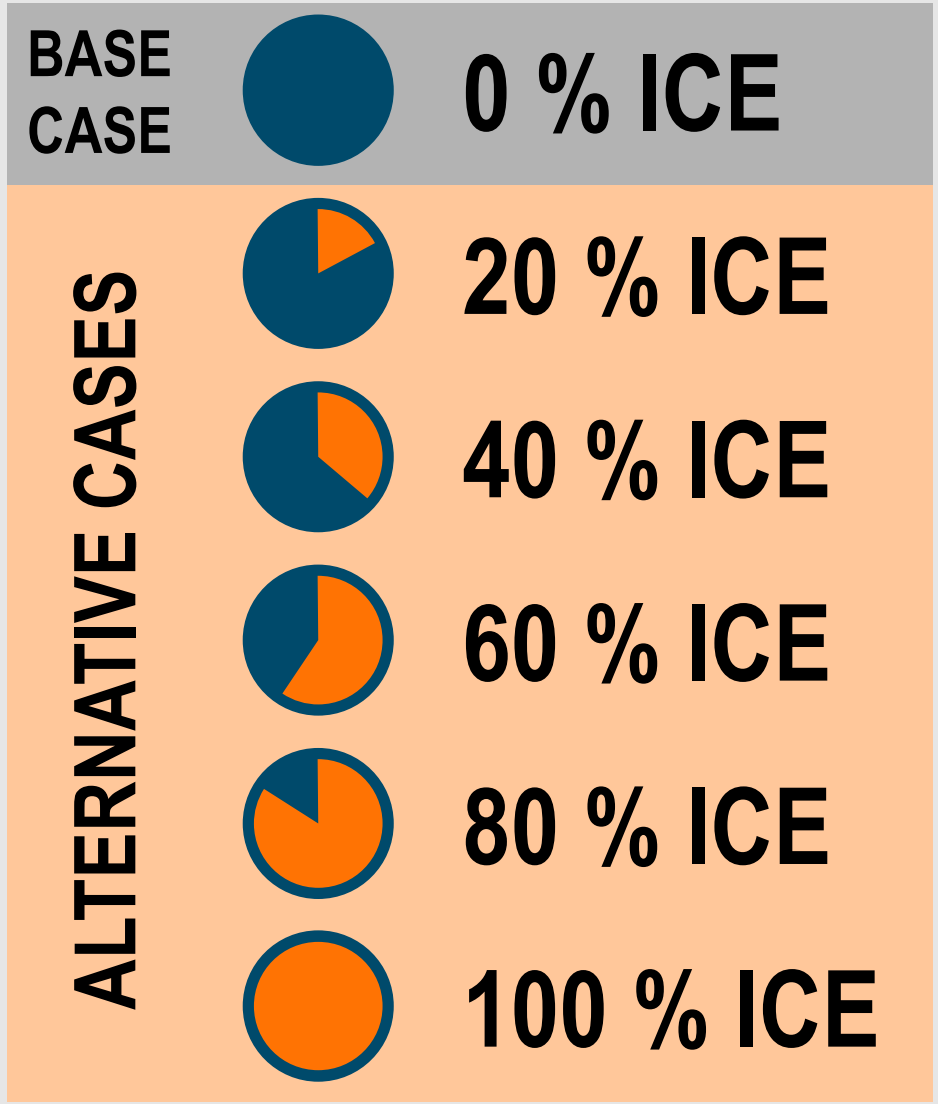
- All the proposed 2 400 MW gas fired units to be CCGT's

ALTERNATIVE CASES

- Replace the proposed CCGT's with increasing amounts of internal combustion engines (ICE)

TARGET

- **minimize total generation cost** and **manage the intermittent renewables** in the grid



Power plants included in the modelled Moroccan power system

- All new build assets are marked with red font

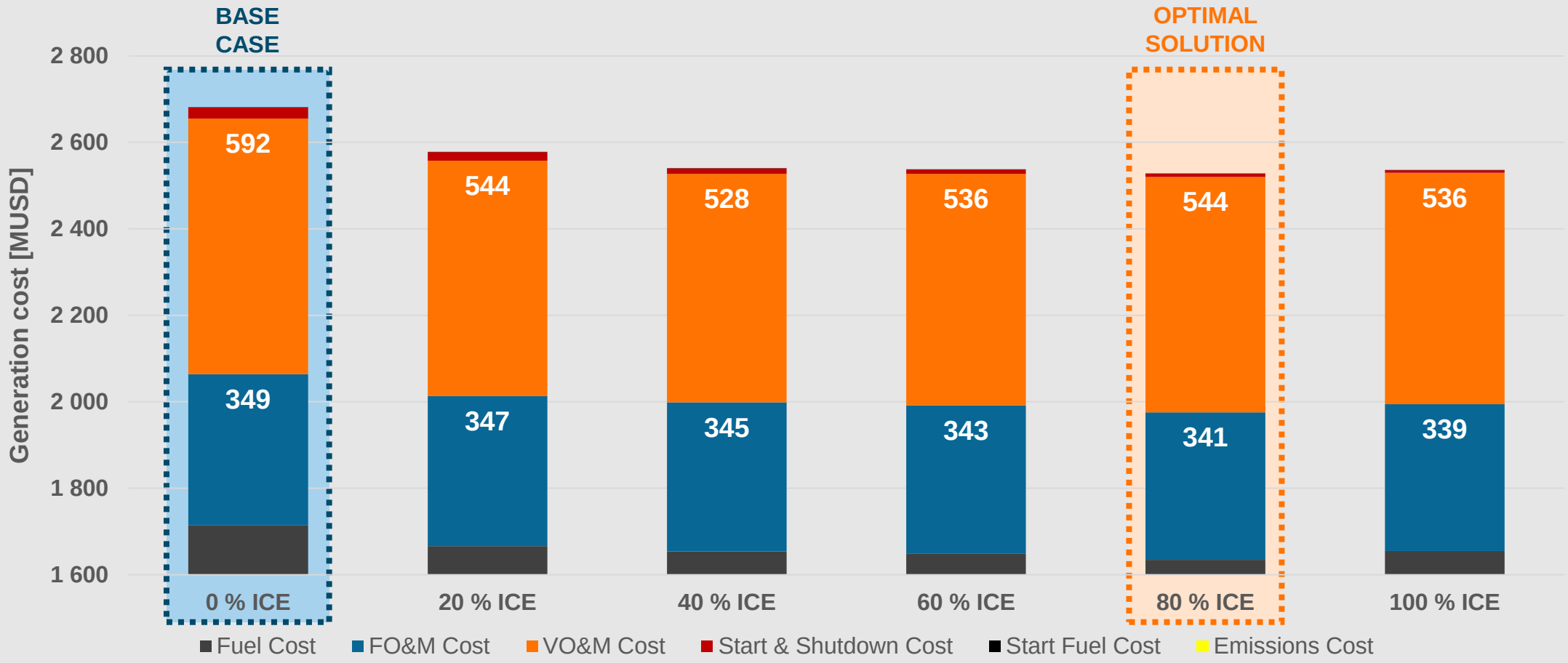
Power plant	Installed capacity
Coal fired	
ST Jerada	165 MW
ST Jorf Lasfar	2 056 MW
ST Kenitra	300 MW
ST Mohammadia (Coal)	300 MW
ST Mohammadia (Oil)	300 MW
New build ST Jerada Extension	318 MW
New build ST Safi	1 386 MW
Combined cycle gas turbines	
CCGT Ain Beni Mathar	450 MW
CCGT Tahaddart	384 MW
New build CCGT	0 MW – 2 400 MW

Power plant	Installed capacity
Open cycle gas turbines	
GT Kenitra II	315 MW
GT Mohammedia (Oil)	99 MW
GT Mohammedia TAG	300 MW
GT Tanger	40 MW
GT Tetouan	139 MW
GT Tit Mellil	198 MW
Internal combustion engines	
ICE Ed Dakhla	38 MW
ICE Tan-Tan	117 MW
New build ICE Laayoune	72 MW
New build ICE Wärtsilä	0 MW – 2 400 MW

Power plant	Installed capacity
Hydro	
Pumped storage	472 MW
Reservoir	1 087 MW
Run of river	98 MW
New build Pumped storage	350 MW
New build Reservoir	125 MW
Renewables	
Solar CSP	180 MW
Solar PV	2 MW
Wind	847 MW
New build Solar CSP	1 450 MW
New build Solar PV	470 MW
New build Wind	1 220 MW
Interconnections	
SpainLINK	900 MW

Already a small amount of ICE in the Moroccan system would create savings

- Non-spinning reserve by ICE



CAPACITY FACTORS

Small improvements in capacity factors of large thermal plants

	0 % ICE	80 % ICE
ST	65%	72%
CCGT	12%	5%
OCGT	2%	0%
ICE	6%	5%
Solar	46%	46%
Wind	34%	34%
Hydro	14%	13%

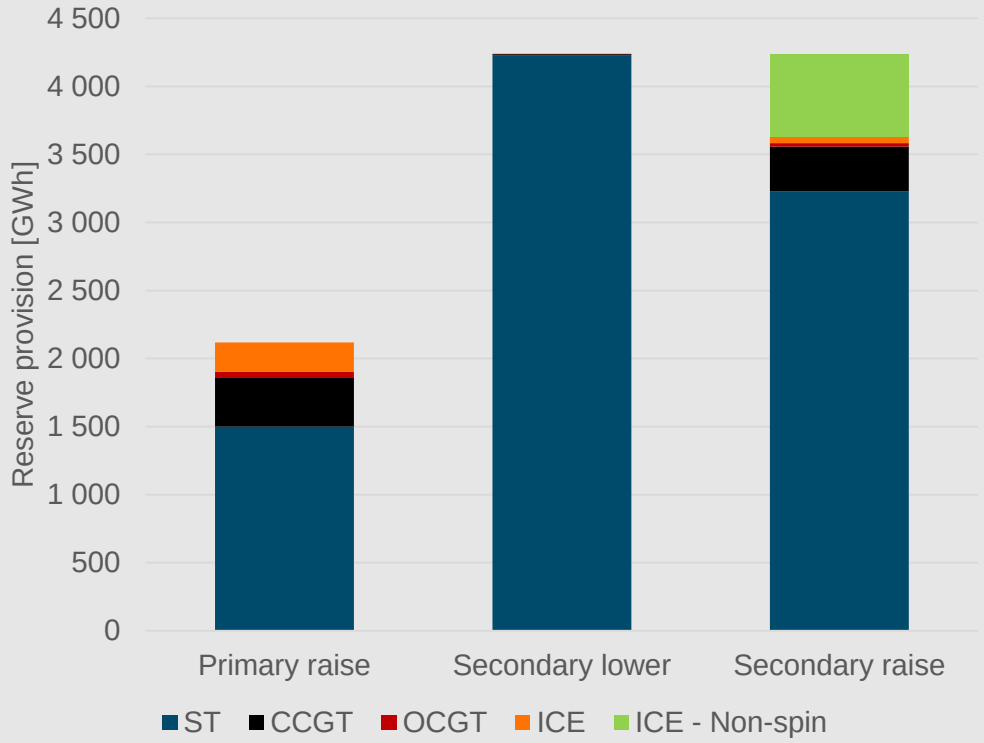
Power system reserves

Assumed reserve margins:

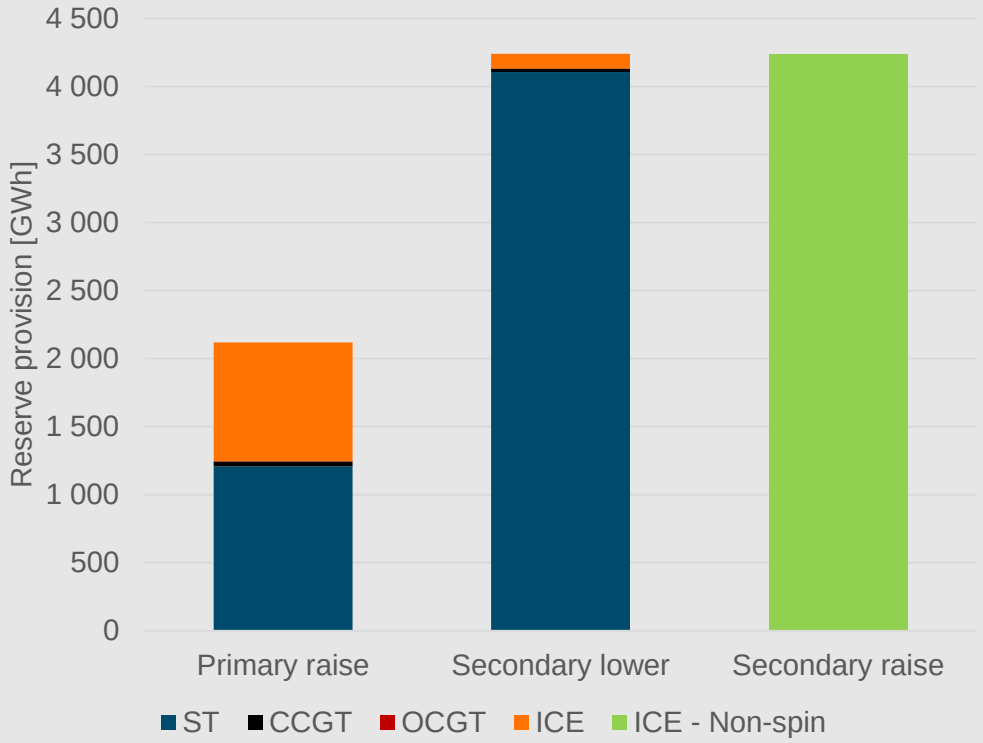
- Primary: 4%
- Secondary raise & lower: 8 %

Engines are providing secondary reserve as **non-spinning**

0 % ICE

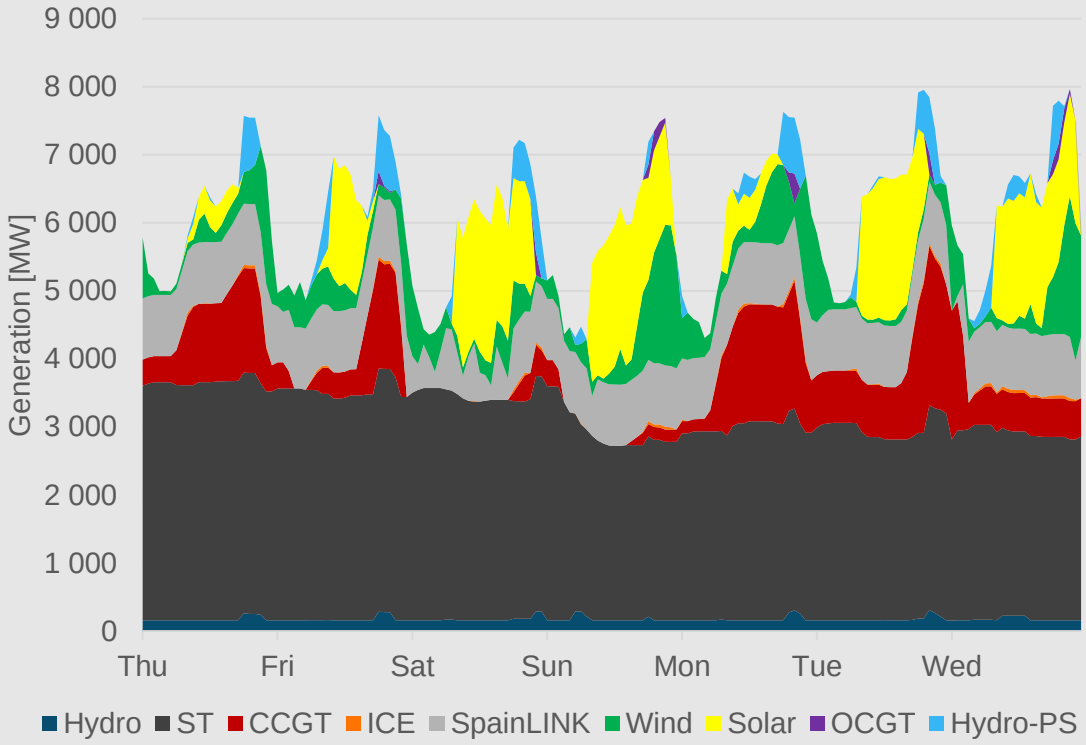


80 % ICE

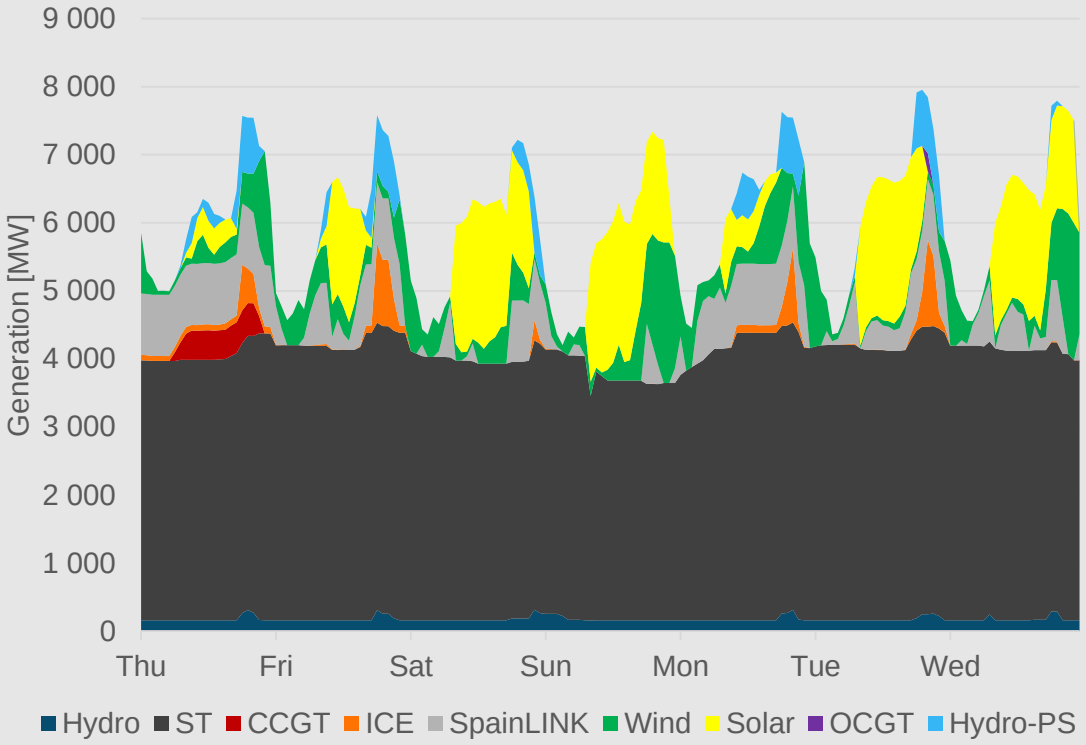


Adding fast starting and ramping engines to the system reduces the amount of cycling in the large thermal plants

0 % ICE



80 % ICE



Spain LINK

	Link utilization	Annual power
0 % ICE	79 %	6 235 GWh
20 % ICE	68 %	5 370 GWh
40 % ICE	64 %	5 080 GWh
60 % ICE	66 %	5 218 GWh
80 % ICE	68 %	5 382 GWh
100 % ICE	66 %	5 227 GWh

SUMMARY

- Engines brings stability to the Moroccan grid
- Annual savings:

150 MUSD

- Large amount of the power system reserves can be provided as **non-spinning**

LET’S TALK

Jerome Jouaville

**Business Development Manager,
Africa West**

Tel.: +33 6 74 97 52 25
E-mail: jerome.jouaville@wartsila.com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