



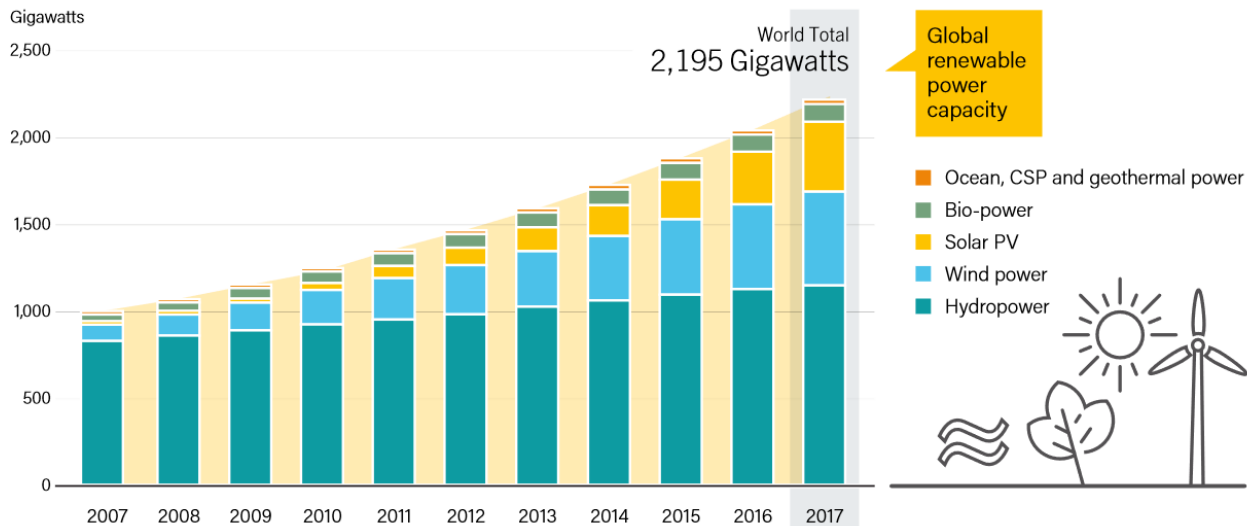
Towards 100% Renewable Energy Pathways

Where we are at...

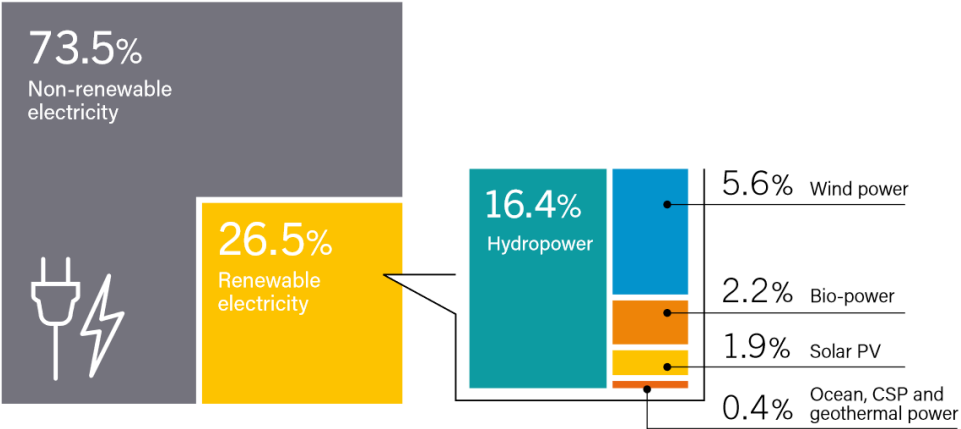
Vera Silva, GE Grid Solutions

15-16 May, 2019

INSTALLED CAPACITY OF RENEWABLE ELECTRICITY GENERATION MORE THAN DOUBLED IN THE LAST 10 YEARS



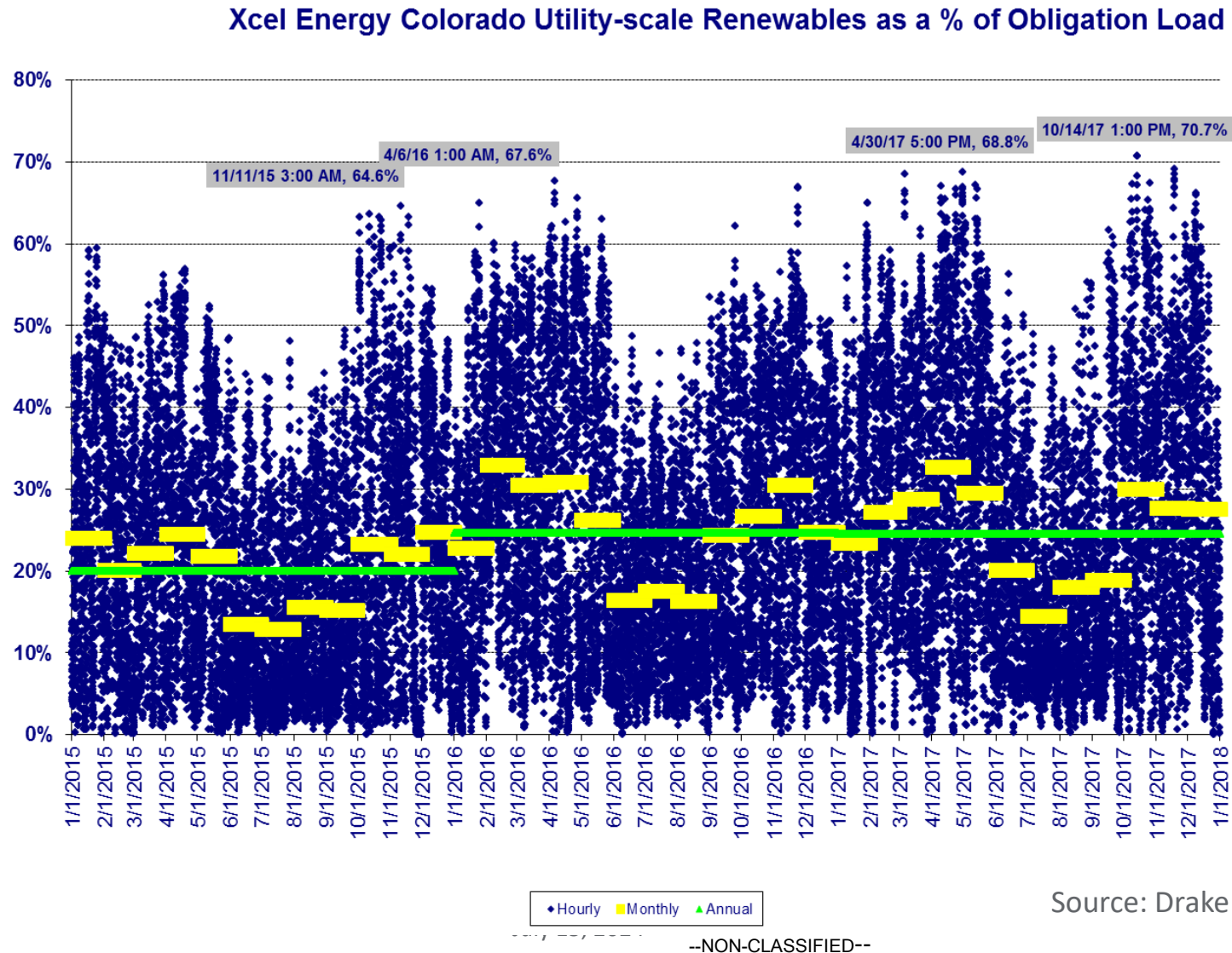
Wind and solar covered ~ 8% of electricity demand in 2017



Source, REN 21, renewables 2018 status report



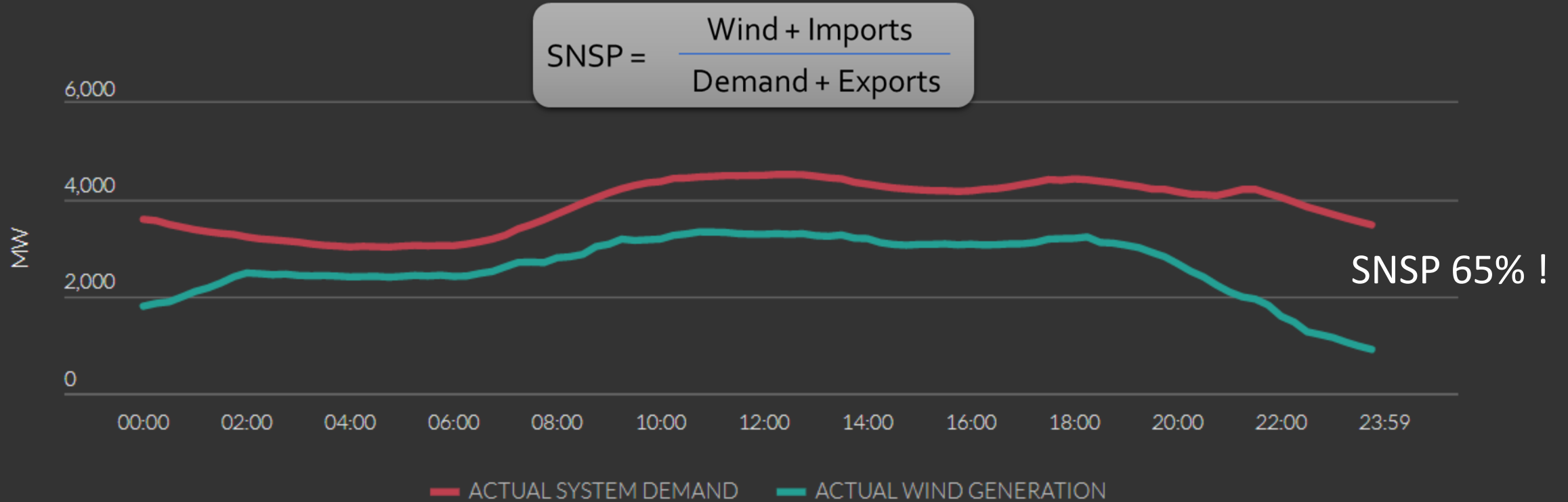
MODERATE ANNUAL AVERAGES TRANSLATE TO HIGH INSTANTANEOUS PENETRATIONS



Source: Drake Bartlett, PSCO, 2018



April 27th 2019 Ireland



Source: Eirgrid

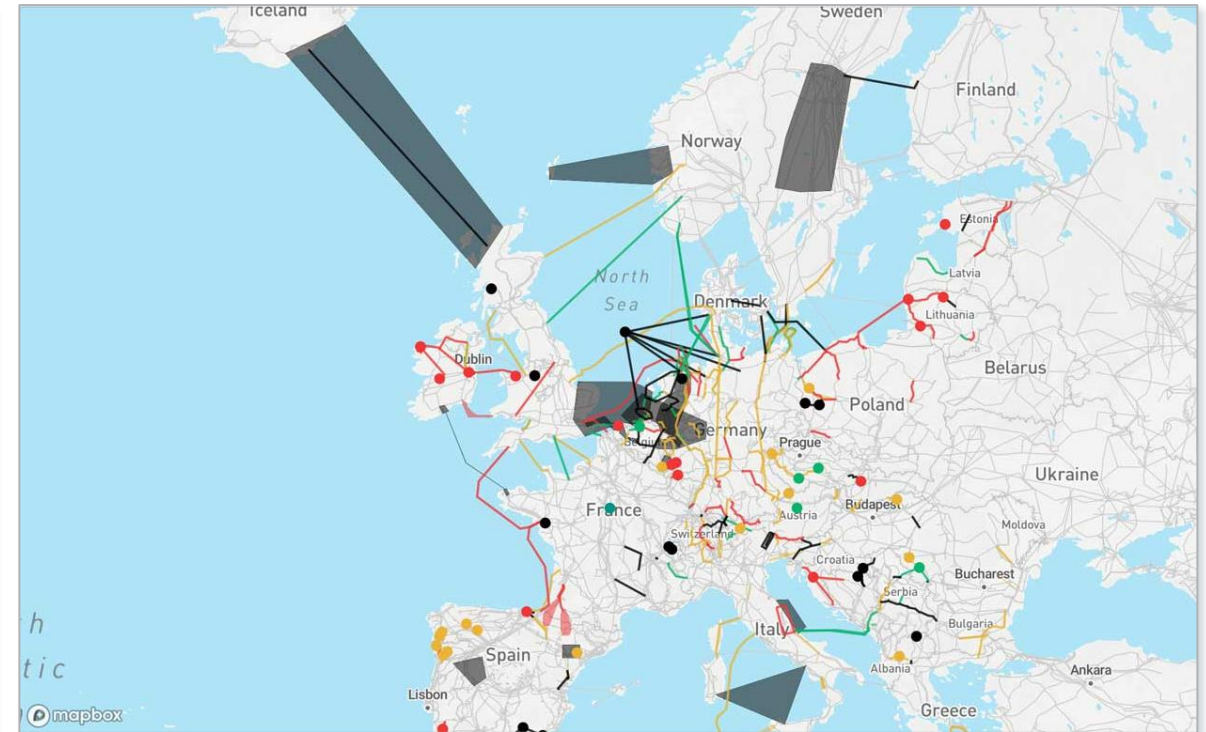


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Systems successfully managing
high penetration of renewables
are a reality!



EUROPE 2030 - 32% RES TARGET...> 50% ELECTRICITY FROM RENEWABLES NETWORK EXPANSION NEEDS



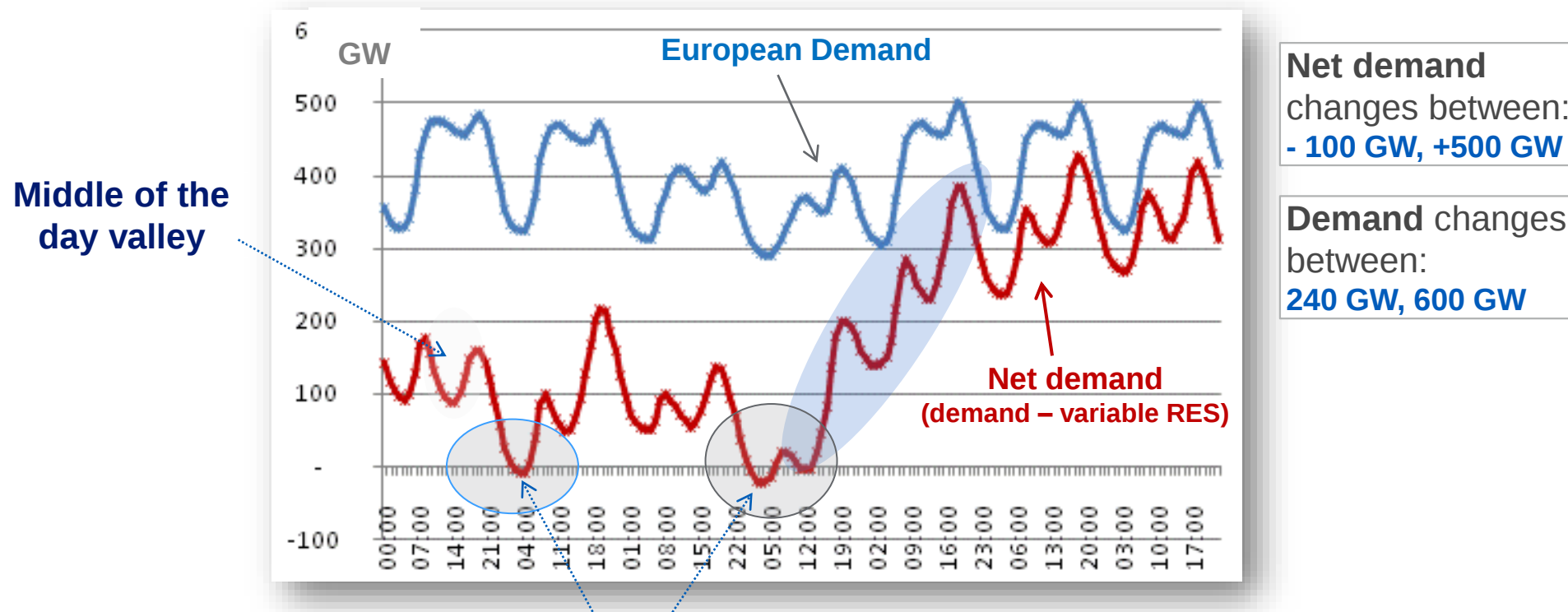
Source: TYNDP 2018, ENSTO-E

The integration of more than 50% renewables in electricity should be accompanied by a coordinated development of electricity grids



EUROPE 2030 - 32% RES TARGET...> 50% ELECTRICITY FROM RENEWABLES THE BALANCING CHALLENGE

European System with 60% Renewables



Source, EDF R&D

Penetration of > 100 % renewables

**New solutions for flexibility and ancillary services
are required to preserve system security**



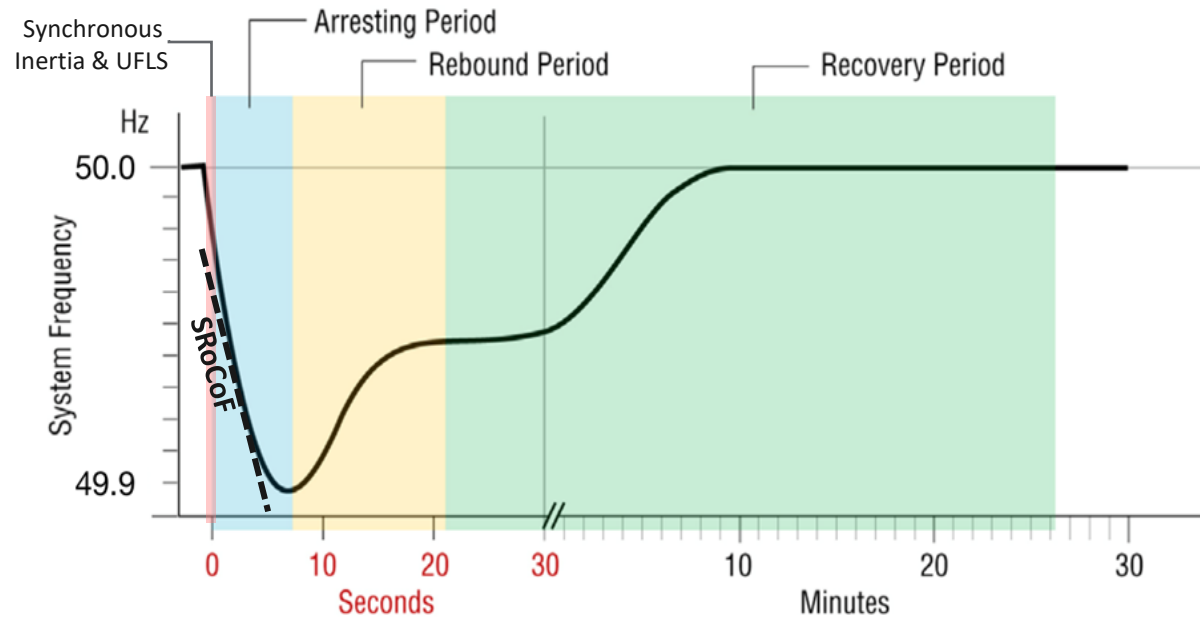
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Reference: V. Silva, A. Burtin, Technical and Economic Analysis of the European System with 60% RES, EDF Technical Report

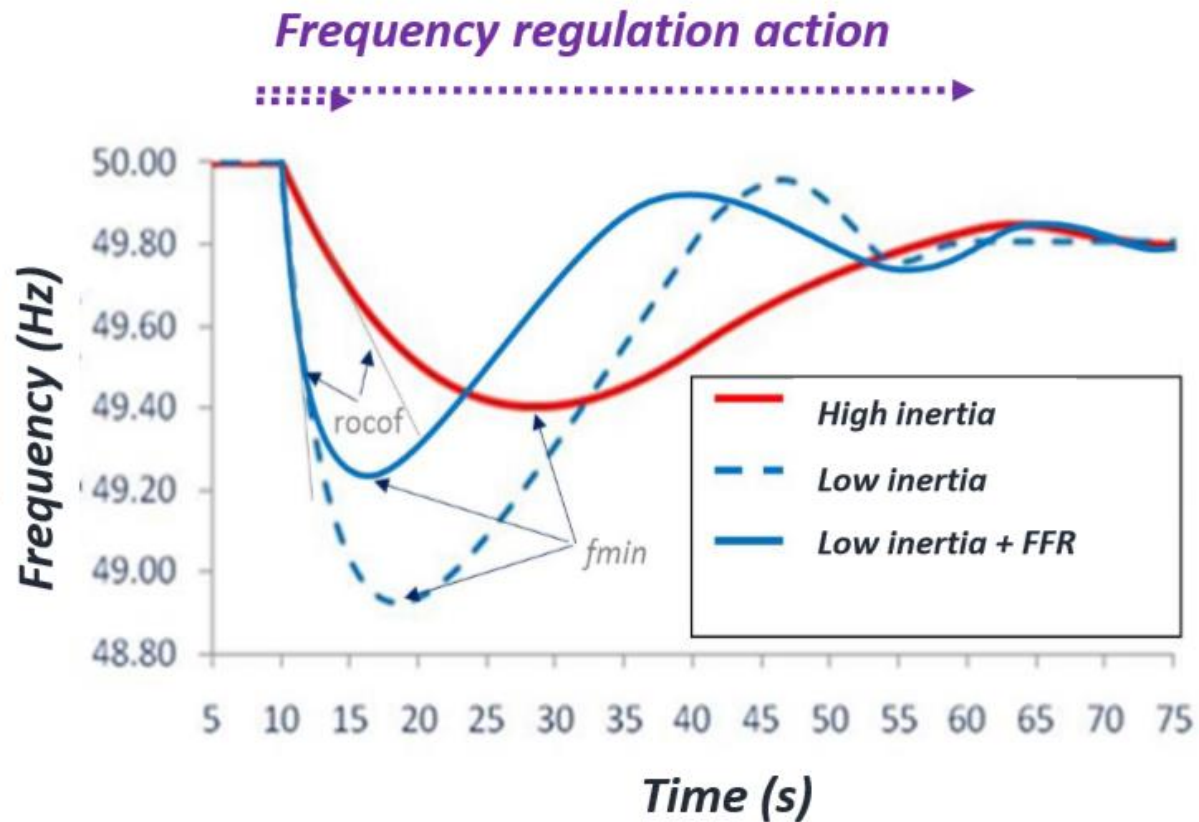
FOCUS ON THE ROLE OF INERTIA FOR STABLE FREQUENCY

When **power in** $\neq$ **power out** of system, the power imbalance accelerates or decelerates the grid's inertia

- ➔ Frequency changes throughout the grid
- ➔ *System* Rate of Change of Frequency (SRoCoF) proportional to power imbalance
- ➔ Frequency slide arrested when power is re-balanced



THE SYNCHRONOUS GENERATOR PARADIGM



Source: EDF R&D

Today's system is built on characteristics of conventional synchronous generators.

These generators are electro-mechanically coupled to the grid.

These generators are massive and have a lot of inertia.

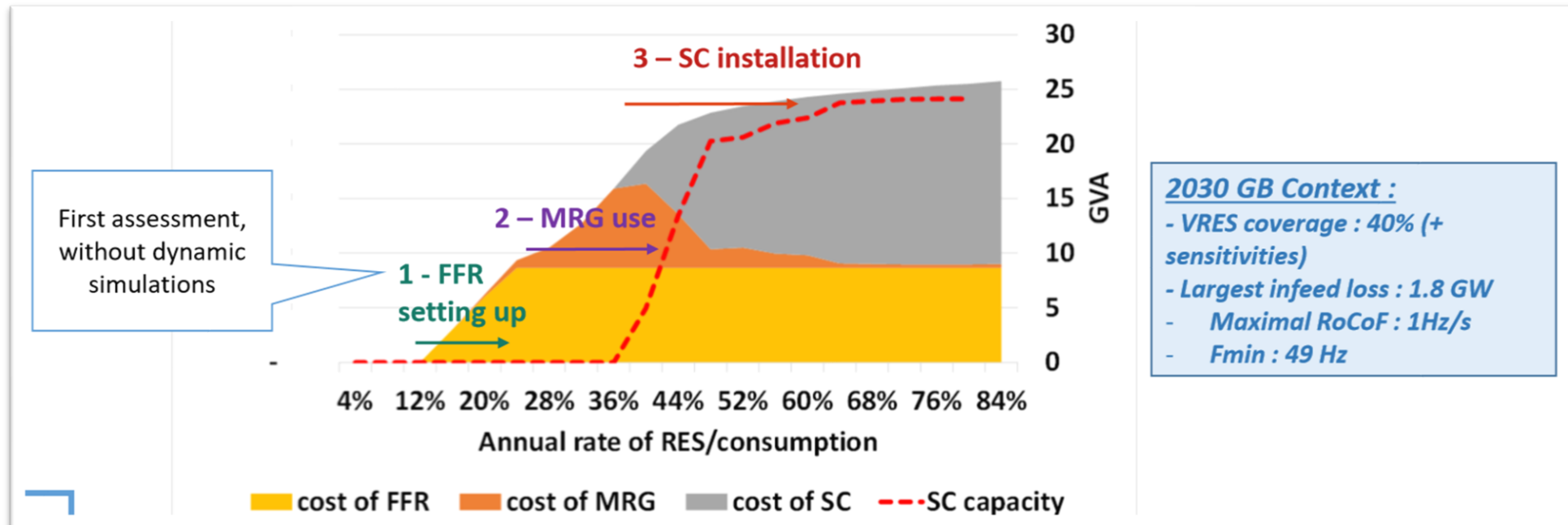
These generators may be able to increase or decrease output but not very quickly.

These generators produce high currents if there is a short circuit



ADAPTING TO A DECREASE IN SYNCHRONOUS INERTIA

SOLUTIONS	EFFICIENCY TO CONTROL		TECHNICAL MATURITY
	ROCOF	NADIR	
1 - Must Run Generation (MRG)	Yes	Yes, indirectly	Commercialized
2 - Synchronous Condenser (SC)			
3 - Fast Frequency Response (FFR)	No	Yes with inertia	R&D
4 - Grid Forming	Yes	Yes, indirectly	



SUPPORTING THE OPERATION OF LOW INERTIA GRIDS

Advanced Energy
Management
Systems

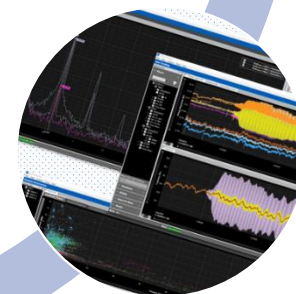
Enabling higher penetration of low
inertia renewable generation using
wide area monitoring and control



The **Inertia Challenges**



Measuring Area-
Inertia with PMUs



Forecasting area-inertia
by machine learning



USING WIDE AREA FAST FREQUENCY RESPONSE

Implementation of locationally sensitive fast acting frequency response services using several diverse technologies in the Icelandic grid.

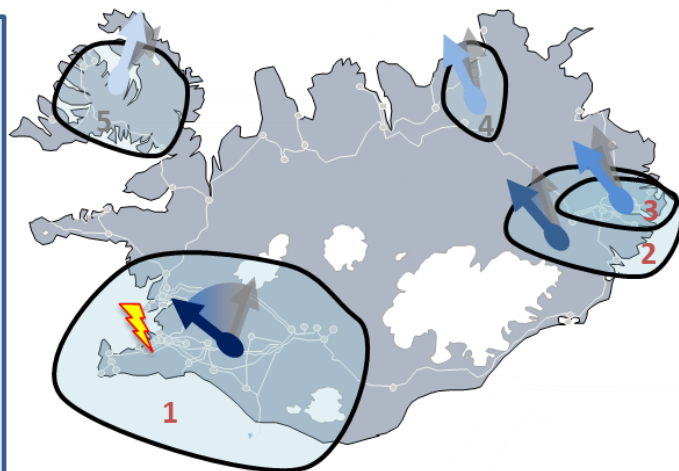
 **Zones** Centres of inertia; islanding may occur between zones, not (successfully) within zones. **Aggregated Angle and Frequency** for each zone shared with all control points.

Angle Difference

⚡ **Angles swing apart** during disturbance → islanding risk

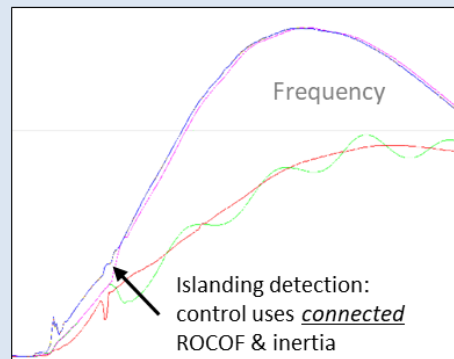
Mean angle

↻ **Act in location** to return angles to system mean angle



Frequency

Disturbance Frequency accelerates in proportion to (MW loss) / (inertia). BUT not uniform across network



System ROCOF Aggregated frequency from all connected zones → system ROCOF*inertia → MW loss.

Lessons learned

Wide area control is working well

- Fast acting (<0.5s) & reliable with fault-tolerant distributed control.
- Frequency containment improved.
- Reduced islanding probability & impact with sparse inertia

Enables flexible fast frequency services

- Diverse loads & generators can contribute. New service capability easily added.
- Cost effective – no new capital equipment or dedicated batteries



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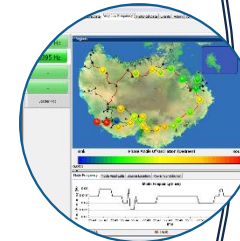
THE GRIDS OF THE FUTURE REQUIRE HOLISTIC SOLUTIONS – ORGANIZATION, DIGITAL AND PHYSICAL EQUIPMENT

SYSTEM SHORTFALL	ASSOCIATED ISSUES
Frequency control	System inertia Reserves and Ramping capability
Voltage control	Short circuit strength Steady state and dynamic voltage control
Stability	Small signal stability Transient stability
Network Congestion	Network hosting capacity RES curtailment Interconnection capacity allocation
System restoration	Black-start capability and load restoration Network reconfiguration
System adequacy	Uncertainty of RES generation System interdependencies



EQUIPMENT AND SYSTEMS

HVDC controls, DLR, storage, FACTS



DIGITAL TOOLS

EMS, WAMS, ADMS, DERMS, MMS, TSO/DSO interface tools, Data Analytics



RULES OF THE GAME

Grid Codes
Market design
TSO/DSO cooperation
TSO-TSO coordination (US: ISO/ISO)

Source: H2020 EU-SysFlex 2019



TECHNOLOGY IS THERE – WE NEED TO MOVE TO LARGE SCALE DEMONSTRATION AND ROLL OUT

SONI

TSO/DSO

System services
qualifier trials



innogy

Forecast

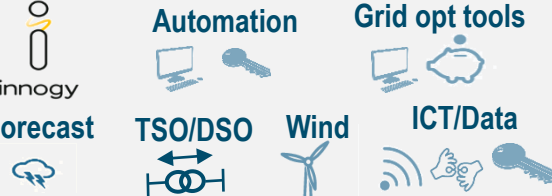
Automation

Grid opt tools

TSO/DSO

Wind

ICT/Data



HELEN

Storage

Forecast

TSO/DSO

VPP tools

Multi-energy



edf

Forecast

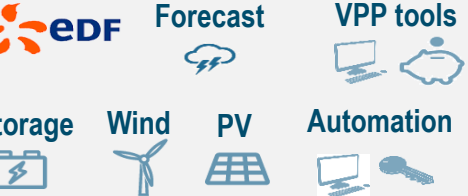
VPP tools

Storage

Wind

PV

Automation

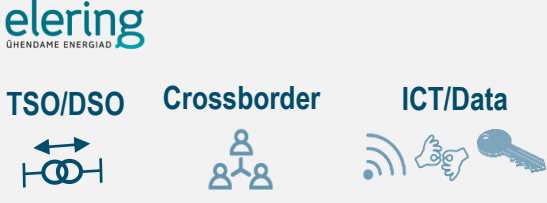


elering
OHENDAME ENERGIAD

TSO/DSO

Crossborder

ICT/Data



edp

TSO/DSO

VPP Tools

Pump storage

Wind

Forecast



Enel Distribuzione

ICT/Data

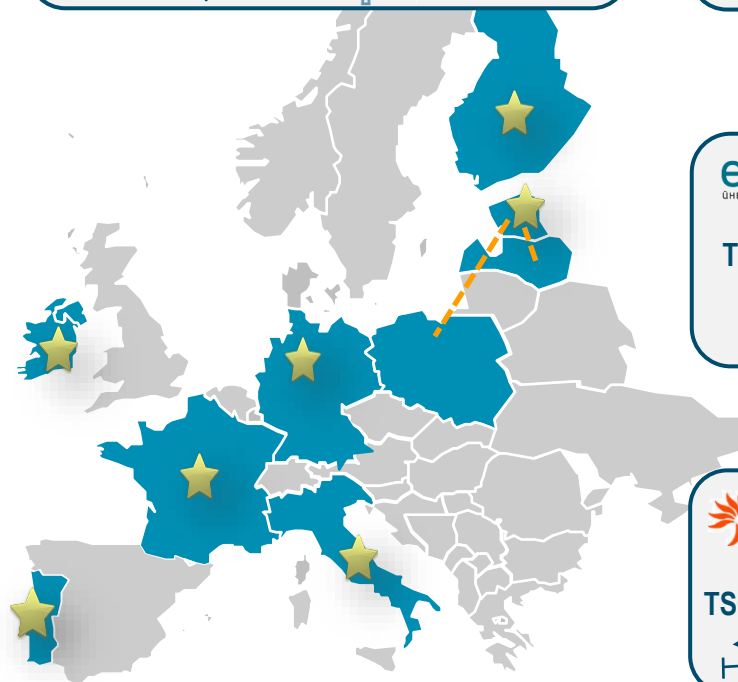
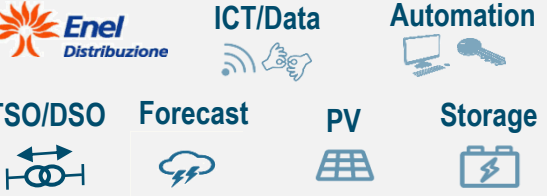
Automation

TSO/DSO

Forecast

PV

Storage



Disclaimer: This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773505.



EU-SysFlex

The road that took us here
won't take us there...

A major transformation of
electricity grid is ahead!



