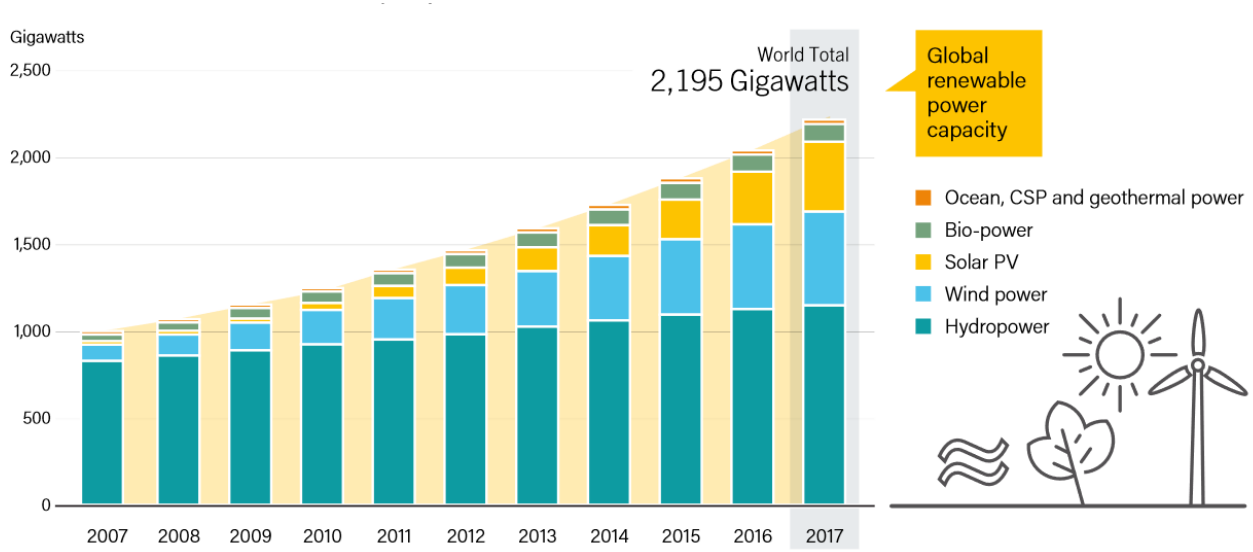
Towards 100% Renewable Energy Pathways

Where we are at…

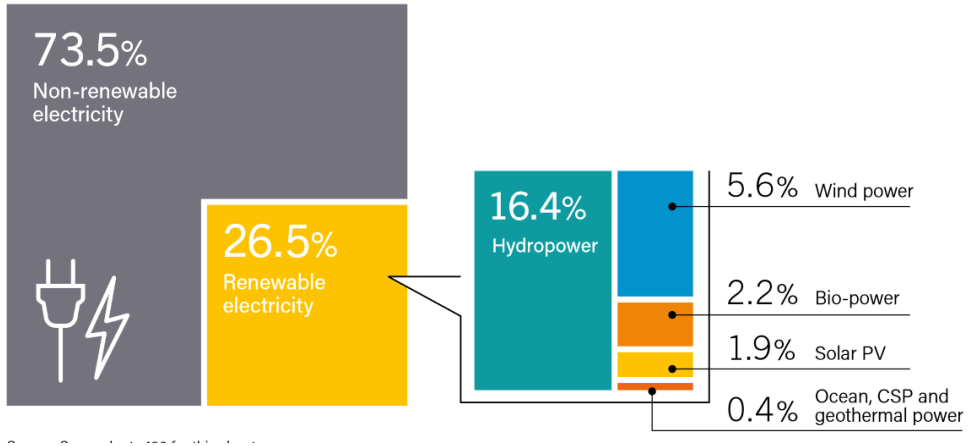
Vera Silva, GE Grid Solutions

15-16 May, 2019

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

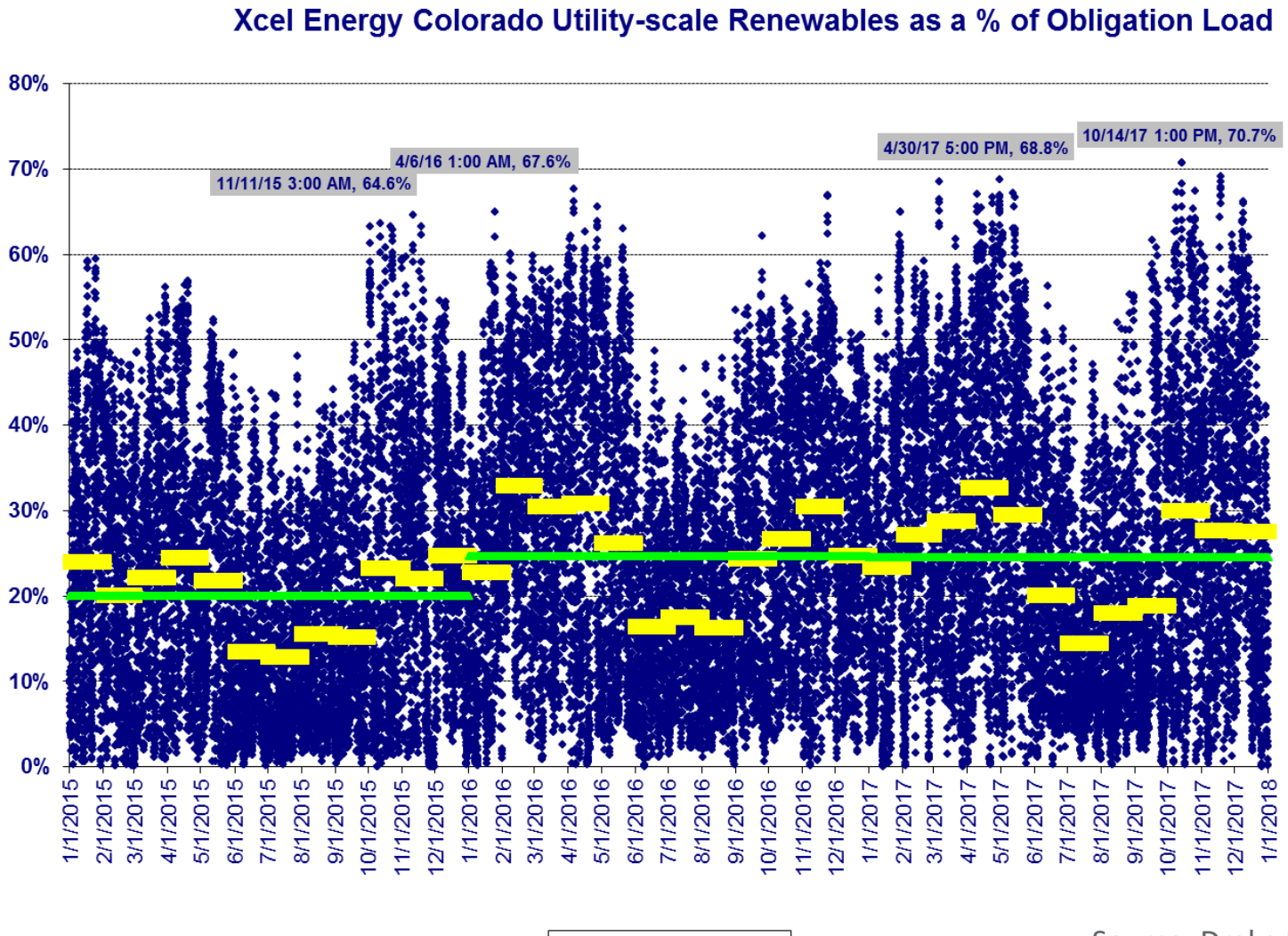


Wind and solar covered ~ 8% of electricty demand in 2017



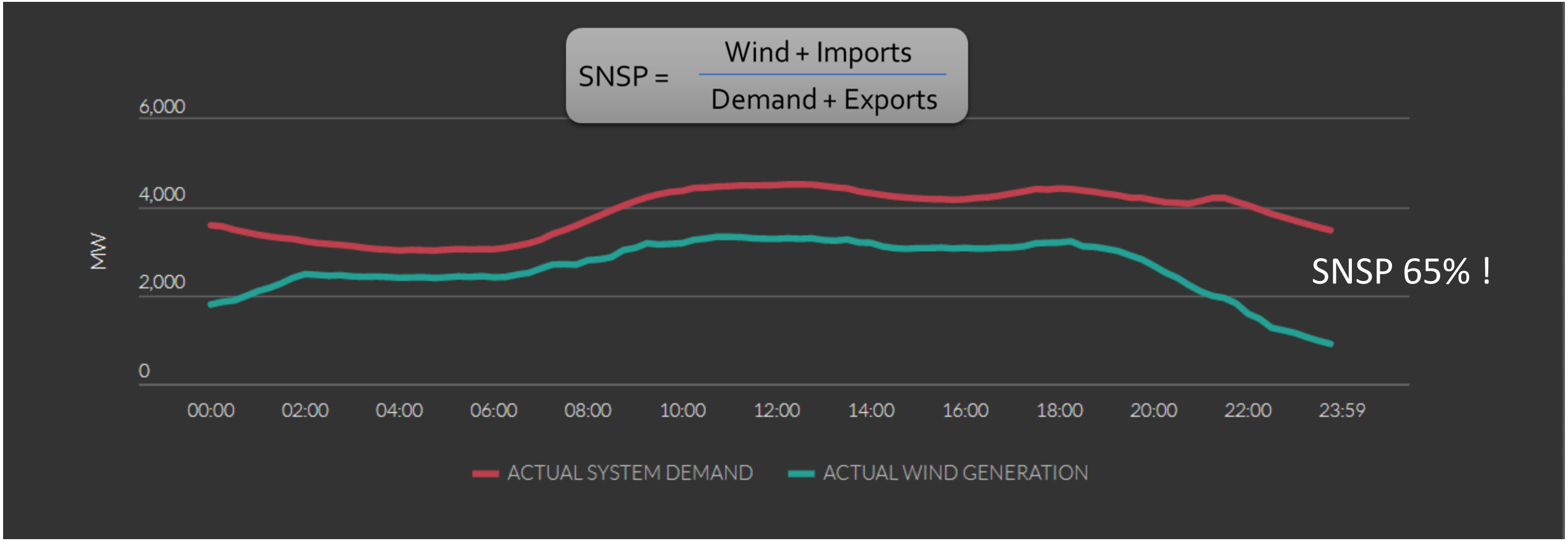
Source, REN 21, renewables 2018 status report

MODERATE ANNUAL AVERAGES TRANSLATE TO HIGH INSTANTANEOUS PENETRATIONS



Source: Drake Bartlett, PSCO, 2018

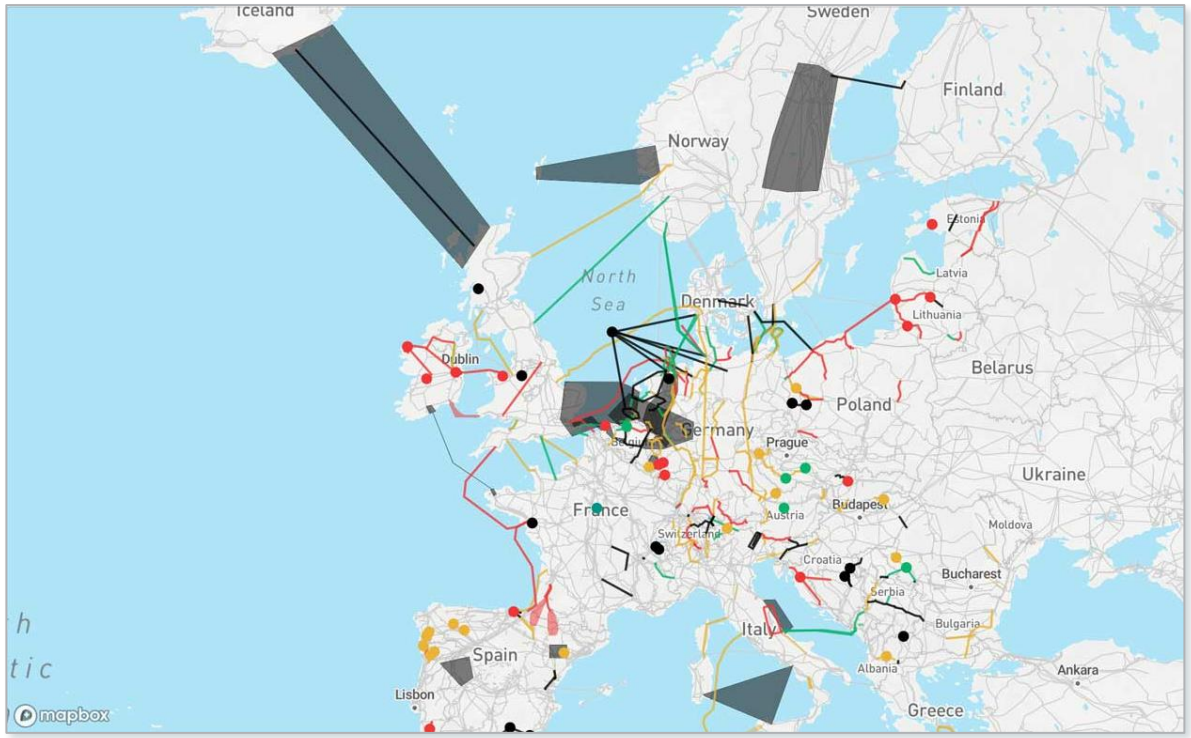
April 27th 2019 Ireland



Source: Eirgrid

Systems successfully managing high penetration of renewables are a reality!

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

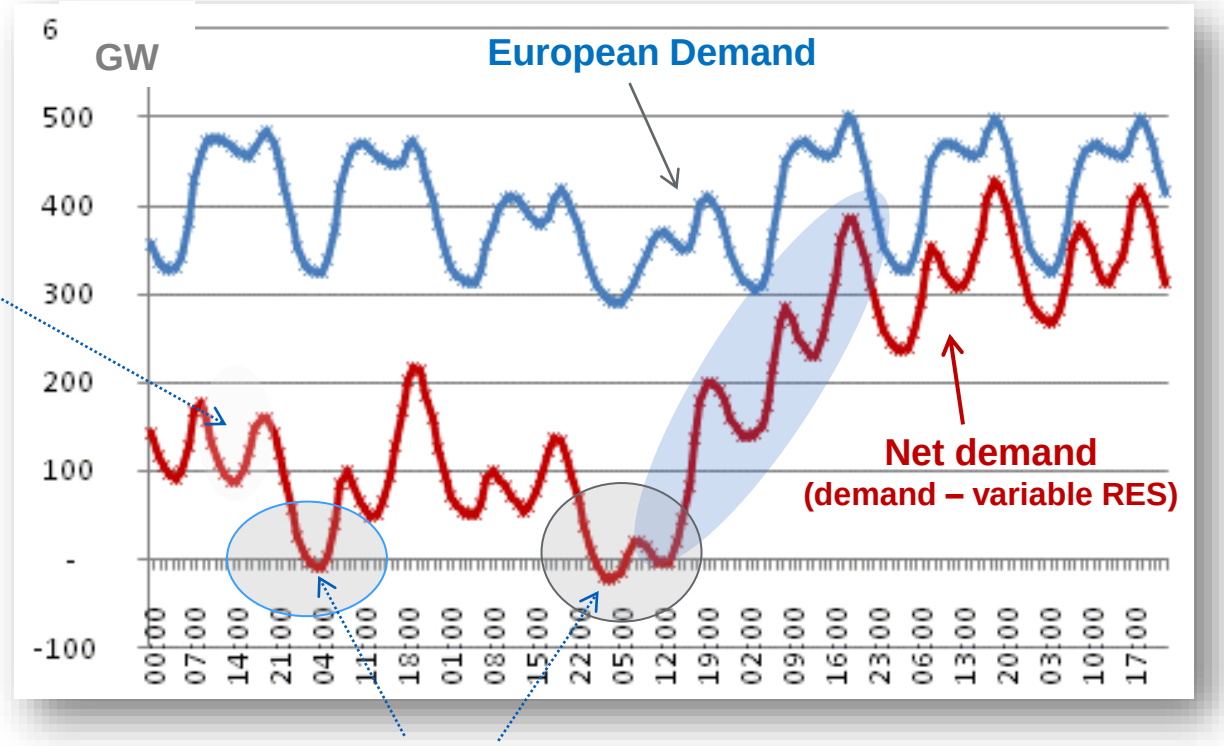


Source: TYNDP 2018, ENSTO-E

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



Middle of the day valley

Net demand changes between:
- 100 GW, +500 GW

Demand changes between:
240 GW, 600 GW

Source, EDF R&D

Penetration of > 100 % renewables

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

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

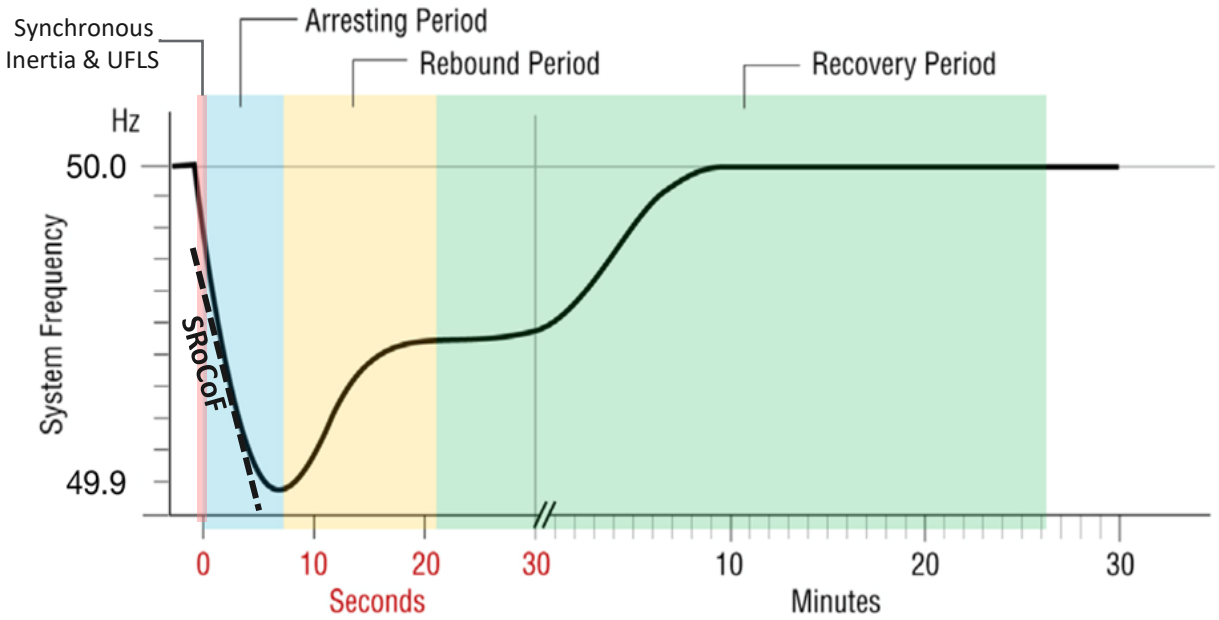
FOCUS ON THE ROLE OF INERTIA FOR STABLE FREQUENCY

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

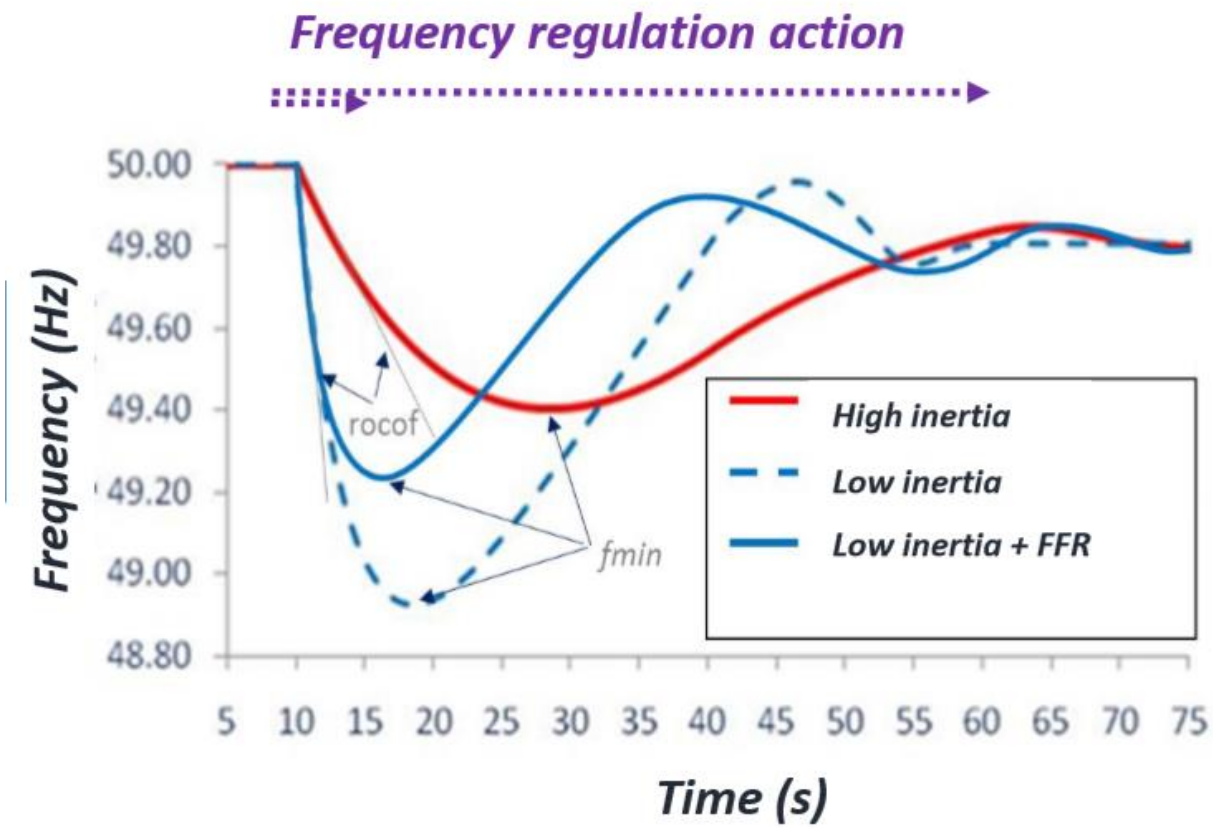
➔ Frequency changes throughout the grid

➔ *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.

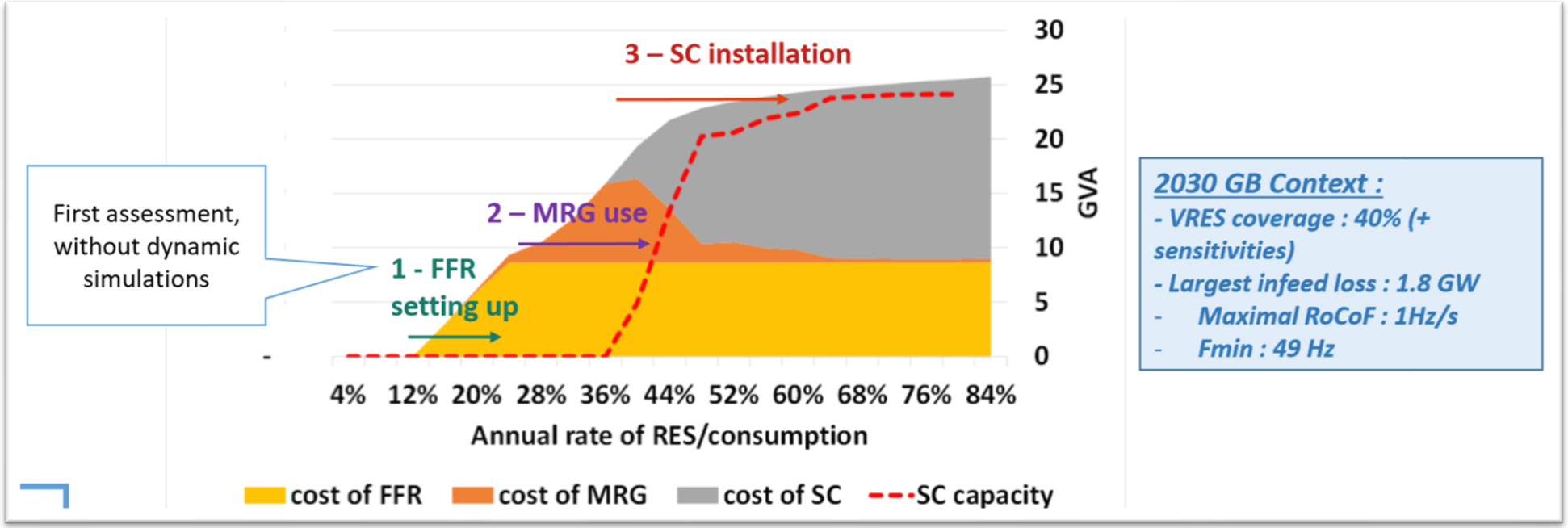
These generators are massive and have a lot of inertia.

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	
4 - Grid Forming	Yes	Yes, indirectly	R&D



Source: EDF R&D 2019

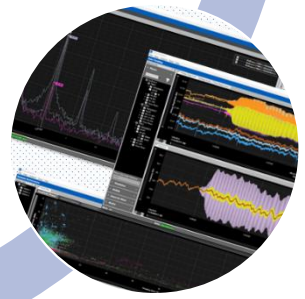
SUPORTING THE OPERATION OF LOW INERTIA GRIDS

Advanced Energy Management Systems

Effective Area Inertia

The **Inertia Challenges**

Measuring Area-Inertia with PMUs

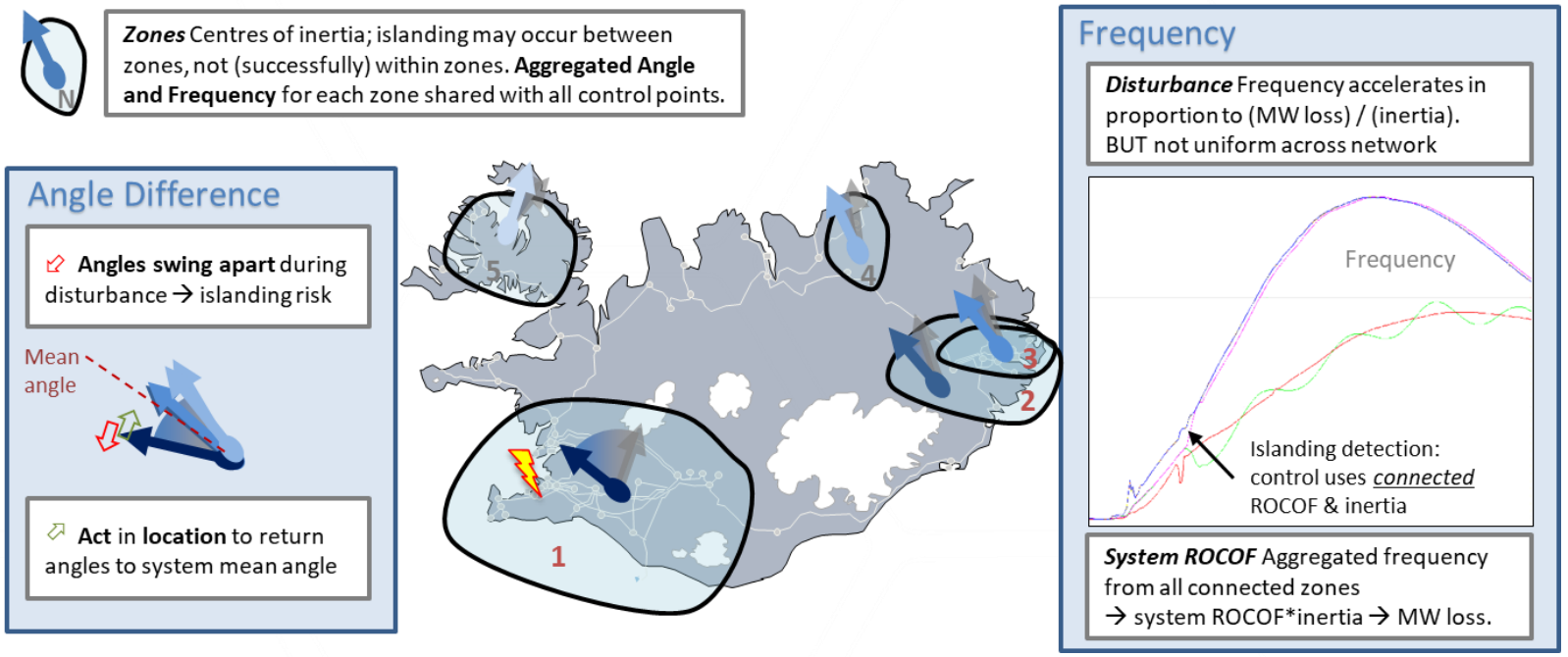


Forecasting area-inertia by machine learning

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

USING WIDE AREA FAST FREQUENCY RESPONSE

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



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

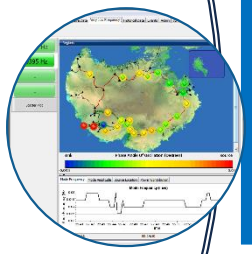
MIGRATE

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

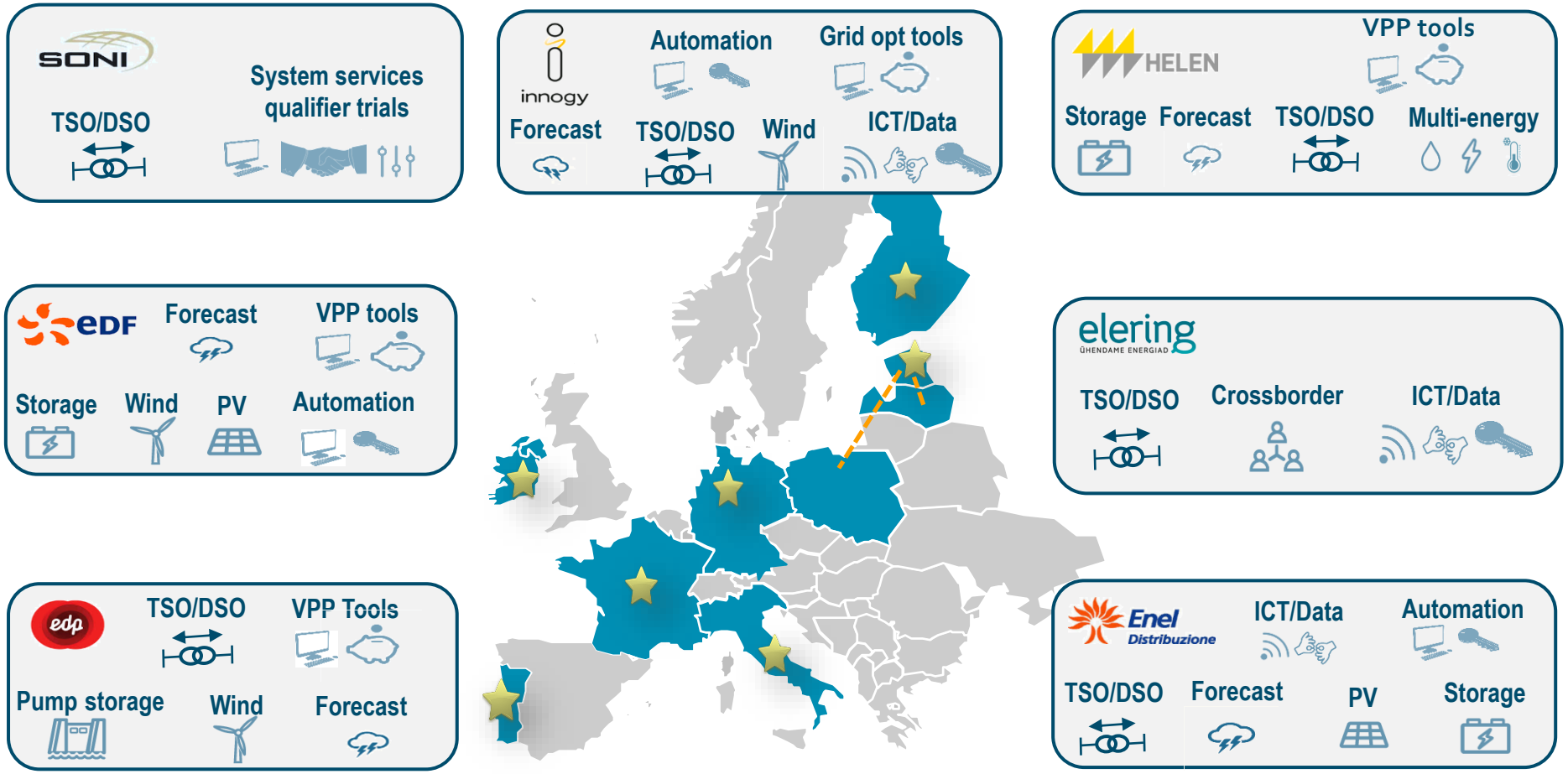
Market design

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



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!