Planning for the Transformation of Power Systems

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IRENA Innovation and Technology Centre

Bonn University/IRENA lecture series - Renewable Future
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Power Sector Transformation in the context of Global Energy Transition

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- Decarbonization of the energy sector
- Increasing cost competitiveness of solar PV and wind based generation

Source:

A global view to 2050 – Energy Transition

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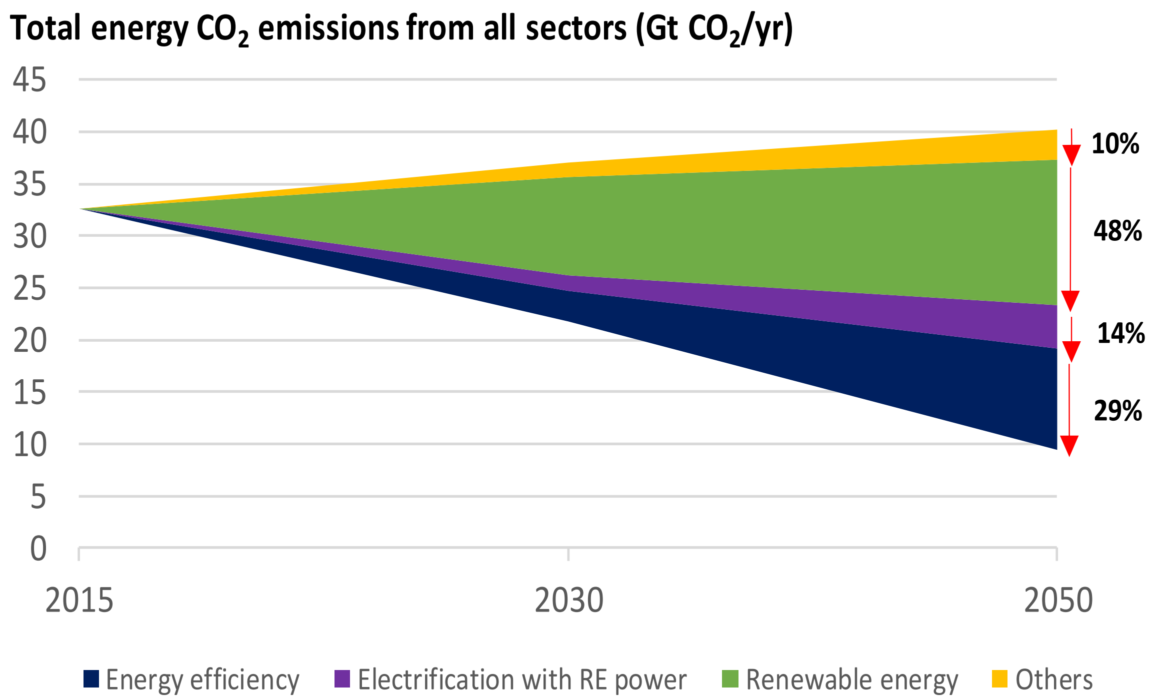
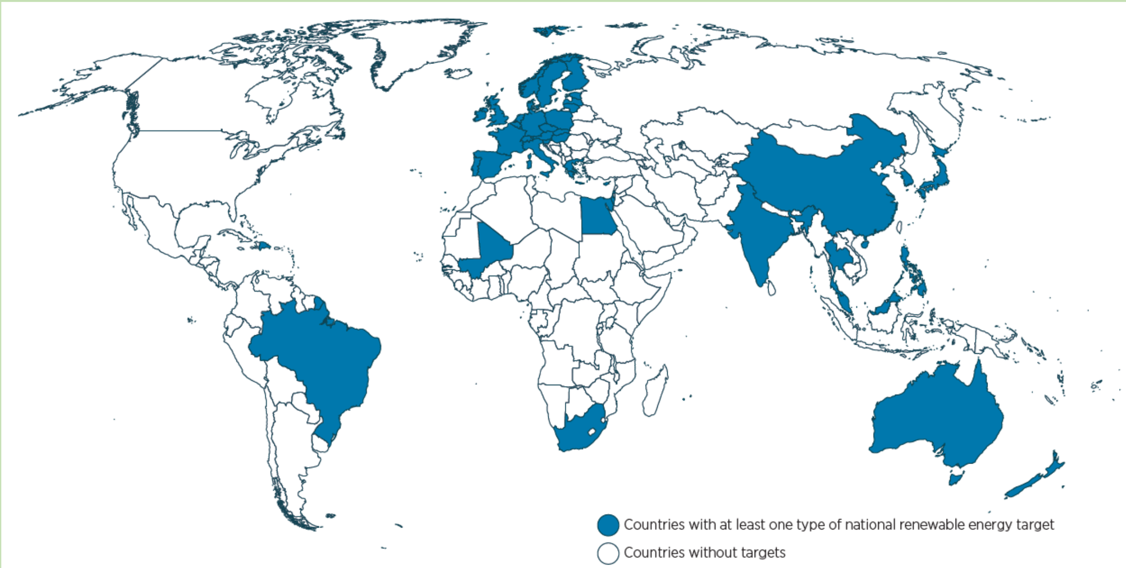
To meet 2°C climate target set at COP 21 in Paris 2015

- Energy-emission budget:
  - 790 Gt CO_2 from 2015 till 2100
- Carbon intensity of energy:
  - needs to fall by 85% in 2015-2050

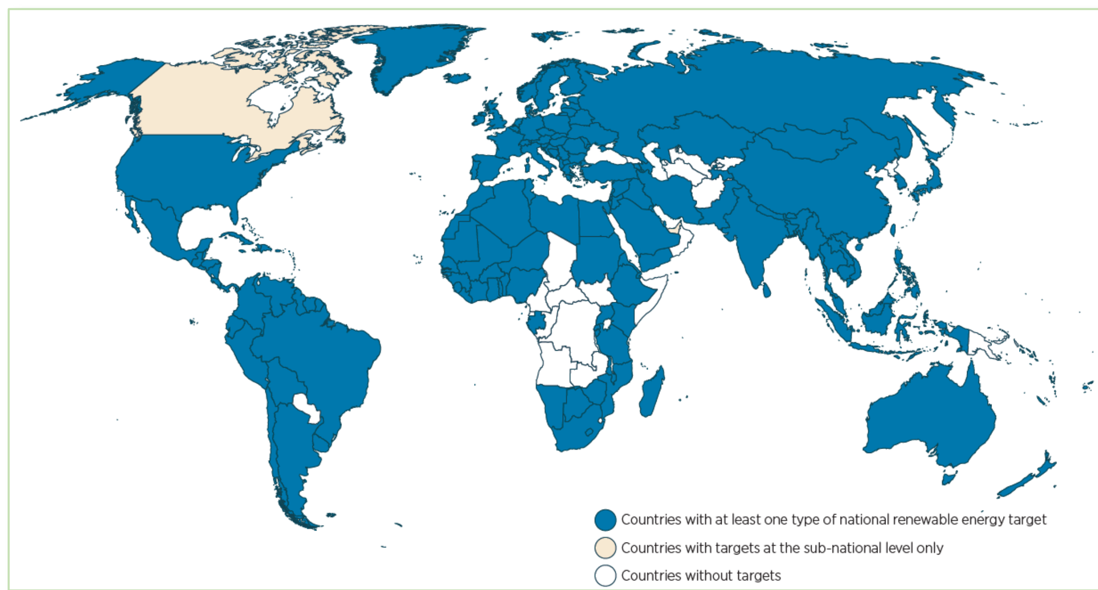


43 countries with RE targets in 2005



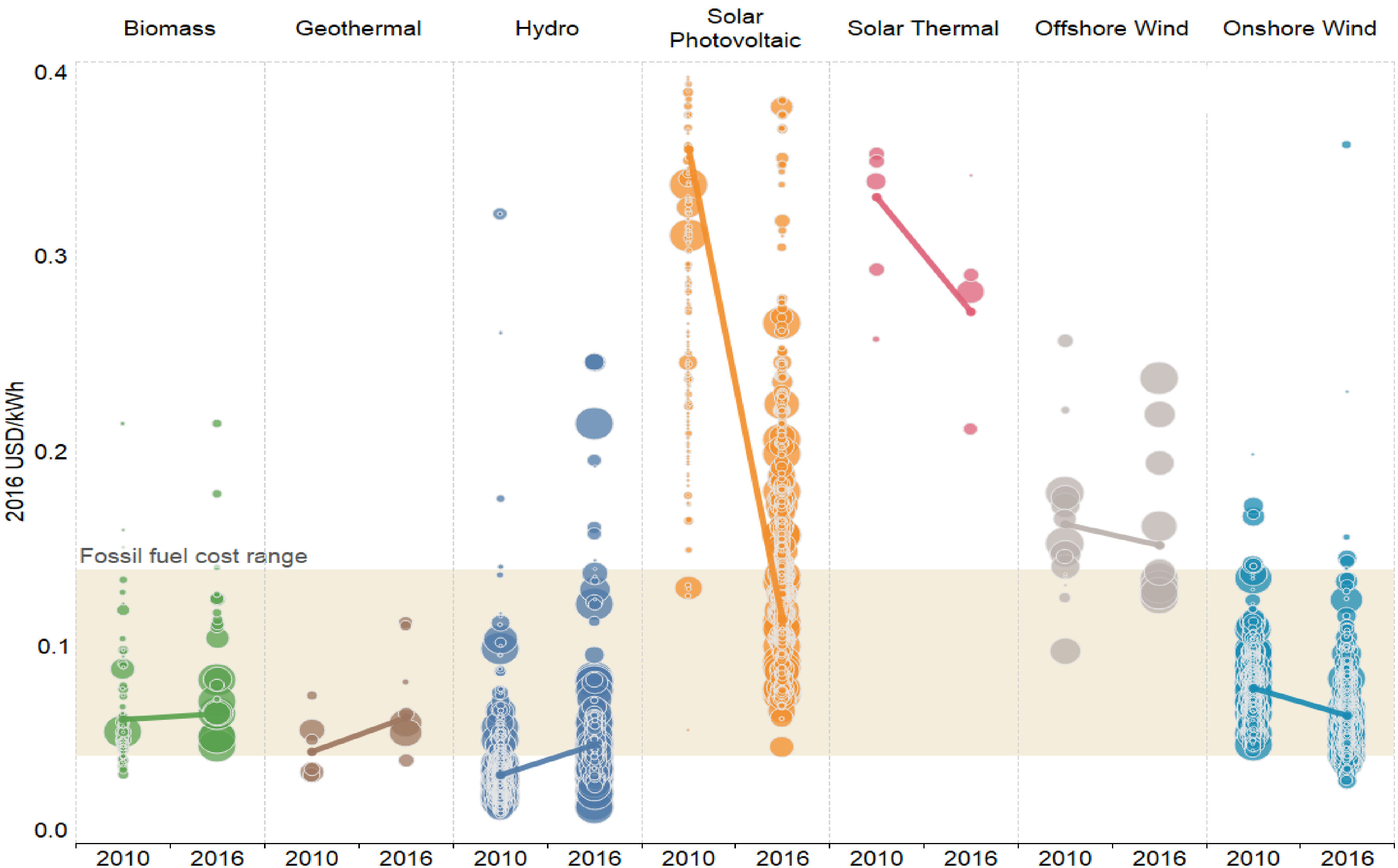
In 10 years …

164 countries



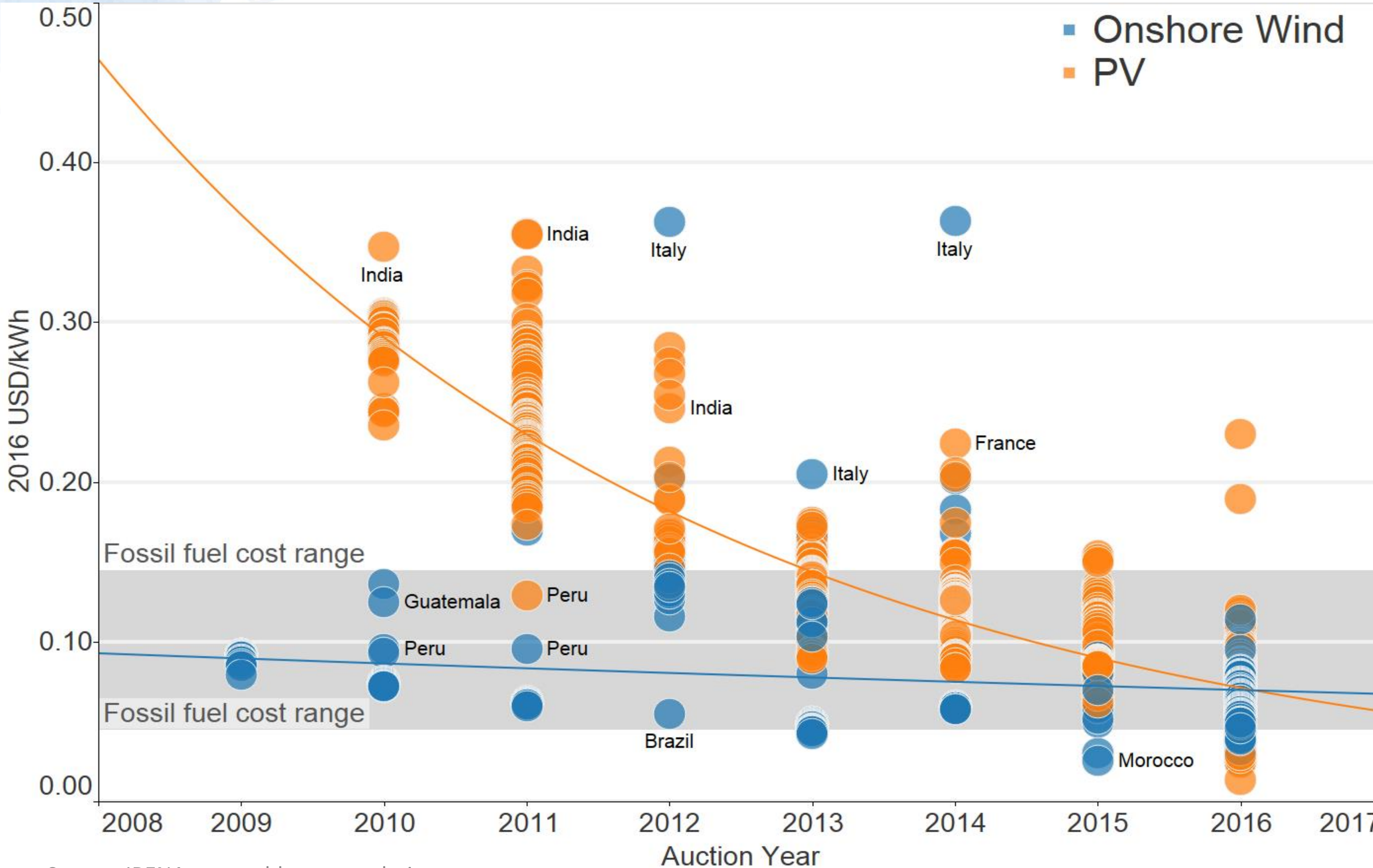
Source: IRENA (2015), Renewable Energy Target Setting

Dropping costs



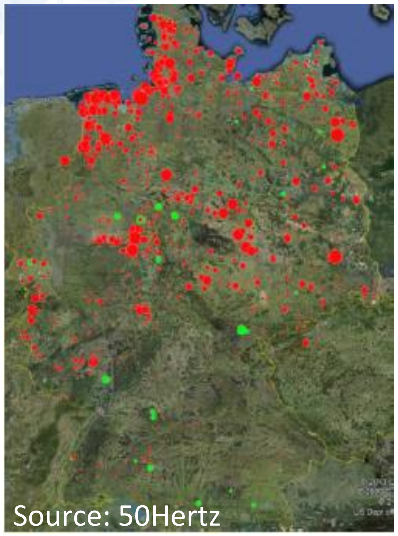
Source: IRENA renewable cost analysis

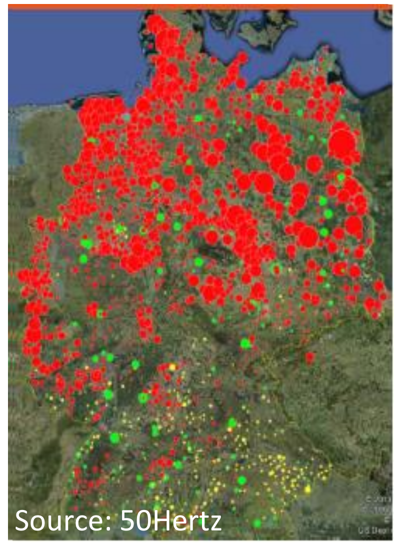
With PPA results for future plants converging for solar & wind

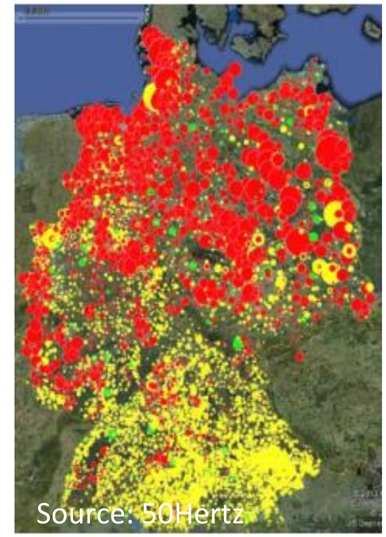


Source: IRENA renewable cost analysis

The transformation of the power system







around 30.000 plants | around 220.000 plants | around 1.500.000 plants

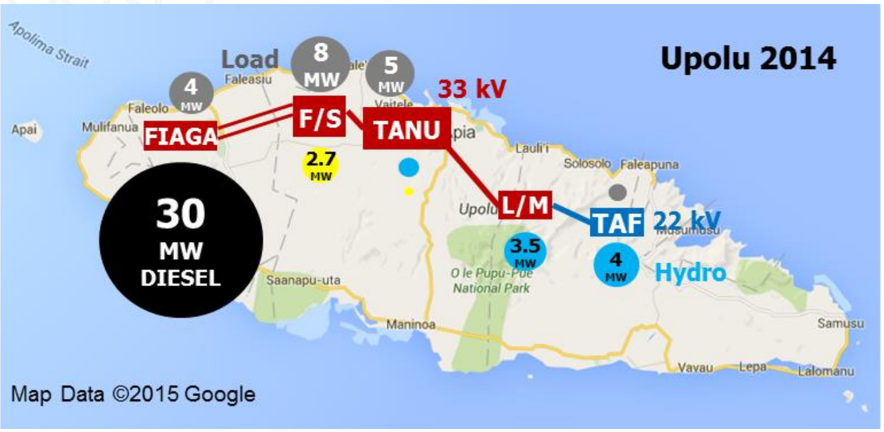
2000 | 2006 | 2014

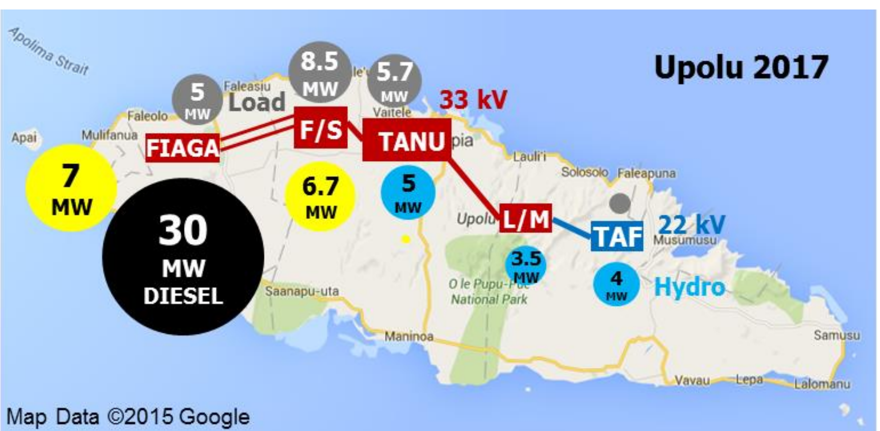
Wind | Photovoltaics | Biomass

Example in Germany

Source: 50Hertz

The transformation is happening everywhere regardless of the size





On-going global power sector transformation

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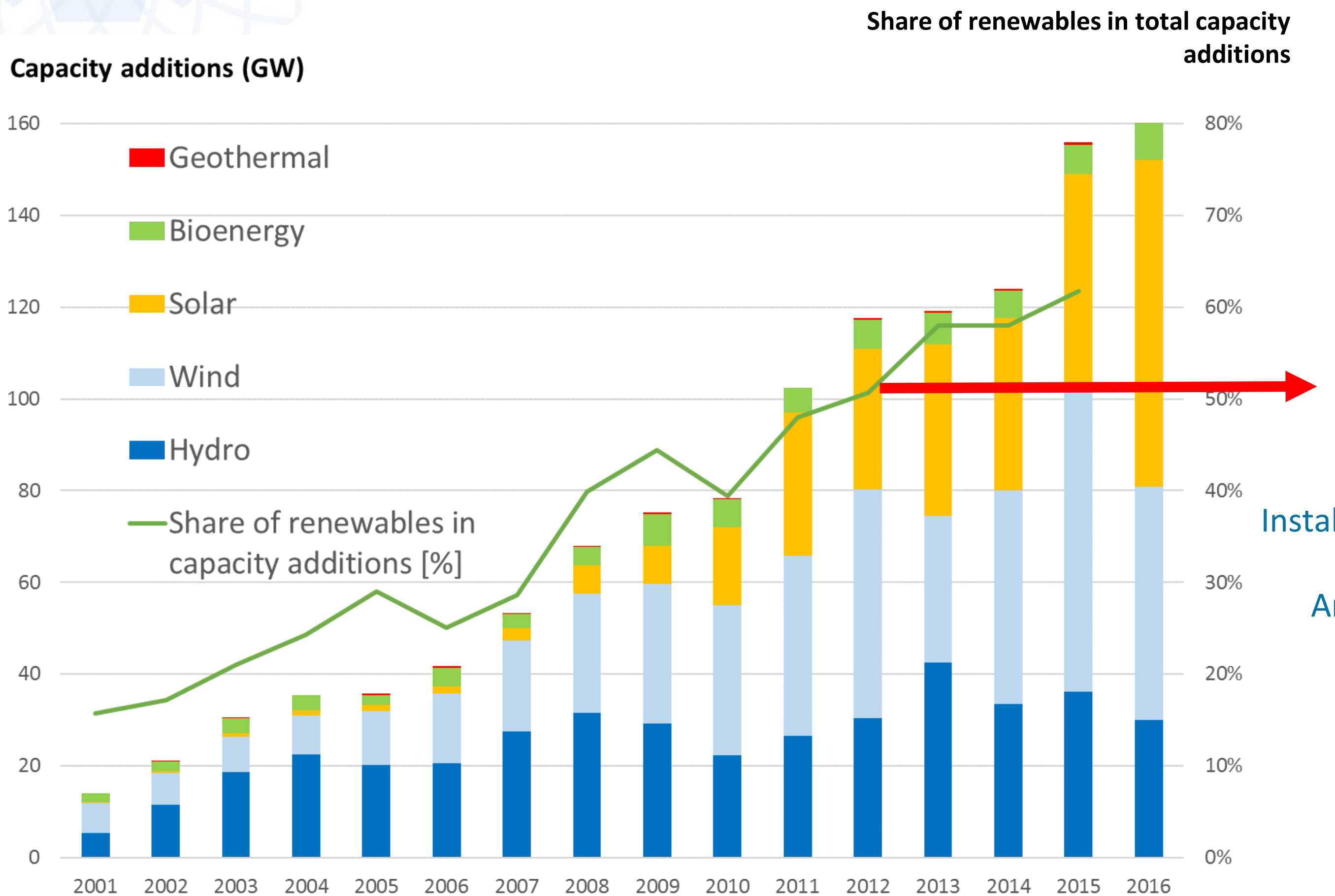
Solar and wind accounted for 50% of total capacity additions in 2015



Since 2012 >50% of total capacity additions

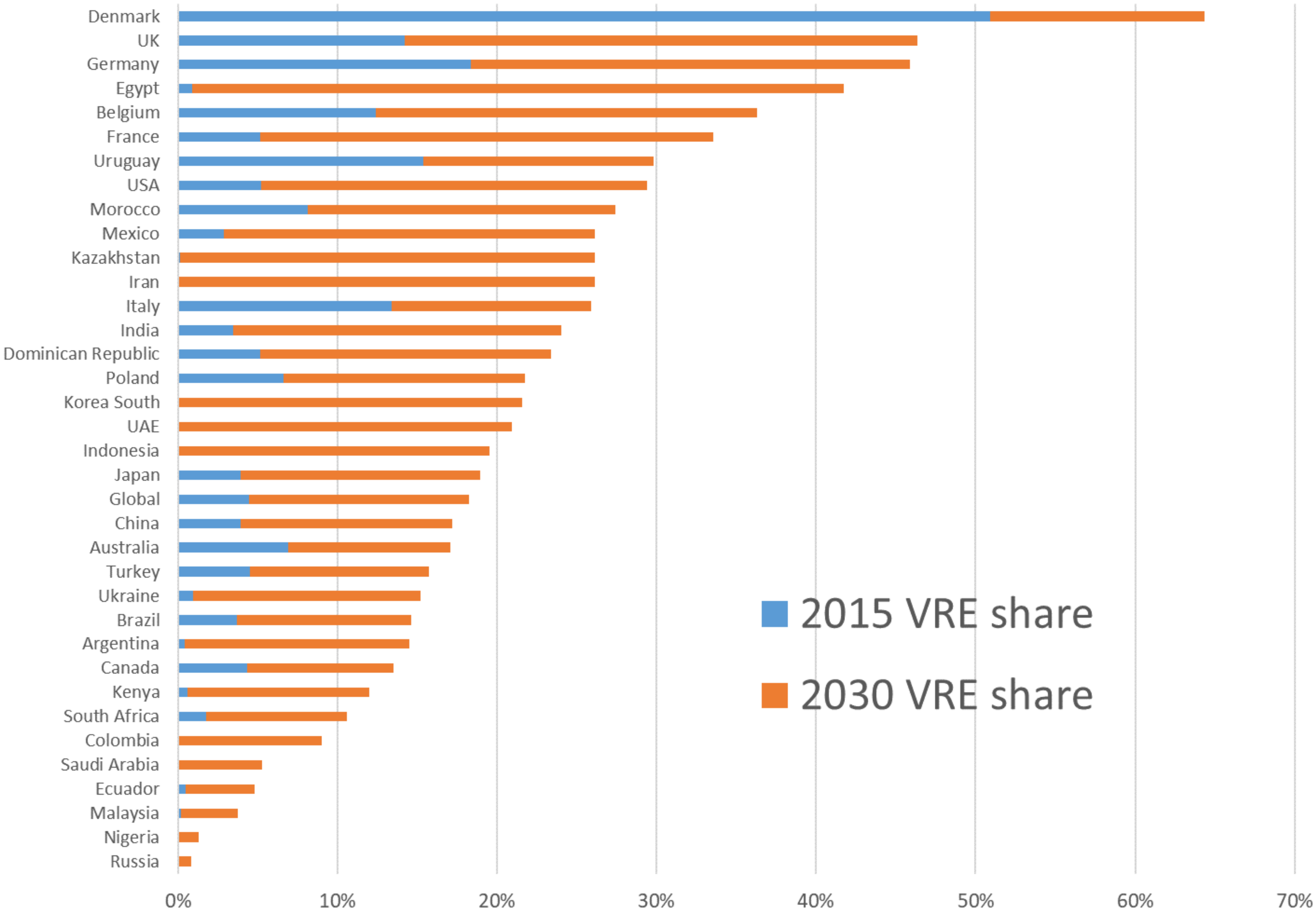
2016

Installed 2006 GW RE power generation capacity
Annual RE capacity addition 161 GW of which:
71 GW solar
51 GW wind
30 GW hydropower
9 GW biomass

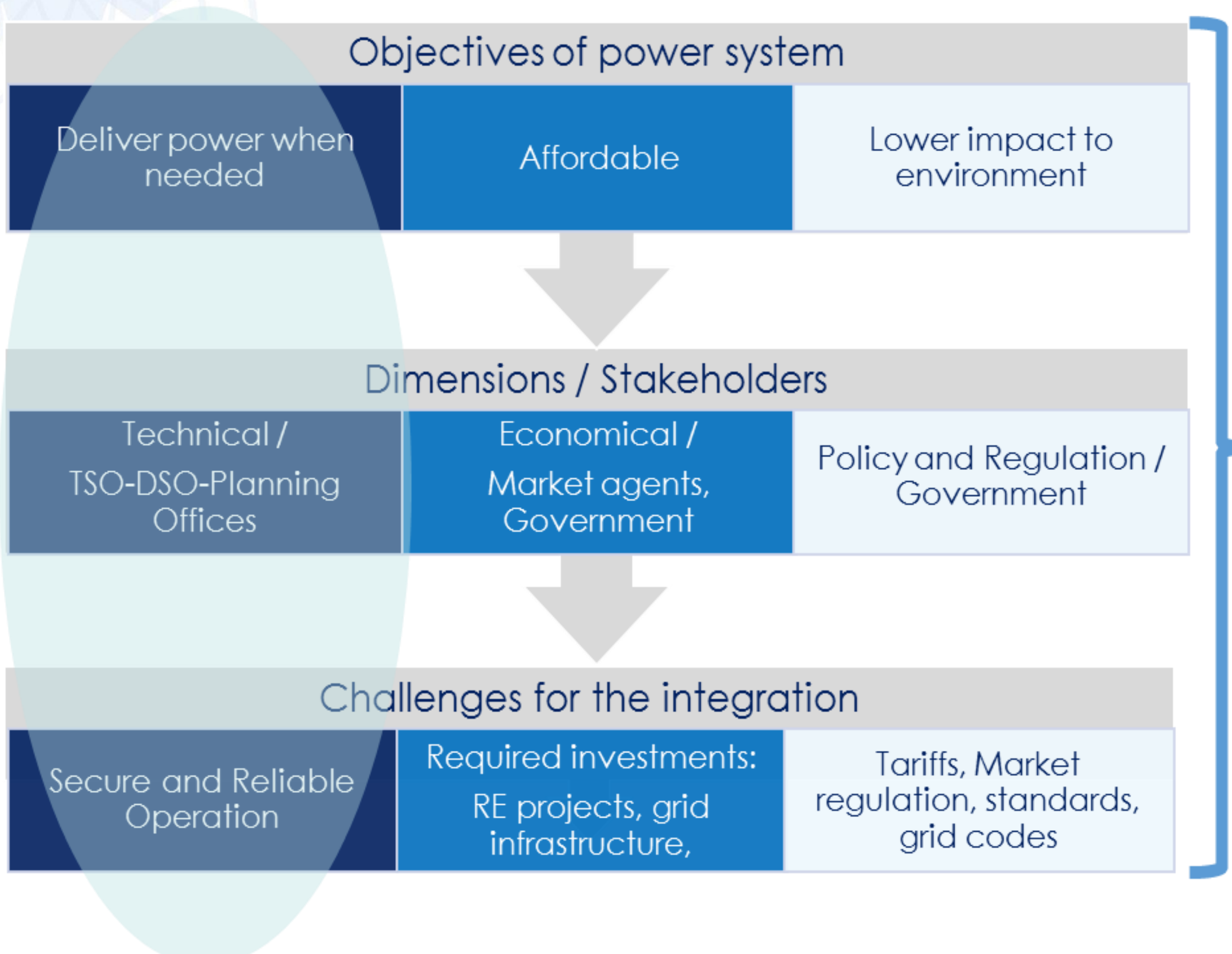
Around **25% RE power generation** share worldwide; growing by **0.7 percentage points per year**

Transition ahead

Source: REmap 2030



Challenges at different levels



Successful transformation requires:

- ✓ **Political commitment - stable regulatory framework**
- ✓ **Planning for coherent energy systems**
- ✓ **Innovative solutions**

Power Sector Transformation at IRENA

Market design, regulation, business models

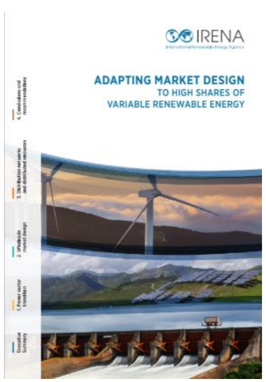
Long term, least cost capacity expansion plan

Unit commitment and economic dispatch

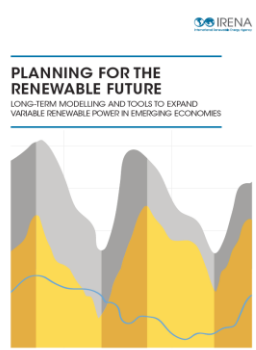
Grid studies

Find the optimal pathway for power sector transformation

- ***Adapting electricity market design to high shares of VRE***
- Country regulatory advice
- **Power sector innovation landscape report** (Q4 2017)



- Best practices in long-term scenario-based modelling report, ***Planning for the renewable future***
- Recommendations were discussed at a **Latin American regional workshop**



- Production cost modeling
- Developing **flexibility assessment** to be applied to 5 REmap countries
- Developing a **global storage valuation framework**, to assess the value of storage in different markets

- Technical network studies
- A guide for **VRE integration studies** is upcoming
- Technical assessments for larger systems

Generation expansion planning

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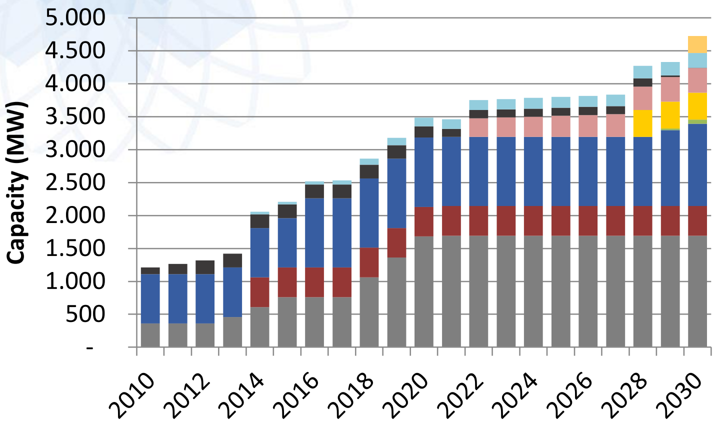
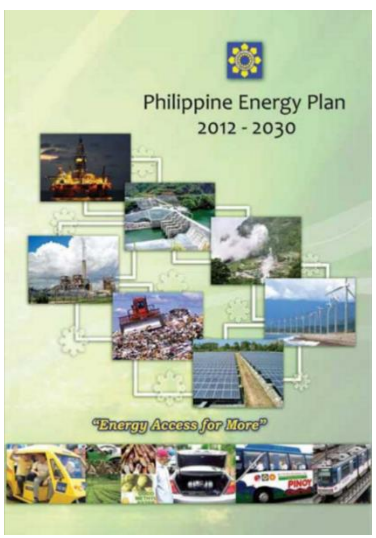
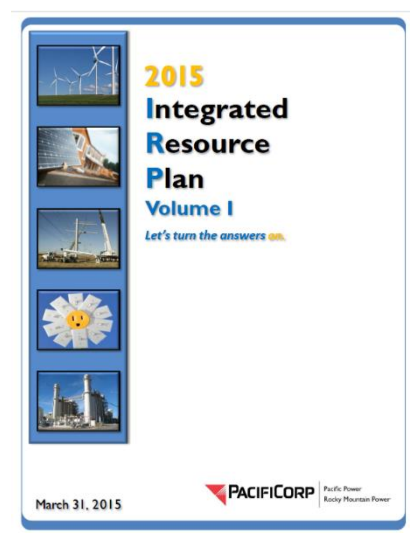


- Future energy mix and investment path
- Compliance with long-term energy policy goals
- Political consensus making
- Linked often with non-power sector planning

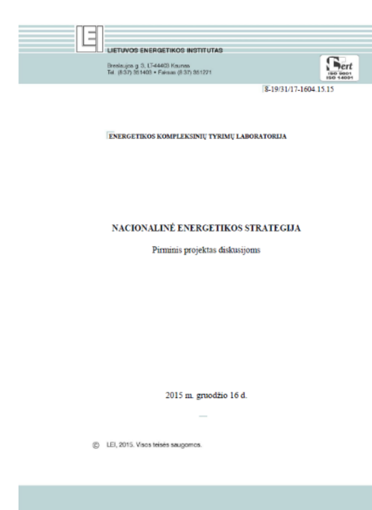


Department of Energy

Regulatory commission



Utility



Specialized agency

Long-term Planning in South America

- Regional workshop in August in Buenos Aires, *"Exchanging best practices to incorporate variable renewable energy into long-term energy/power sector planning in South America"*
- Energy planners from 10 countries with 50 participants

Planning reports from the governments

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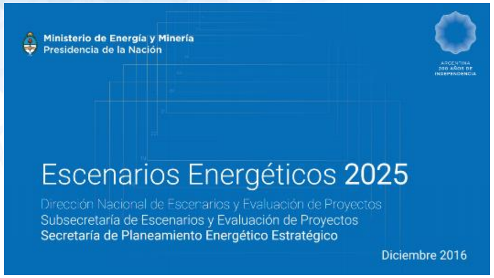
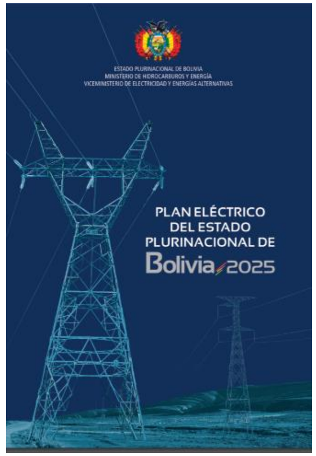
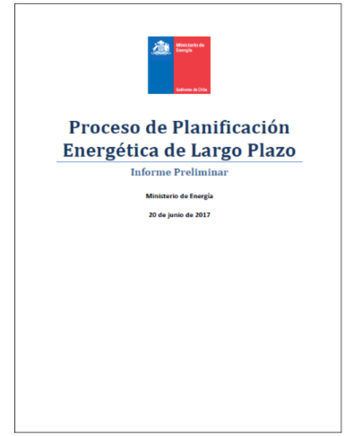


Argentina

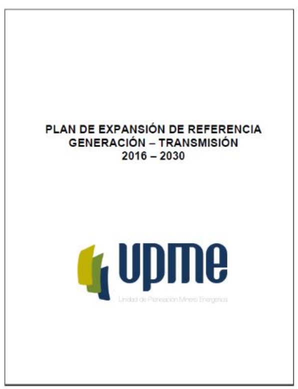


Bolivia

Brazil



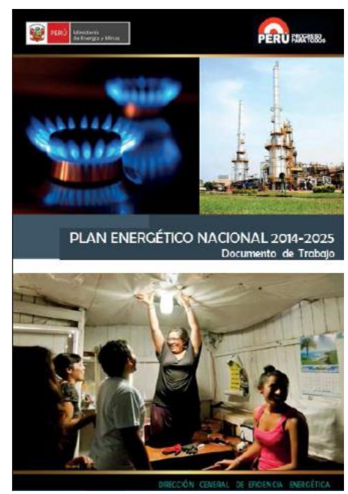
Chile



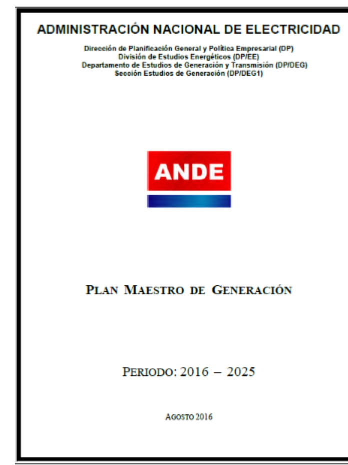
Colombia

Ecuador

Mexico



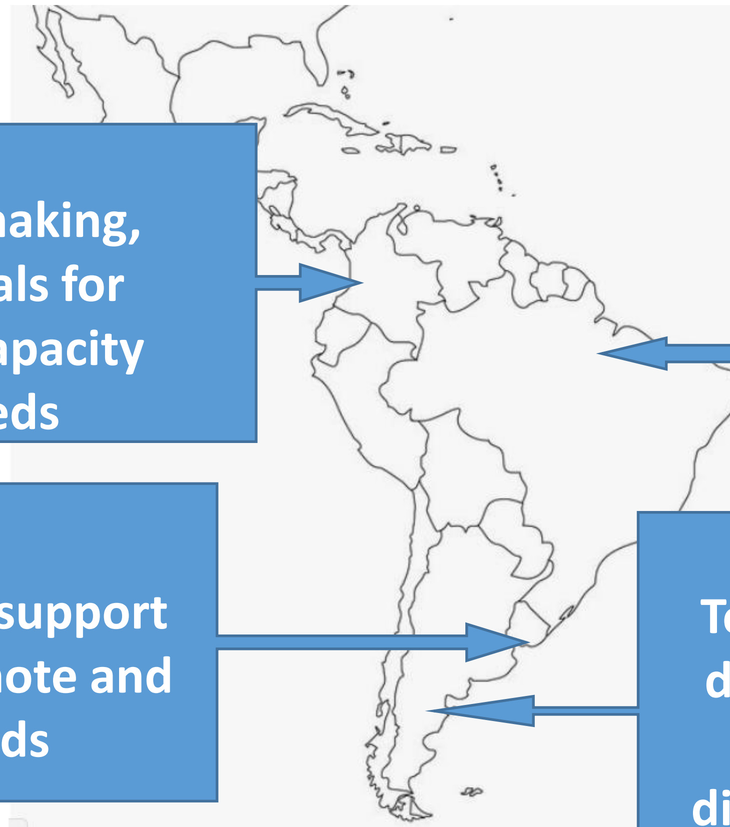
Peru



Paraguay

* Uruguay does not make the planning document publically avaiable

Purpose of long-term planning
Basis for policy making



Colombia:
Bases for policy making, establishing signals for investment and capacity expansion needs

Brazil:
To be used as a basis for formulating public policies

Uruguay:
To design policies to support technologies to promote and investment needs

Argentina:
To establish a framework of discussion for the design of new policies and for the discussion with actors of the sector.

Planning scopes

Country	Scope	Planning horizon	Update
Argentina	Energy	2025	Annual
Bolivia	Electricity	2025	NA
Brazil	Energy	2050	5 -10 years
Chile	Energy	2046	5 years
Colombia	Electricity	15 years	Annual
Ecuador	Electricity	2025	2 years
Mexico	Electricity	15 years	Annual
Paraguay	Energy / electricity	2040 / 2025	5 / 2 years
Peru	Energy	10 years	2 years
Uruguay	Energy / Electricity	2035 / 2040	Annual

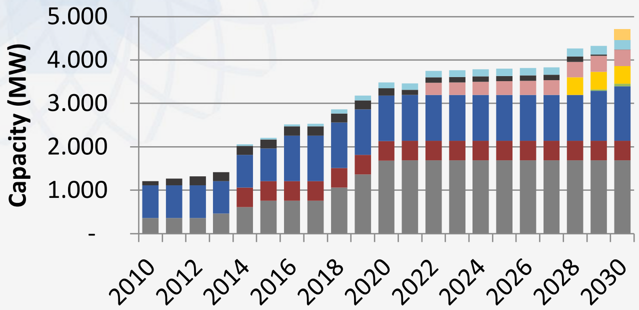
Long-term planning – African context

Summary from "*Planning renewable energy strategies: Africa power sector, Achievements and way forward*", Abu Dhabi January 2015

Long-term energy planning, if done properly,

- Can help to avoid costly investment mistakes
- Creates consensus among stakeholders
- Reduces uncertainties in policy directions/project selection
- Sends investors signals on types & quantity of investment needs
- Accelerate service delivery

Power sector planning:
Focus areas for techno-economic analysis

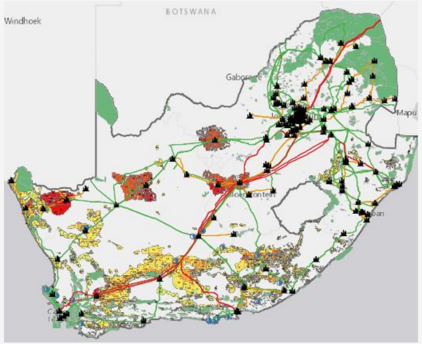


Generation expansion planning

- Government planning office
- Planning agency
- Utility

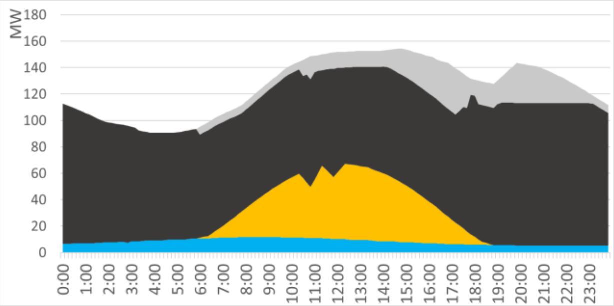
Geo-spatial planning

- Government planning office
- Planning agency
- Utility
- TSO



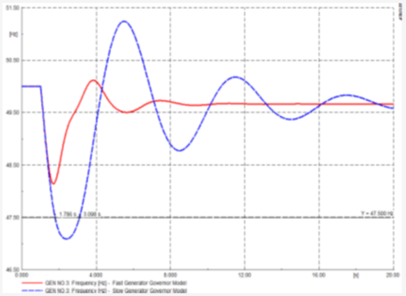
Dispatch simulation

- Utility
- Regulators
- TSO



Technical network studies

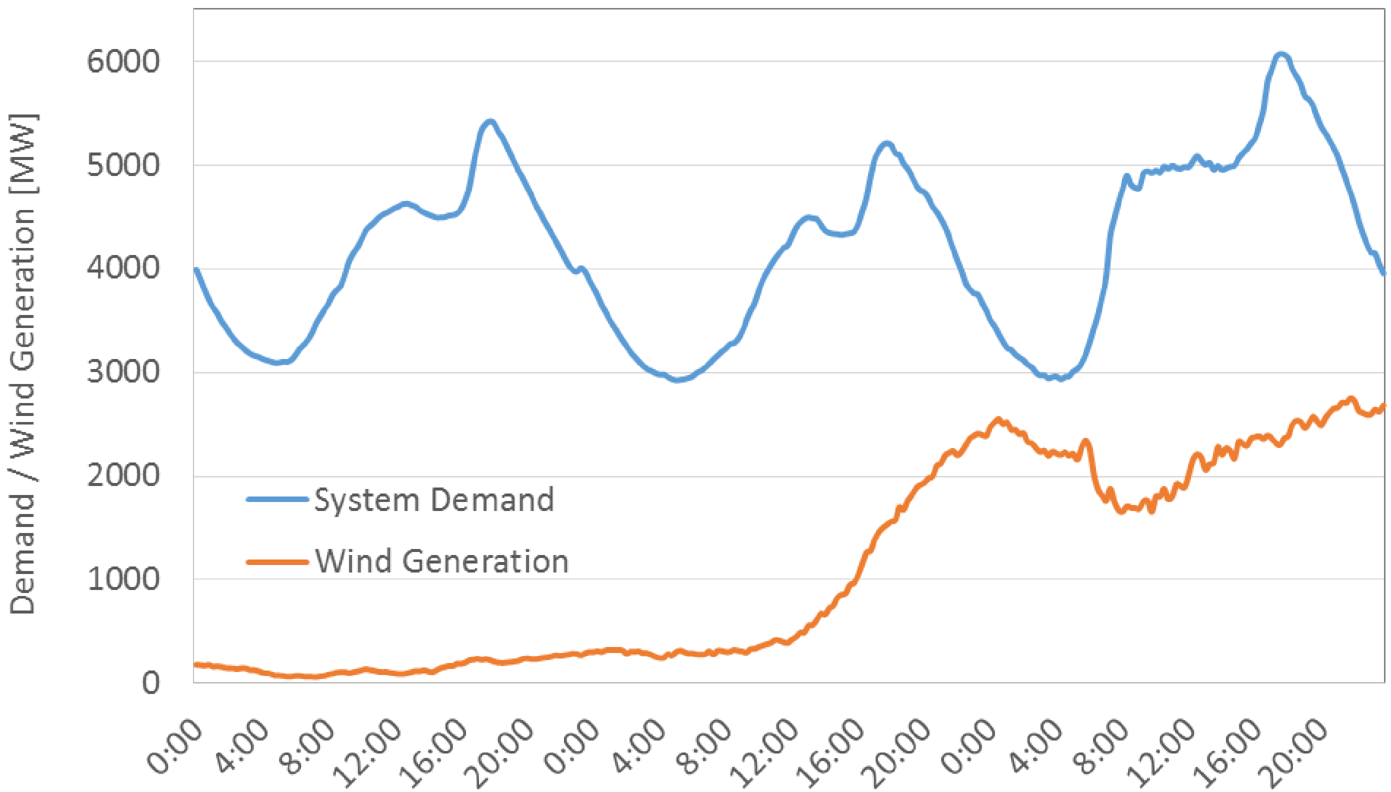
- TSO
- Regulator
- Project developer



VRE characteristics that influence the long-term investment decision

- Dependent on weather conditions
  - Change quickly
  - Limited predictability
- Site specific quality
- Generators are non-synchronous

Variability – lack of correlation with demand



Good solar and good wind are not guaranteed when needed
Too much generations when not needed

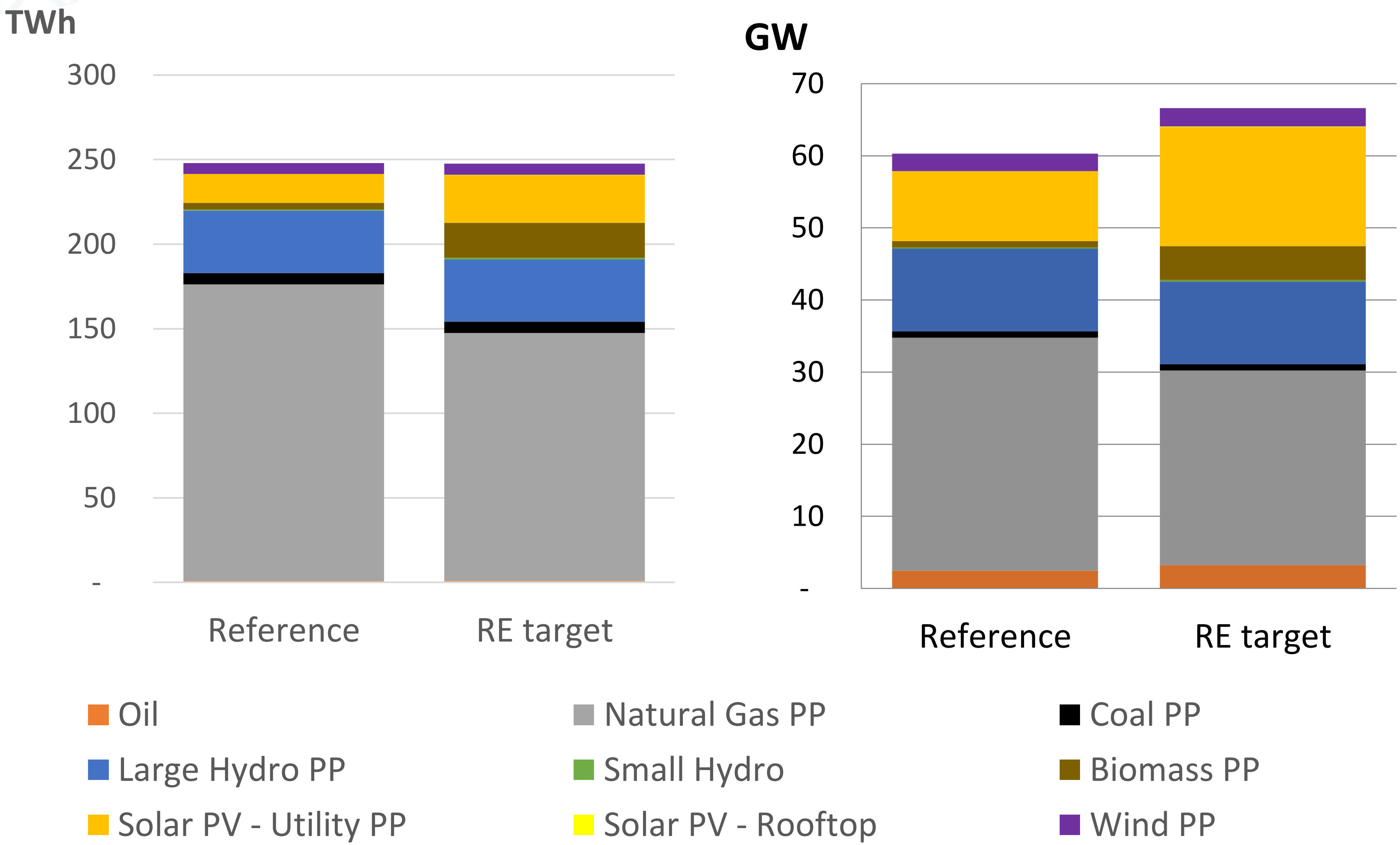
Back

Source: http://www.eirgridgroup.com

More capacity is needed to meet the same demand

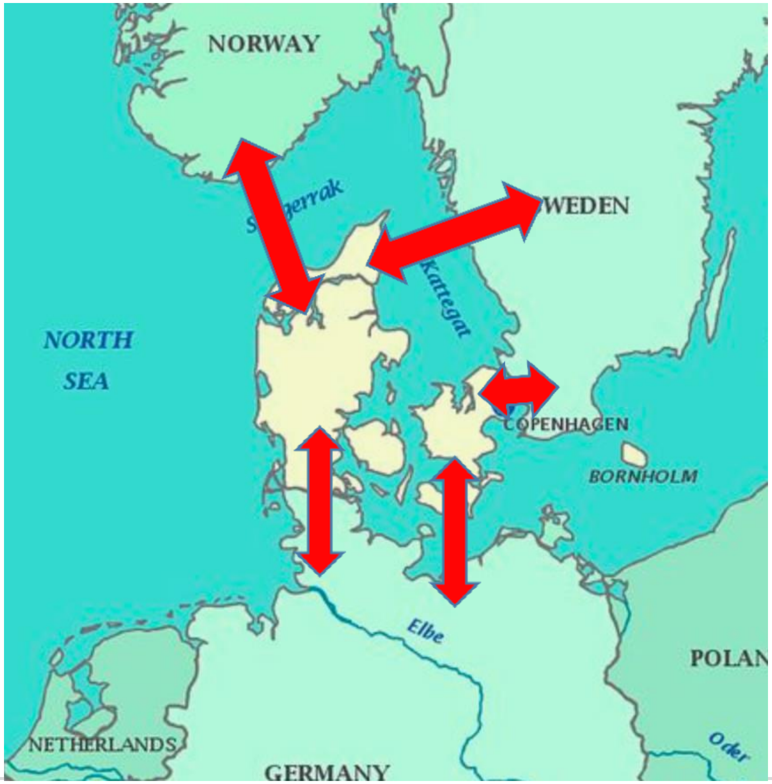
2030 scenarios for West Africa

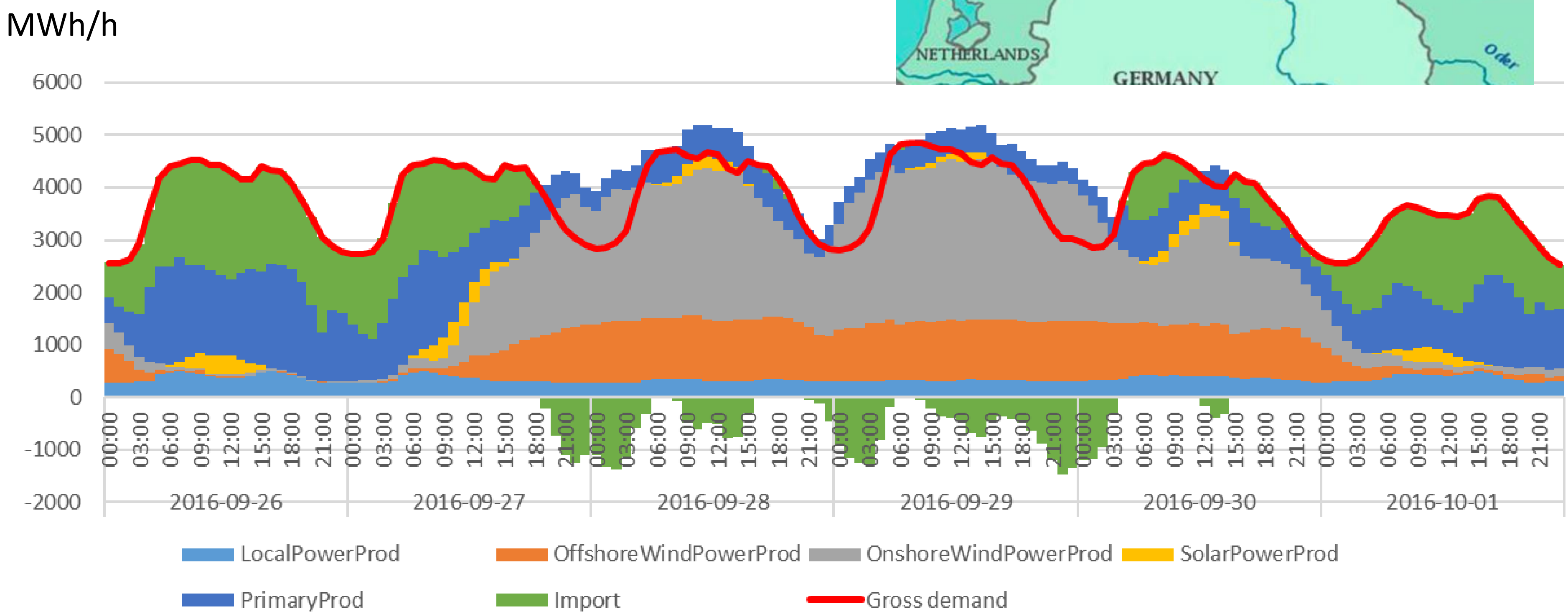
And utilization rates of thermal generators get reduced



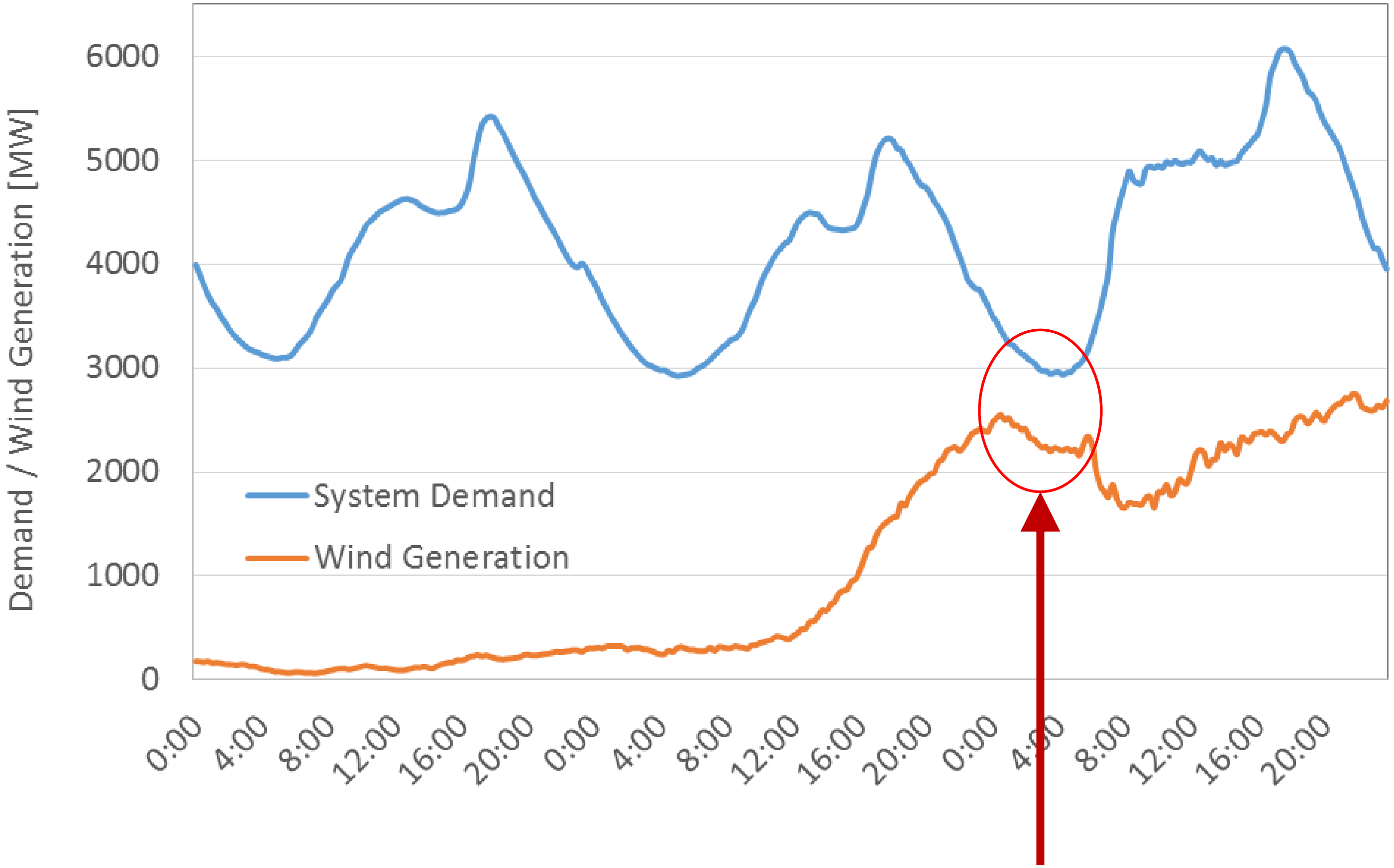
Interconnector

Balancing through trade
Eg. Denmark





Operational constraints (stability)



High instantaneous penetration levels, security & stability of the system must be ensure

→ **This may lead to curtailment**

Stability of a power system

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- Synchronized generators (fossil generators, large hydro, CSP) conventionally provide grid stability (support recovering from the disturbance)
- Having a fewer synchronized generators pose a challenge to a grid stability
- New engineering solutions are avaiable – but not all are economical

Source:

Variability – fast changes in generation

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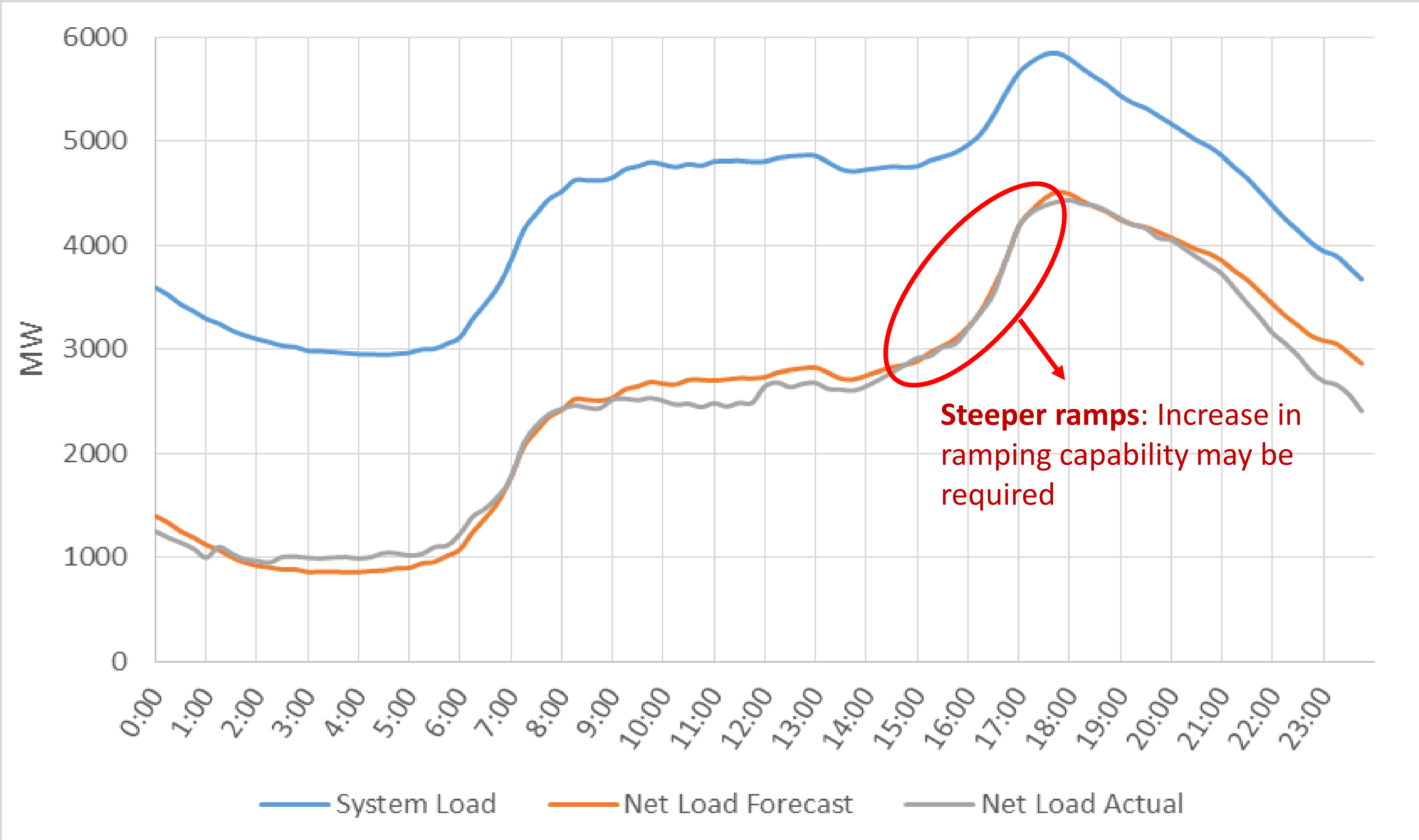
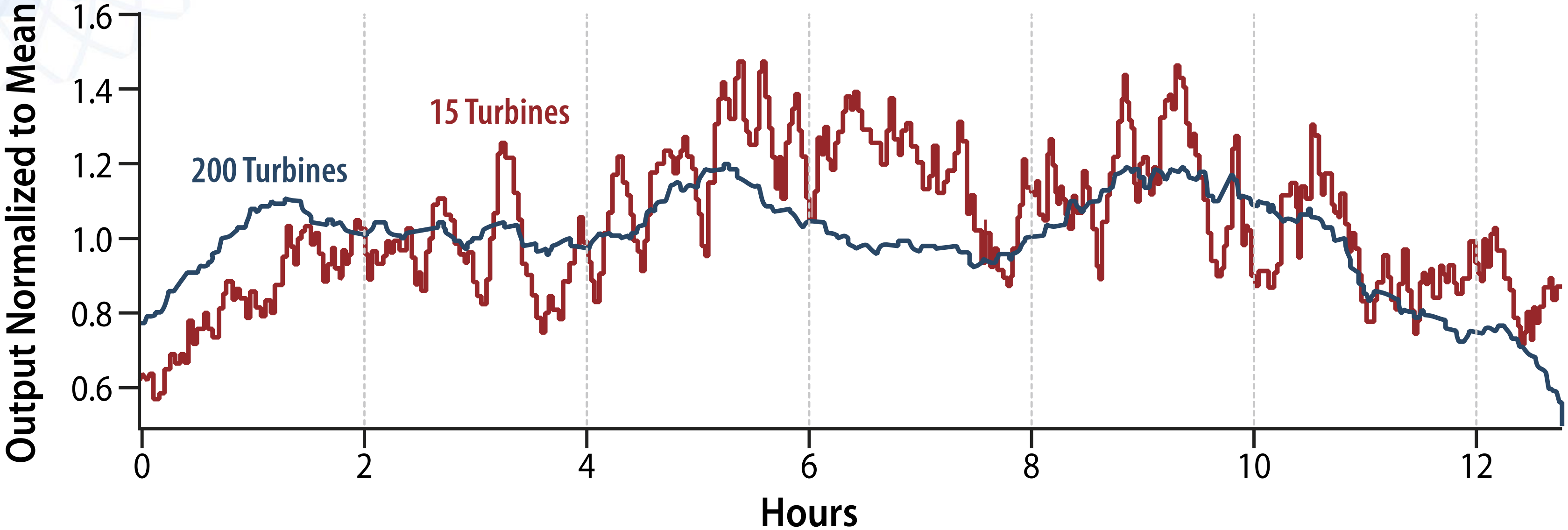


Source: www.eirgridgroup.com

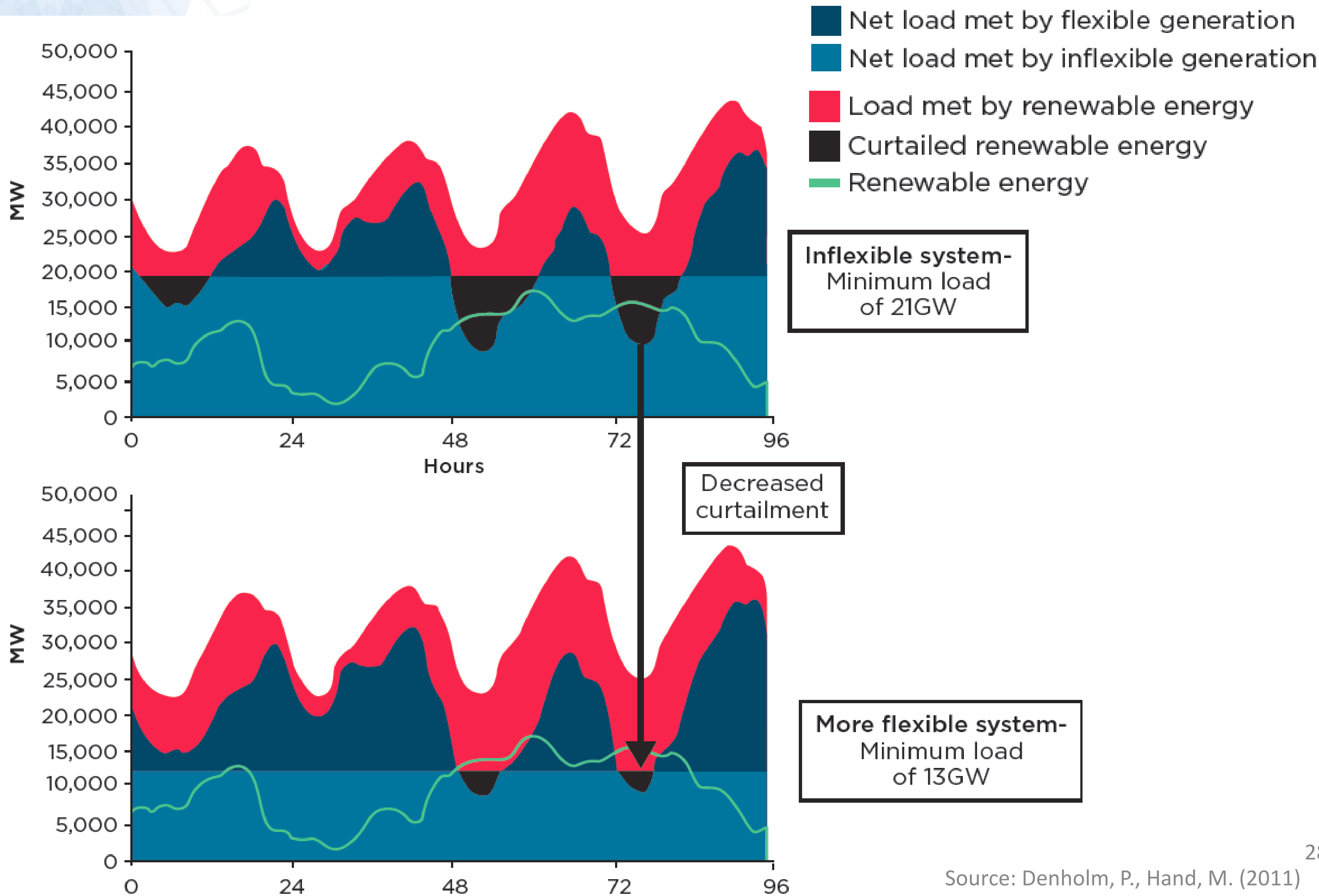
Aggregation and geographic diversity



Source: NREL/FS-6A20-63037

… can smooth out variability

Flexibility of a system matters



Source: Denholm, P., Hand, M. (2011)

Flexible thermal generation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News

The CEM Launches New Advanced Power Plant Flexibility Campaign

Thursday, June 08, 2017

ADVANCED POWER PLANT FLEXIBILITY

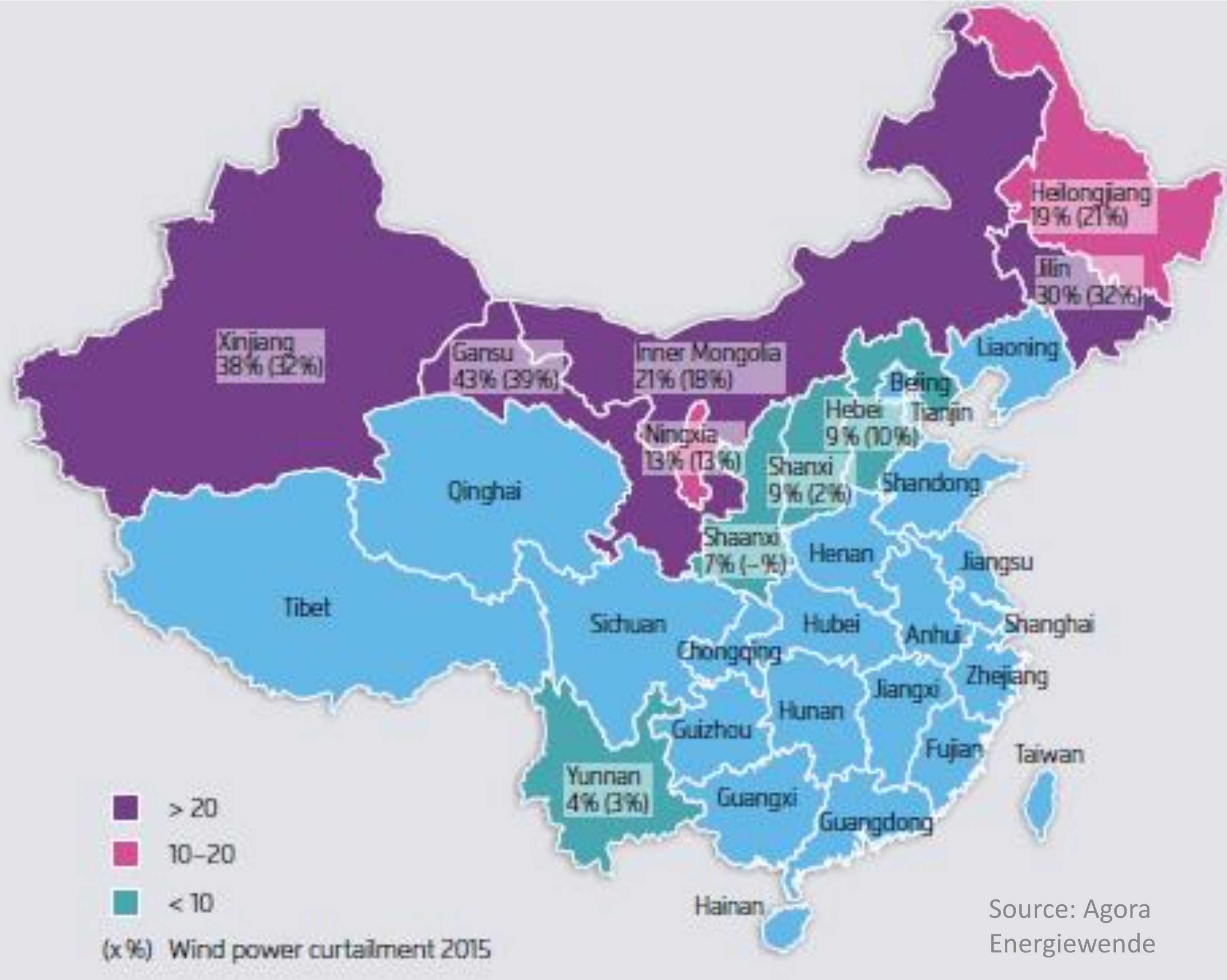
- Higher speed of output change
- Lower minimum generation level
- Shorter start up time

Location specificity

Case study: China wind curtailment 17% on average in 2016 with less than 5% VRE generation

A combination of market design and technical factors causes high levels of curtailment:

- Wind resource in NW, demand in East
- Guaranteed operating hours for coal plant and fixed prices – no flexibility
- Lack of transmission capacity
- Provincial level power system balancing



Source: Agora Energiewende

Overcoming technical and operational bottlenecks

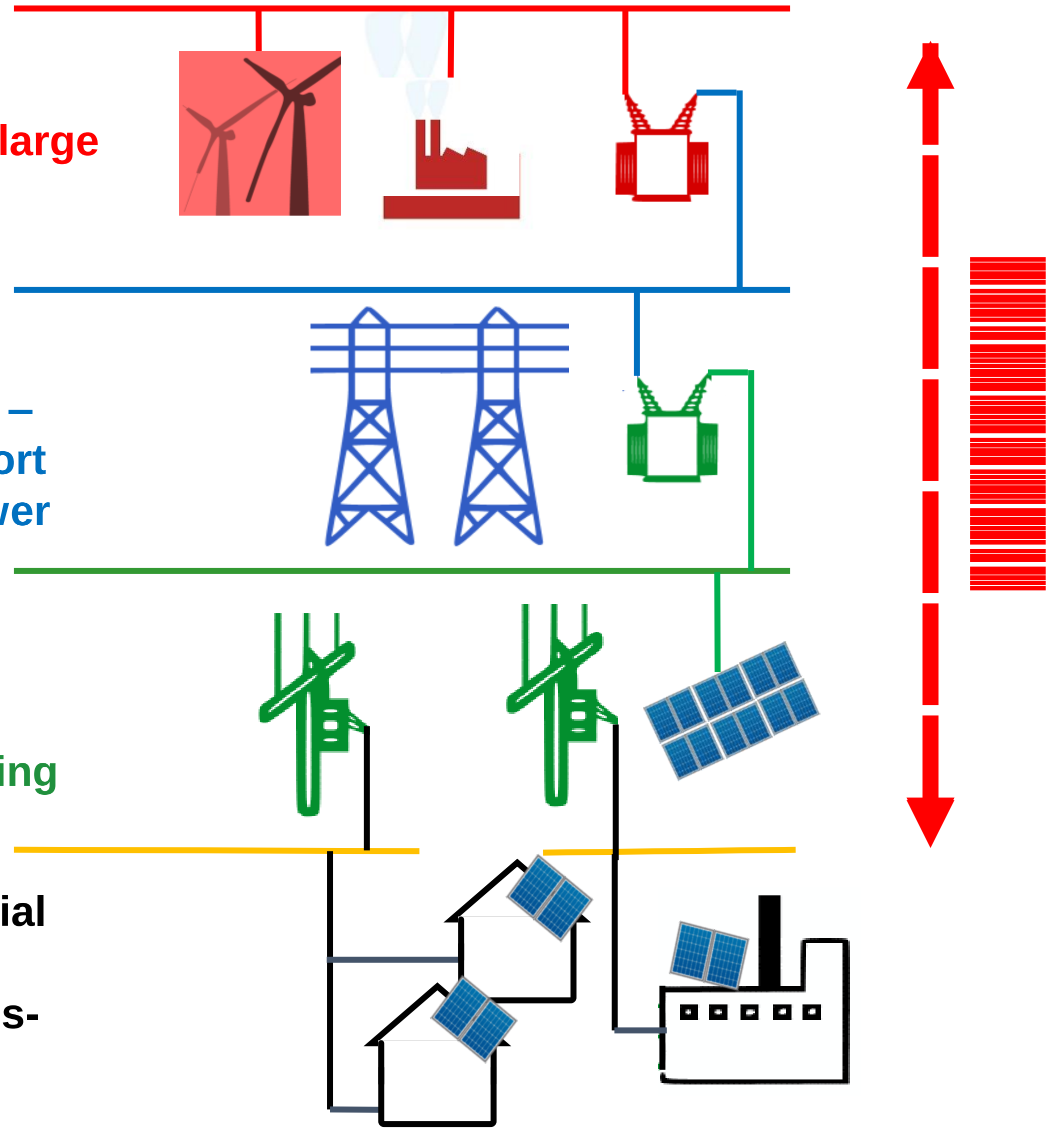
The transformation of the power system

Centralised Power Generation including large scale VRE

Power Transmission: High Voltage Network – Long distance transport of large blocks of power

Power Distribution Medium/Low Voltage power delivery including VRE

Residential, commercial industrial customers Different voltage levels- Distributed VRE



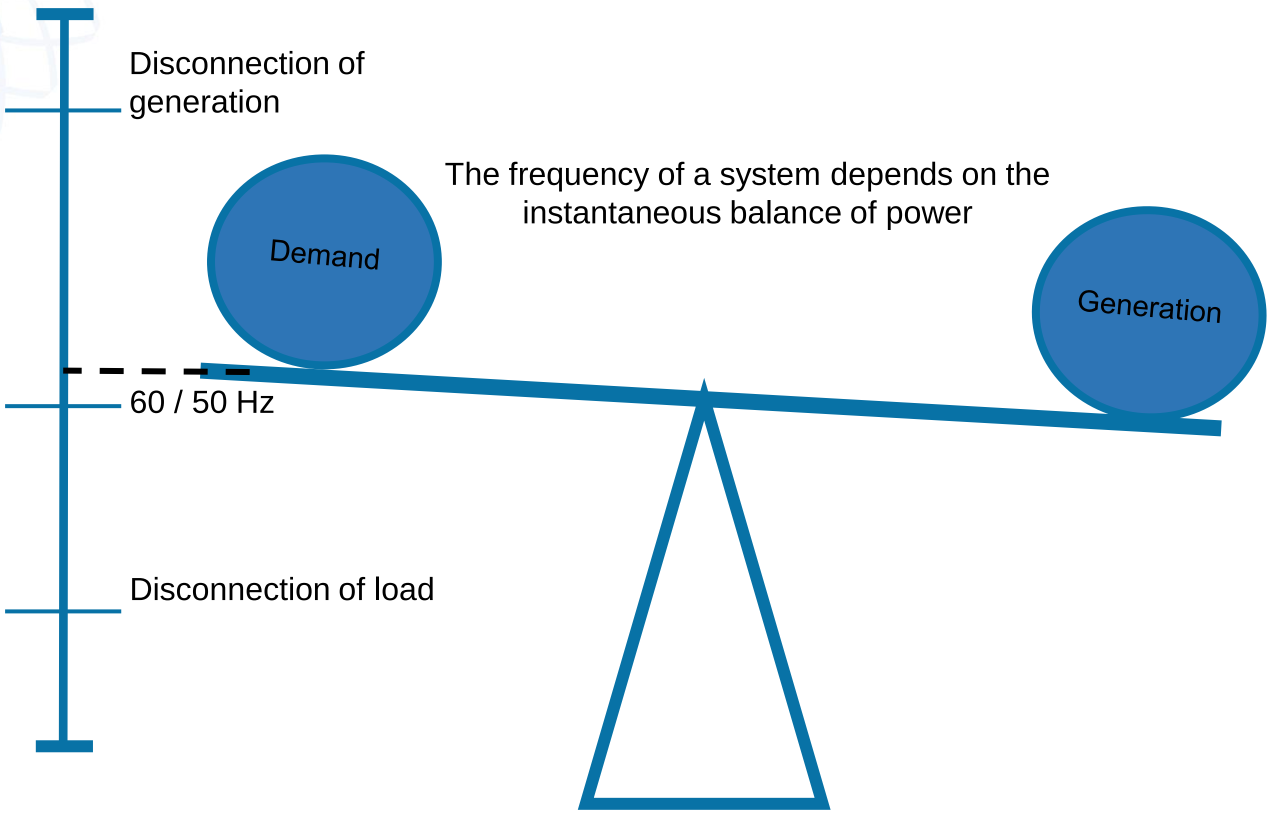
The technical Challenges

How to develop the system to maximize the value of VRE generation as it comes - and still ensure the security of supply?

Preconditions for secure system operation:

- ✓ Availability of power to cover demand (adequate generation fleet)
- ✓ Adequate network and associated infrastructure
- ✓ Availability of ressources to cover system imbalances in the operational hour
- ✓ System stability

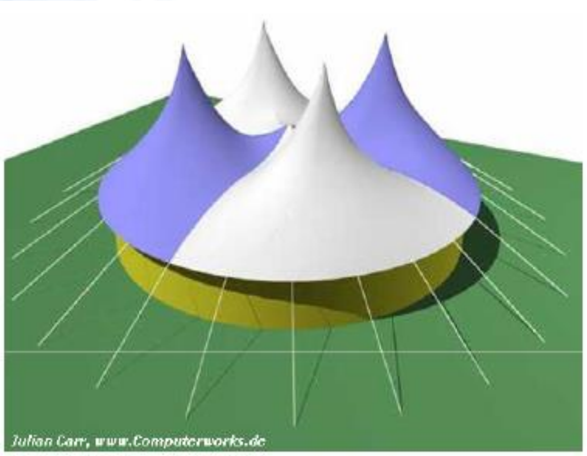
Frequency Control

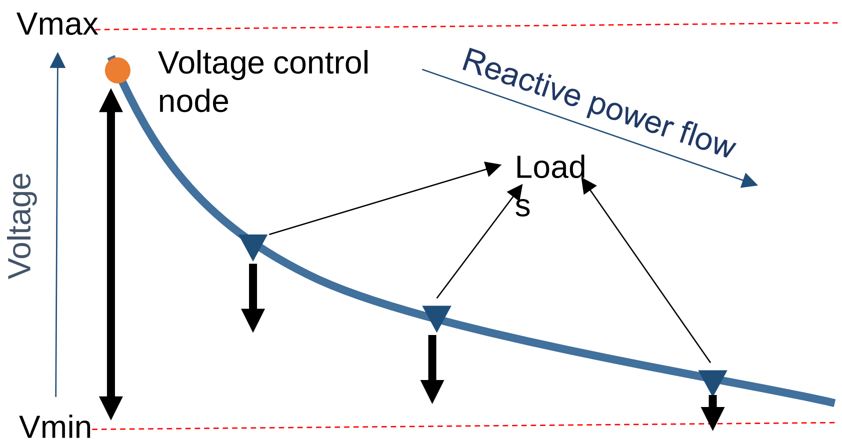


System operators schedule generation resources to meet demand, however 100% accuracy is not possible

flexibility to rapidly adapt schedules to changing conditions and **regulating reserves** to cover unavoidable deviations are necessary

Voltage control

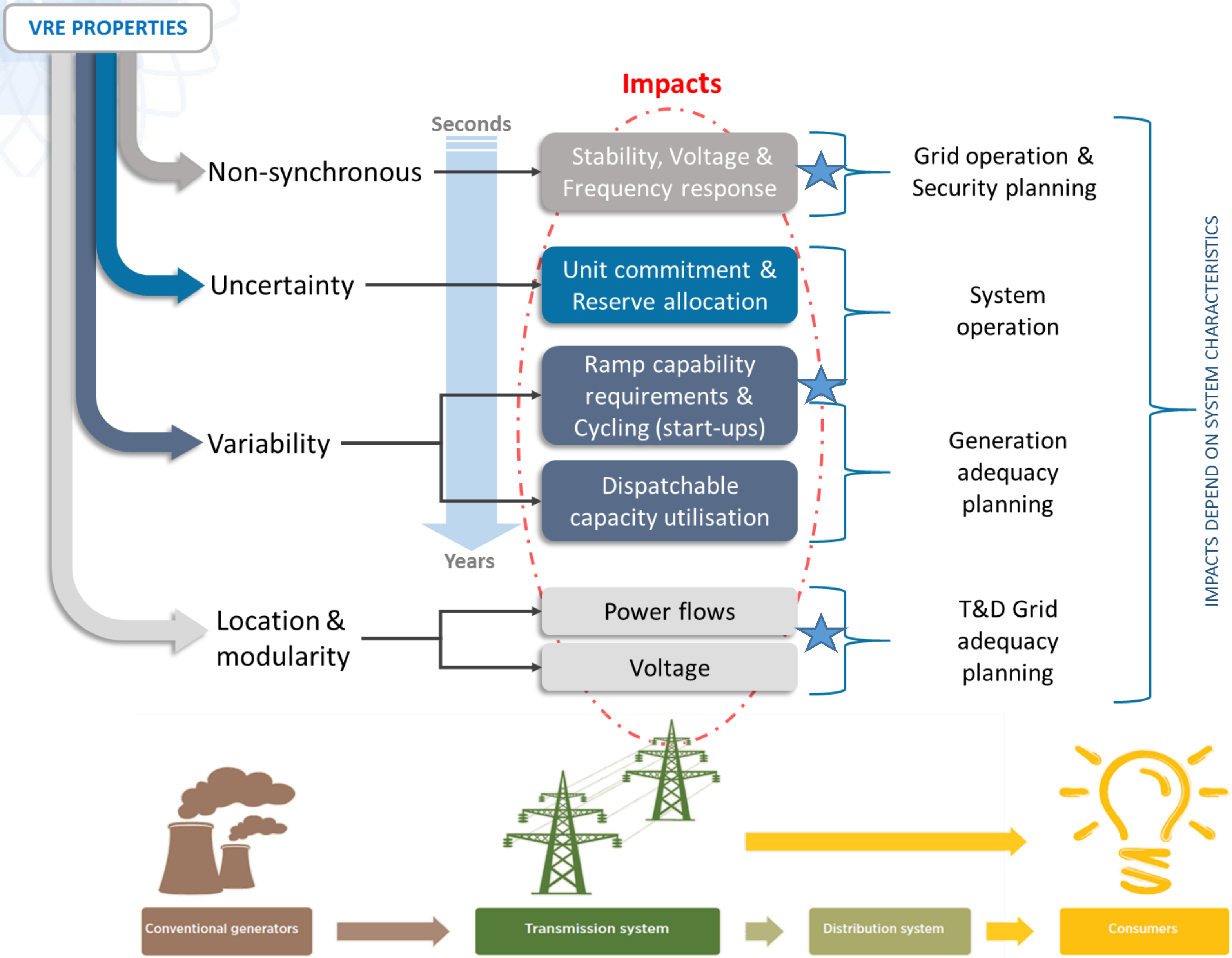




Injection of active power also affects voltage → higher influence in distribution networks (i.e. PV in distribution feeders affect voltage)

- Voltage at terminals of connection of equipment must be within acceptable limits (i.e. +/- 10% of nominal voltage)
- Voltage control is achieved by production and absorption of reactive power
- Reactive power sources:
  - Generators, capacitor banks, underground cables
- Reactive power sinks:
  - Generators, reactors, motors, transformers
- Methods of Voltage control:
  - Generator AVR
  - Controllable sources or sinks of reactive power (i.e. capacitor banks, SVC, STATCOM, etc)
  - Regulating transformers (i.e. tap changing transformers)

The technical Challenges



Solutions for the recognised issues are already in place

- Provision of grid services from VRE
- Strong transmission grids.
- Interconnection with neighbour systems.
- Flexible conventional generation.
- Storage/ demand side management.
- Specialised forecasting and operational planning tools
- SmartGrids to SmartEnergy to optimize RES utilization across energy sectors and support price flexibility
- …

Looking forward for new innovative solutions

Planning the secure operation of the power system

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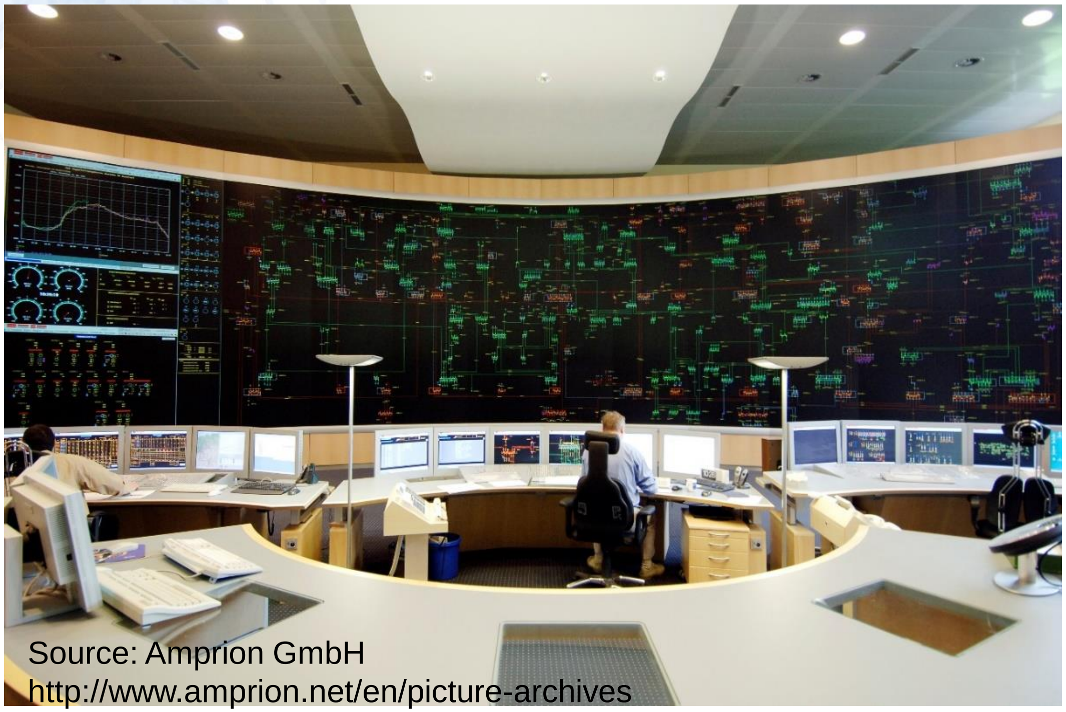


Source: Amprion GmbH
http://www.amprion.net/en/picture-archives

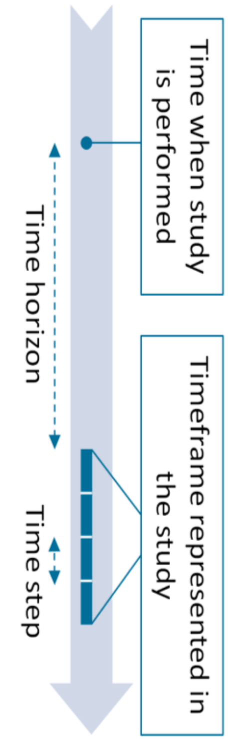
Long term generation adequacy planning

Long term grid adequacy planning

Update of operational constraints / reserve requirements

Outage planning and programming

Day ahead generation scheduling & Security Checks



Real time operation

- Power system operation and planning aims to provide a **reliable** and **efficient** supply of electricity at any time.
- Operation of the power system is a very **complicated and critical task** that must be supported by a **strong planning process.**

Engagement with Member Countries

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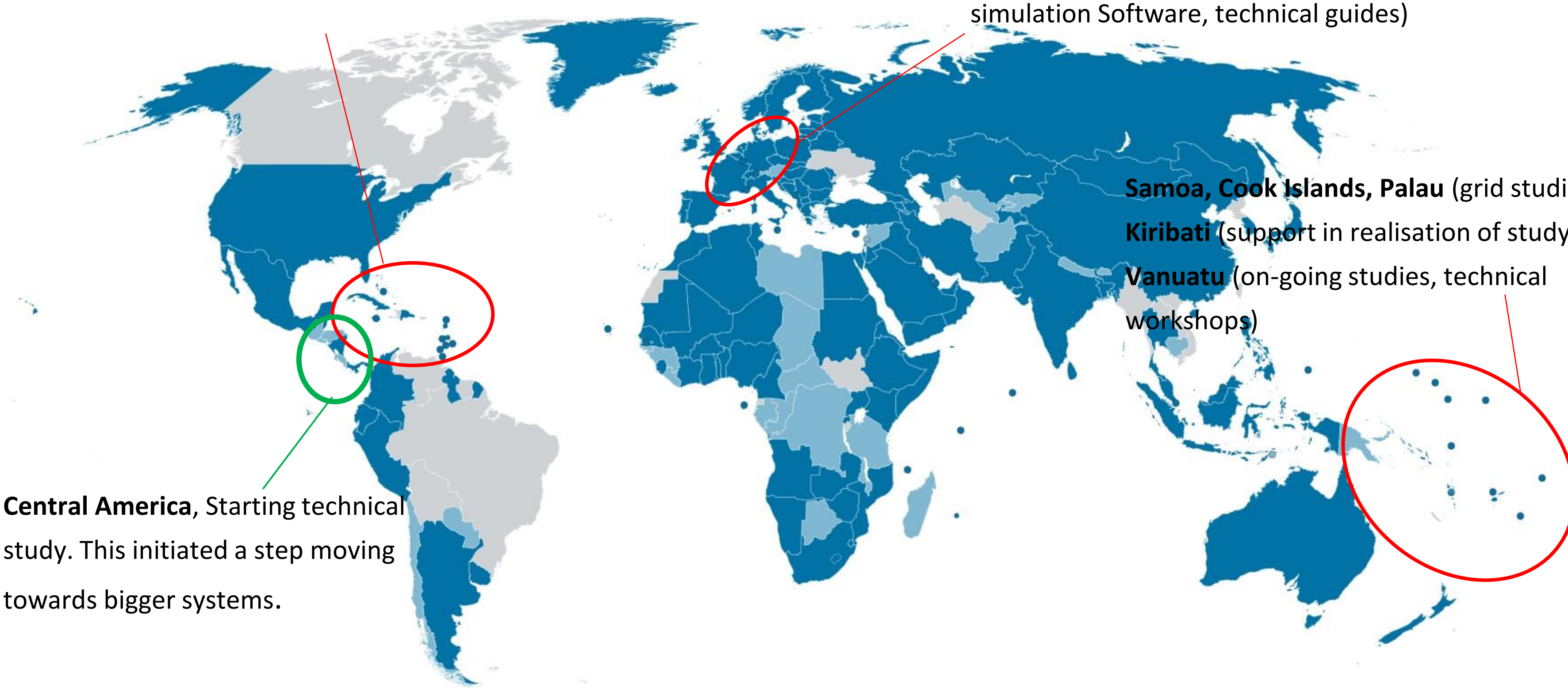
Cooperation with decision makers, network operators and technical experts at a global level supporting exchange of experiences on grid operation & expansion – Until now focus on small islands but moving towards larger interconnected systems

Dominican Republic (grid study**), Antigua & Barbuda** (grid study), **Barbados** (revision of studies), **CARILEC** (technical workshops), **CUBA** Workshop Planning and Operating the Electricity System

DIgSILENT, TU Darmstadt, TRACTEBEL-ENGIE (Access to simulation Software, technical guides)



Samoa, Cook Islands, Palau (grid studies), **Kiribati** (support in realisation of study), **Fiji, Vanuatu** (on-going studies, technical workshops)

Central America, Starting technical study. This initiated a step moving towards bigger systems.

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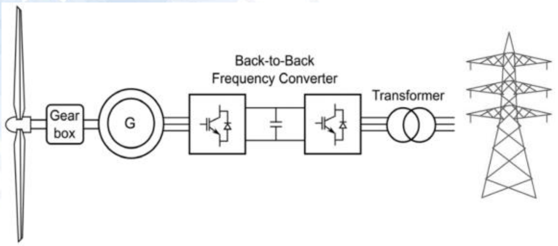
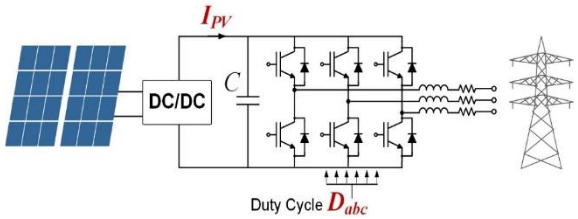
Different interaction with the grid

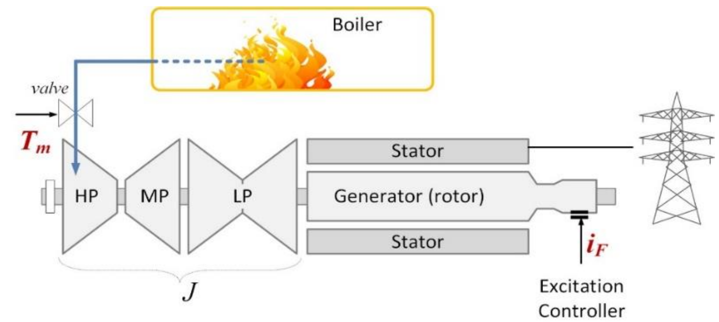


Solar power plant



VS

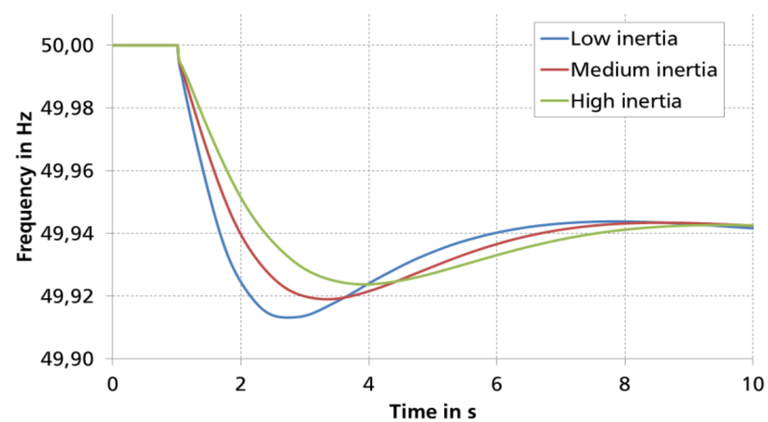
Conventional power pant



Source: CPES Virginia Tech

- Physical principle, and included interface between the grid and the source of energy is different.
  - Robustness of the system and capability to control frequency and voltage may be affected (stability).
- **Minimum grid performance requirements and technical assessment to identify security threads are required.**

Inertia



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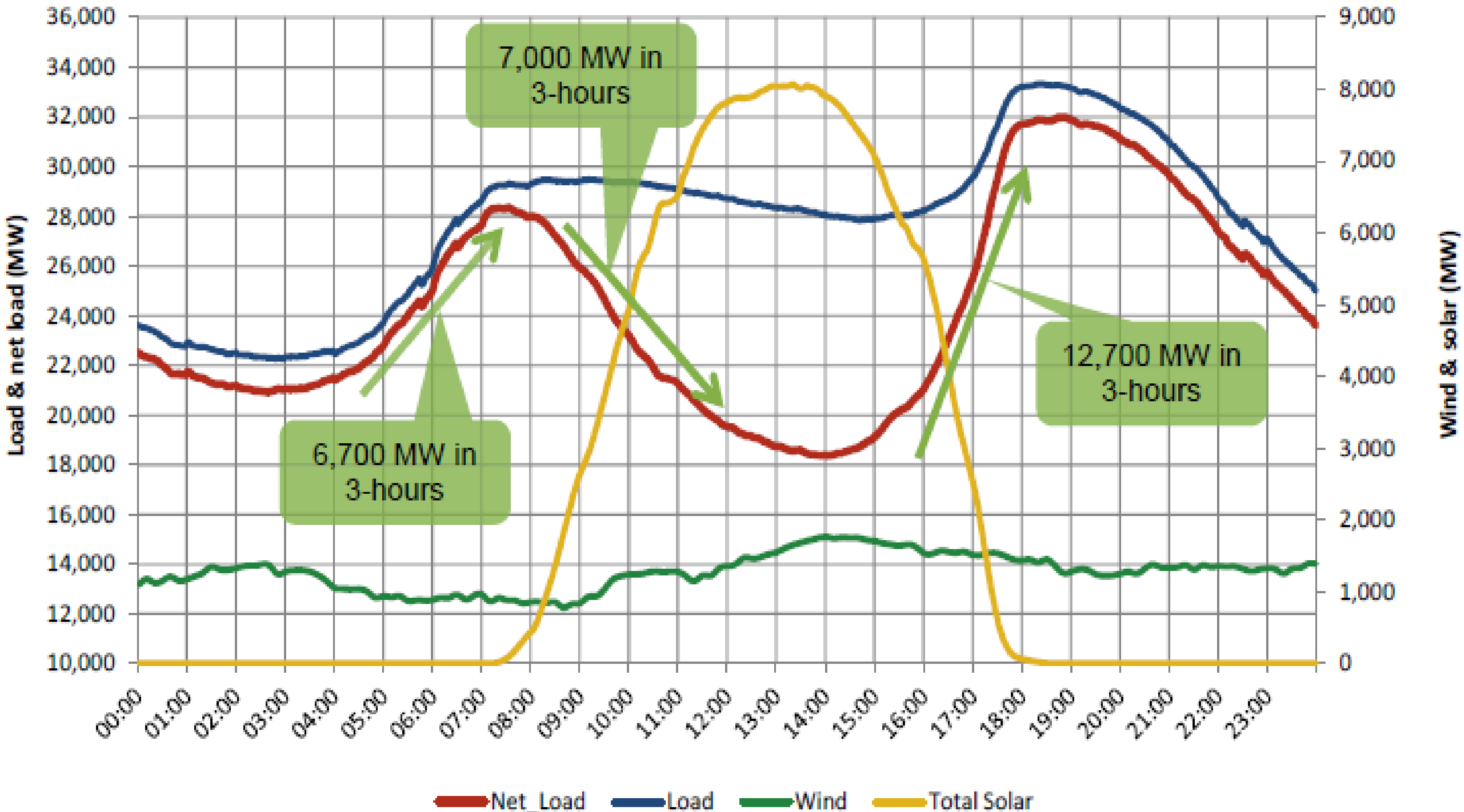
Source:

VRE properties and challenges example California



Source: CAISO and L. Jones

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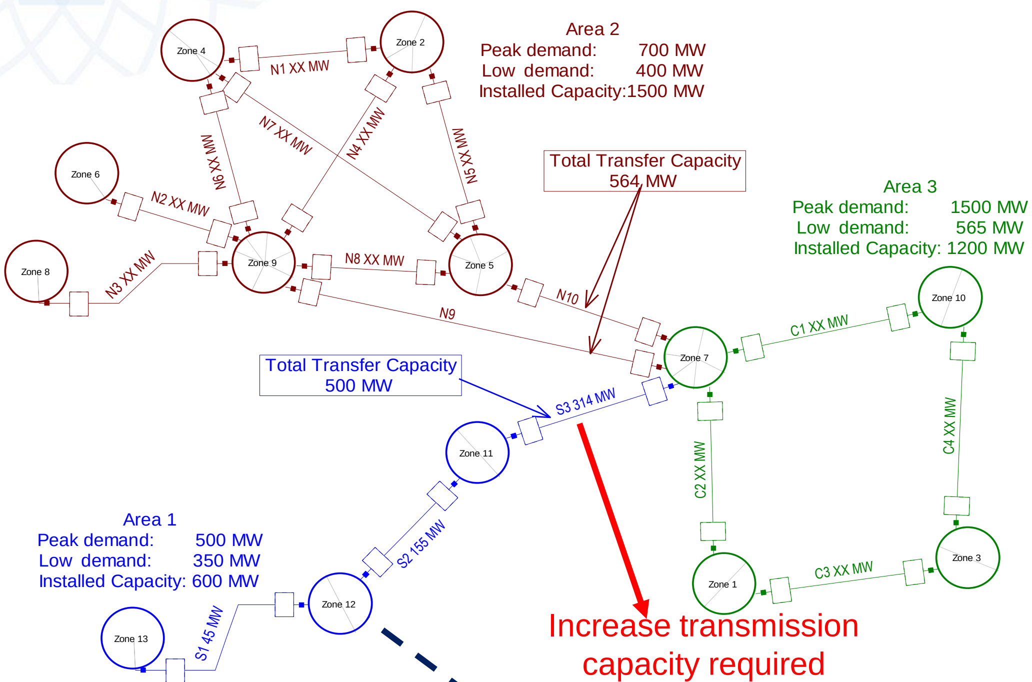
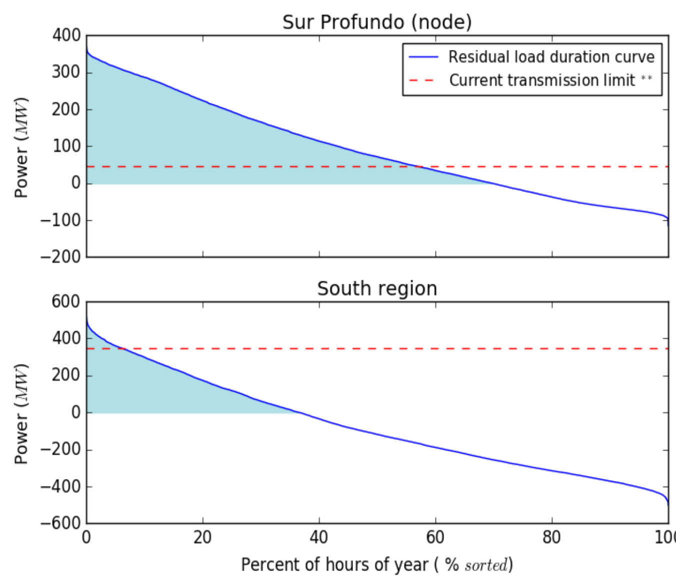
Transmission system adequacy

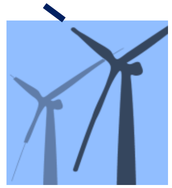
IRENA
International Renewable Energy Agency

TRANSMISION SYSTEM OVERVIEW 2016





** Source: Transmission system restrictions study for 2016-2019, OC-SENI 2015



High Wind Resources Zone identified for future development

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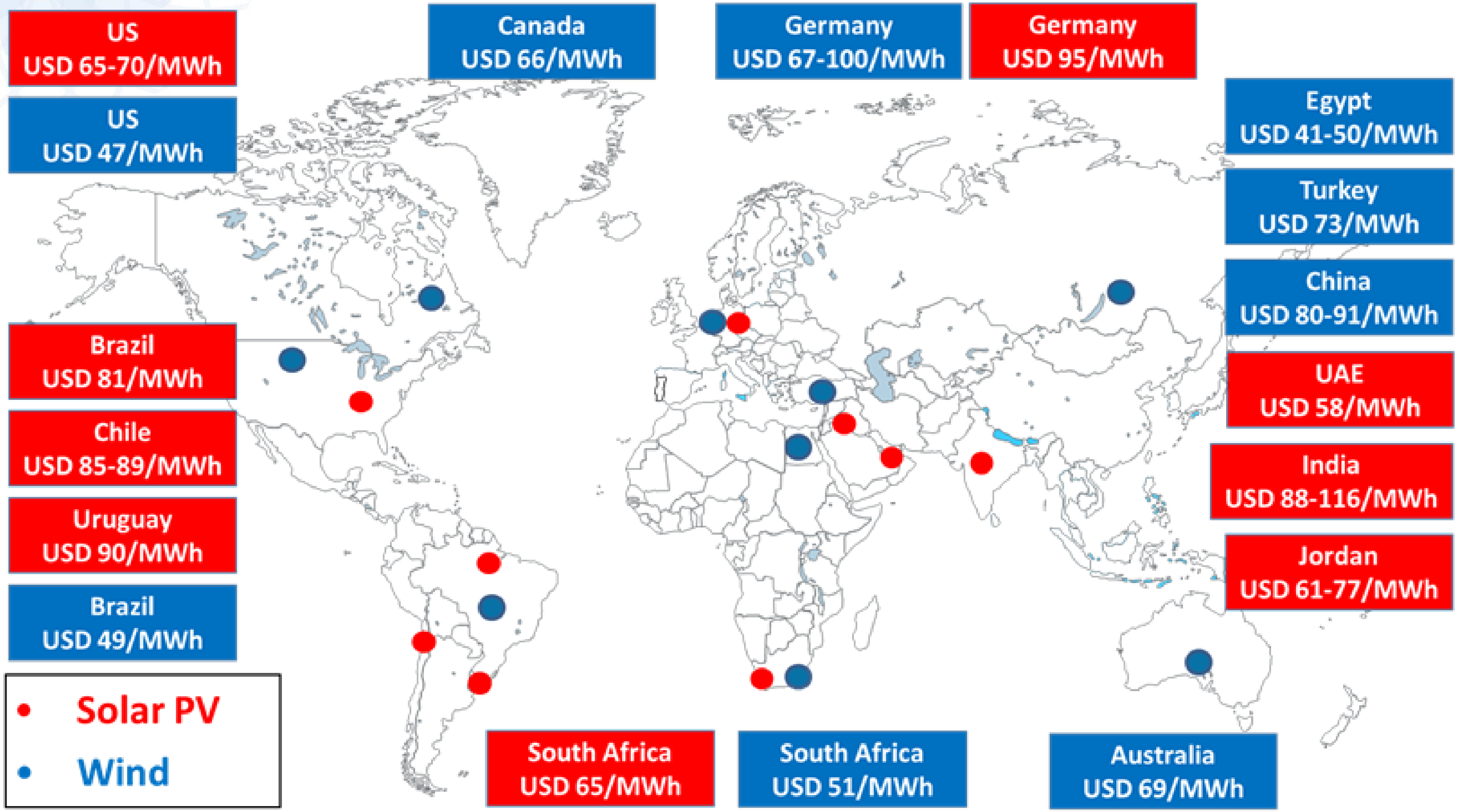
Rapidly declining costs



Source: IRENA