System Integration of Renewables

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IEEJ seminar, Tokyo, 7 August 2017

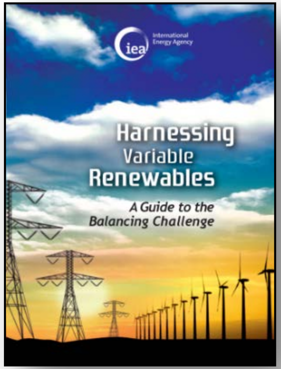
Outline

- **Overview of IEA work and introduction**
- Properties of variable renewable energy (VRE) and impact; system integration phases
- Handling challenges during initial phases
- Mastering higher shares – system transformation
  - System friendly deployment: system value and next generation RE policies
  - System and market operations / Additional system flexibility
- Distributed energy resources – the future of local grids

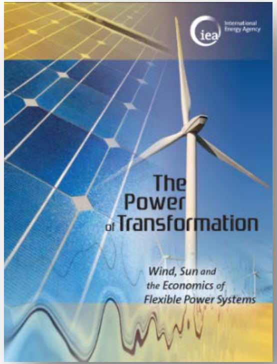
IEA System Integration of Renewables analysis at a glance

- Over 10 years of grid integration work at the IEA
  - Grid Integration of Variable Renewables (GIVAR) Programme
    - Use of proprietary and external modelling tools for techno-economic grid integration assessment
    - Global expert network via IEA Technology Collaboration Programmes and GIVAR Advisory Group
  - Dedicated Unit on System Integration since June 2016
  - Part of delivering the IEA modernisation strategy

2011	2014	2016	2017	2017

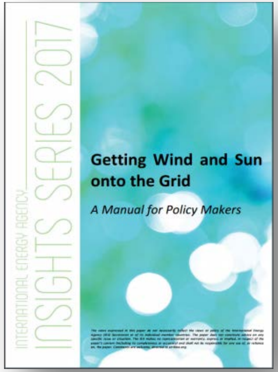


Technical

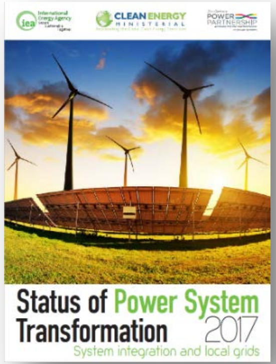


Framework, Technology, Economics

Policy



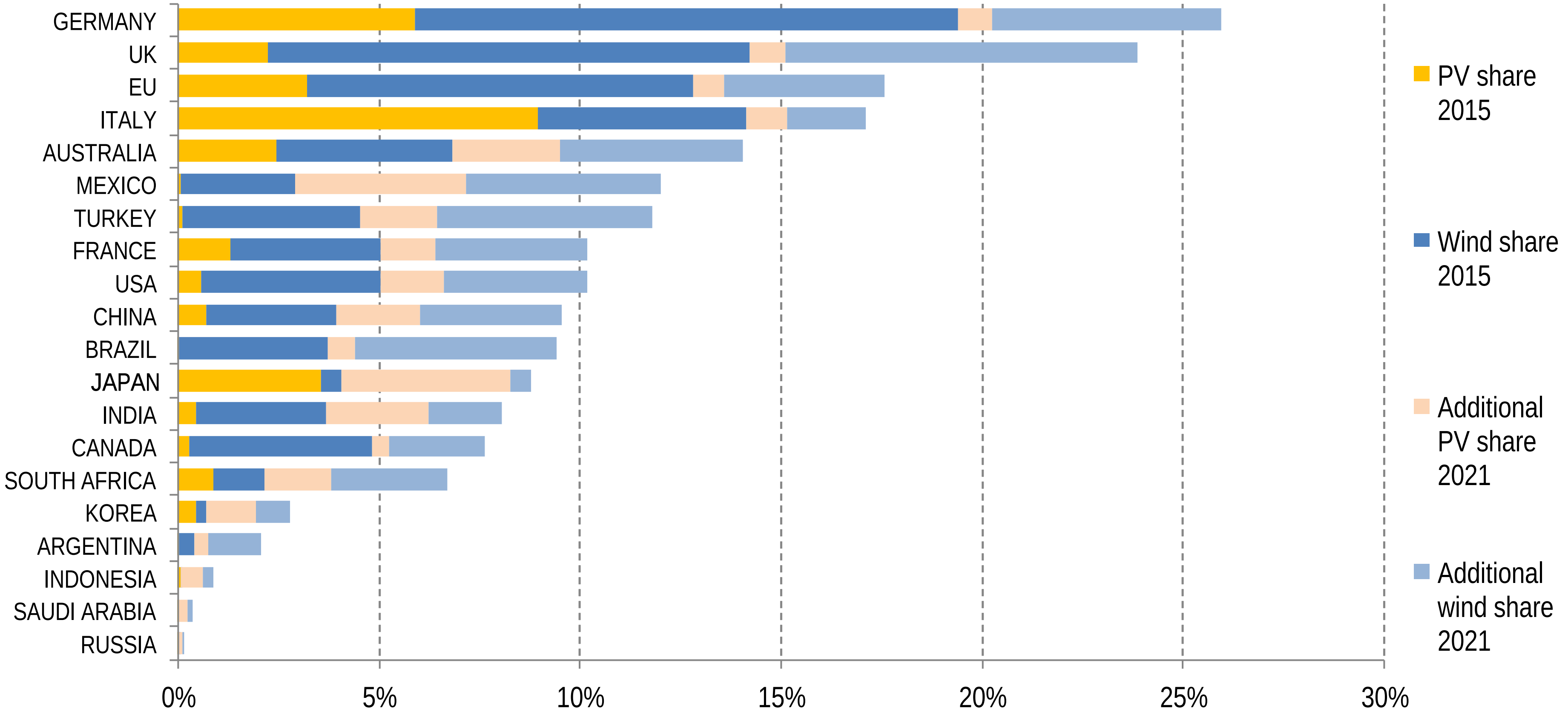
Implementation



Progress & Tracking

Variable Renewable Energy (VRE) on the rise

VRE share in annual electricity generation, 2015-21

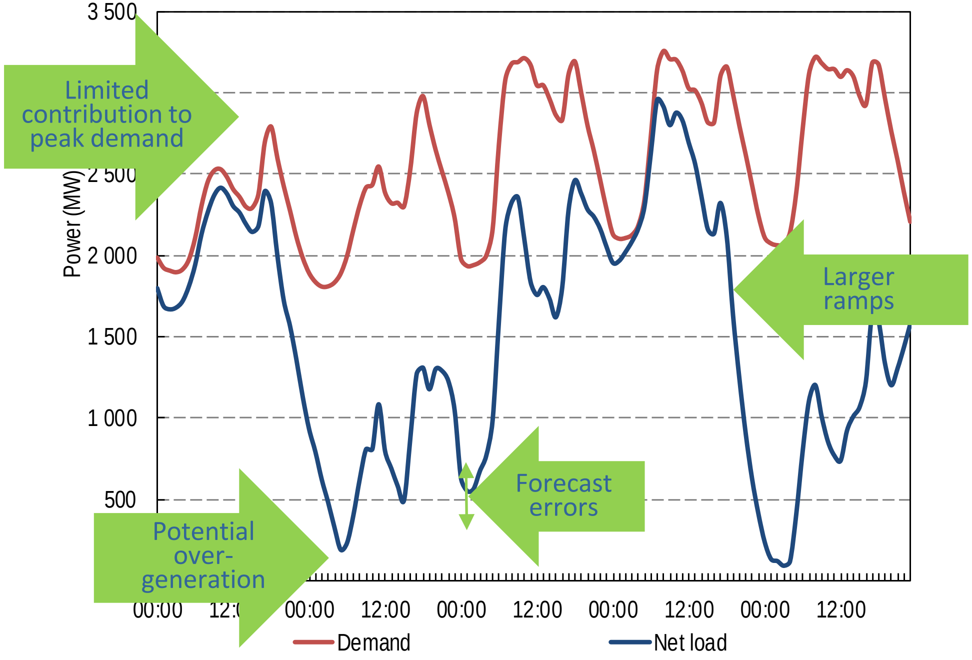


Source: Medium Term Renewable Energy Market Report, 2016

… leading to new challenges for energy security

Net load =
power demand
minus
wind and solar output

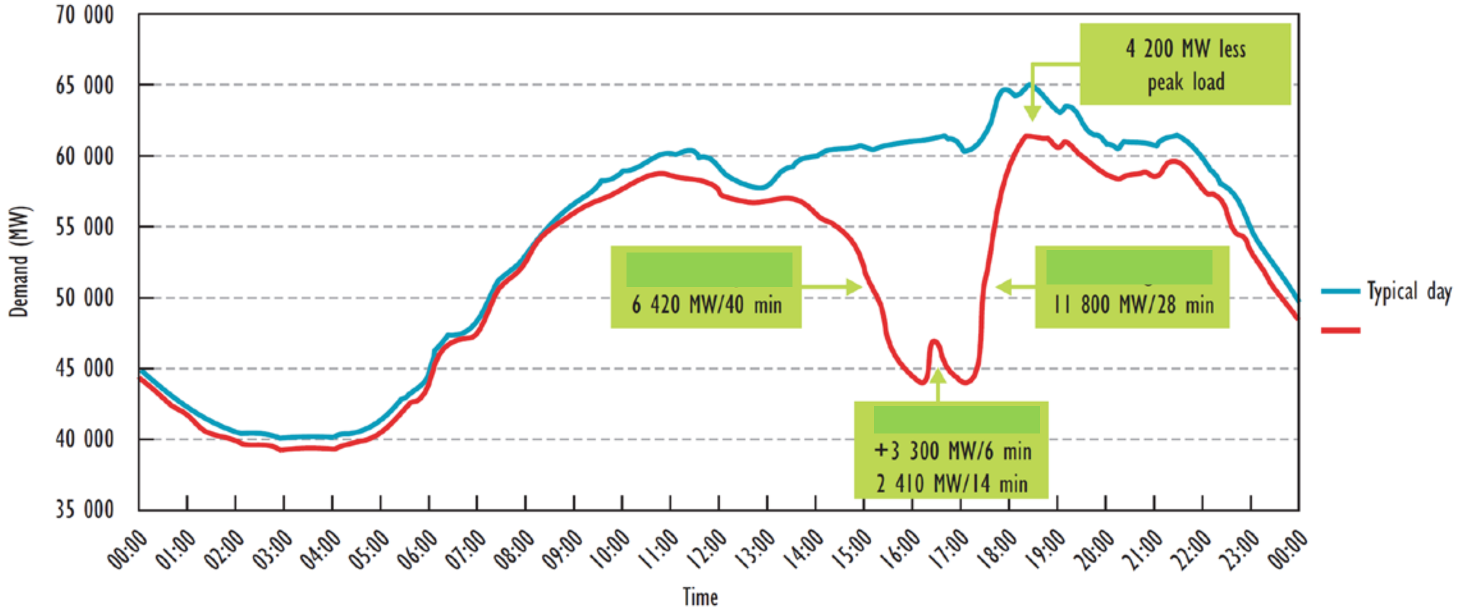
New operational requirements



Higher shares of variable renewables pose new challenges for power systems

Variability – a familiar challenge

Exceptionally high variability in Brazil, 28 June 2010

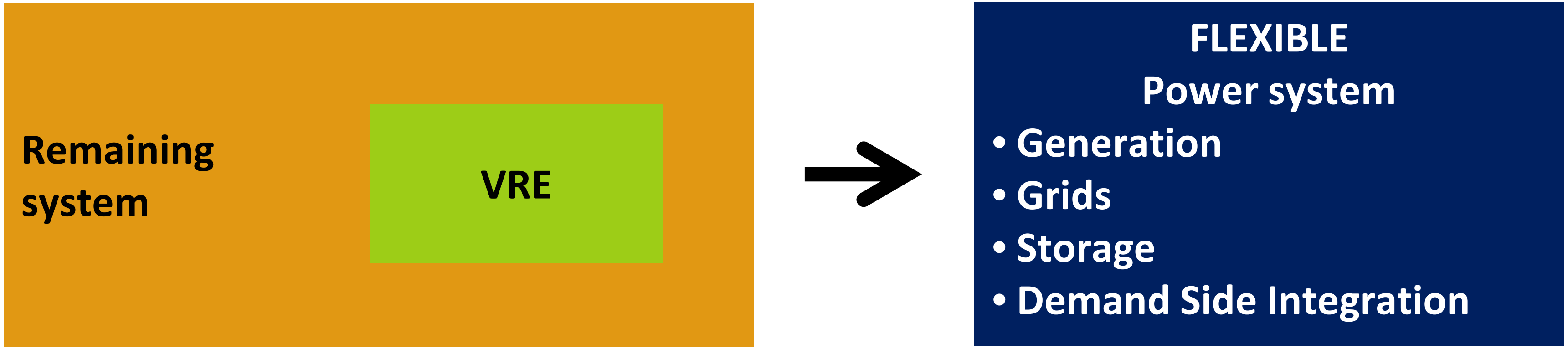


Power systems already deal with demand variability; they have flexibility available from the start.

Source: ONS, Brazil

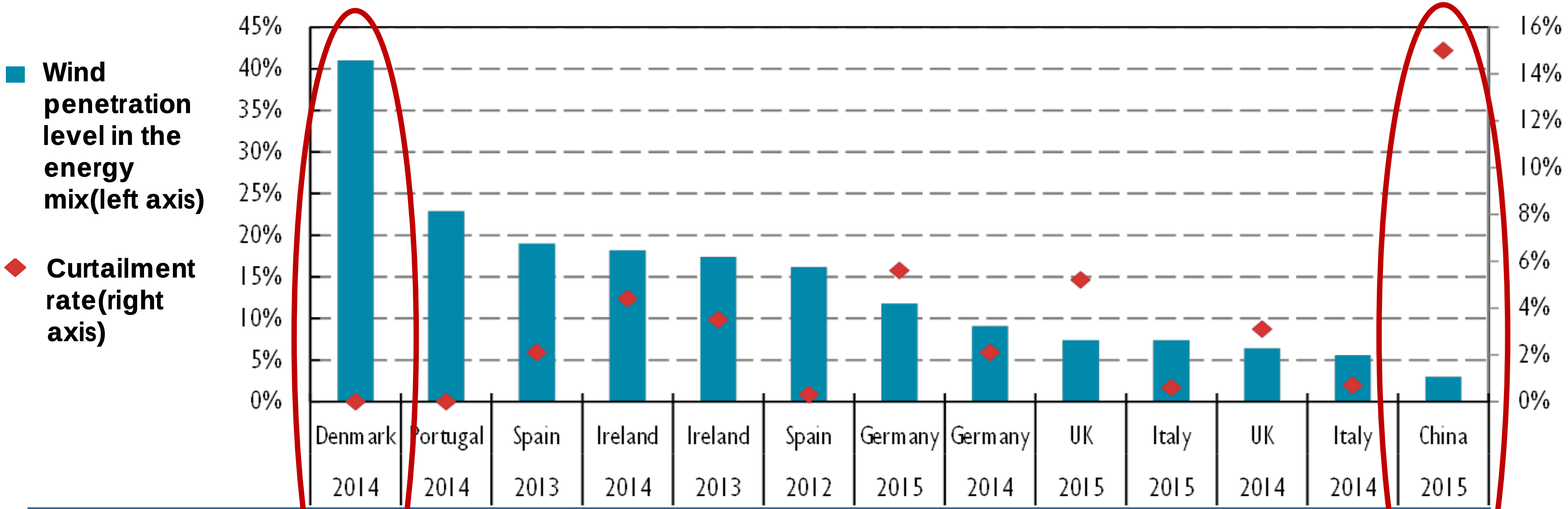
Three main messages on system integration

1. Very high shares of variable renewables are technically possible
2. No problems at low shares, if basic rules are followed
3. Reaching high shares cost-effectively calls for a system-wide transformation



System integration strategies key to use wind and solar effectively

Wind penetration and curtailment in selected countries, 2012-2015



	Denmark 2014	Portugal 2014	Spain 2013	Ireland 2014 / Ireland 2013	Spain 2012	Germany 2015 / Germany 2014	UK 2015	Italy 2015	UK 2014	Italy 2014	China 2015
Grids	+	+	+	o	+	o	o	o	o	o	o
Generation	+	+	+	+	+	o	o	+	o	+	-
Operation	+	+	+	+	+	+	+	+	+	+	-

Curtailment levels are a good indicator for successful VRE integration – growing curtailment signals shortfalls in power system flexibility

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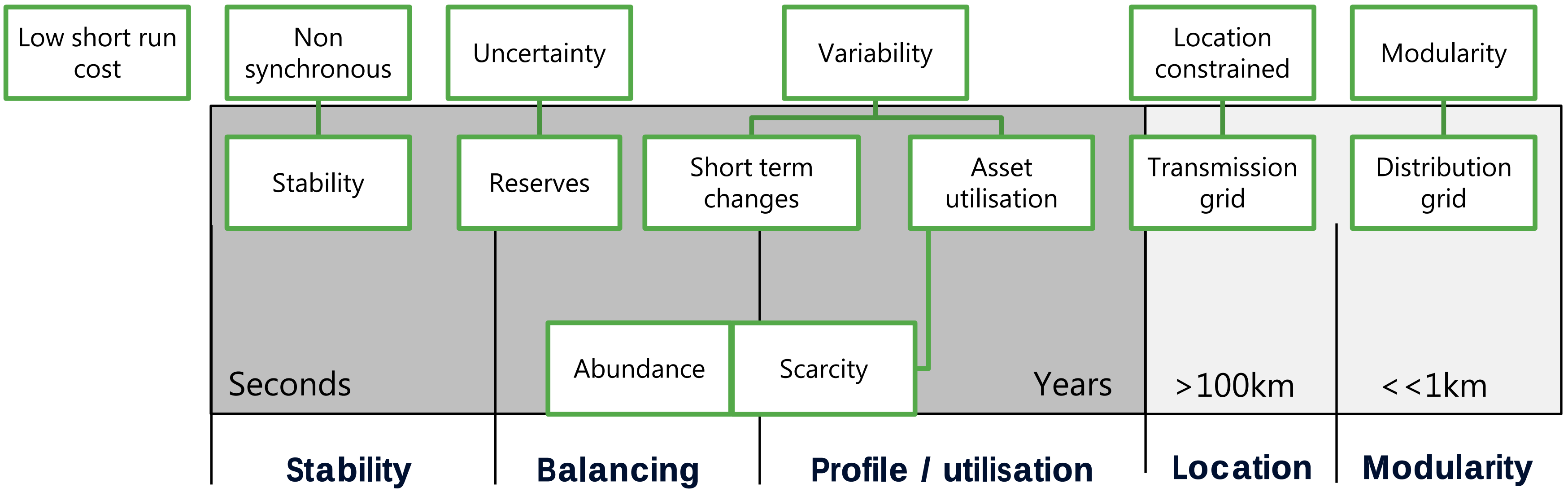
Properties of wind and solar and their impacts



The different properties of variable renewable energy lead to different impacts on the power system.

Different Phases of VRE Integration

Phase	Description
1	VRE capacity is not relevant at the all-system level
2	VRE capacity becomes noticeable to the system operator
3	Flexibility becomes relevant with greater swings in the supply/demand balance
4	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
5	Structural surpluses emerge; electrification of other sectors becomes relevant
6	Bridging seasonal deficit periods and supplying non-electricity applications; seasonal storage and synthetic fuels

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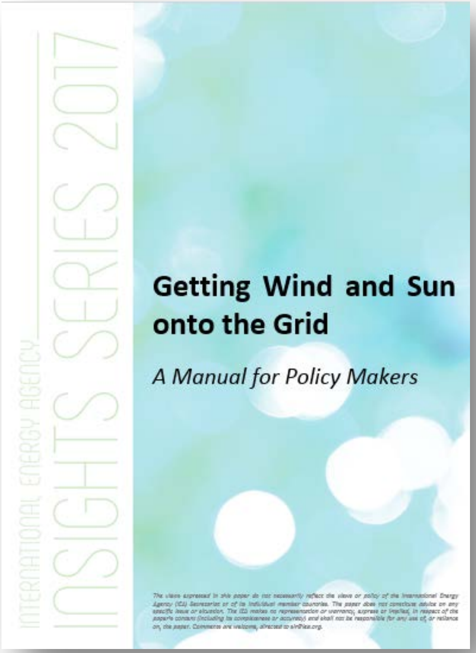
Phases 1 & 2: Getting Wind and Solar Onto the Grid

Myths related to wind and solar integration

1. Weather driven variability is unmanageable
2. VRE deployment imposes a high cost on conventional plants
3. VRE capacity requires 1:1 “backup”
4. The associated grid cost is too high
5. Storage is a must-have
6. VRE capacity destabilizes the power system

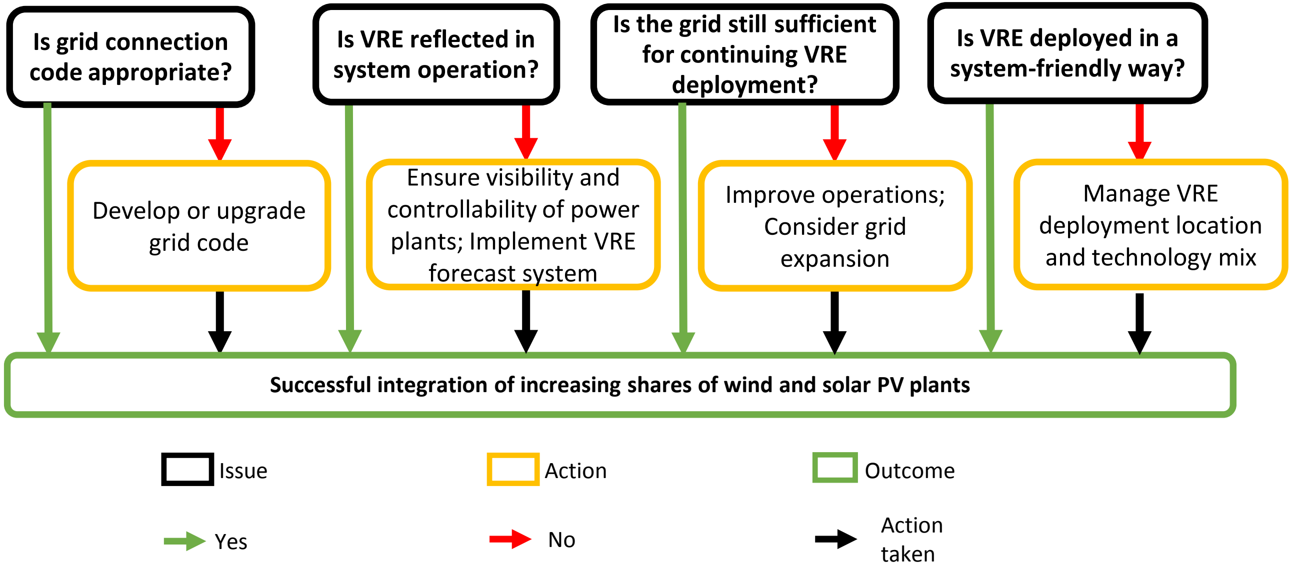
New Publication released March 2017



Focus on Phase 2 of VRE integration

- First instances of grid congestion
- Incorporate VRE forecast in scheduling & dispatch of other generators
- Focus also on system-friendly VRE deployment

Priorities for VRE Integration – Phase 2



Source: IEA 2017, *Getting wind and sun onto the grid*

Updated system operations, sufficient visibility & control of VRE output becomes critical in Phase II

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Phases 3 & 4: System transformation

Policy and market framework

Level of VRE penetration

System-friendly VRE deployment

- Distributed resources integration
- System services
- Generation time profile
- Technology mix
- Location
- Integrated planning

Actions targeting VRE

Flexible resources planning & investments

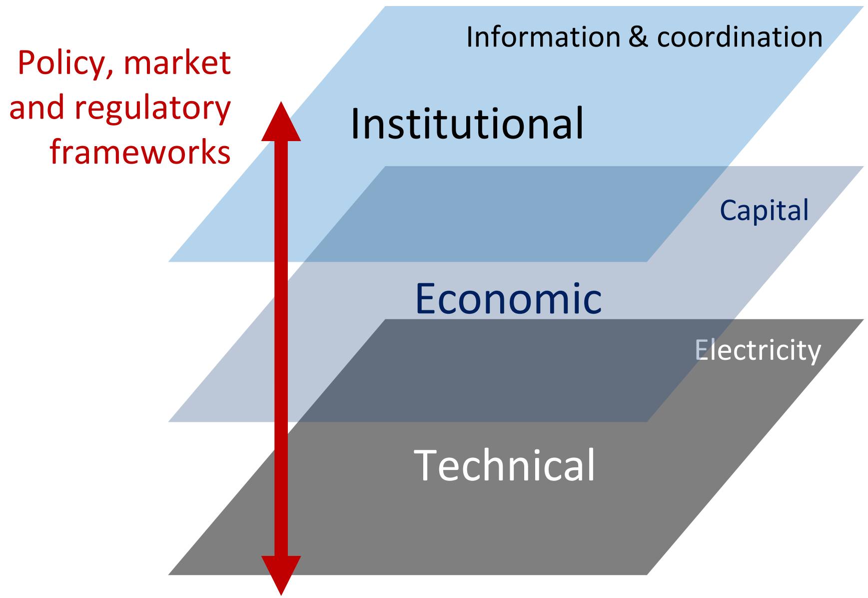
Grids | Generation | Storage | Demand shaping

System and market operation

Actions targeting overall system

Integrating large shares of VRE requires system transformation

System transformation requires holistic approach

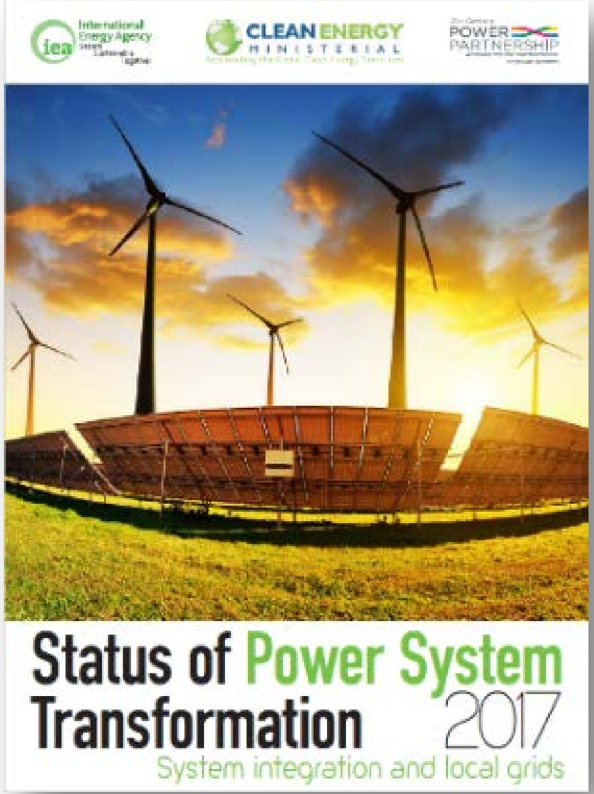


- **Institutional** – defining roles and responsibilities
- **Economic** –market design, regulation, planning frameworks
- **Technical** – operation of power system, safeguarding reliability

Policies, markets and regulatory frameworks link technical, economic and institutional aspects

Recent publication: Status of Power System Transformation 2017

- Overview of trends and developments in the power sector
  - System Integration of Renewables
  - Future of local grids
- Provides over two dozens of best practice examples for integrating wind and solar power
- Introduces a framework for assessing power system transformation, applied to case studies
  - Indonesia, South Africa, Mexico, Australia



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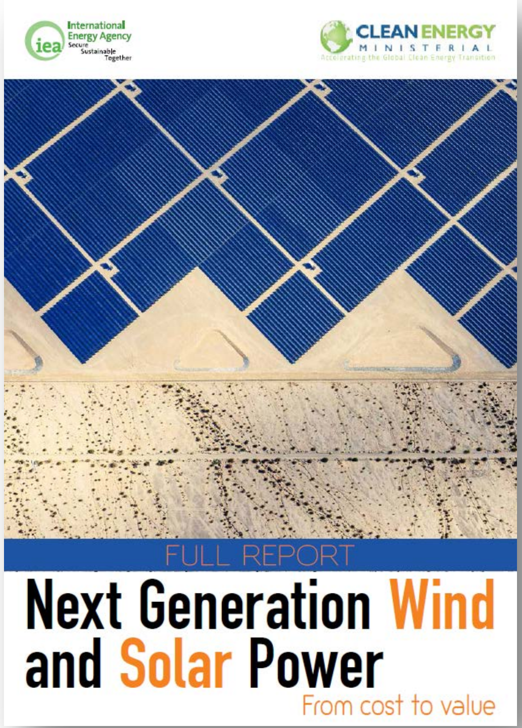
System friendly VRE deployment

- New phase of wind and solar deployment:
  - Low-cost
  - Technologically mature
- Requires new policies to achieve integration:
  - Focus on generation cost no longer enough
  - Policies need to consider system-wide impact
- Case studies with specific recommendations:
  - Brazil, China, Indonesia, Mexico, South Africa
- Strong focus on country implementation



Next generation wind and solar PV need 'next generation policies' focusing on system value and not just costs

Factoring in value

Less useful:

Lower value

More useful:

Higher value

The value of electricity for the power system depends on where, when and how it is generated.

	Low value electricity	High value electricity
When	When electricity is abundant	When electricity is most needed
Where	Far away from demand	Close to demand
How	No additional system services	Provides additional services for system

Going beyond generation costs – system value

LCOE

- Installation costs
- Operation and maintenance costs (fuel, emissions)
- Financing cost
- …

SV

+

- Reduced fuel and emission costs
- Reduced costs/ need for other generation capacity

–

- Increased operational costs for other power plants
- Additional grid infrastructure costs
- Curtailment

LCOE and System Value (SV) are complementary:
LCOE focuses on the level of the individual power plant, while SV captures system-level effects

Implications for deployment priorities

	Traditional approach	Next generation approach
When *is electricity produced?*	Not considered	Optimised: best mix of wind and solar; advanced power plant design; strategic choice of location
Where *is electricity produced?*	Best resources, no matter where	Optimised: trade-off between cost of grid expansion and use of best resources
How *is electricity produced?*	Do not provide system services	Optimised: better market rules and advanced technology allow wind and solar power to contribute to system services

Next-generation wind and solar power require next generation polices.

Example of next generation policy priorities

Action area	Policy example
Integrated planning: wind and solar embedded in energy strategy	**Denmark:** integrated energy strategy
Location: siting VRE closer to existing network capacity and/or load centers	**Location:** new auction design for wind and PV
Technology mix: balanced mix of VRE resources can foster lasting synergies	**Technology mix:** Integrated Resource Plan
Optimising generation time profile: design of wind and solar PV plants	**California:** incentive to produce at peak times
24/7 **System services:** wind and sun contribute to balance system	**System services:** wind active on balancing market
Local integration with other resources such as demand-side response, storage	**Australia:** policies for self-consumption

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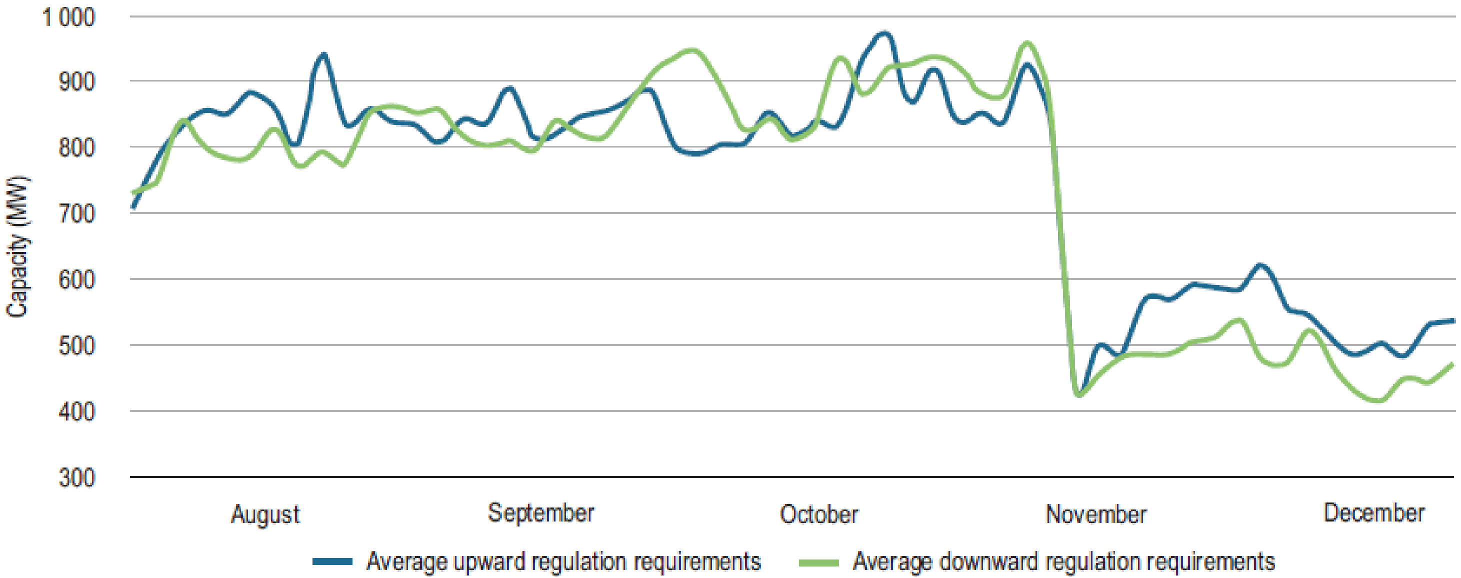
System operation and market design

Efficient operation of the power system	• Ensuring least-cost dispatch • Trading close to real time • Market integrations over large regional areas
Unlocking flexibility from all resources	• Upgrade planning and system service markets • Generation, grid, demand-side integration and storage
Security of electricity supply	• Improve pricing during scarcity/capacity shortage • Possibly capacity mechanisms mechanism as safety-net
Sufficient investment in clean generation capacity	• Sufficient investment certainty • Competitive procurement (with long-term contracts)
Pricing of externalities	• Reflecting the full cost (i.e. environmental impacts)

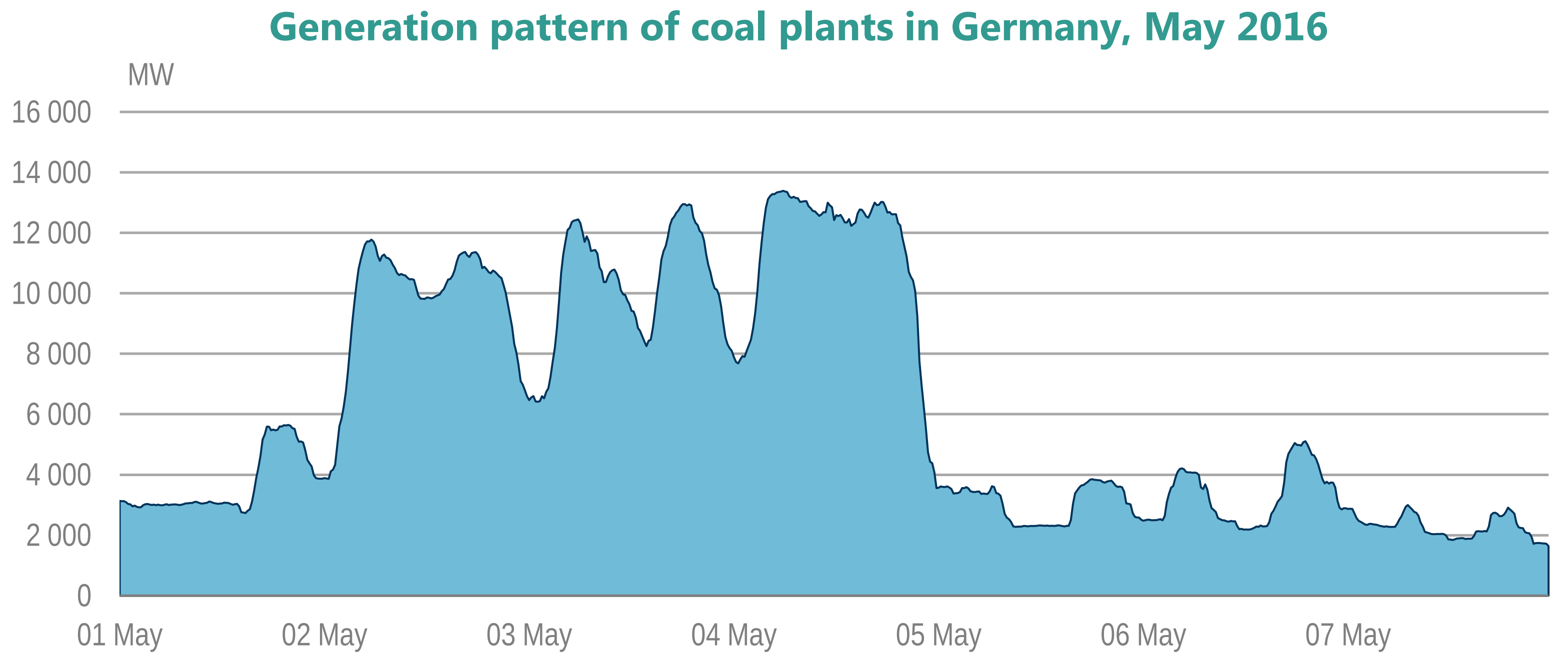
Example: shorter dispatch intervals in Texas

Regulating reserve requirement in ERCOT before and after reducing dispatch intervals



- Shorter dispatch intervals can lead to more efficient and cost-effective operation
- In ERCOT, dispatch intervals were reduced from 15 to 5 minutes in 2010
  - Less regulating reserve requirements were needed

Example: power plant flexibility



Power plants are an important source of flexibility, evident in countries such as Germany, Denmark, Spain, the United States

Why focus on power plant flexibility?

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- Flexible power plants currently major source of flexibility in all power systems

- Technical potential is often poorly understood and/or underestimated

- Significant barriers hinder progress:
  - Technical solutions not always known
  - Market design favors running 'flat-out'
  - Inflexible contracts with manufacturers

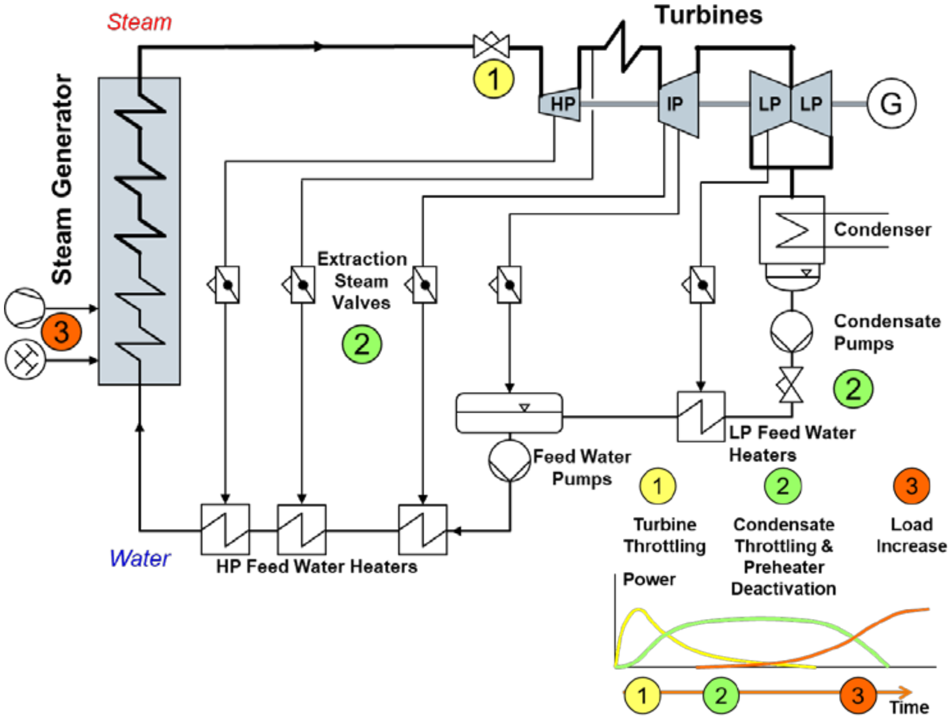
- IEA coordinating new imitative to promote enhanced power plant flexibility

Example North-America
From baseload operation to starting daily or twice a day (running from 5h00 to 10h00 and 16h00 to 20h00)
Source: NREL

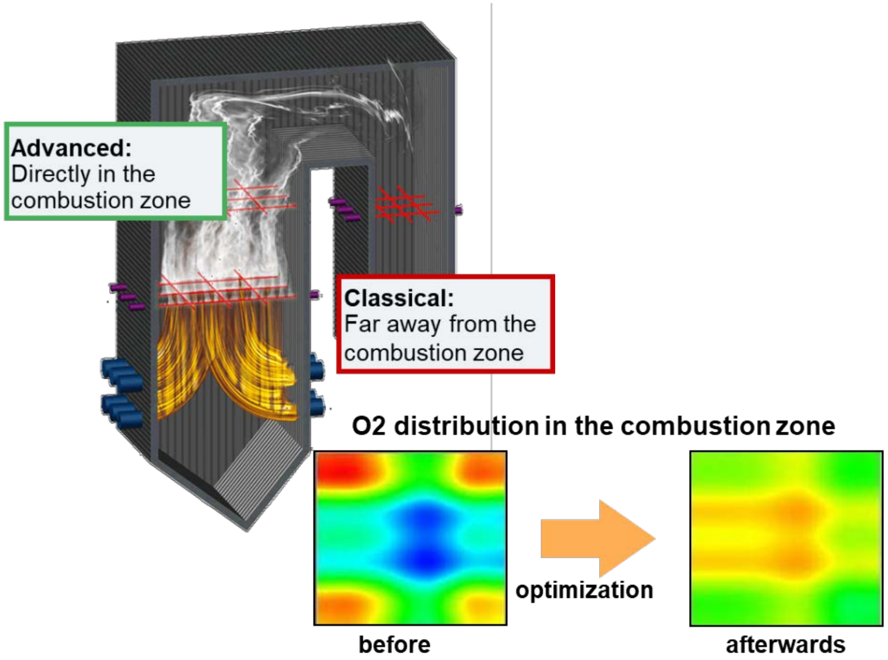
ADVANCED POWER PLANT FLEXIBILITY
A Clean Energy Ministerial Campaign

Examples of interventions to make coal plants more flexible

Enhanced output flexibility via multiple controls



Better monitoring and control of combustion



Thermal power plants can be made more flexible via enhanced monitoring and control equipment.

Source: SIEMENS AG

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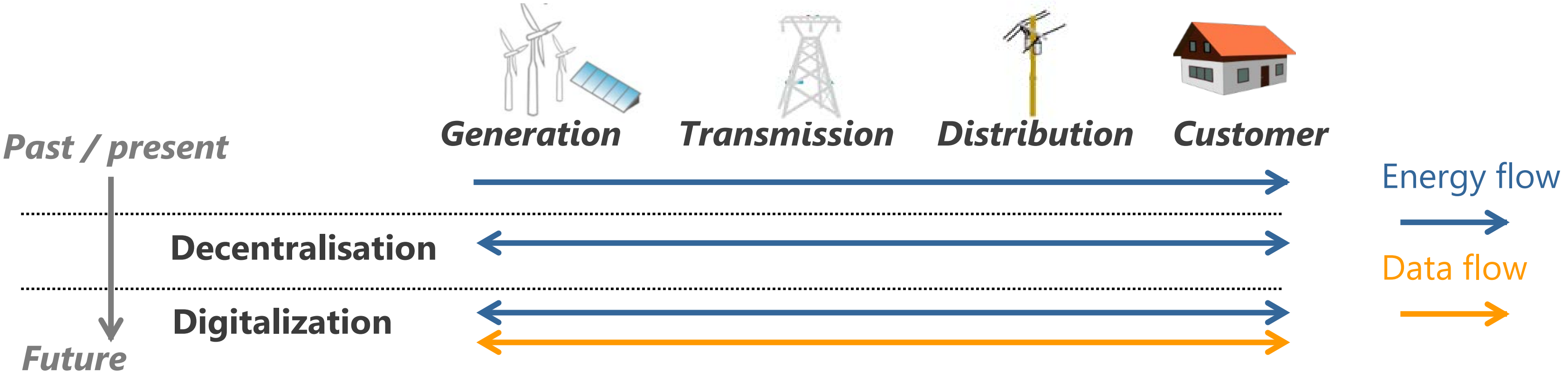
A paradigm shift - local grids in future energy systems



- High uptake of DERs are changing the way local grids are planned and operated
- Successful transition rests on changes in three dimensions
  - **Technical** – more dynamic (bi-directional) energy flows require changes in system operations
  - **Economic** – High uptake of DERs raise the need for retail tariff reform. Consideration of time and place can foster greater flexibility
  - **Institutional** - roles and responsibilities are changing. Better co-ordination between local grid and transmission system operators is key

Value of solar PV approach

Energy services	Avoided capacity	Grid Support	Financial	Additional benefits
■ Energy ■ Tranmission and distribution losses	■ Generation ■ Transmission and distribution	■ Reactive power ■ Voltage control ■ Frequency support ■ Operating reserves	■ Fuel price hedge ■ Market price	■ Grid security ■ Environmental/ carbon emissions ■ Socio-economic development

Note: Depending on deployment scenario, the value components may be negative. For example, if deployment of distributed solar PV leads to grid upgrade requirements, it would contribute to increasing rather than decreasing capacity costs.

Accurately remunerating distributed generation requires a detailed understanding of its effects on the power system.

Reforming electricity tariff design

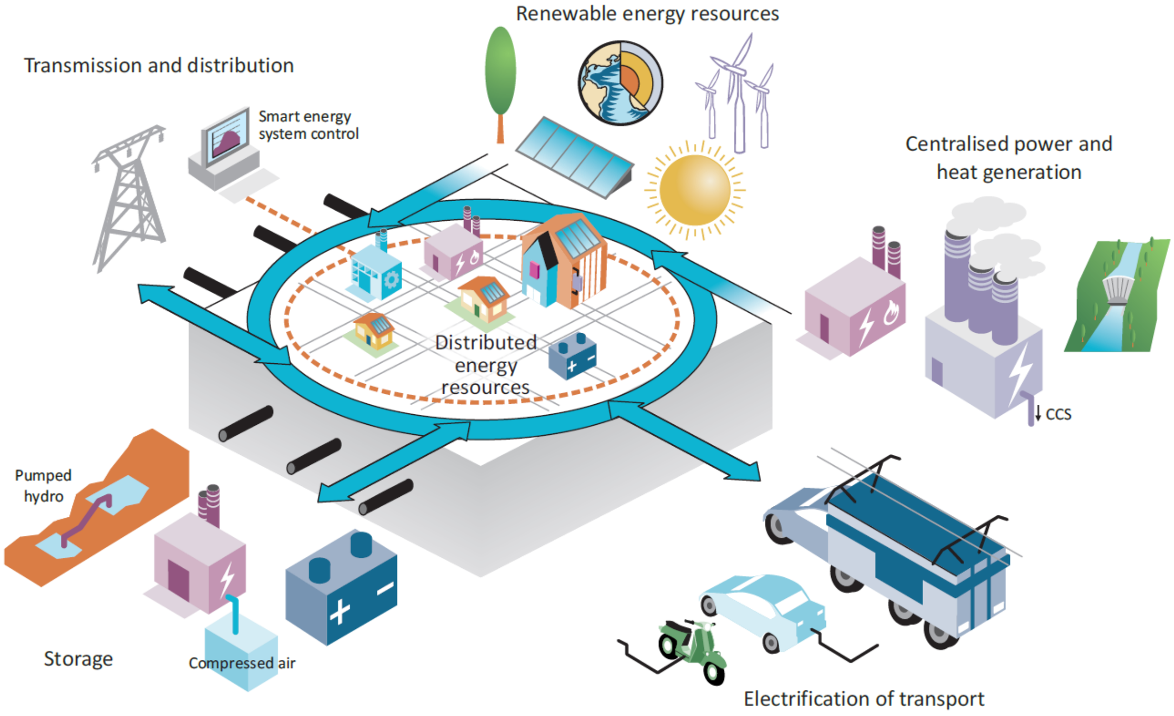
Granularity (– → +)

	–		Granularity		+
Time - Energy	Flat tariff	Seasonal time-of-use (summer/winter)	Daily time-of-use (weekday/weekend)	Intra-daily time-of-use (peak/off-peak hours)	Real-time pricing
Time - Demand	No demand charge	Customer peak	Expected system coincident peak, annual	Expected system coincident peak, monthly	Real-time coincident peak
Location	Single price	Zonal disaggregation	Nodal disaggregation	Locational marginal price (LMP)+Txlosses	LMP +Tx/Dx losses

Notes: Tx = transmission; Dx = distribution; LMP = locational marginal price.

Rise of distributed resources rasises importance of retail tariff design, in particular grid charges

Putting together the pieces – towards a new paradigm?



Smart local grids, linking a diverse set of distributed resources across different sectors, may emerge as main pillar of future energy systems.

Conclusion

- Power systems experiencing technological, institutional and economic innovations, combining to transform the sector.
- Market structures, regulations, system operation and technological capabilities have evolved to support power system transformation, including cost-effective wind and solar integration.
  - Better understanding of system operation at high VRE shares
  - Converging set of priorities for electricity market design
  - Emerging frameworks for managing decentralization and digitalization
- Integration of distributed resources in smart local grids calls for tariff reform and changes in roles and responsibilities

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