Power system flexibility:
Vertically integrated systems

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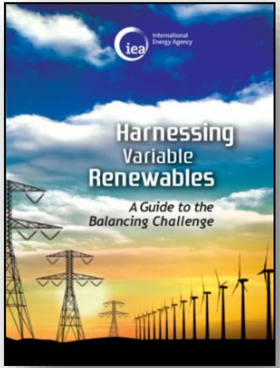
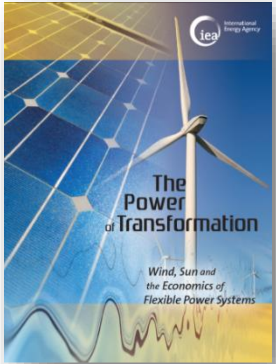
IEA System Integration of Renewables analysis at a glance

- 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
  - Part of delivering the IEA modernisation strategy

2011	2014	2016	2017	2017

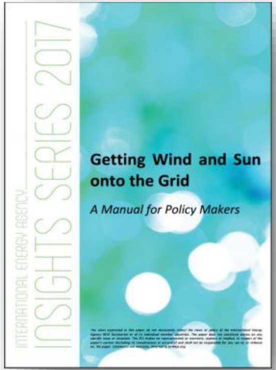


Technical

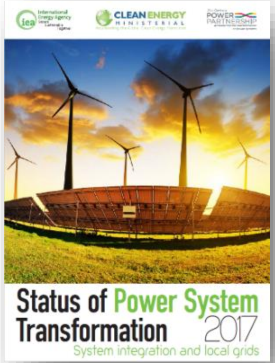


Framework, Technology, Economics

Policy

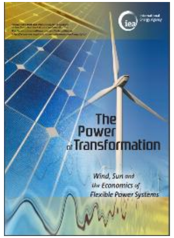


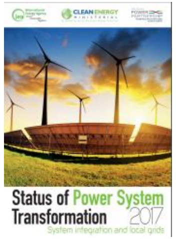
Implementation



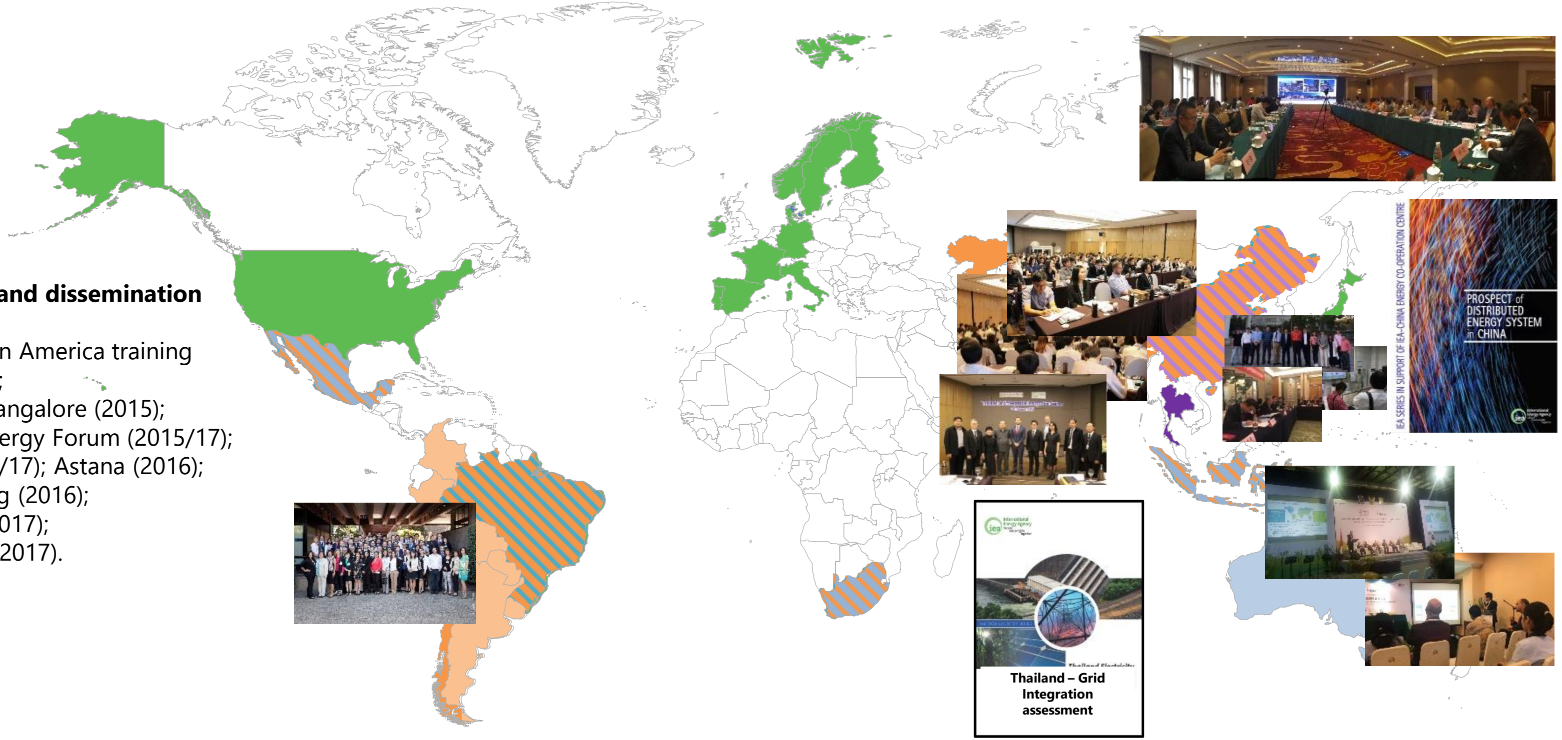
Progress & Tracking

IEA System Integration of RE analysis and engagement since 2014





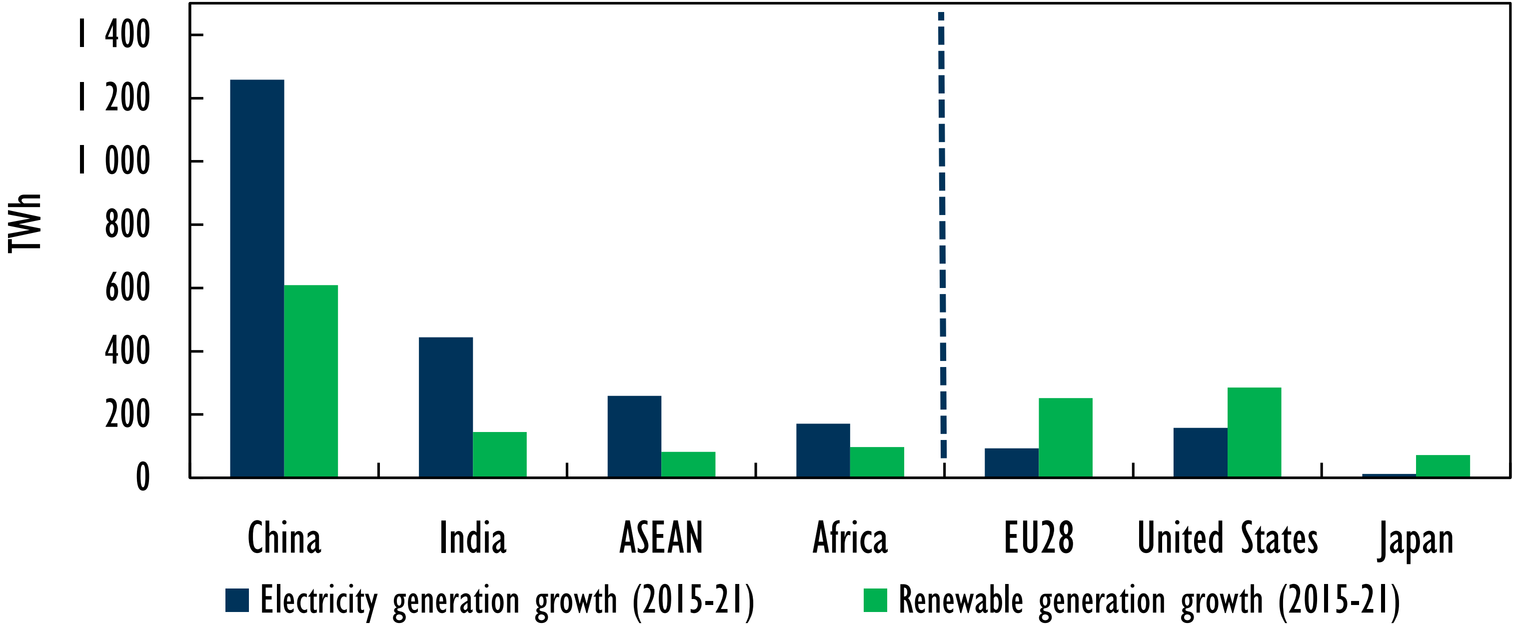
Workshops and dissemination events
Regional Latin America training (2014/15/16);
New Delhi/Bangalore (2015);
Bali Clean energy Forum (2015/17);
Beijing (2016/17); Astana (2016);
Johannesburg (2016);
New Delhi (2017);
Mexico City (2017).



Since 2014, IEA System Integration analysis covered over 20 countries in the five continents. Association and partner countries have been systematically prioritized.

A two-speed world for renewable electricity

Electricity and renewable generation growth by country/region

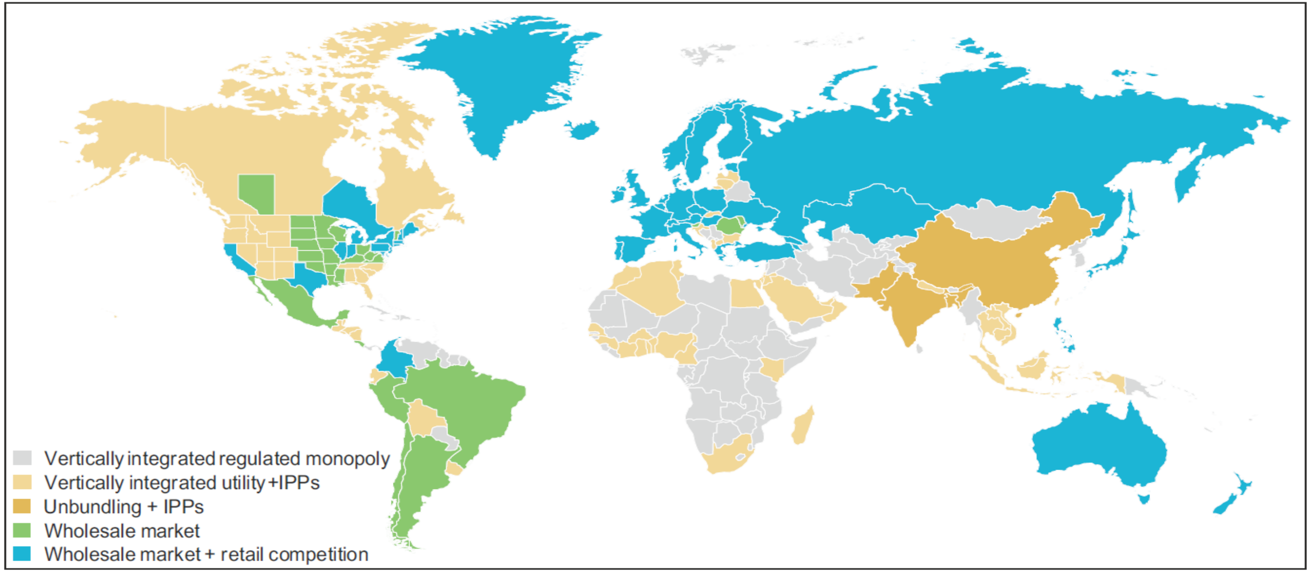


Source: Total electricity generation from World Energy Outlook 2016.

The increase in generation from renewables in 2015-2021 represents 60% of the global increase in electricity output, but prospects vary across regionally. Most growths are in regulated markets

Transformation pathways depend on market structure

Status of liberalisation in the electricity sector

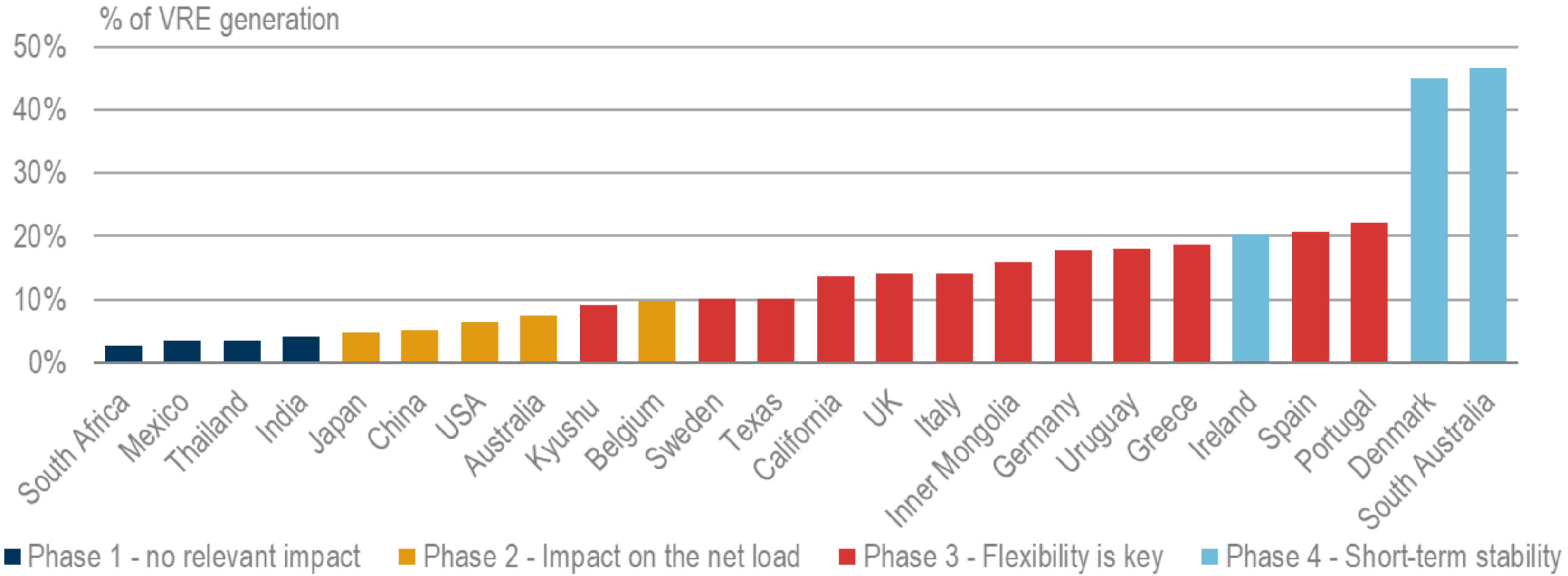


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

- Power system transformation is under way in many countries, although the speed and scope of change varies significantly.
- Changes to power systems are path dependent;
  - Influenced by the prevailing market structure and roles and responsibilities of actors.

VRE deployment phase in selected countries

VRE share in annual electricity generation and system integration phase, 2016



Each VRE deployment phase can span a wide range of VRE share of generation; there is no single point at which a new phase is entered

Power system flexibility can mitigate energy security risks

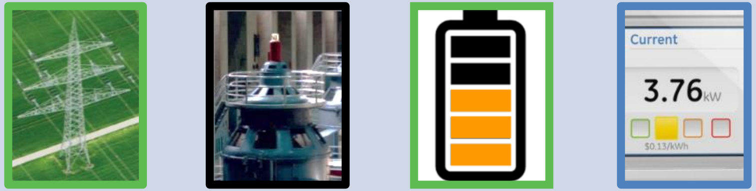
Benefits of renewables

- **Diversification**
  - Balanced generation portfolio
  - Diversify fuel mix
- **Domestic supply**
  - Reduce import bills and lower fossil fuel price risks
- **Environment**
  - Greenhouse gas and local pollution reduction

Risks of renewables

- **Variable and uncertain**
  - Outputs depend on weather and climate

Power system flexibility



Grids | Generation | Storage | Demand shaping

More secure and resilient system

Layers of power system flexibility

Roles and responsibilities — *Institutional ("Who")*

Technical rules and economic incentives — *Policy, regulatory and market frameworks ("How")*

Dispatchable generation | **System-friendly VRE** | **Demand-side resources** | **Electricity storage**

Grid infrastructure

Hardware and infrastructure ("What")

Policies aimed at unlocking flexibility should aim beyond the technical level, taking into account markets and institutions

Policy options to enhance inflexibility

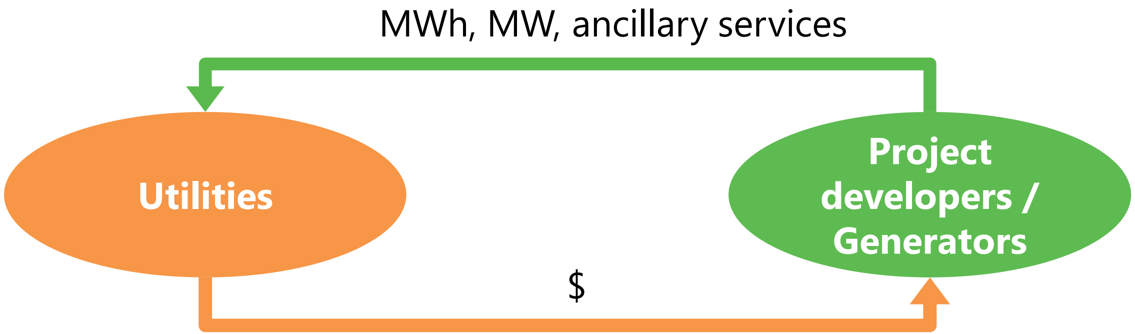
Sources of system-wide inflexibility	Policy options to enhance flexibility
Inflexible generation fleet	- **Mobilise flexibility** in existing power plants - **Facilitate investment** in flexible plants - **Enhance long-term planning** processes
Limited access to flexible resources in neighbouring power systems	- **Co-ordination among neighbouring balancing areas** through *institutional co-operation* and *additional interconnection*
Frequent transmission network congestion – when transmission lines operate at or near their rated capacity	- **Increase available grid capacity**. Investments in HV lines, distribution networks, protection schemes and other components.
Limited storage capacity and lack of demand that can be shifted	- **Enable demand shifting** and create rules that encourage DSR participation. - Introduce instruments that reflect the system value of electricity storage.

Inflexibility of electricity and fuel supply contract in regulated systems

Power purchase	Fuel purchase
• Power purchase agreement (PPA) between electric utility and private power producers • Capacity and energy payments ➢ *"Capacity payment"* based on the availability - guarantees revenue requirement ➢ *"Energy payment"* – based on the dispatch amount	• **Gas contract** between electric utility and gas suppliers for utility-owned power plants. • **For electric utilities** ➢ Minimum take requirement (yearly) ➢ "Take or pay" – if below minimum take • **For gas suppliers** ➢ Guaranteed supply amount (daily) ➢ Penalty for the shortfall

- The gas supply contracts should be more flexible, to make sure that what power plants can do technically is also possible commercially.
- Increasing the contractual flexibility of fuel and PPA is estimated to provide a greater operational cost savings to the system.

PPA and risk allocation in a vertically integrated system in ASEAN



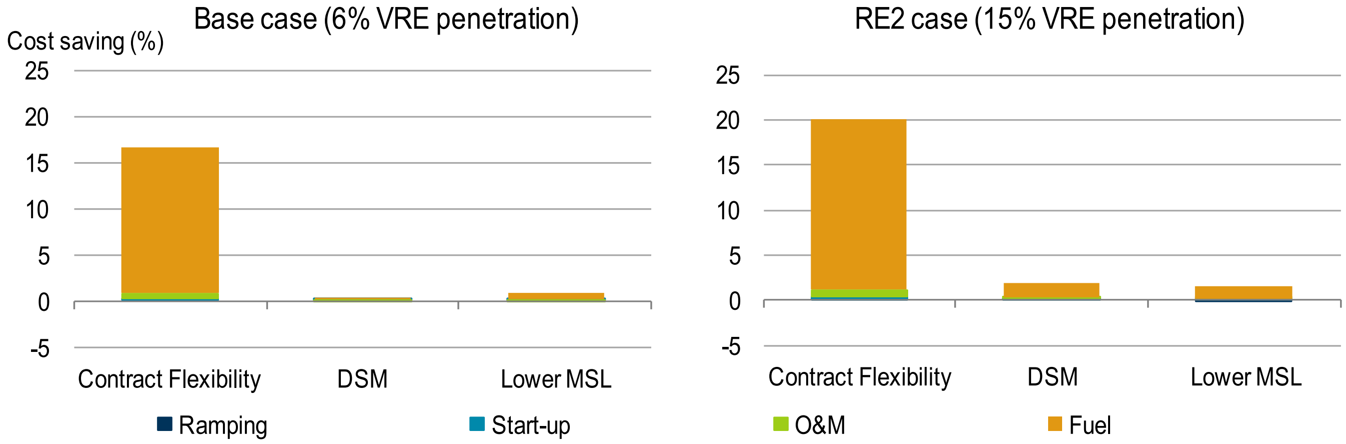
Utilities

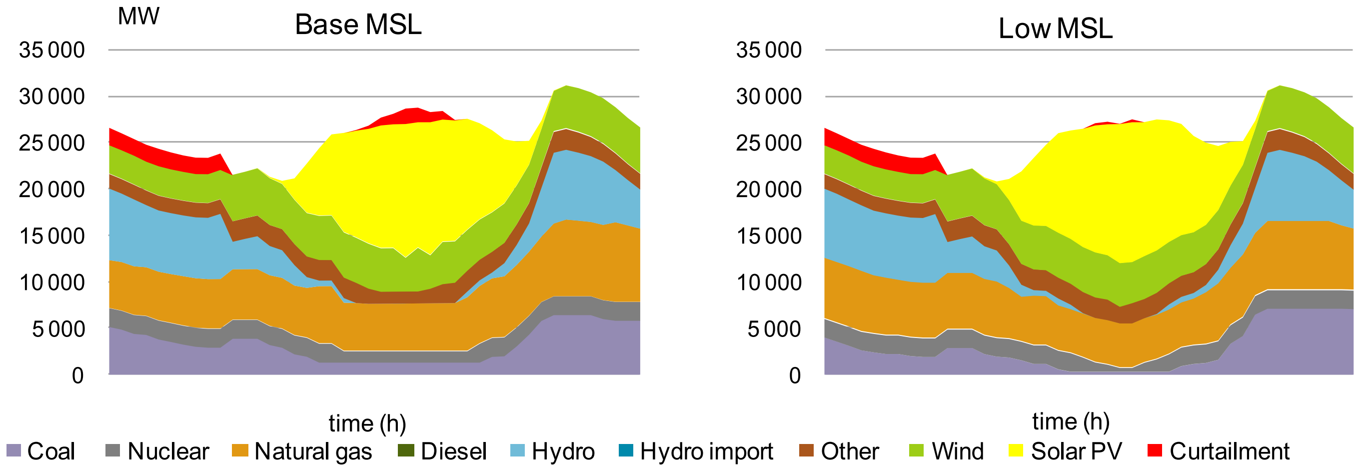
- Take or pay obligations
- Dispatch risks – due to congestion
- Reliability risk – due to variability and forecasting errors
- Regulatory risk – rules change

Project developers / generators

- Performance risk (construction and operation)
- Purchasing tariff ($/kWh), must cover debt and provide return
- Weather related risks (wind not blowing, cloudy)
- Non-compensable risks (due to certain curtailments)

Evaluation of flexibility measures – An example in a regulated system

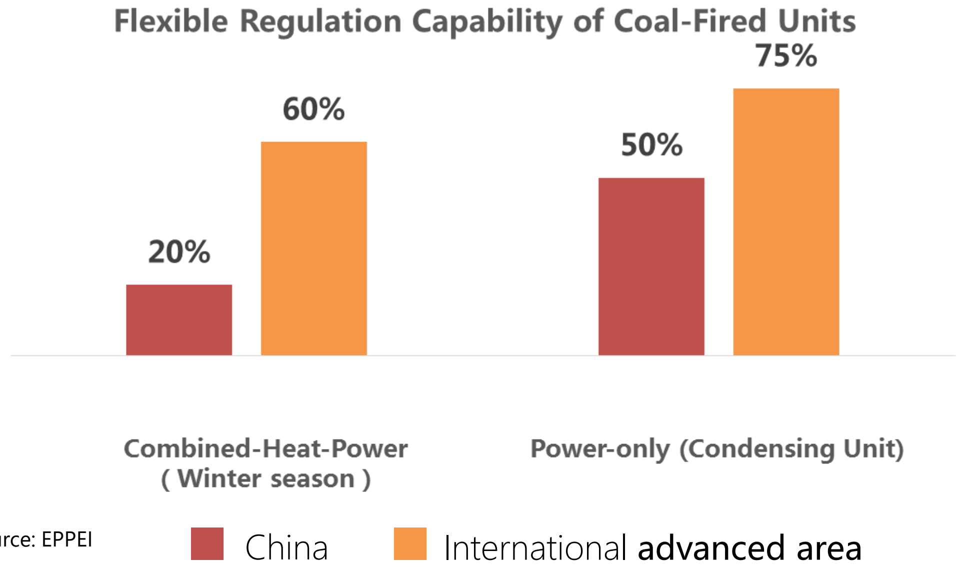


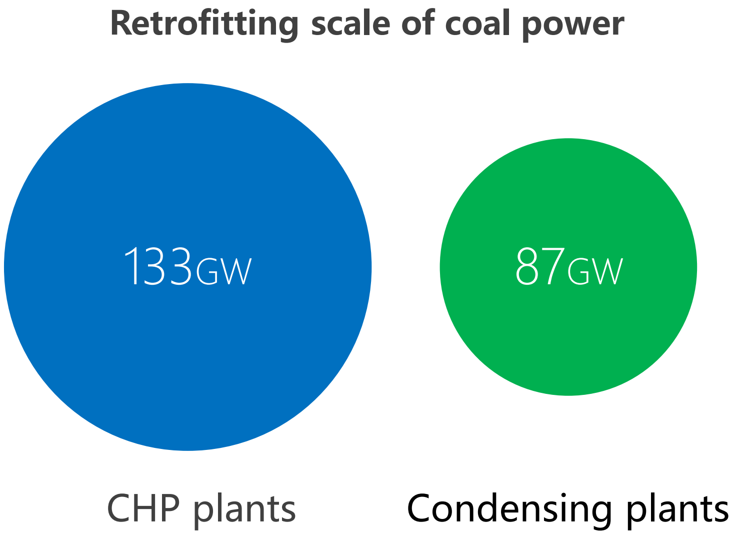


Power System Flexibility Enhancement & 13th FYP in China

- Huge potential of flexible operation ability for thermal power units in China.

- 133GW CHP plants and 86GW condensing power plants will be retrofitted by 2020, which is 20% of the overall capacity of coal power in China. A flexible regulation capacity of 46GW is expected to be achieved.





Source: EPPEI

Some examples of vertically integrated systems

Indonesia		
	**Markets and operations**	• Very low level of VRE, vertically integrated (with IPP) model. Electrification is the primary driver
	Planning and infrastructure	• Electricity planning is not well coordinated, which can lead to high system costs.
	Uptake of innovative technology	• Lack of generation capacity during peak demand, DSM options may address this challenge.
	Efficiency and sector coupling	• Tariffs and fuel prices subsidies reform could play a role in increasing energy efficiency

South Africa		
	**Markets and operations**	• Single IPP buyer model. Successful RE investment program. • Interest in distributed PV has increased.
	Planning and infrastructure	• Location-specific incentives may be needed direct projects towards the RES development zones.
	Uptake of innovative technology	• DSM programmes are limited to load-shedding contracts. heating demand, could uncap significant flexibility
	Efficiency and sector coupling	• Advancements in the understanding the future impact of EVs will avoid system costs.

Power plant flexibility

- 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

清洁能源 · 创新使命峰会
EIGHTH CLEAN ENERGY MINISTERIAL (CEM8)
SECOND MISSION INNOVATION MINISTERIAL (MI-2)

CLEAN ENERGY MINISTERIAL
Accelerating the Global Clean Energy Transition

MISSION INNOVATION
Accelerating the Clean Energy Revolution

ADVANCED POWER PLANT FLEXIBILITY

A Clean Energy Ministerial Campaign

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Denmark
Germany

Participating CEM Members

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Canada
EC
India
Indonesia
Japan
Mexico
Saudi Arabia
South Africa
UAE

Partners

Enel
DONG energy
ENERGINET DK
COWI
Agora Energiewende

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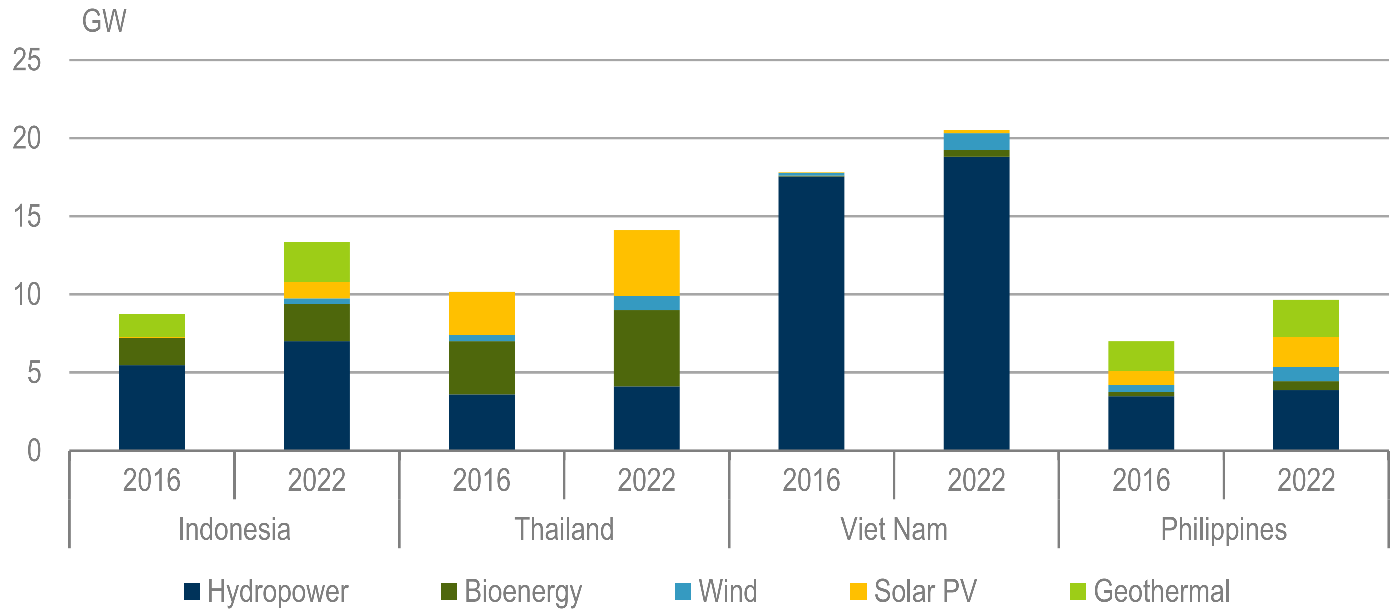
Back up slides

Some examples of (former) vertically integrated systems

Mexico 	**Markets and operations**	• From a conventional monopoly plus IPP to a competitive market. • The reform introduced a highly sophisticated auction scheme that recognise system value
	Planning and infrastructure	• Planning of the transmission system and procurement of new generation are currently done in isolation • The country has a conscious policy to facilitate system friendly deployment.
	Uptake of innovative technology	• The VRE auctions signal the value of electricity, providing long-term investment certainty
	Efficiency and sector coupling	• Structural transformation of power demand may assist in achieving higher shares of clean energy • The country has a conscious policy to facilitate system friendly deployment.

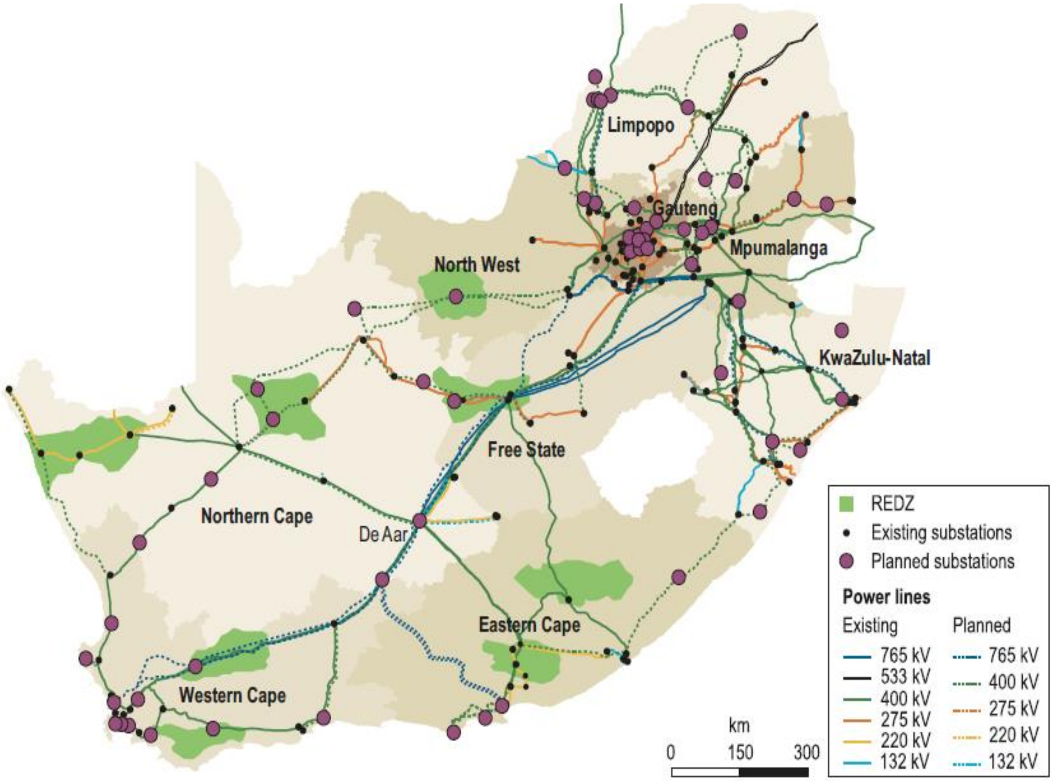
ASEAN's non-hydro renewable capacity to double by 2022

Cumulative renewable capacity in selected countries in ASEAN in 2016 and 2022



Energy diversification needs and growing power demand drive renewable capacity growth in ASEAN but grid integration, policy and regulatory uncertainties remain important challenges

South Africa Renewable Energy Development Zone (REDZ)



- 8 REDZ approved in 2016
  - Based on grid expansion and areas most appropriate for VRE development
- 5 power corridors were identified
- Location-specific incentives were included in subsequent bidding for the next rounds of auctions

Regulatory frameworks to incentivise flexibility

- Carrots:
  - Provide incentives to leave the market or reduce market share
  - Allow very high prices during periods of scarcity
- Sticks:
  - Give priority to other generation resources (priority dispatch)
  - Allow very low / negative prices during abundance periods
- … and other tricks:
  - Consider flexibility potential when nominating must-run units
  - Remunerate new types of services (synchronous inertia, ramping capability)
  - Adjust KPIs for plant operators

Different Phases of VRE Integration – Towards Sector Coupling

Phase	Description	Country Examples
1	VRE capacity is not relevant at the all-system level	Most countries, incl. Mexico, Indonesia, South Africa
2	VRE capacity becomes noticeable to the system operator	Brazil, China, India, Sweden, Texas
3	Flexibility becomes relevant with greater swings in the supply/demand balance	Italy, Germany, Portugal, Spain, UK
4	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times	Ireland, South Australia, Denmark
5	Structural surpluses emerge; electrification of other sectors becomes relevant	
6	Bridging seasonal deficit periods and supplying non-electricity applications; seasonal storage & synthetic fuels	

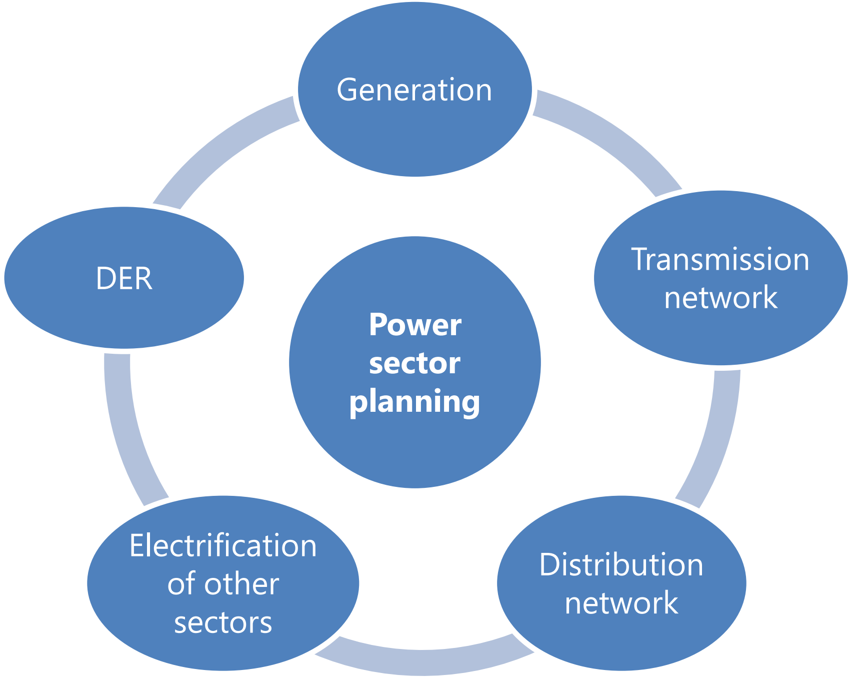
Electricity only accounts for around one fifth of total final energy demand today. The next rise in renewables will require multiplying their uses in buildings, industry and transport

Time-horizons for flexibility needs

Flexibility type	Short-term flexibility			Medium term flexibility	Long-term flexibility	
Time-scale	**Sub-seconds to seconds**	**Seconds to minutes**	**Minutes to hours**	**Hours to days**	**Days to months**	**Months to years**
Issue	Ensure system stability	Short term frequency control	Meeting more frequent, rapid and less predictable changes in the supply / demand balance,	Determining operation schedule in hour- and day-ahead.	Addressing longer periods of VRE surplus or deficit	Balancing seasonal and inter-annual availability of VRE generation
Has relevance for following areas of system operation and planning	Dynamic stability (inertia response, grid strength)	Primary and secondary frequency response (includes AGC)	AGC, economic dispatch (ED), balancing real time market, regulation	ED for hour- ahead, unit commitment (UC) for day- ahead,	UC, scheduling, adequacy	Hydro-thermal coordination, adequacy, power system planning

Flexibility is needed across different time scales from sub-seconds to years

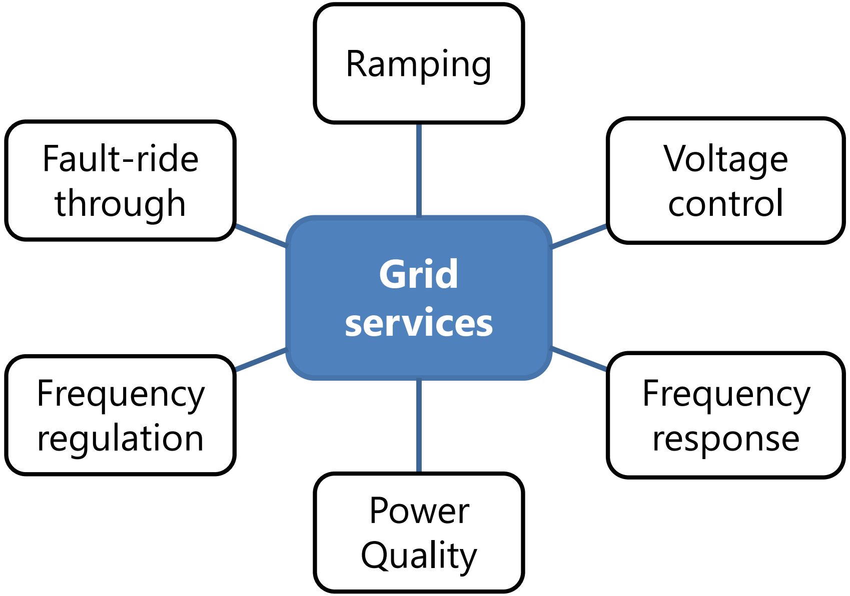
Power sector planning needs to be more integrated



- Power sector planning traditionally focused on developing supply sources and infrastructure to meet demand
- But the landscape of the power sector is changing due to
  - Uptake of VRE, DER
  - Demand side participation
  - Electrification of transport and heat
- Implications of VRE, DER, should be taken into consideration in power sector planning

PPA plays a key role to facilitate RE integration

- PPAs (along with grid codes) can play a key role to facilitate integration of renewables (and increasing flexibility
- Incentivising and/or mandating RE generators to provide grid services (ancillary services)
- To ensure controllability and visibility of VRE generators
  - SCADA
  - AGC capability
  - Share relevant forecasting data (centralised or decentralised)



Summary

- Power systems are experiencing *technological*, *institutional* and *economic* innovations, combining to transform the sector
- Flexibility is needed for the integration of wind and solar
  - Many flexible resources: *power plants, grid infrastructure, demand side, and storage*
- A number of layers in power system flexibility
  - Market structures, regulations, system operation and technological capabilities
  - Making better use of available flexibility is most often cheaper than new options
- Integrated planning is crucial for long term success
- International examples of best practice, combined with a comprehensive assessment framework, allow to transfer experience between jurisdictions
  - Wholesale and regulated markets

