TOKYO, MARCH 8, 2017, RENEWABLE ENERGY INSTITUTE- RE VISION 2017

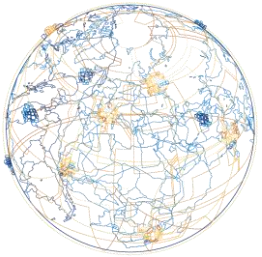
Energy Revolution and Sustainable Solutions

Rajendra Iyer, ABB Group Vice President

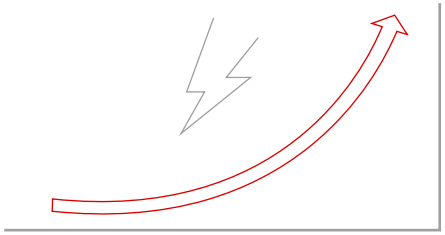
The energy revolution

Elements of the evolving grid

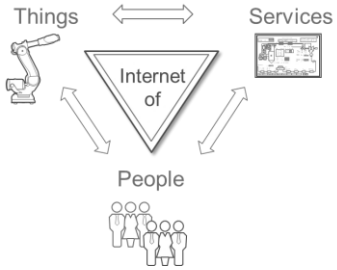
Grid interconnection



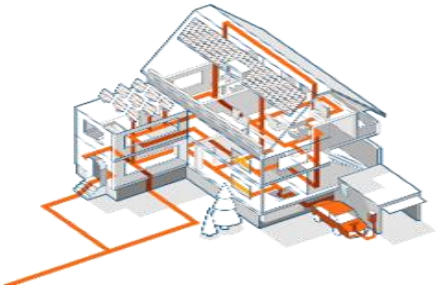
Power quality & demand mgmt.



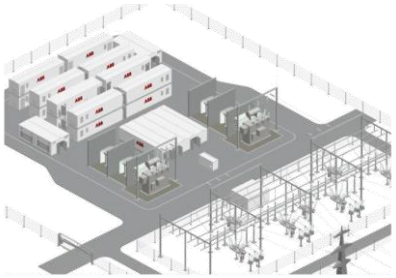
Digitalization



Residential roof top solar plus Micro- and Nano-grids



Energy storage



New business models

UBER airbnb NETFLIX

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Changing power generation balance

Power generation

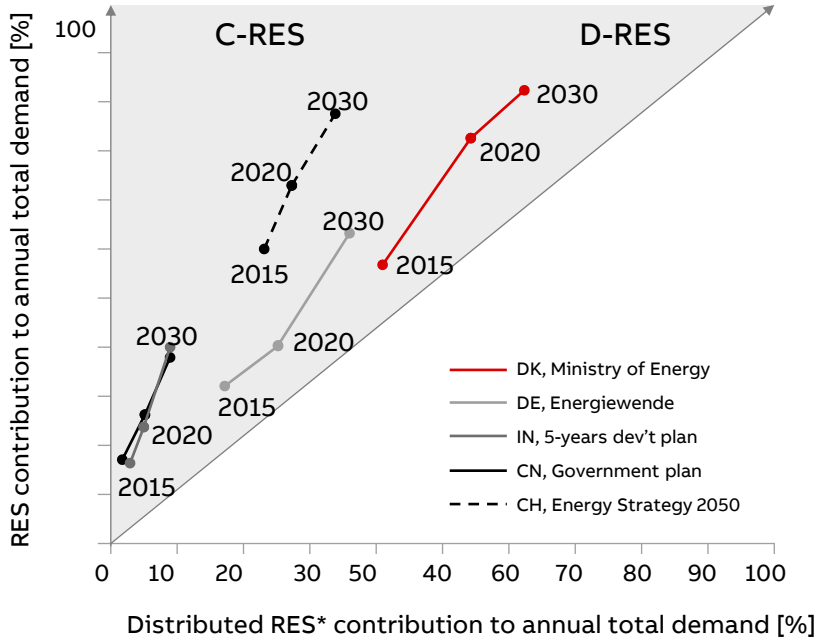
Power balance tipping towards renewables, driven by policy & disruptive technology cost reduction

Main growth in variable renewables such as wind and solar

Two growth paths

- Mainly centralized renewables
- Mainly distributed renewables

Centralized vs decentralized



Renewables expected to be dominant source for electrical power generation

* units <50 MW connected to MV/LV grids, source: governmental plants, ABB analysis

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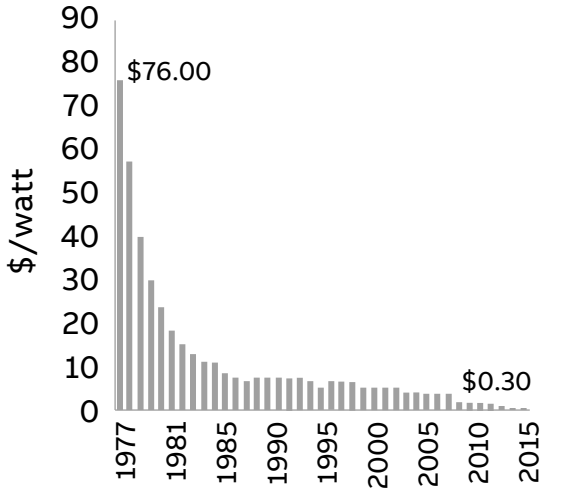
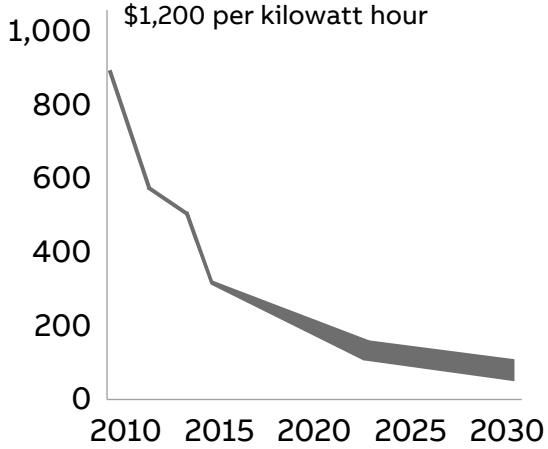
Disruptive developments driving key changes in future grids

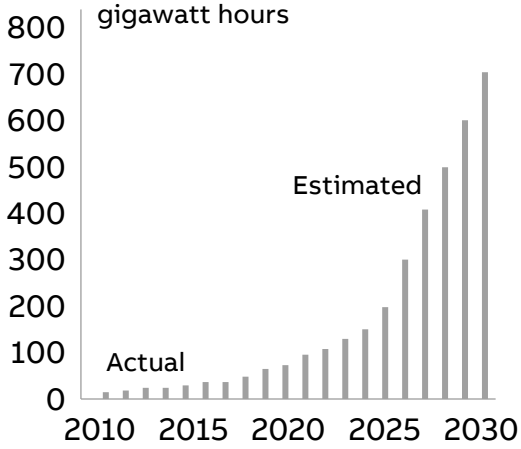
Price history of silicon PV cells[1]



Cost for lithium-ion battery packs[2]



Yearly demand for EV batt. power[2]



Batteries & photovoltaic

- Dramatic cost reduction – to be continued
- Scalability of technologies
- Consumer investment across market segments accelerating developments

[1] Source: Bloomberg New Energy Finance & pv.energytrend.com
[2] Source: Data compiled by Bloomberg New Energy Finance

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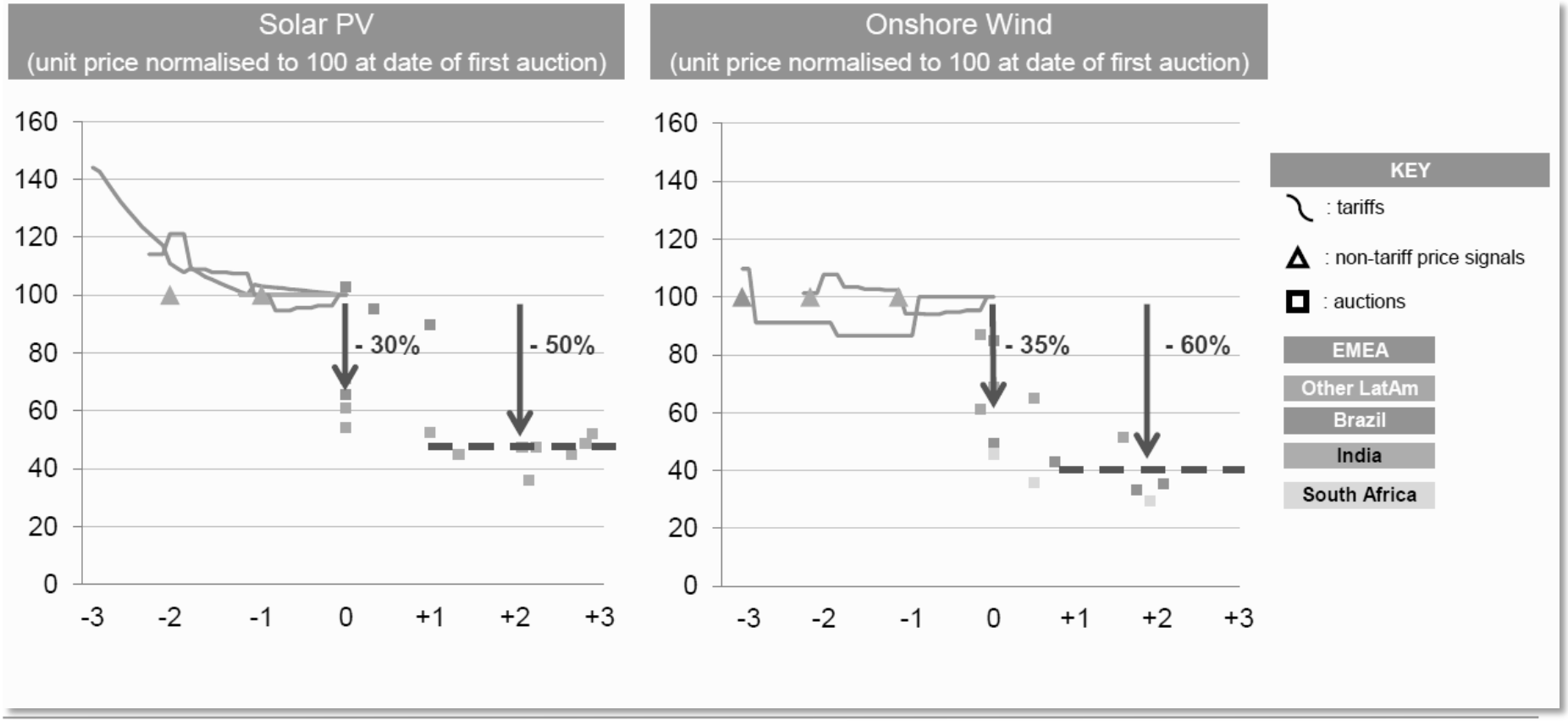
Microgrids and integration of renewables

Volume development of Variable renewable brings it to more affordable cost levels for consumers



Source : Bloomberg New Energy Finance

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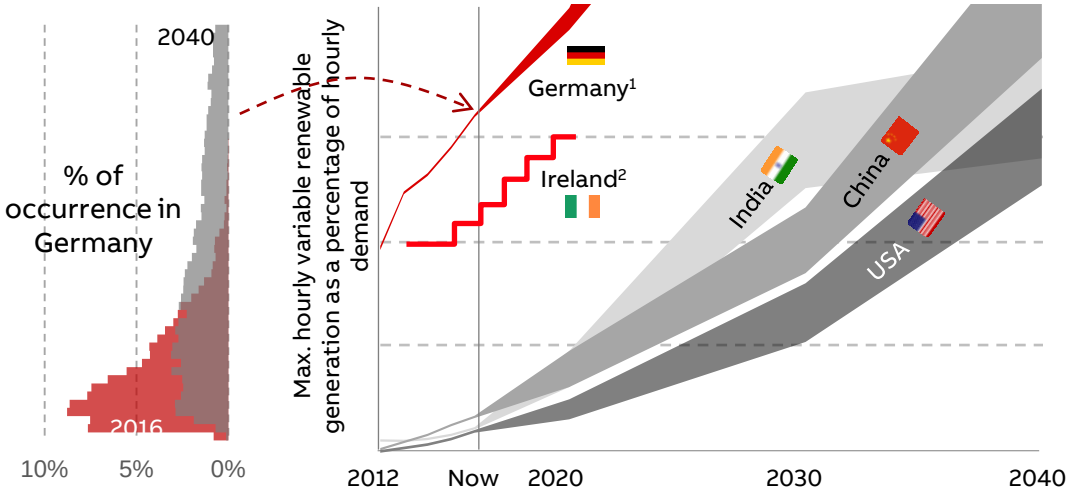
Grid – an evident enabler for the future

Technical challenges countries encounter



Short circuit capacity & V-RES utilization

System inertia & grid voltage

Grid capacity & reserve

Conventional operation

Investments in grid and flexible technologies required to address challenges

[1] Germany may operate at very high V-RES levels due to strong connections to the ENTSO-E grid.
[2] Ireland limits instantaneous percentage of non-synchronous resources (SNSP) by 60% in 2017. The plan is to reach SNSP=75% in 2020.

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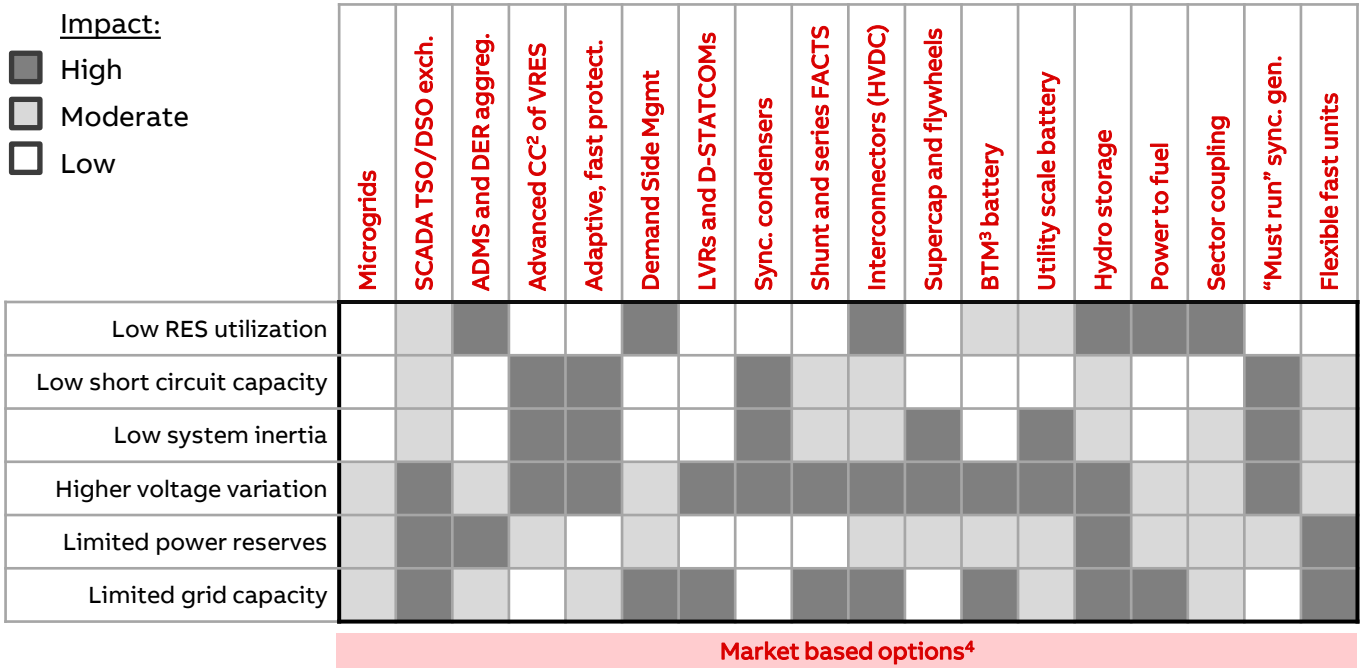
Need for more flexible power system
Technology options[1] at different system level



1. Not exhaustive list
2. Converter controlled
3. Behind the meter
4. Wholesale energy market, ancillary services, capacity markets, p2p retail markets, etc.

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Grid interconnection

Opportunities

Renewable integration across regions

- Fluctuations during the day
- Seasonal variations

Optimal use of reserve and peaking capacities

Diversification of electricity supply

Reduction of wholesale electricity price volatility

Strengthening grid operation in case of fault conditions

Increase capacity utilization factor of conventional generation

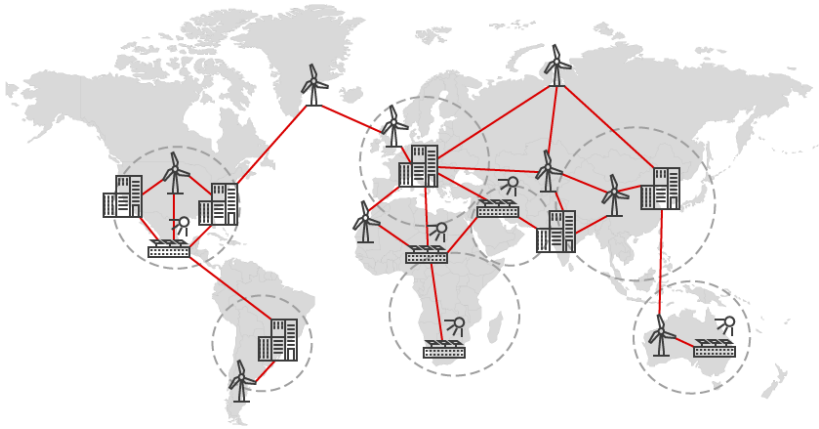
Challenges

Political factors

Economic framework

Technological capabilities

Coordinated operation (global harmonization of standards, grid codes and operational practices)



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Grid interconnection: Ultra High Voltage

World's most powerful UHVDC link

Chiangji-Guquan, China

1100kV DC

12000MW

>3000km

World's first multi-terminal UHVDC link

North-East Agra, India

800kV DC

6000MW

>1700km

UHVAC transmission

Bina Substation, India

1200kV Circuit breaker & transformer

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Microgrids and integration of renewables

Resilient and cost-effective technology

Grid code compliant integration of wind & solar

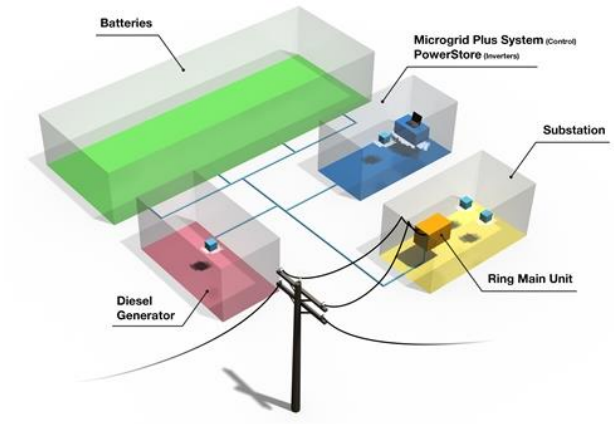
Stabilizing weak grids

Microgrids acting as one controllable generator or load

Access to power in remote locations

Kodiak Island, Alaska, USA

- Wind (9MW)
- Diesel
- Flywheel (2 x 1MW)



AusNet, Victoria, Australia

- Weak grid support
- Diesel (1MW)
- Battery (1MWh)

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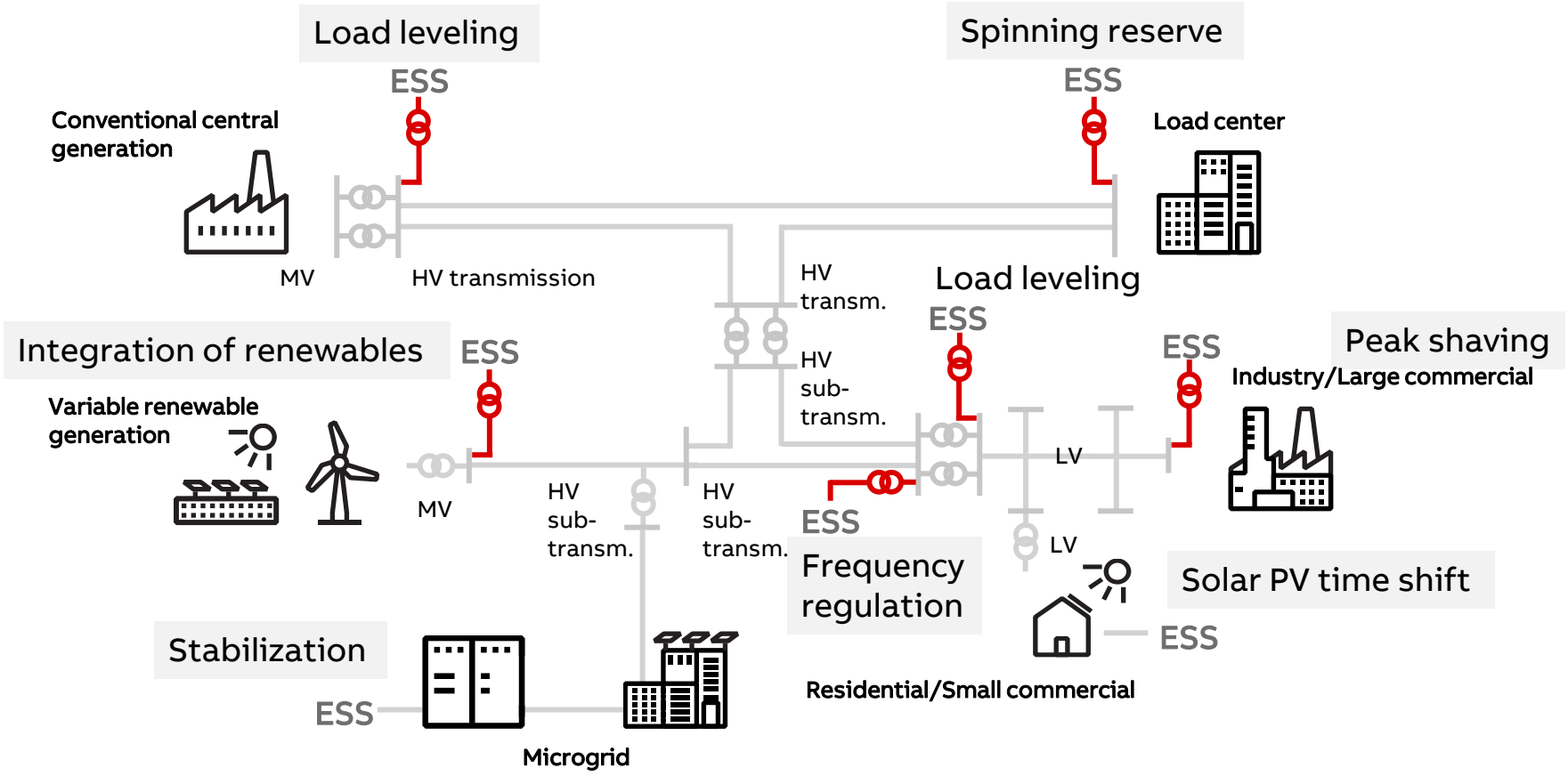
Energy storage – a key element across the power value chain



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Power quality & demand management

Distributed renewables

Smart control

Power electronic technologies (e.g. FACTS)

Transformer based technologies (e.g. Line Voltage Regulators)

Bulk renewables

Demand response management

Frequency regulation through short term balancing of supply and demand

Smart home and building management

Electric vehicle (charging) infrastructure

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From conventional to a digital substations

Fit for future grid requirements

CAPEX reduction

- Reduced footprint (AIS)
- Up to 80% less copper cabling

Reduced engineering & installation time

Improved safety

OPEX reduction

- Asset health & predictive maintenance
- Up to 50% reduction in outages

Safety

Fast & easy reconfiguration

Queensland, Australia

275 kV digital substation with digital sensors & 61850 digital communication bus, in operation since 2011

Enabling flexibility for new and existing substations

[1] NCIT – Non Conventional Instrument Transformers

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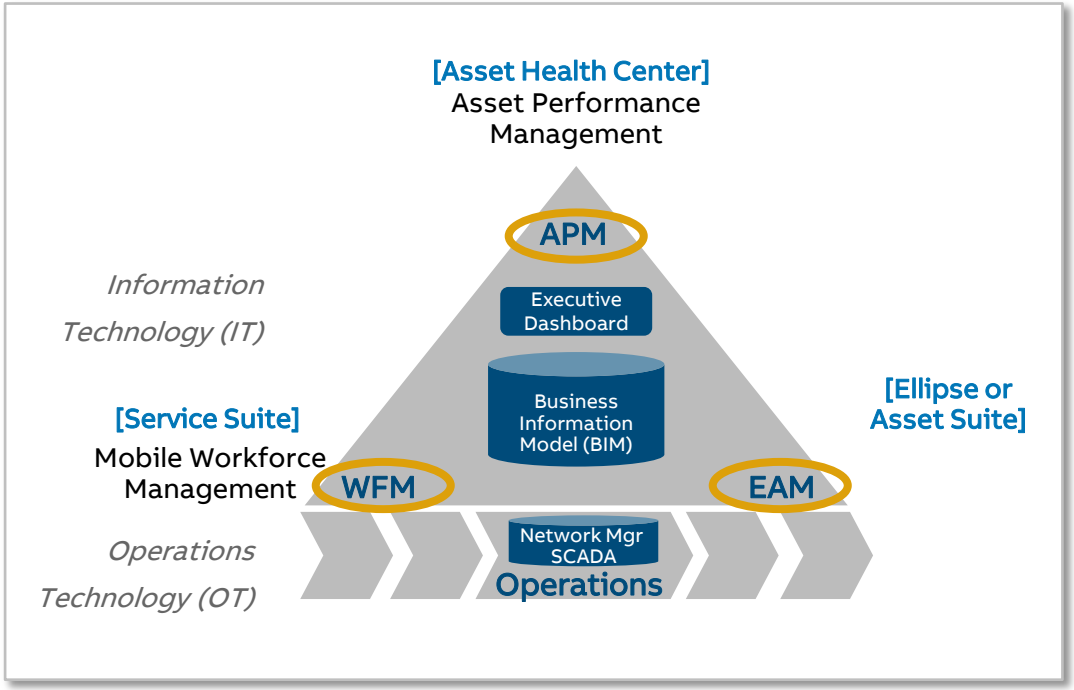
Connected Asset Lifecycle Management

Multiple products, multiple industries, diverse and overlapping functionality

- Different perspectives of the SAME asset are observed / monitored / controlled by different roles in organizations
- Without consolidation, multiple perspectives seldom yield a “complete” picture of the asset
- Each perspective has its own strength, but together the perspectives can create a whole that is greater than the sum of its parts



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Interconnectors help countries realize the full benefits of the internal energy market

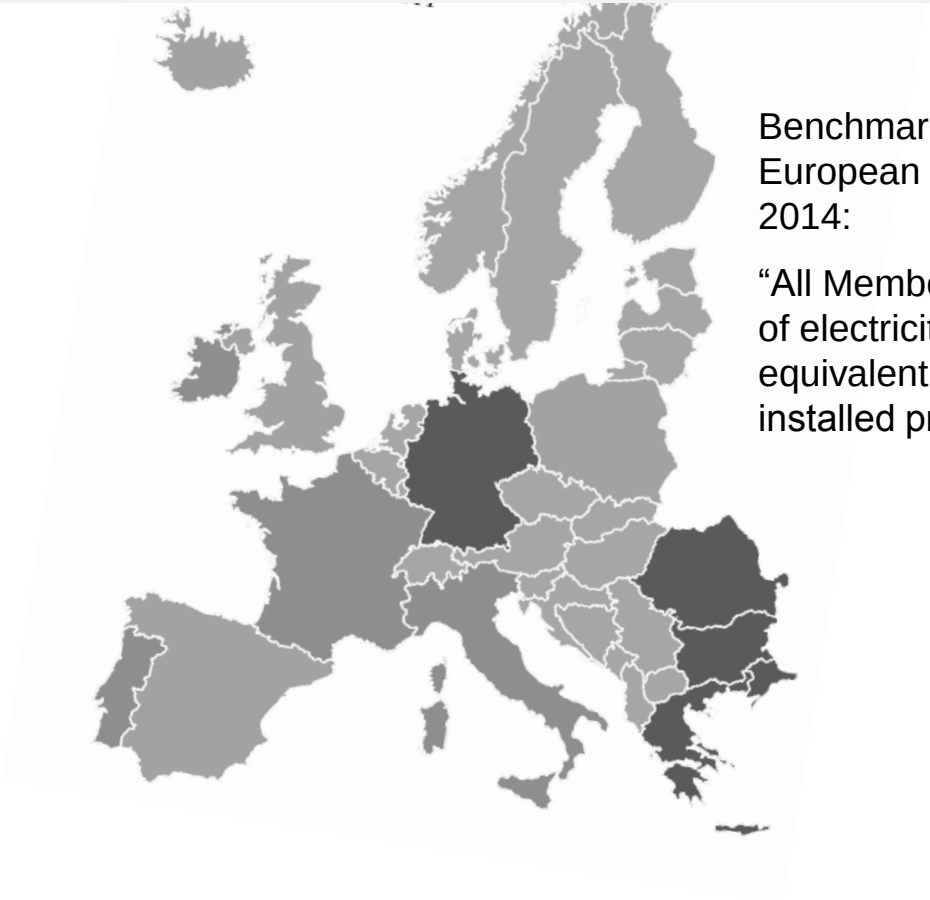
>15%

≥10% & <15%

≥5% & <10%

<5%

Import capacity as a % of net generation capacity in 2011



Benchmark highlighted by the European Commission in January 2014:

"All Member States to have a level of electricity interconnection equivalent to at least 10% of their installed production capacity"

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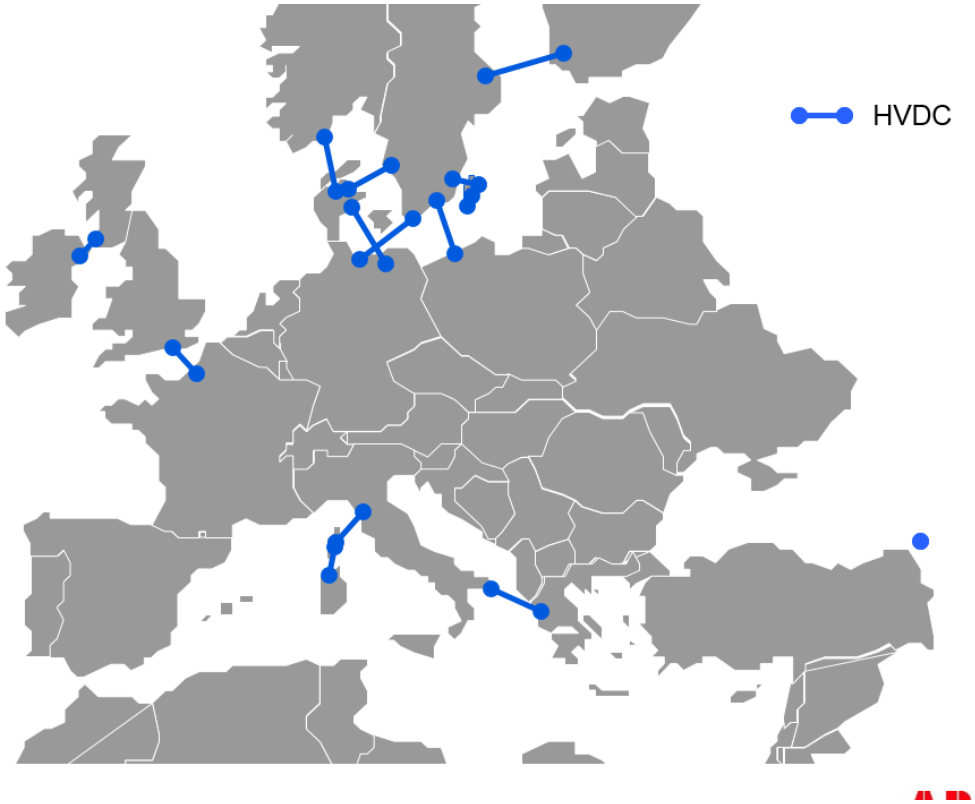
European scenario 2000



HVDC 2000 – a solution for

- Energy trading
- Security of supply
- Integration of renewables

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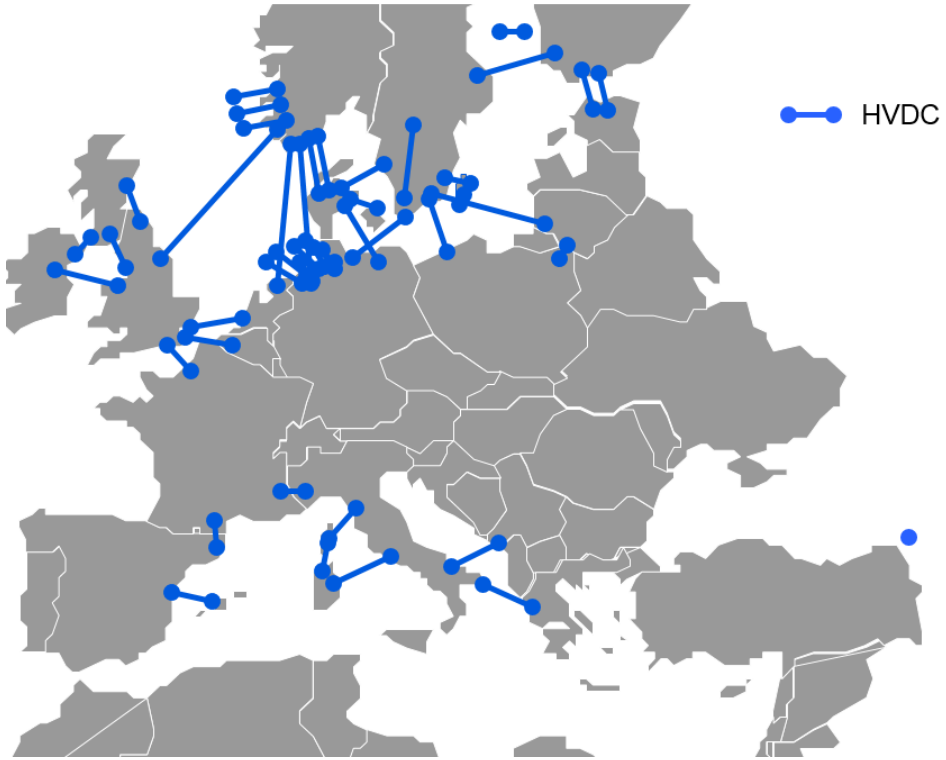
European scenario 2015



HVDC 2015 – a solution for

- Energy trading
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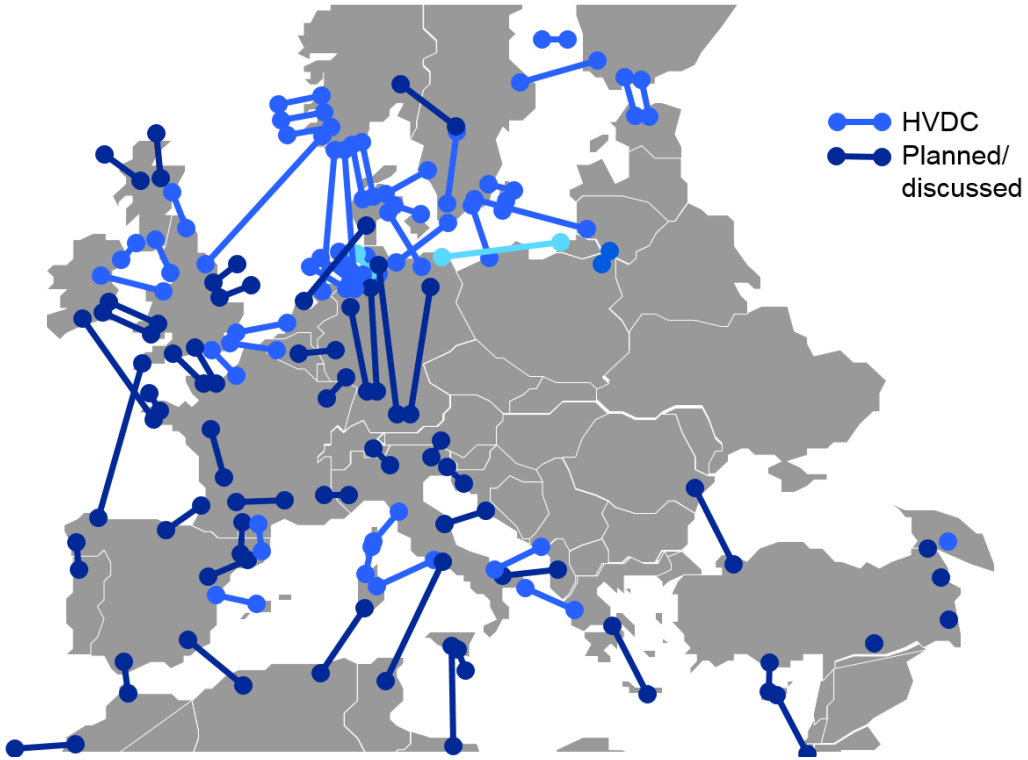
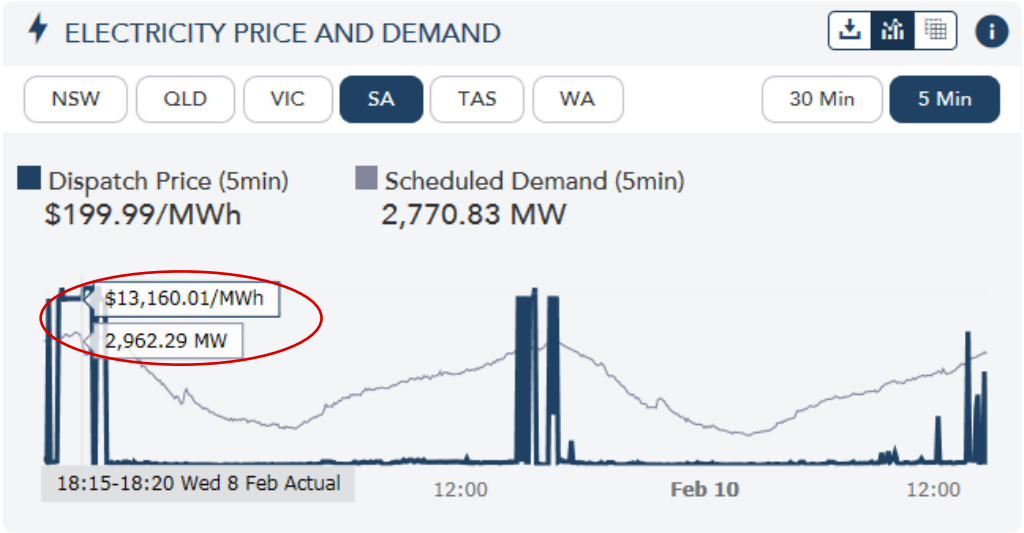
European future plans



HVDC a future solution for

- *Energy trading*
- *Security of supply*
- *Integration of renewables*
- Balancing of intermittent power
- Closing nuclear and fossil
- Optimizing total grid efficiency

System issues in South Australia



February 09, 2017 - 3:45 PM

High temperatures across the eastern states is increasing electricity consumption levels in South Australia and New South Wales, placing additional strain on the national power system. This has resulted in reduced generation reserves within these two states.

AEMO is in discussion with a number of generators within New South Wales and the New South Wales government to mitigate the need for local load shedding. Load shedding can sometimes be required when there is an imbalance between electricity demand and electricity supply. When there is a shortfall in the electricity supply, there can be a need to reduce demand very quickly to an acceptable level, or risk the electricity network becoming unstable.

Under the National Electricity Rules, AEMO has authority to implement emergency rotational load shedding during power system emergencies to ensure the system remains secure and to avoid prolonged power outages.

Load shedding arrangements vary from state to state, but the objective of rotational load shedding is to minimise the impact on any one group of customers. Sometimes rotational load shedding is not an option – for example, if the supply-demand balance changes rapidly, then load shedding can happen almost instantly.

The safety of the community is the energy industry's number one priority during power system emergencies, and AEMO is working closely with industry to restore and maintain reliable, secure electricity supply to affected regions in the National Electricity Market as quickly as possible.

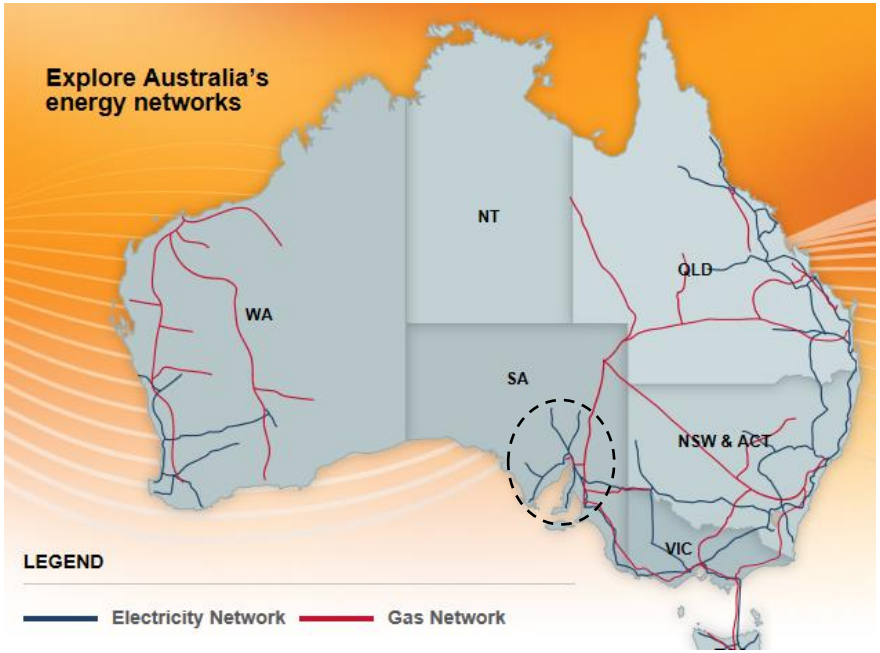
South Australian Grid

Key South Australia power system properties

Weakly interconnected system

Lack of capacity reserves to meet exceptional demand (e.g. heat wave periods).

system will be upgraded to accommodate more renewables



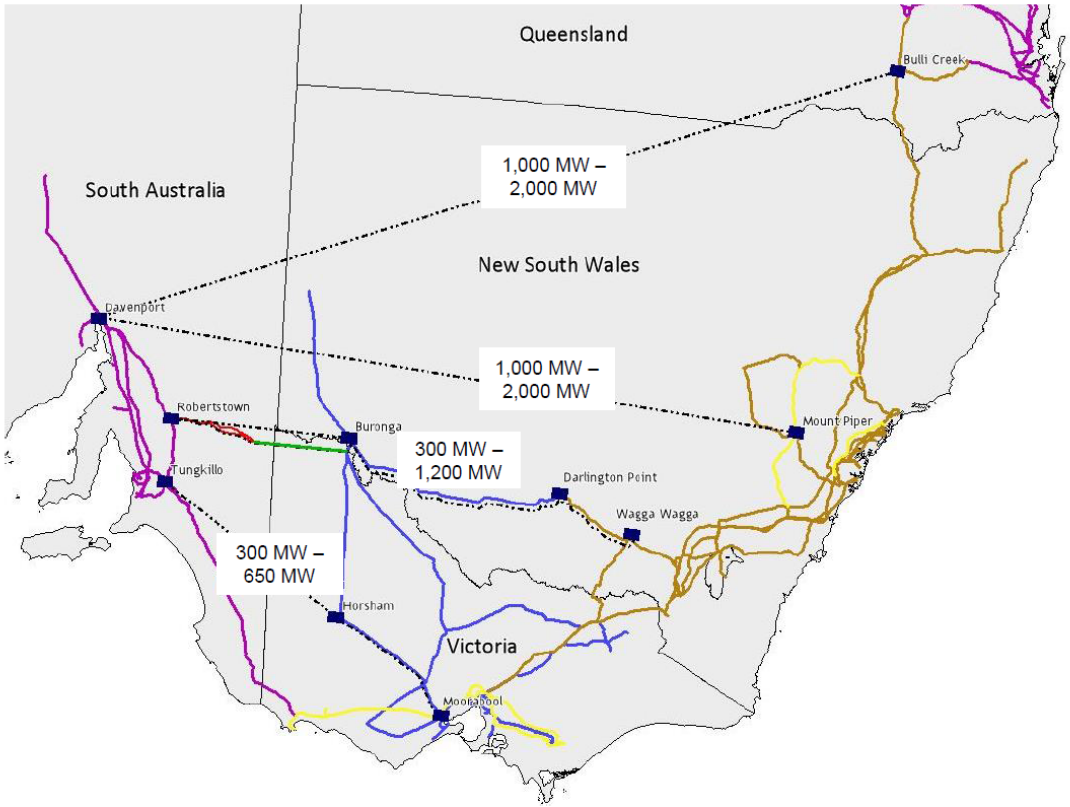
System issues in South Australia

Proposal for regional interconnections

"Additional interconnection between National Electricity Market (NEM) regions can result in greater competition between generation sources, thereby delivering lower overall energy prices for customers, in addition to facilitating an increase in renewable generation and addressing security of supply concerns associated with energy market transition."

- South Australian Energy Transformation, a report by ElectraNet

Figure 1 Four new interconnector options are proposed to be investigated as part of this RIT-T (line corridors are indicative only)



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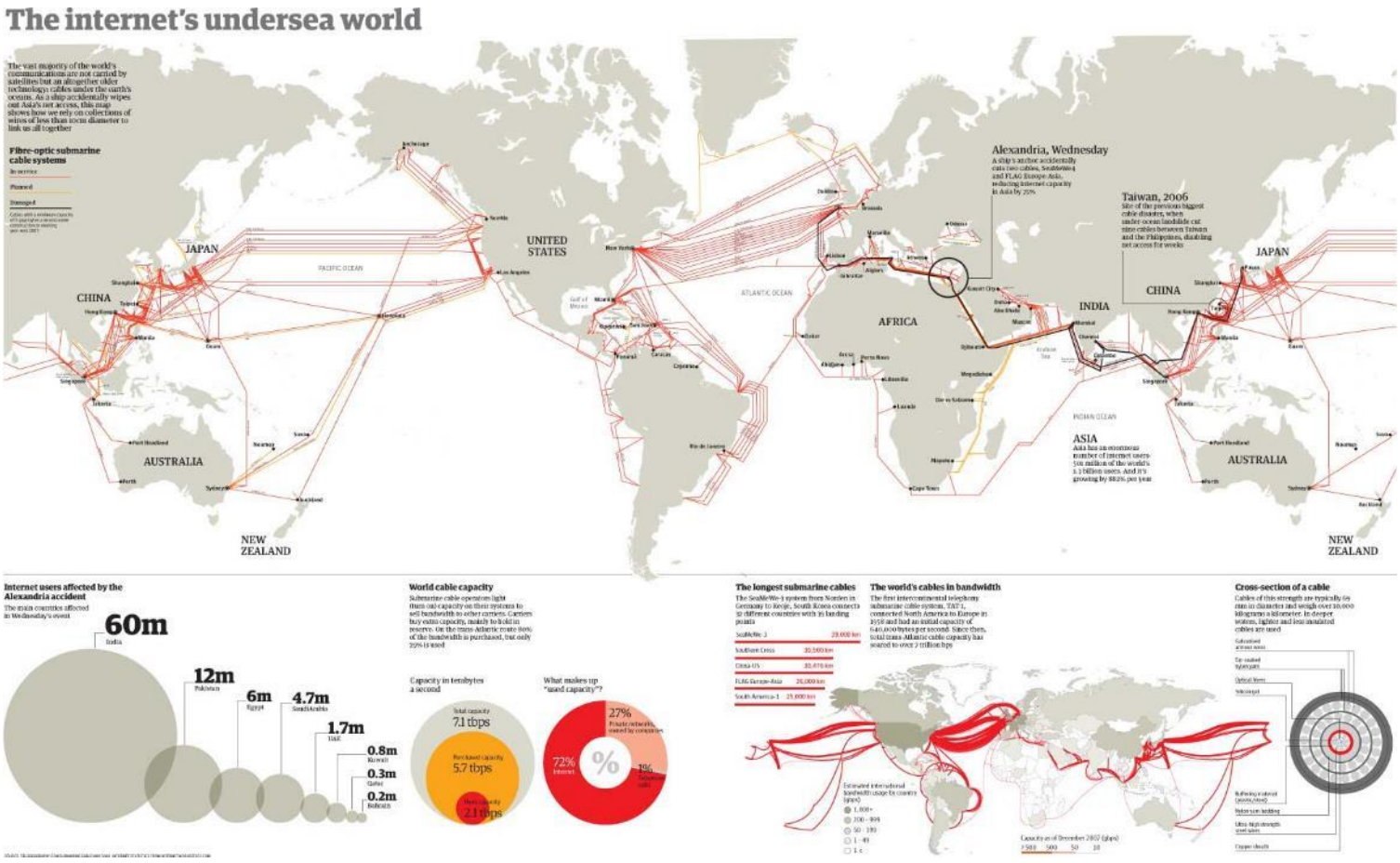
The world is already connect by cables for internet…..why not for energy



Source : Global Energy Interconnection Development and Cooperation organization