Renewable power rapidly becoming competitive

**Cost reduction in the period 2010 - 2017**
- **Solar PV**: 73%
- **Onshore Wind**: 23%

**Expected cost reduction in the period 2015 - 2025**
- **Solar PV**: 54%
- **CSP**: 37%

- **Offshore Wind**: 15%
- **Onshore Wind**: 12%

- All renewable power options will compete with fossil fuels on price by 2020
- Wind and PV are abundant and available in most countries

Implication: Wind and PV at the core of the energy transition

- Electricity production would double between 2015 and 2050
- Renewables generating 85% of total electricity in 2050
- Share of wind and PV in electricity sector would increase from 10% today to 60% in 2050
- Wind and PV are variable energy sources – addressing variability is crucial to achieve the needed deployment
- Next stage is integrating such a high share of wind and PV in power systems

Wind and PV electricity share in generation mix 2015 and 2050

- Solar PV (today): 3%
- Solar PV (2050): 22%
- Onshore Wind (today): 7%
- Onshore Wind (2050): 36%

Source: IRENA (2018), Global Energy Transformation: A roadmap to 2050
Innovation unlocking flexibility across whole power system

### Conventional providers of flexibility
- Supply
- Grids
- Demand

### Emerging providers of flexibility
- Supply
- Grids
- Demand
- DER* (Distributed Energy Resources)

**Flexibility sources:**
- Flexible generation
- Regional interconnections and markets
- Demand response
- Storage
- Power to X

* *Distributed Energy Resources (demand, distributed generation, small battery etc.)*
Innovative solutions to increase power systems flexibility propelled by three trends

- **Decentralisation.** Wind and PV is largely centralized today but distributed generation - notably rooftop PV, ~ 1% of all electricity generation today – is growing bringing new flexibility opportunities at demand side.

- **Digitalisation.** Key enabler to amplify the energy transformation by managing large amounts of data and optimizing systems with many small generation units.

- **Electrification.** It plays in two ways, may decarbonize end-use sectors through renewable electricity and, if done in a smart way, become a flexibility source to integrate more renewables in power systems.
Numerous innovations are emerging to facilitate wind and PV integration.

Innovations come from different dimensions: Enabling technology, Business models, Market design and Systems operation.

- **Enabling Technology**
  - Electric Vehicles
  - Battery Storage
  - Artificial Intelligence
  - Internet of Things
  - Blockchain
  - Aggregators- VPP

- **Business Models**
  - Platform business model

- **Market regulation**
  - Encourage Flexibility, pricing that supports DSM/DSR
  - Decentralized system through distributed generation

- **System Operation**
  - Massive expansion of interconnections and creation of regional markets
  - Value complementarities in RES

**RE Tech**
### Innovation Landscape for Renewable-Power Integration

- **Enabling Technologies**
  - Battery storage
    - Utility-scale battery
    - Small-scale battery
  - Electrification
    - EV smart charging
    - Power-to-heat
    - Power-to-hydrogen
  - Digitalisation
    - Internet of Things (IoT)
    - Artificial intelligence and big data
    - Blockchain
  - New grids
    - Supergrids
    - Renewable-based mini-grids

- **Business Models**
  - Empowering consumers
    - Virtual power plants (VPPs)/Aggregators
    - Peer-to-peer trading
    - Energy as a service
  - Enabling renewable energy supply
    - Community-shared ownership
    - Pay-as-you-go plans

- **Market Design**
  - Wholesale markets
    - Increase time and space granularity in energy markets
    - Redefine balancing market products
    - Innovations in capacity markets
    - Regional markets
  - Retail markets
    - Allow distributed energy resources to participate in markets
    - Price-based demand-response programmes
    - Net billing schemes for self-consumption

- **System Operation**
  - Accommodating uncertainty
    - Advanced renewable energy generation forecasting
    - Innovative operation of hydro plants
  - Innovative DER operation
    - Expanded role of DSOs in operating distribution systems
    - DSO as market facilitators and DSO-TSO co-ordination
    - Virtual power lines

- 27 Innovations grouped under four dimensions
- Which solutions are suited to which context?
Solutions come from interactions between different innovations

Innovations do not emerge in isolation. Synergies between innovations result in the needed to form real solutions.

Example of solution:

- Distributed energy resources (DERs) providing services to the grid
Digitalisation and Decentralisation

**Considerations**

- In 2015 in Germany, 35% of the country’s installed renewable energy systems are owned by citizens.
- Ongoing studies and pilot projects estimates that digital systems and data analytics can increase RE production, reduce RE curtailments, and O&M costs.
- Decentralisation, together with Digitalisation, are changing power system’s paradigm, creating new opportunities for a renewable-powered future.
- Some risks and challenges associated need to be better understood and addressed.
Thank you!