On behalf of

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

of the Federal Republic of Germany

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Transformation of energy systems for high shares of vRE

Deep Dive Workshop
Variable Renewable Energy (vRE) Grid Integration: Issues, Enabling Policies, and Finance Measures

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June 16. 2015

Content

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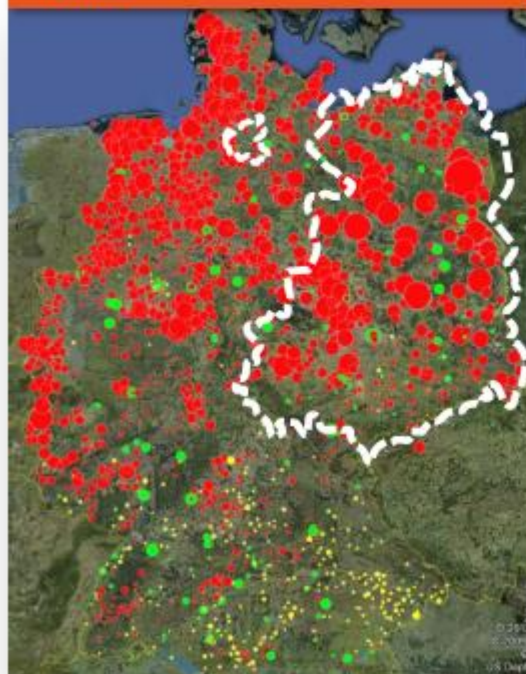
1. **RE Development in Germany**
   - Its challenges for grid stability
   - Its solutions to balance the grid
     - forecasting especially PV power
2. Is Smart Grid the answer?
3. The Options for the future
   - Curtailment and active control of vRE
   - Storage for power management and frequency control
   - Demand side and load management
4. Challenges for the transformation process

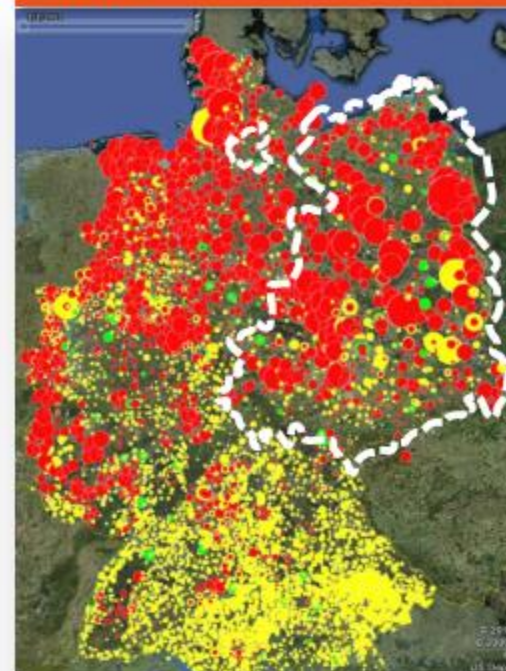
Development of RES in Germany

2000

2006



2012



- wind
- photovoltaics
- biomass

Area proportional to installed capacity

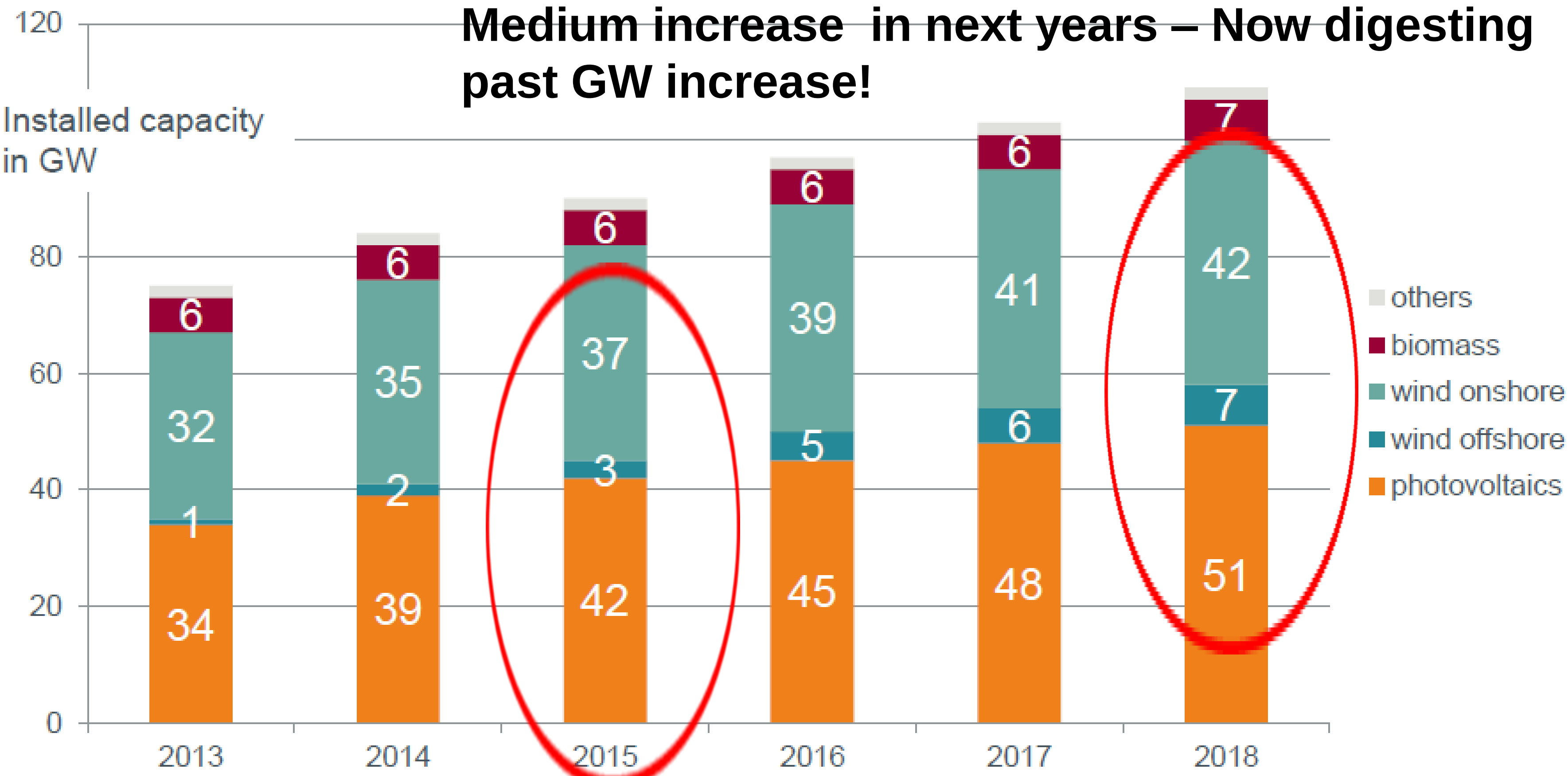
Source: 50HertzT, TenneT, Amprion, TransnetBW, Google Earth

Forecasted RES capacity in Germany

Trend-Scenario to determine the RES-surcharge in 2014

Source: r2b

In 2014: around 25% of electricity generation
Medium increase in next years – Now digesting past GW increase!

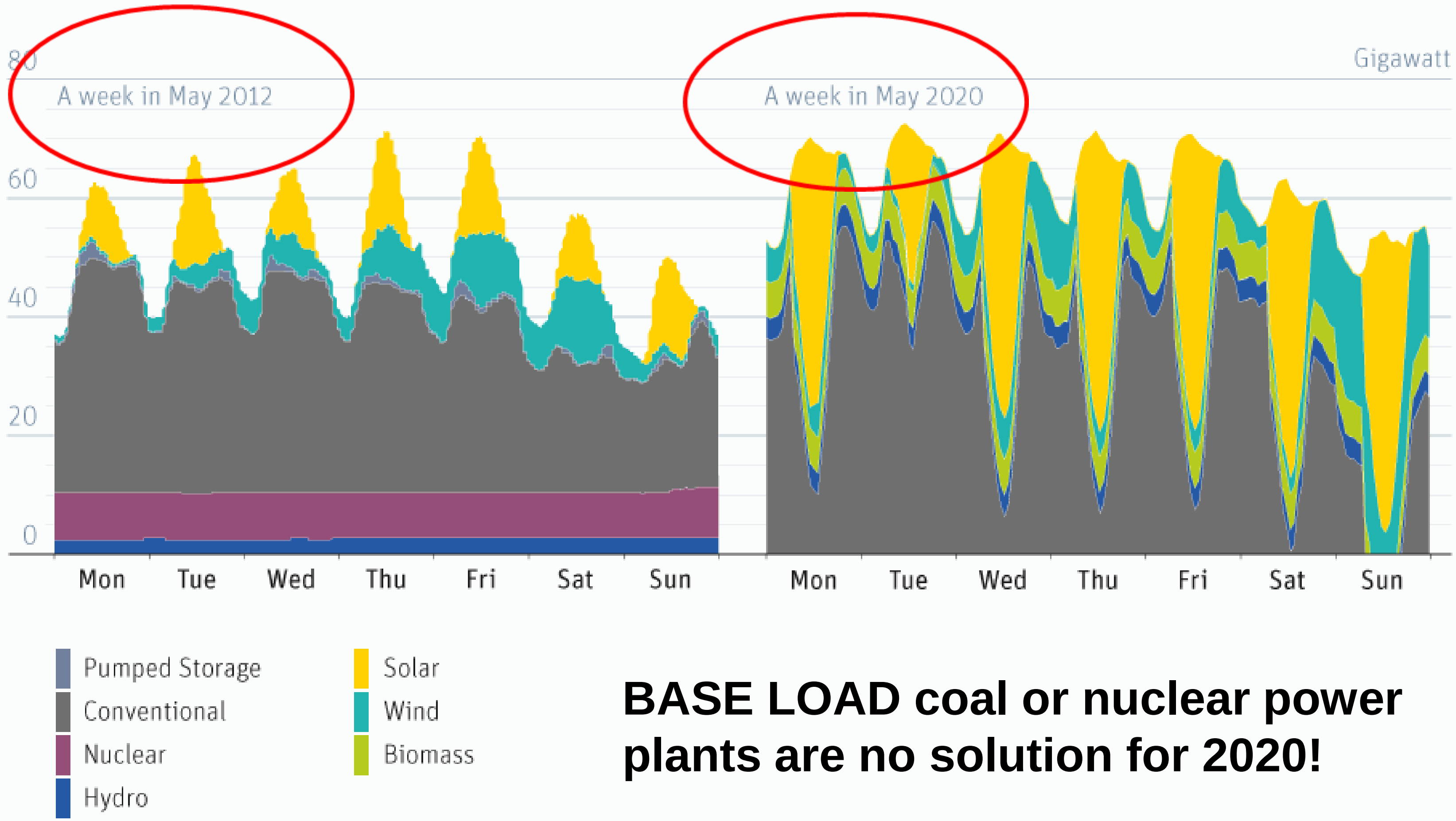


Wind and photovoltaics remain dominant players in RES development.

Renewables need flexible backup, not baseload

Estimated power demand over a week in 2012 and 2020, Germany

Source: Volker Quaschning, HTW Berlin



BASE LOAD coal or nuclear power plants are no solution for 2020!

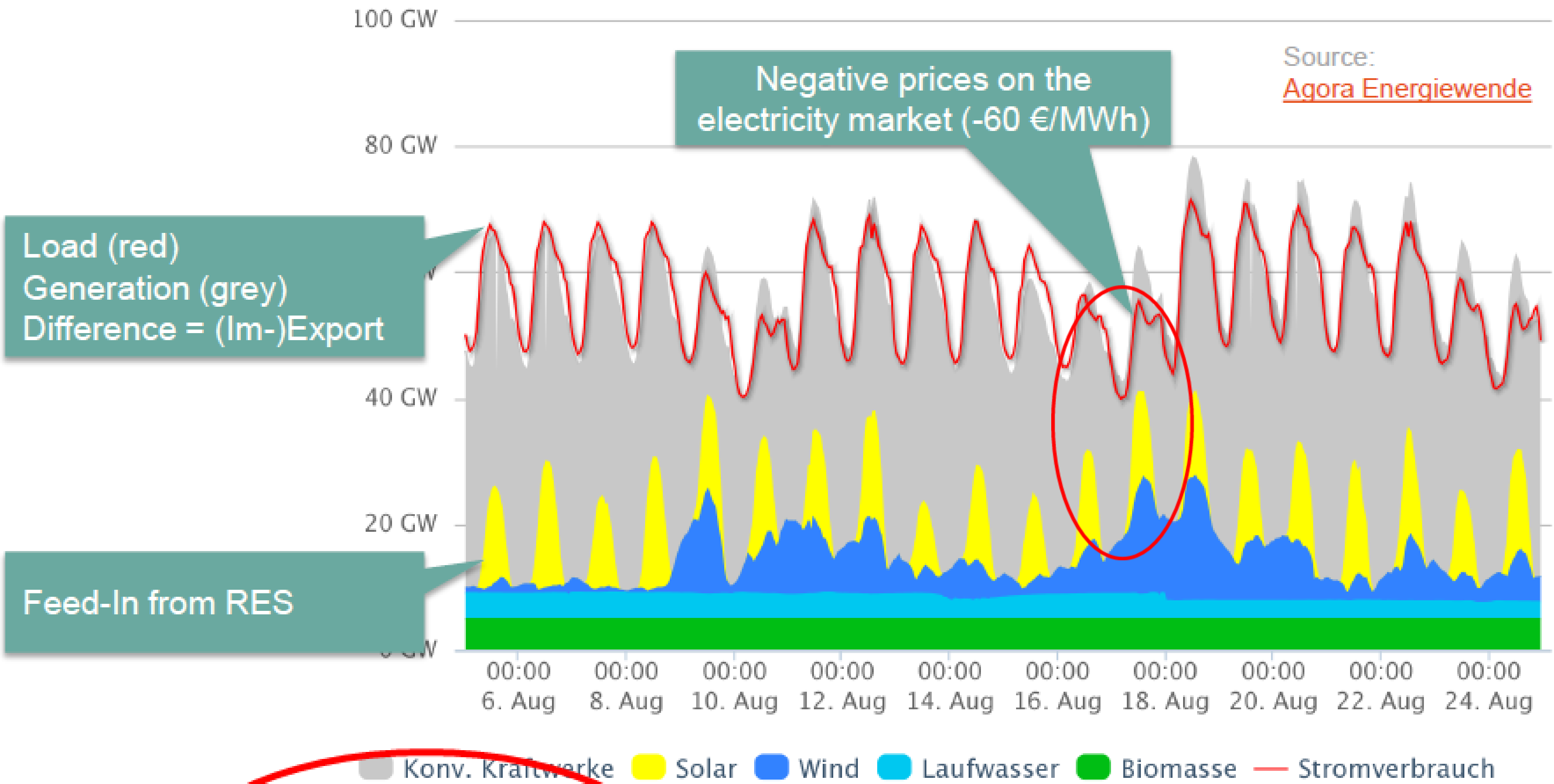
German Energy Transition energytransition.de

Source: www.energiewende.de, by Heinrich-Böll-Stiftung, 2013

50hertz

Ensure positive contribution to system balance

Load situation in Germany in August 2014



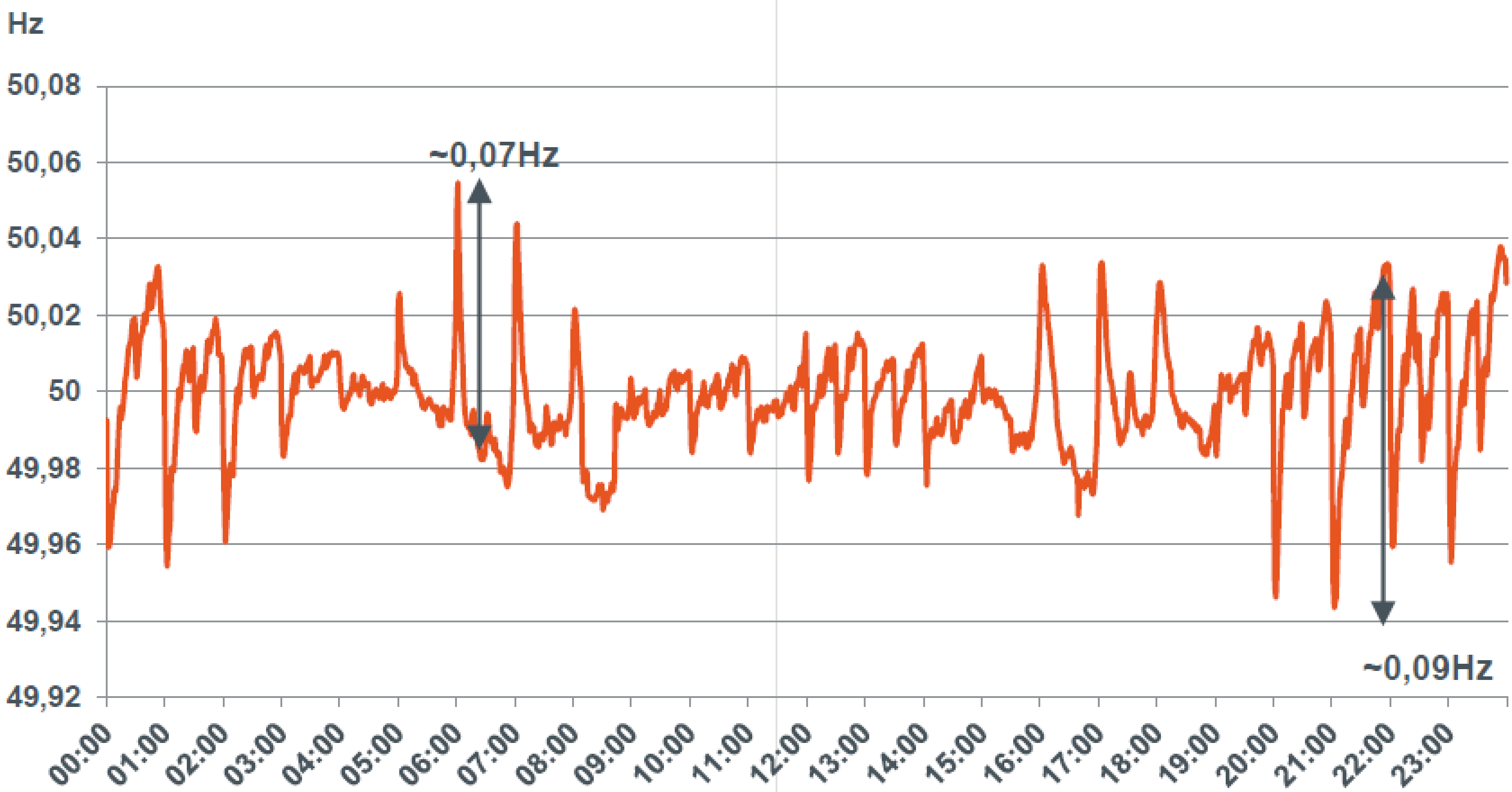
- Allow for efficient curtailment in times of oversupply
- Incentivice efficient forecasting and marketing of RES to minimize balancing

High speed of RES development imposes significant challenges on system balance

- High frequency volatility and challenging frequency control
- Extremely steep RES power ramps (>1,000 MW in 15 min in 2012)
- RES trading errors because of RES trading on an hourly basis
- RES forecasts inaccuracy, very short-term PV forecast changes
- Price spikes in the intraday market

Frequency control is getting more and more challenging due to steep RES power ramps and RES forecasts inaccuracy

Average intraday frequency volatility October – December 2013



Source: 50Hertz

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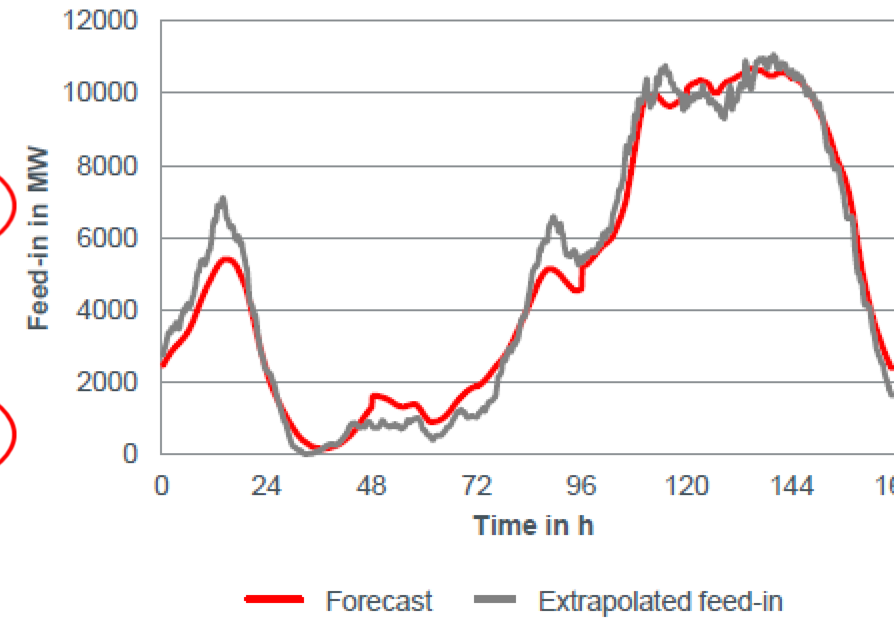
Fluctuating feed-in of renewable energies – wind energy

Data feed-in of wind energy at 50Hertz (2013)	
Maximum feed-in	11,064 MW
Minimal feed-in	0 MW
Biggest increase within ¼ hour	+1,431 MW
Biggest decrease within ¼ hour	-901 MW
Biggest difference between Min and Max within one day	9,675 MW

Feed-in wind energy (01/12/2013 – 07/12/201

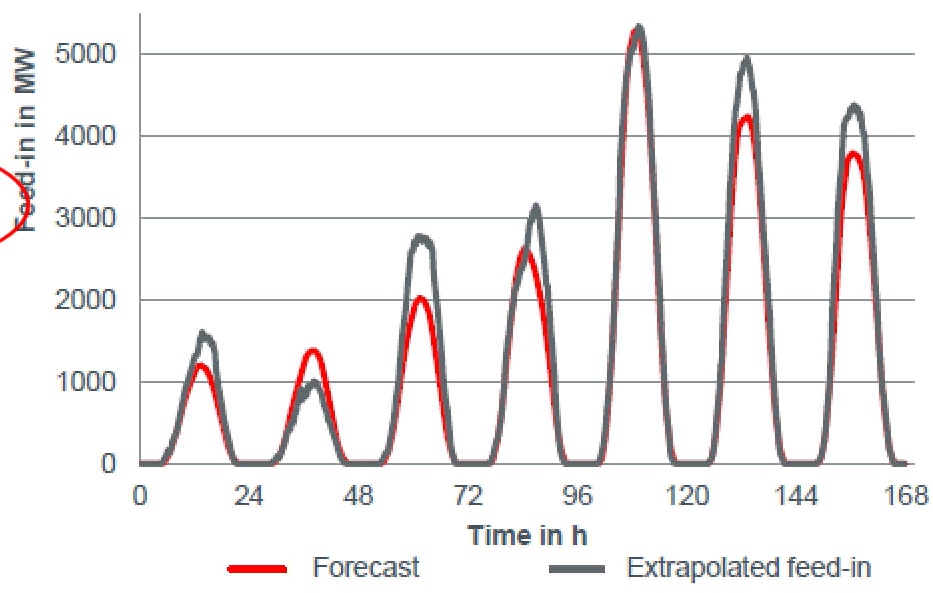


High requirements on forecasts, controlling ability and system operation.

Fluctuating feed-in of renewable energies – wind energy - photovoltaics

Data feed-in of pv at 50Hertz (2013)	
Maximum feed-in	5,346 MW
Minimal feed-in	0 MW
Biggest increase within ¼ hour	1,594 MW
Biggest decrease within ¼ hour	752 MW
Biggest difference between Min and Max within one day	5,346 MW

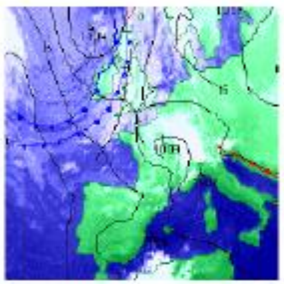
pv-feed-in (01/06/2013 – 07/06/2013)



High requirements on forecasts, controlling ability and system operation.

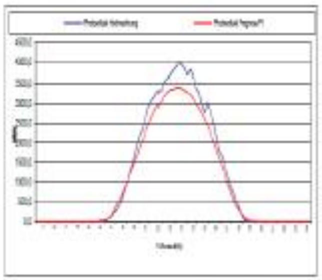
Solution: Improved solar power forecasting!

Day Ahead Forecast Solar power


Wheather observation


SMA Database


Conversion to power

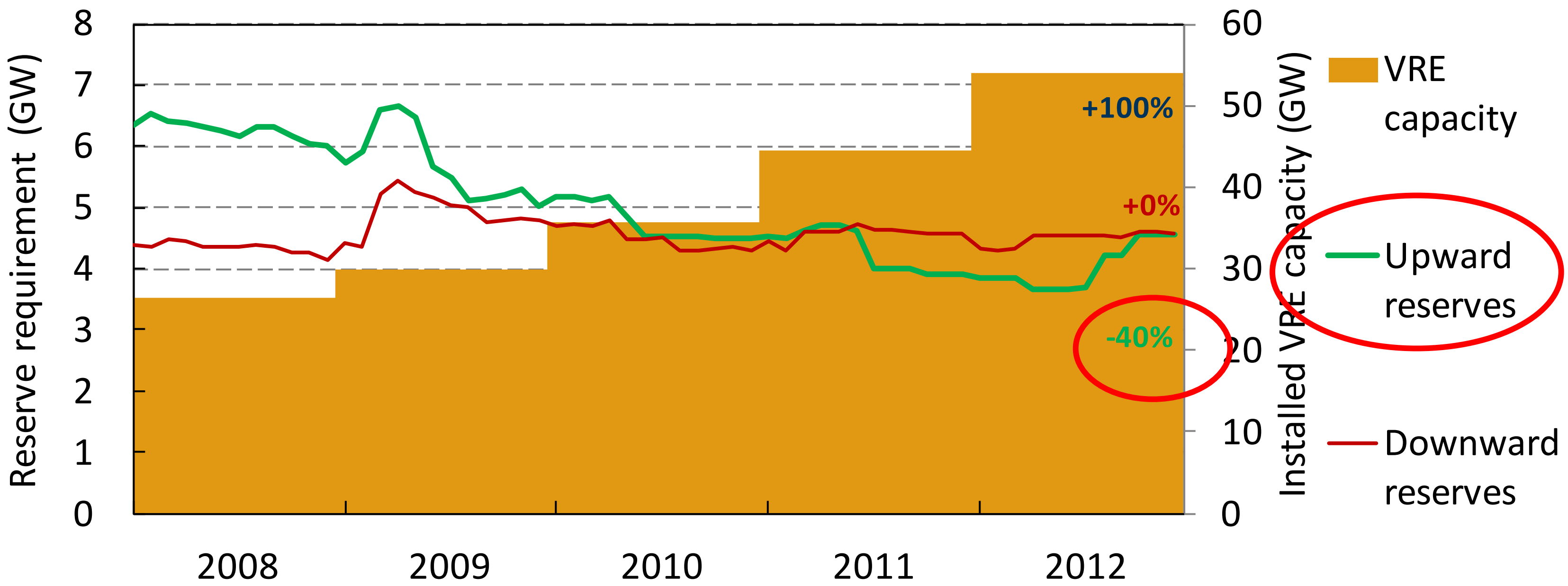

PV power forecast

- External input of forecast values:
  - solar power forecast 2 suppliers (EnergyMeteoSystems, Meteocontrol)
  - Areas: Germany, 50Hertz, DSO-regions
  - Horizon day-ahead <= 96 hours; horizon short term <= 8 hours
  - 3 daily updates; ¼ hour short term updates
- Combined Forecast with weighted experience by 50Hertz
  - Linear combination of commercially available forecasts

Accuracy of solar forecast has reached 5-7% Root Mean Square Error (RMSE)

Co-operation with neighbours reduce reserve power

Required frequency restoration reserves in Germany



- Germany has four balancing areas (historic reasons)
- Reserve sharing mechanism across four areas
- Reduced requirements despite rapid increase of VRE

Source: OECD/IEA 2014

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Why do we need a Smart Grid in future? Because framework conditions are changing rapidly!

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1. **Consumer** will become **Prosumer** (producer **&** consumer)
2. **Massive increase** of variable RE (vRE), **especially PV** into grid!
3. **Future** of conventional **electricity supply system** has major **challenges**:
   1. **Central versus decentralize** energy supply in the future? **Ownership?**
   2. **PV system cost**, based on LCOE, have come down dramatically:

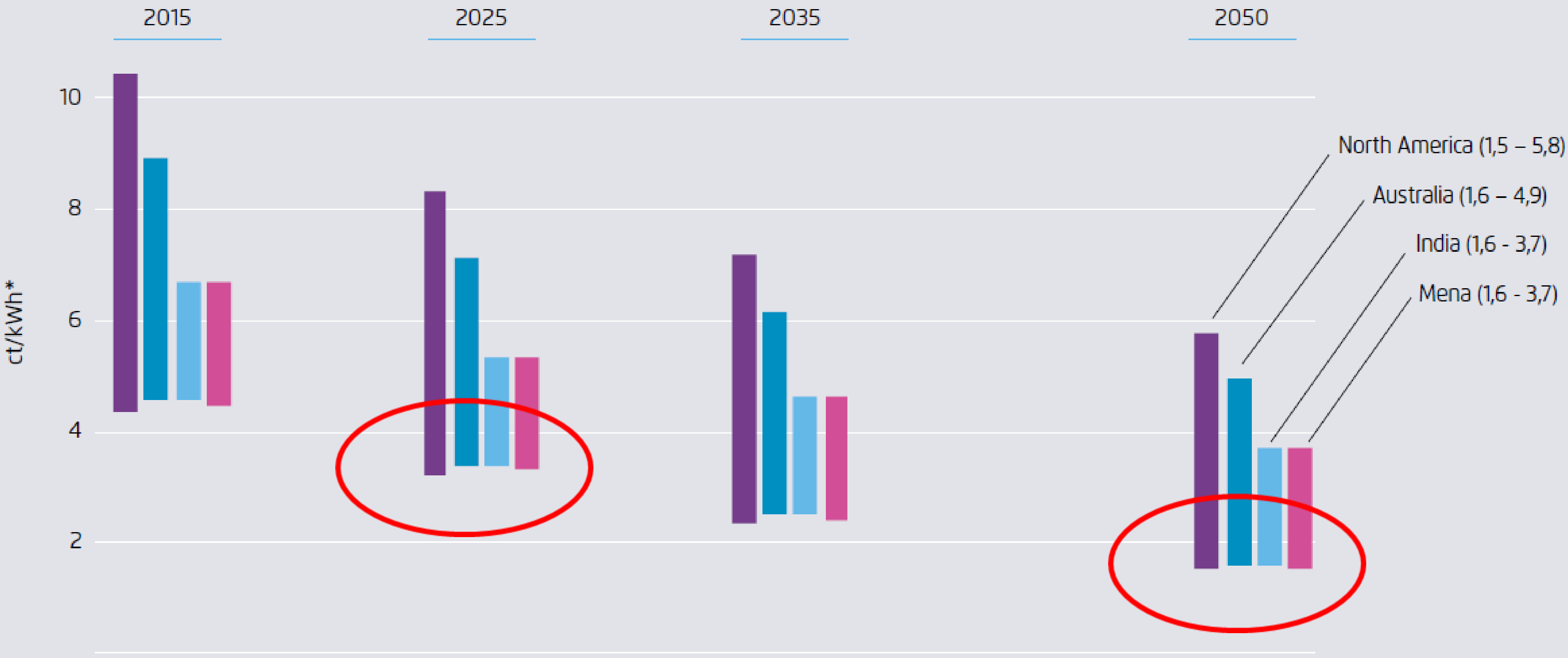
      - expected: **4 EURct/kWh (5 US$ct/kWh**) in **2025** in ASEAN

      - even **2 EURct/kWh** (30 years lifetime) for 2050 for ASEAN
4. **Storage costs,** especially **battery** are showing same development recently
5. **Climate change commitments** will curtail **conventional fuel supply**

   => **How will countries position themselves in this environment?**

Generation costs of 3 – 8 c€/kWh for 2025!
For 2050: less then 2 c€/kWh are possible!

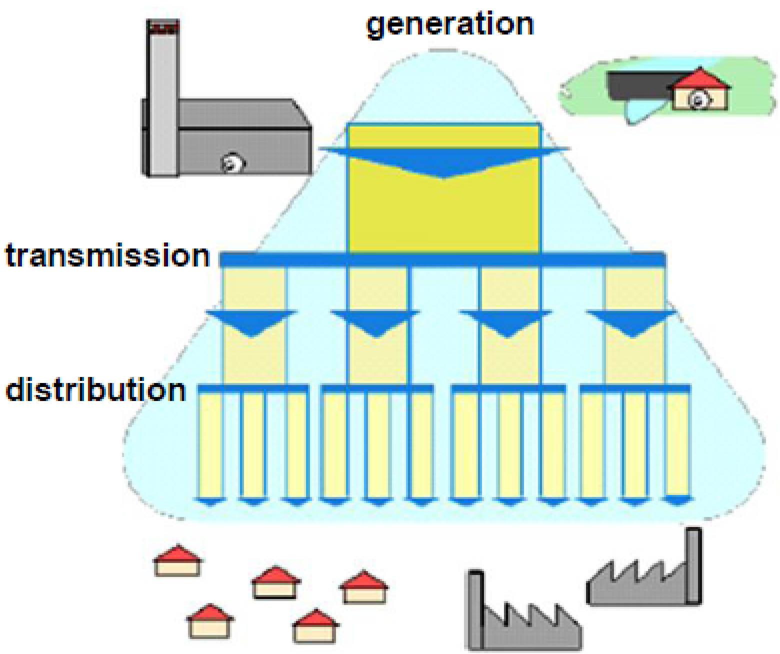
Cost of electricity from new solar power plants in North America, Australia, India and Mena region* Figure E5

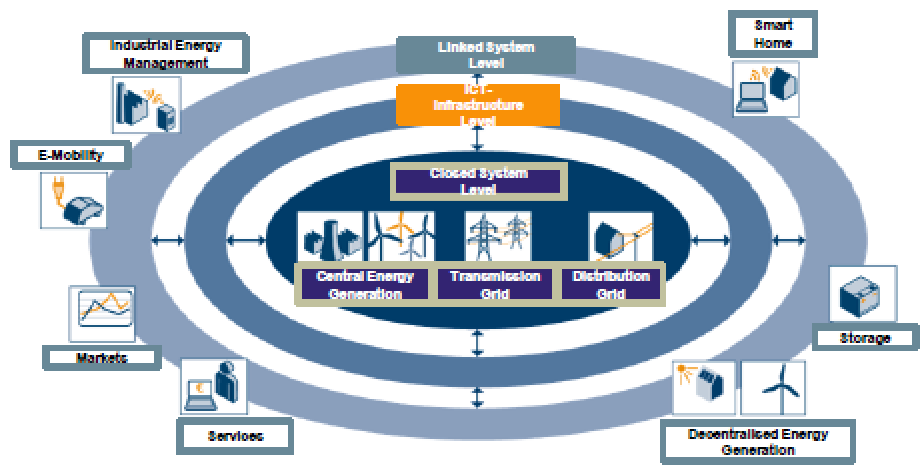


* Real values EUR 2014; full load hours based on [27], investment cost bandwidth based on different scenarios of market, technology and cost development; assuming 5% (real) weighted average cost of capital.

Source: Agora Energiewende: Current and Future Cost of Photovoltaics, 2015

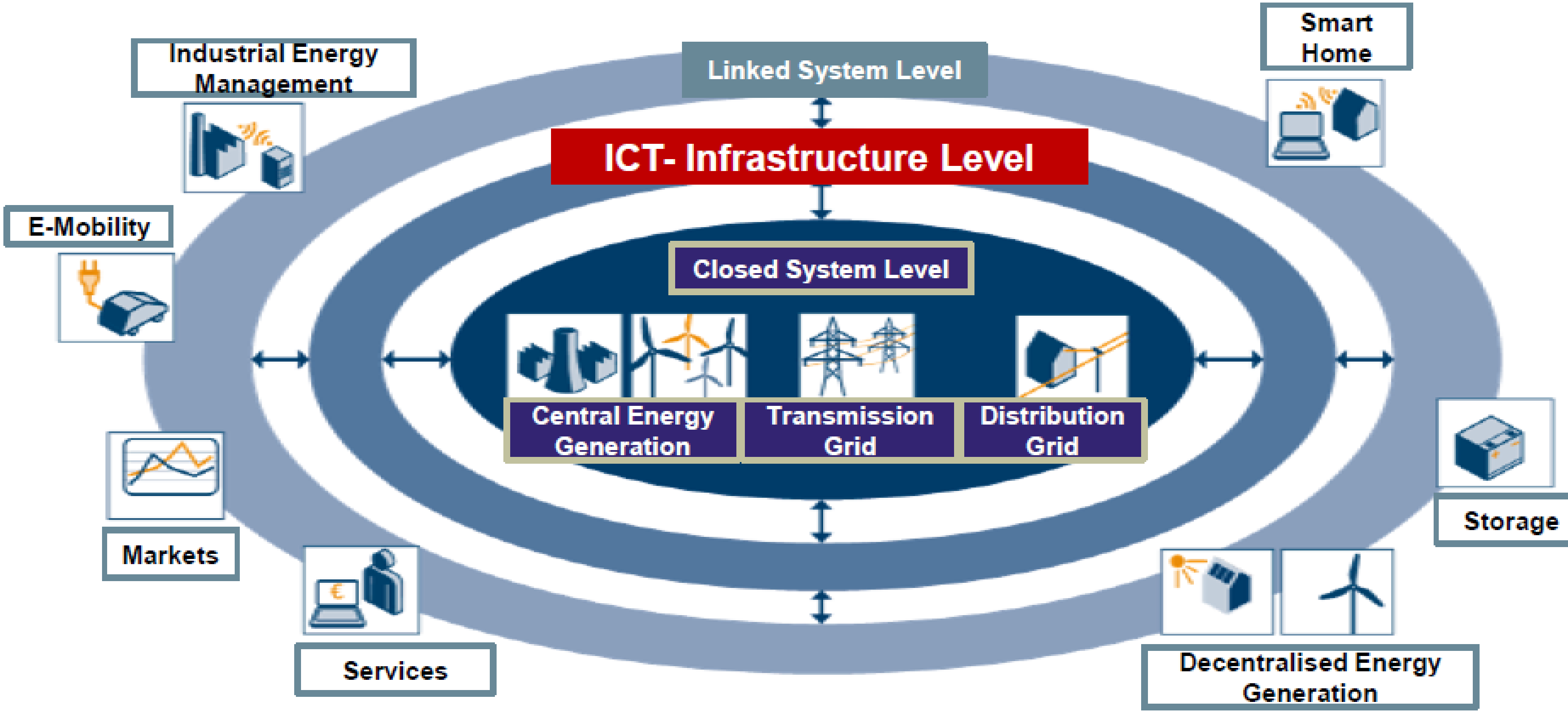
The energy transformation demands a **new energy ecosystem model** of **interaction** and **coordination**



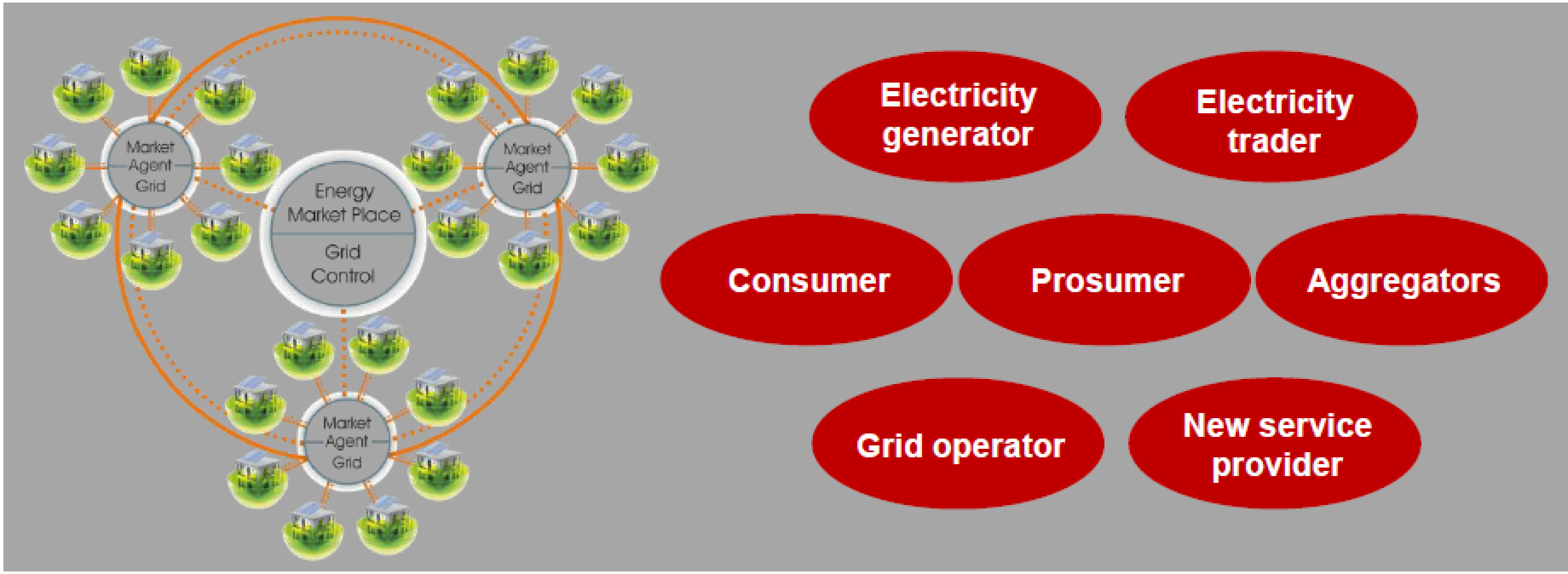


Paradigm shift from **consumption-oriented** electricity production to **generation-optimised** consumption

Smart grid enables real time coordination of generation and consumption



The future **energy market** significantly differs from a traditional market



- Real time access
- Actors need to interact more frequently
- Changing roles of actors
- Data integrity & trust even more important
- Higher flexibility of consumption necessary

Source: Ludwig Karg, B.A.U.M Consult

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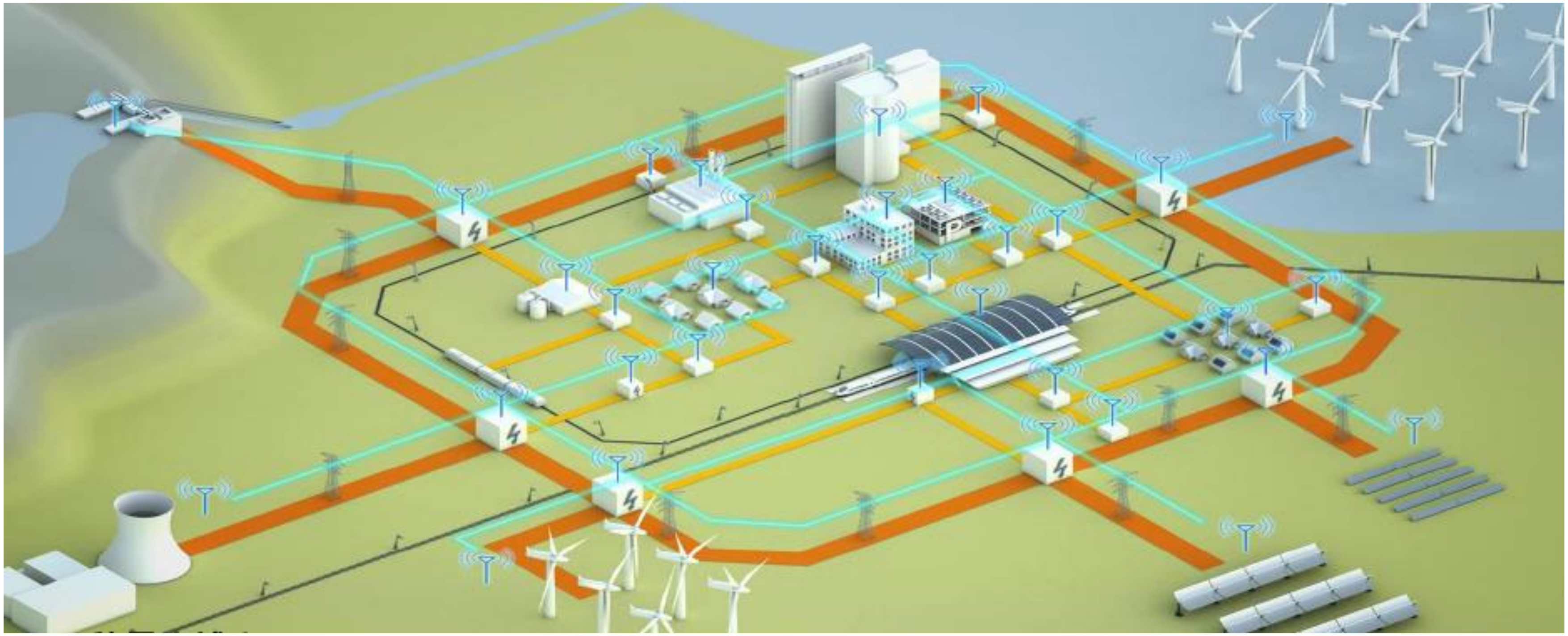
Challenge:

How does the future energy system look like?

We do not know exactly, but it will be different from today!

But we need a **national energy vision** to define the a smart grid plan for a nation so utilities plan their investments!



Picture source: Siemens AG

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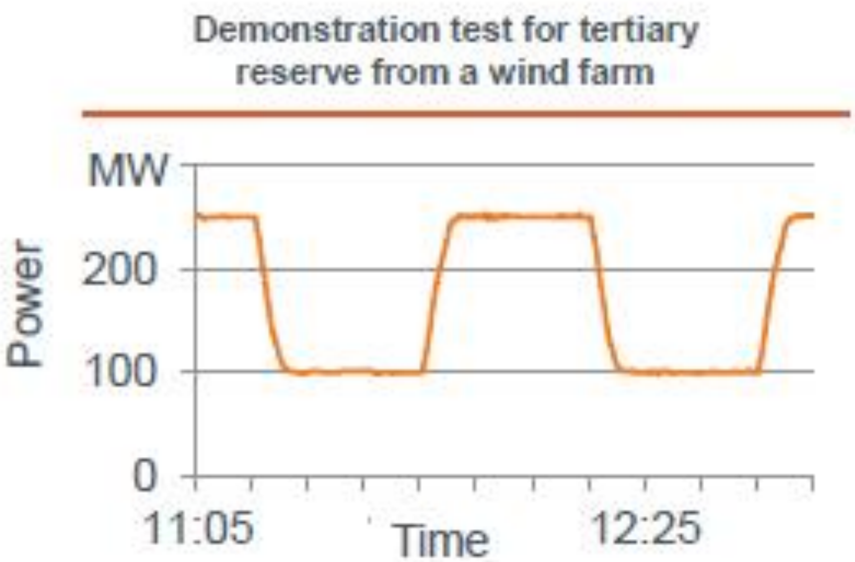
50hertz

Ensure positive contribution to system balance
Balancing with wind power



- Wind farms have the technical capability to provide negative balancing energy
- Current challenges are in the calculation method for the reference production „What would have been the production without the request from the TSO?“

50hertz

New providers of control power are very welcome: Batteries prequalified in the 50Hertz control area

Source: YOUNICOS

Battery Berlin-Adlershof

- **Power:** 1 MW
- **Capacity:** 6.2 MWh
- **Technology:** ~~Lithium-Ion~~ Sodium-Sulphur
- **Commissioning:** 01/2012
- **Usage:** primary control

Battery Schwerin

- **Power:** 5 MW
- **Capacity:** 5 MWh
- **Technology:** Lithium-Ion
- **Commissioning:** 09/2014
- **Usage:** primary control

New providers of control power are very welcome: Electric boilers and a steel mill prequalified in the 50Hertz control area

Electric boilers Stadtwerke Schwerin

- Three electric boilers prequalified for **secondary control** (aFRR) provision
- Up to **10 MW** aFRR
- Start of aFRR marketing in December **2013**

Steel mill Hamburg

- Electric furnace 3 of ArcelorMittal Hamburg GmbH prequalified for **tertiary control** provision (mFRR)
- Up to **70 MW** mFRR
- Start of mFRR marketing in **2010**

Sources: Stadtwerke Schwerin, ArcelorMittal Hamburg GmbH

Example: PV storage and back up system for PV integration

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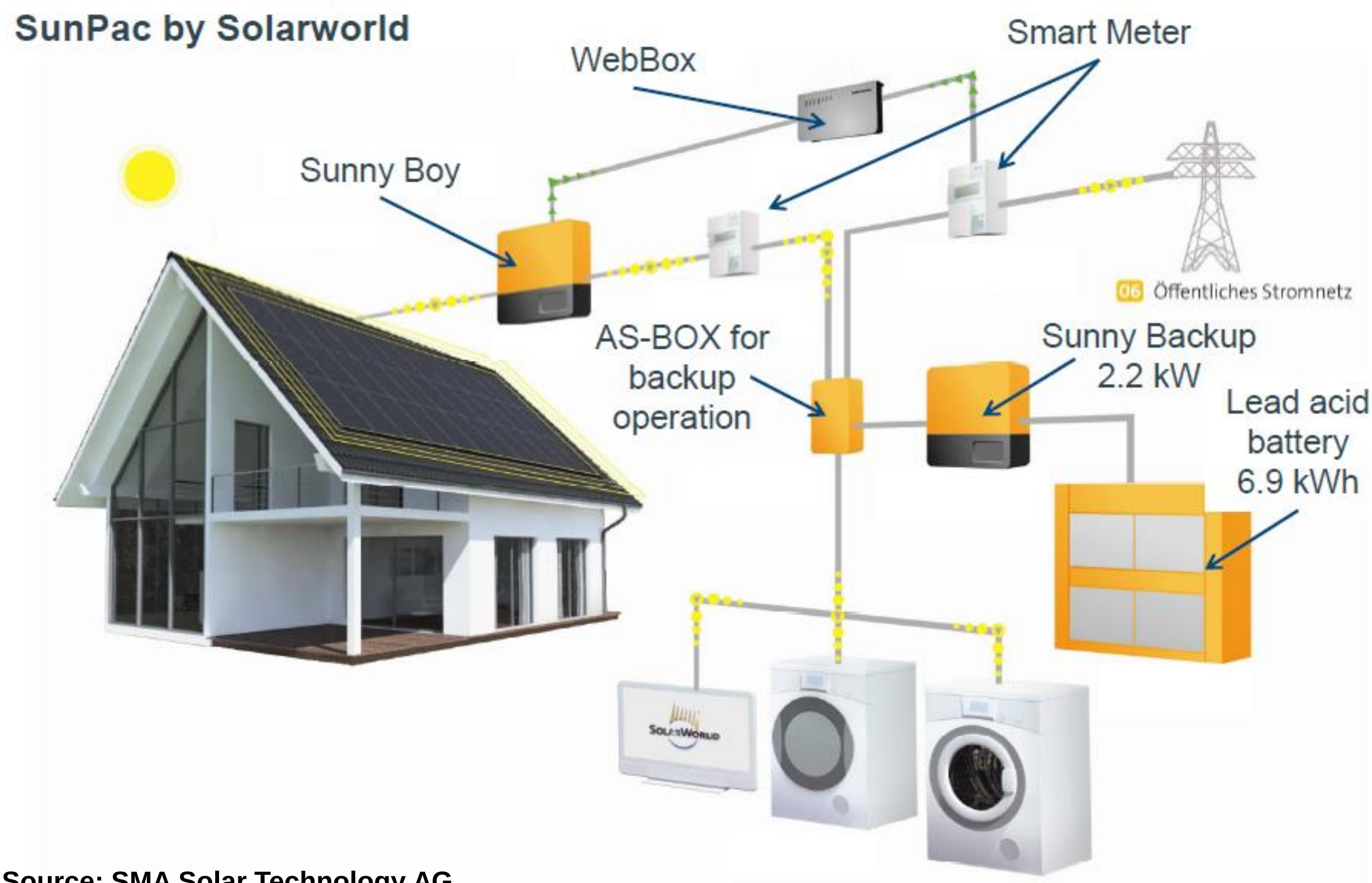
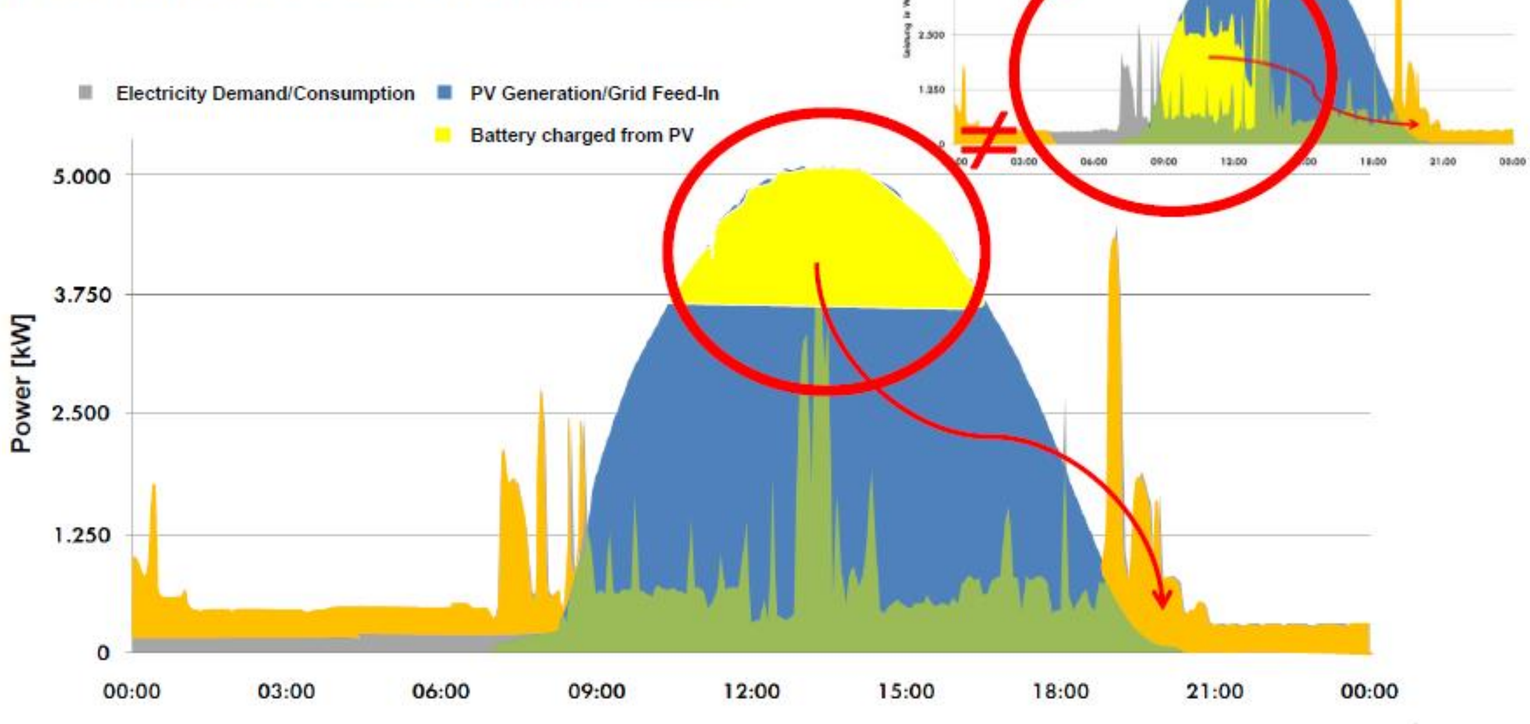


Source: SMA Solar Technology AG

Option: PV storage as peak load reduction

Using storage to reduce grid peak loads



- Reduction of **peak loads** and **grid feed-in** significantly reduces the grid loads and guarantees **tong-term capacity for PV generated electricity!**

Source: SMA Solar Technology AG

Conclusions for Transformation of energy systems for high shares of vRE:

1. Need to adopt **energy vision** and **energy planning** for rapid changes of **PV cost development regularly**!

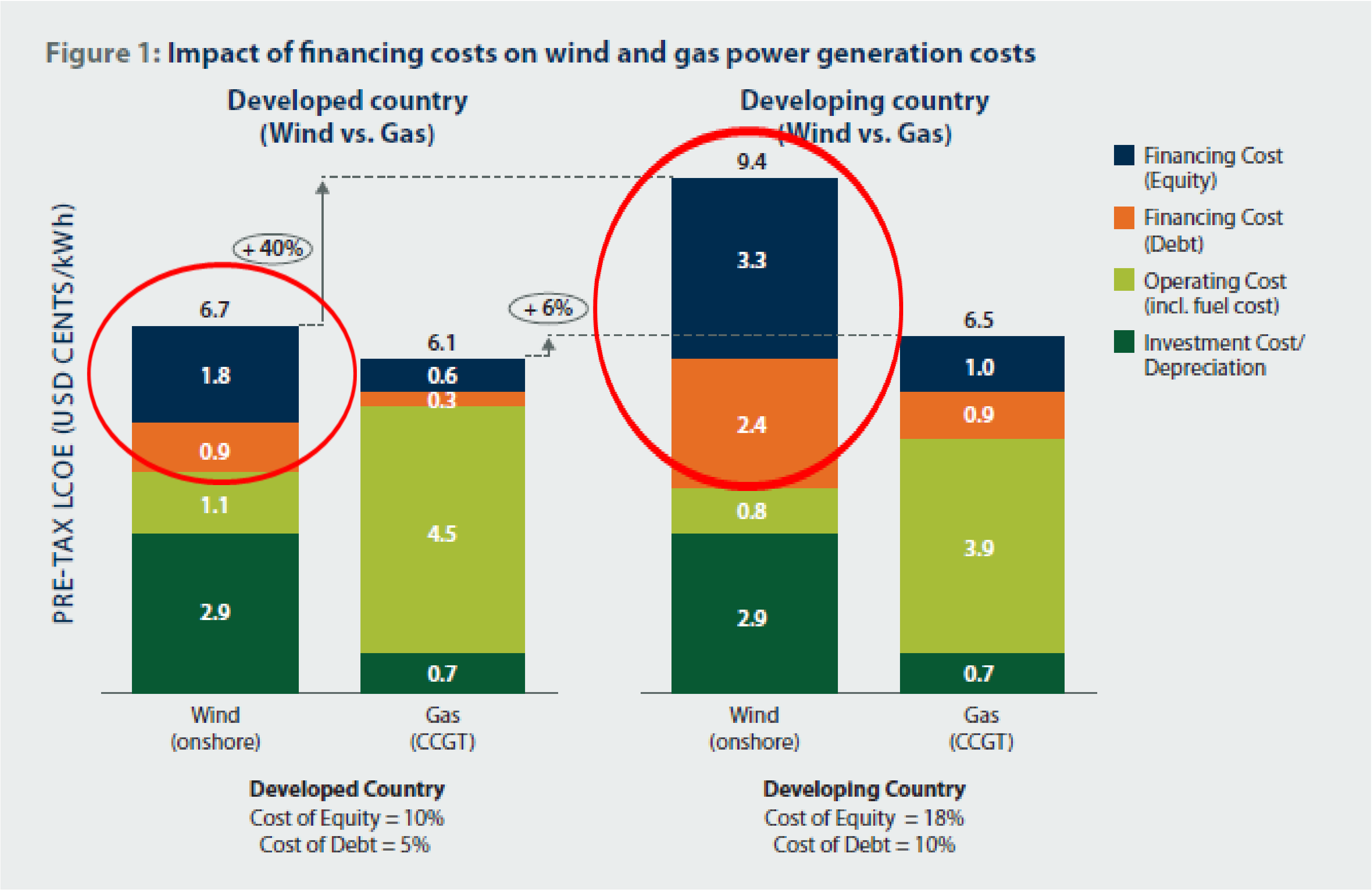
2. **Test smart grid** applications in grid, like **storage** at low and medium voltage level; like DSM and load management.

3. Develop and **improve forecasting for wind** and for **solar (PV)**!

4. **Transform energy market**, so that vRE can be integrated **and** can **offer system services**, like ramping, active power control, inertia, etc.

5. In **near** future technically more than **25% - 30% of energy can come from vRE** if **grid** is **managed right** and **energy market design** is **adequate**. In long term much more, like technically 100% is possible.

RE policy objective: De-risking RE investment



Source: De-risking Renewable Energy Investment, UNDP 2013

Thank you for your kind attention!

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