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Integration of wind and solar in power systems

Cédric Philibert

Renewable Energy Division

International Energy Agency

,

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Outline

1. **Competitive solar and wind power will play a central role in future power systems**

2. **Variability of wind and solar PV electricity raises issues, which leading countries show can be addressed**
   - ❑ No problem at 5% - 10%, if well-managed
   - ❑ Going to larger shares: the balancing and utilization challenges
   - ❑ The three pillars of system transformation:
   - ➢ System friendly RE deployment
   - ➢ Use best what you have: markets, forecasts
   - ➢ Invest in more flexibility: grids, demand side, flexible generation, storage

3. **Specific issues from distributed generation**

4. **Conclusions and recommendations**

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Wind and solar: lower costs on the horizon

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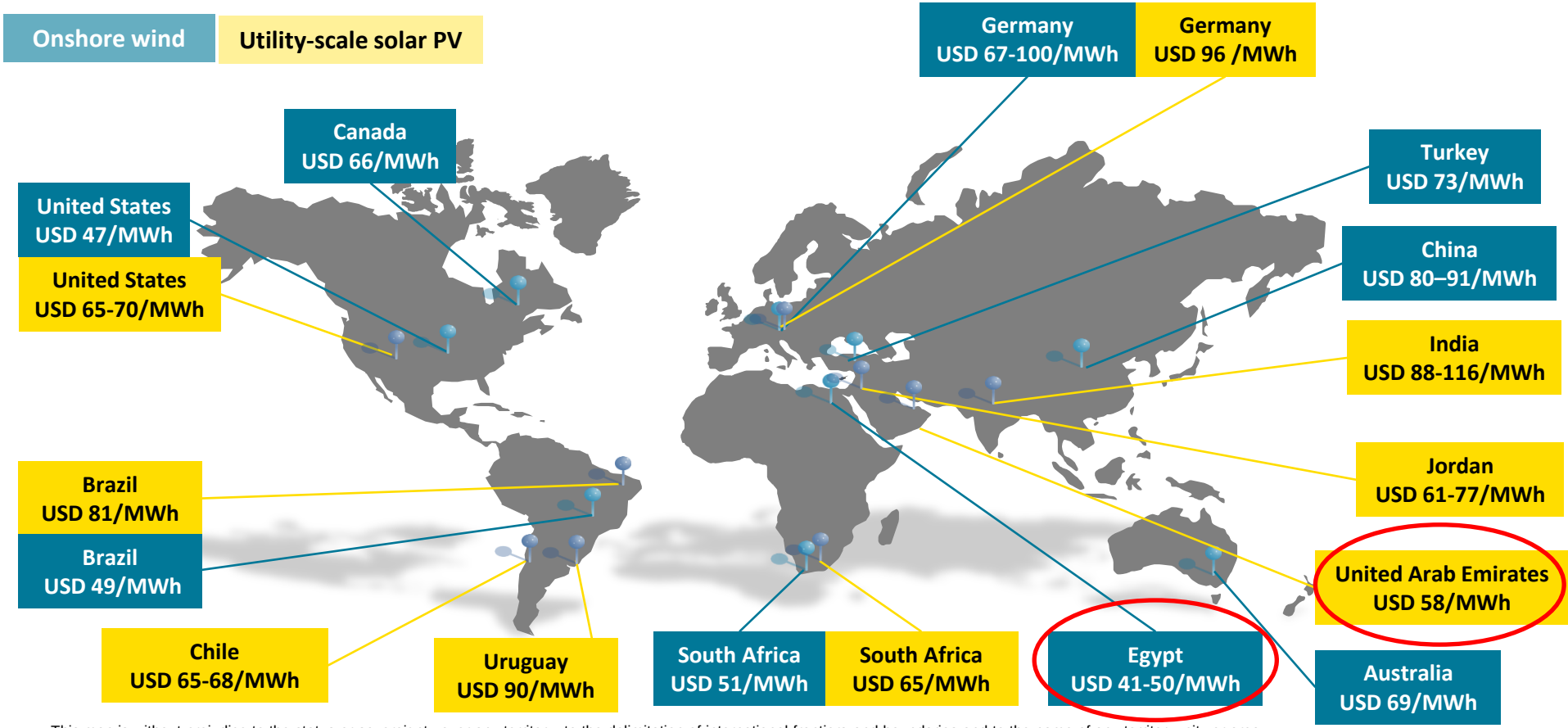
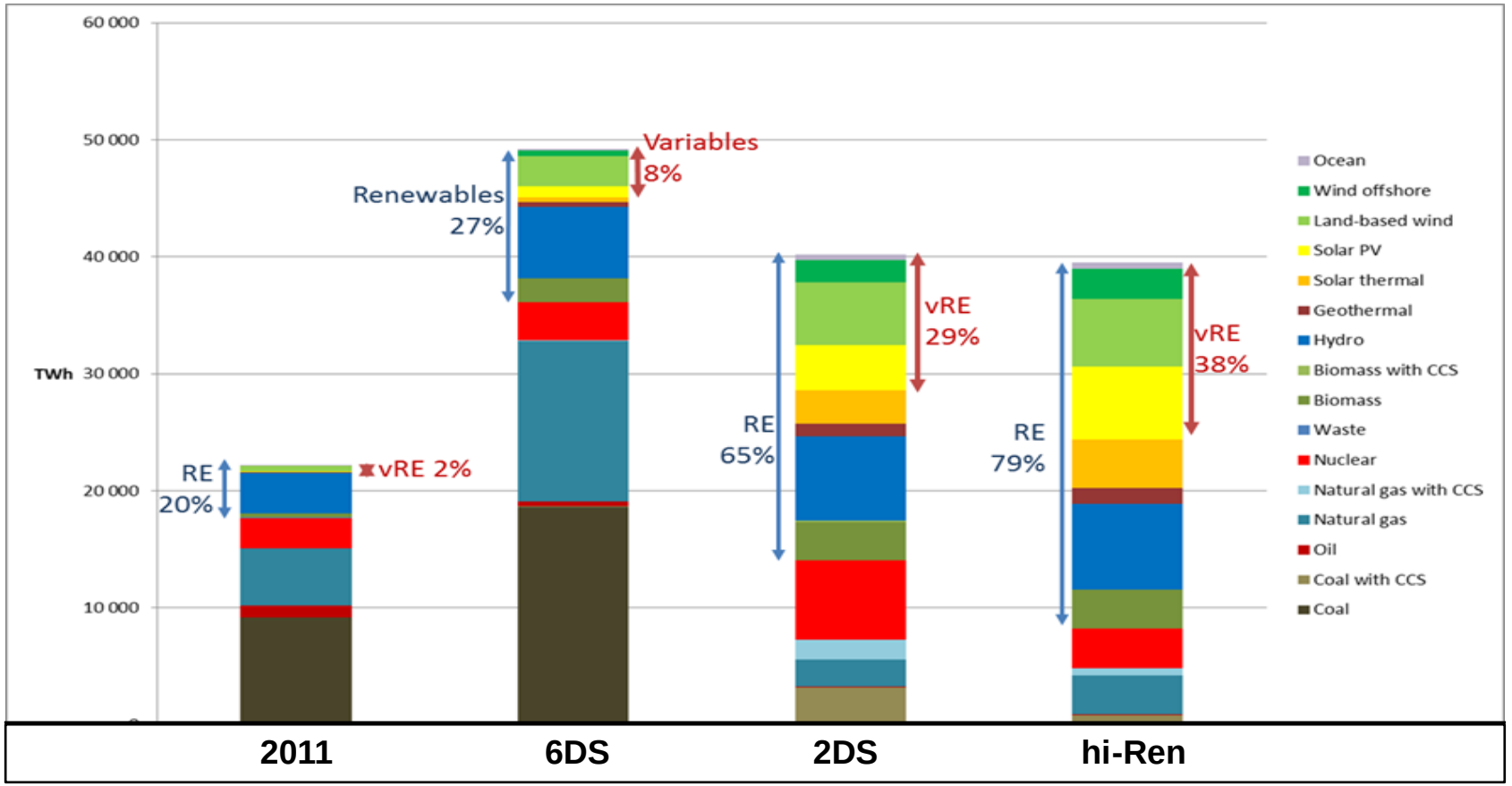
Recent announced long-term contract prices for new renewable power



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

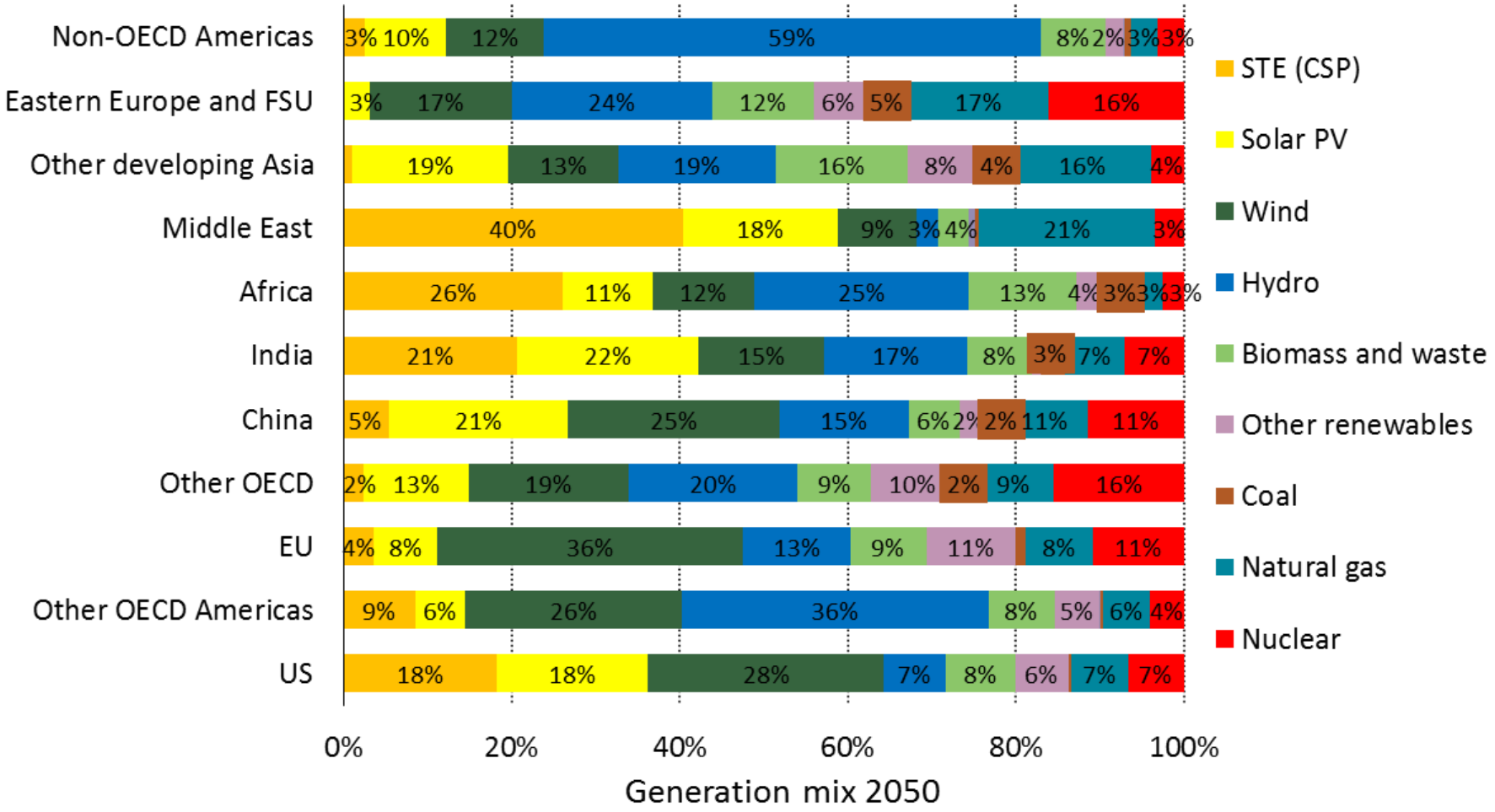
A combination of price competition, long-term contracts, good resources and financial de-risking measures is creating deployment opportunities in newer markets and at lower costs

Power mix: a shift reversal



- **Generation today:**
  - **Fossil fuels: 68%**
  - **Renewables: 20%**
- **Generation 2DS 2050:**
  - **Renewables: 65 - 79%**
  - **Fossil fuels: 20 - 12%**

Regional power mixes differ by 2050 in 2DS hi-REN



Source: *Energy Technology Perspectives 2014*

Differences in resources but also in load shapes lead to quite different technology mixes

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Evolution of the ASEAN power mix in the 2DS hi-Ren

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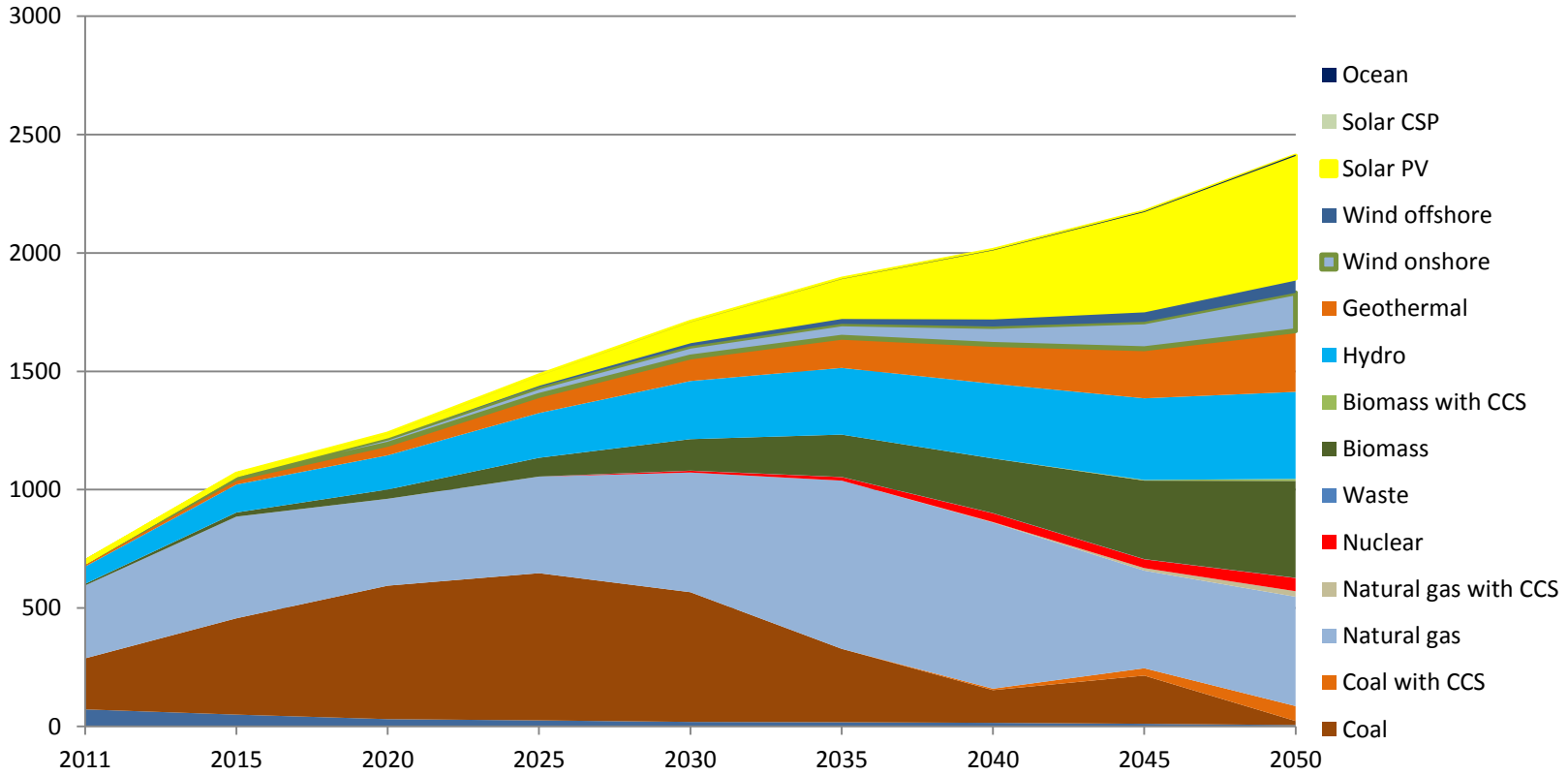


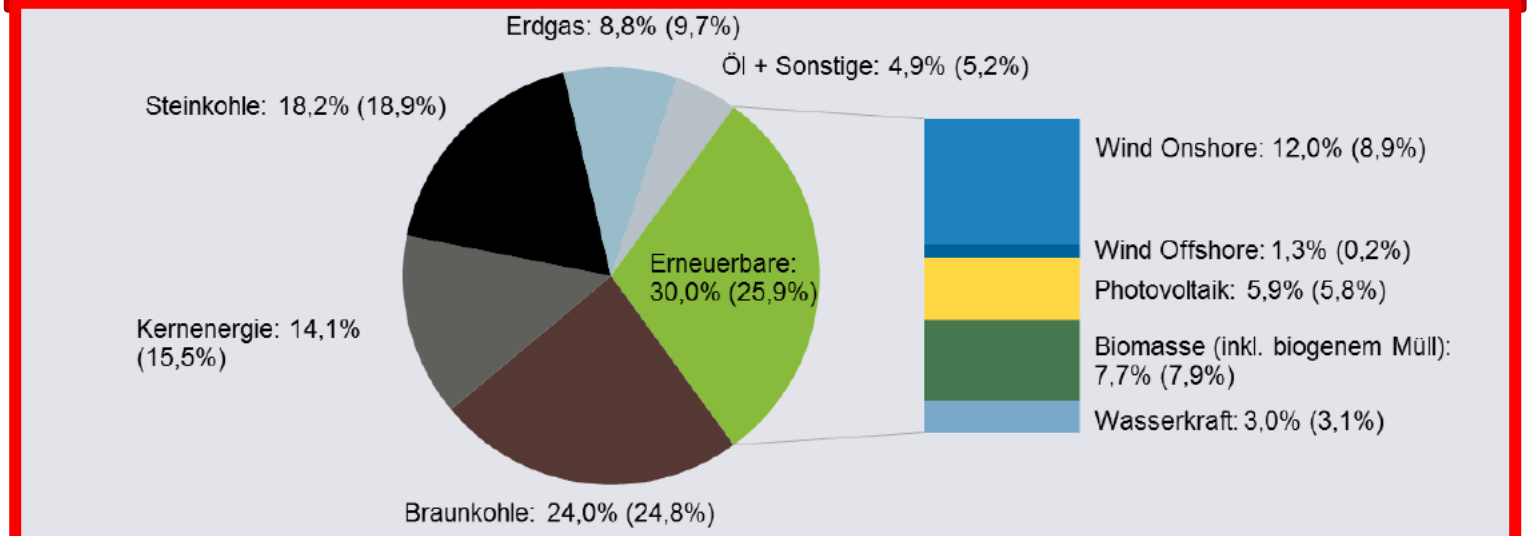
Variable renewable renewables (mostly solar PV) would generate 1/3 of electricity in ASEAN region by 2050 in the 2DS hi-Ren scenario

Variable renewables (vRE) and initial concerns

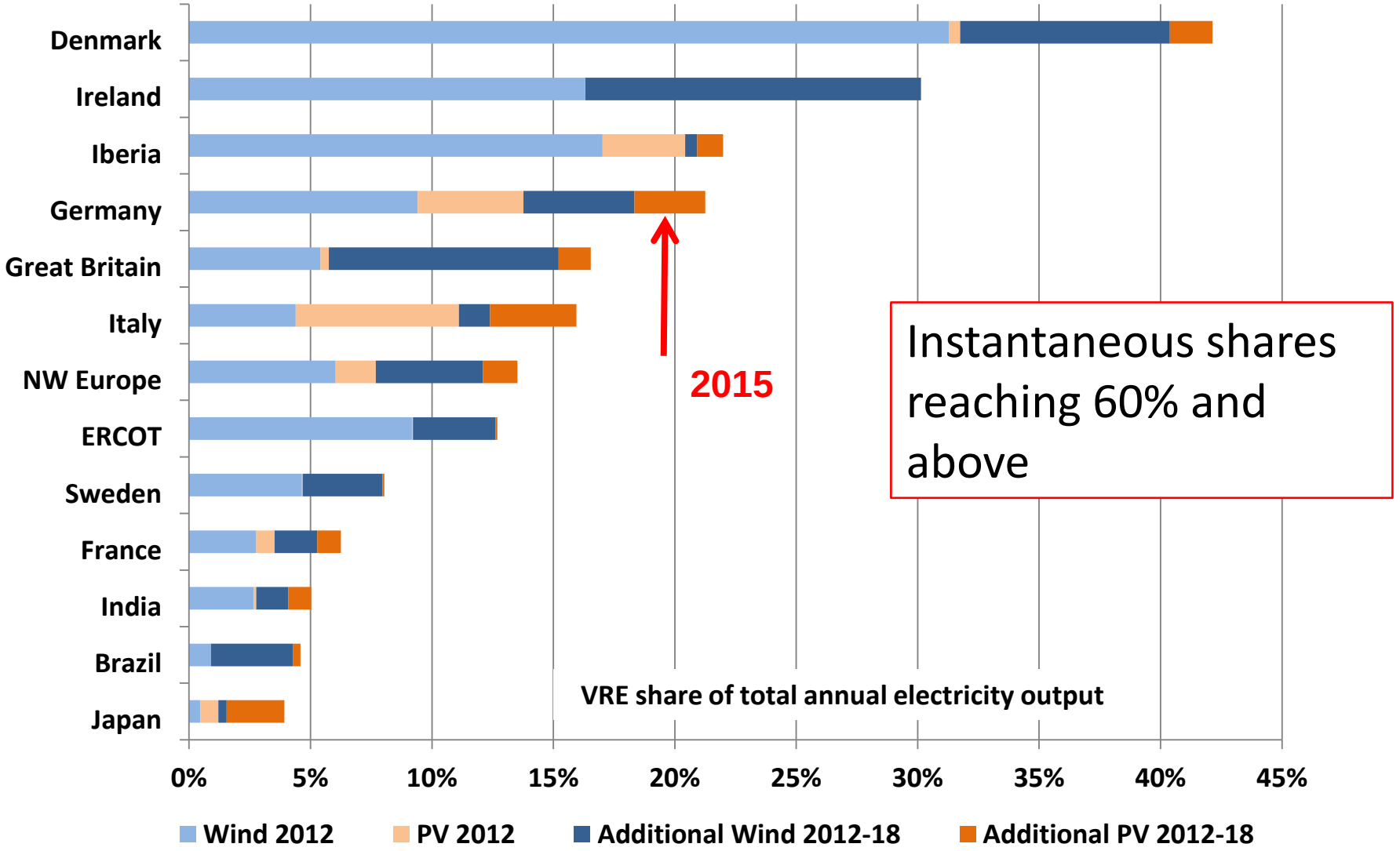
Germany, 1993, 0.1% wind power in total generation – power utilities issue a joint statement:

"Renewable energies such as sun, hydro or wind cannot cover more than 4% of our electricity consumption – even in the long run" Source: *Die Zeit*, 30 July 1993, p. 10

In 2015 already, Germany got almost 20% of power from wind and solar, 30% from RE!



Large-scale integration accomplished today, and more to come



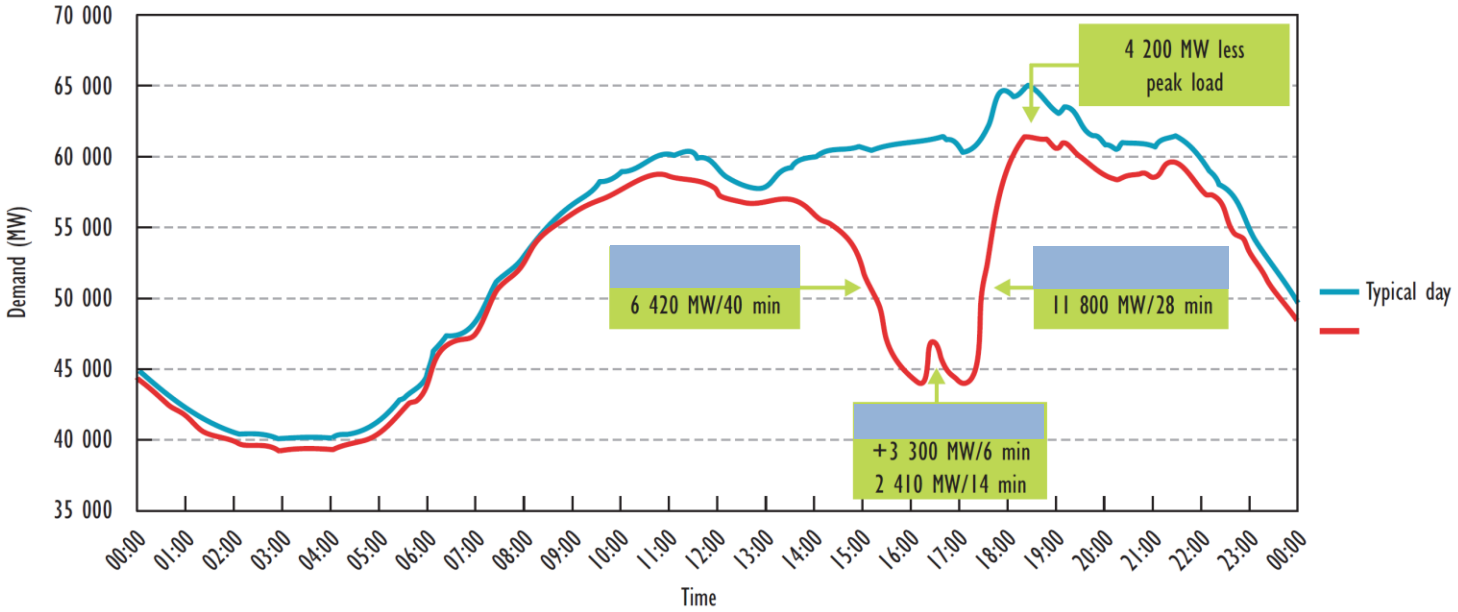
Note: ERCOT = Electricity Reliability Council of Texas, United States

Source: IEA estimates derived in part from IEA Medium-Term Renewable Energy Market Report 2013.

No problem at 5% - 10%, if …

- **Power systems already deal with a vast demand variability**
  - **Can use existing flexibility for VRE integration**

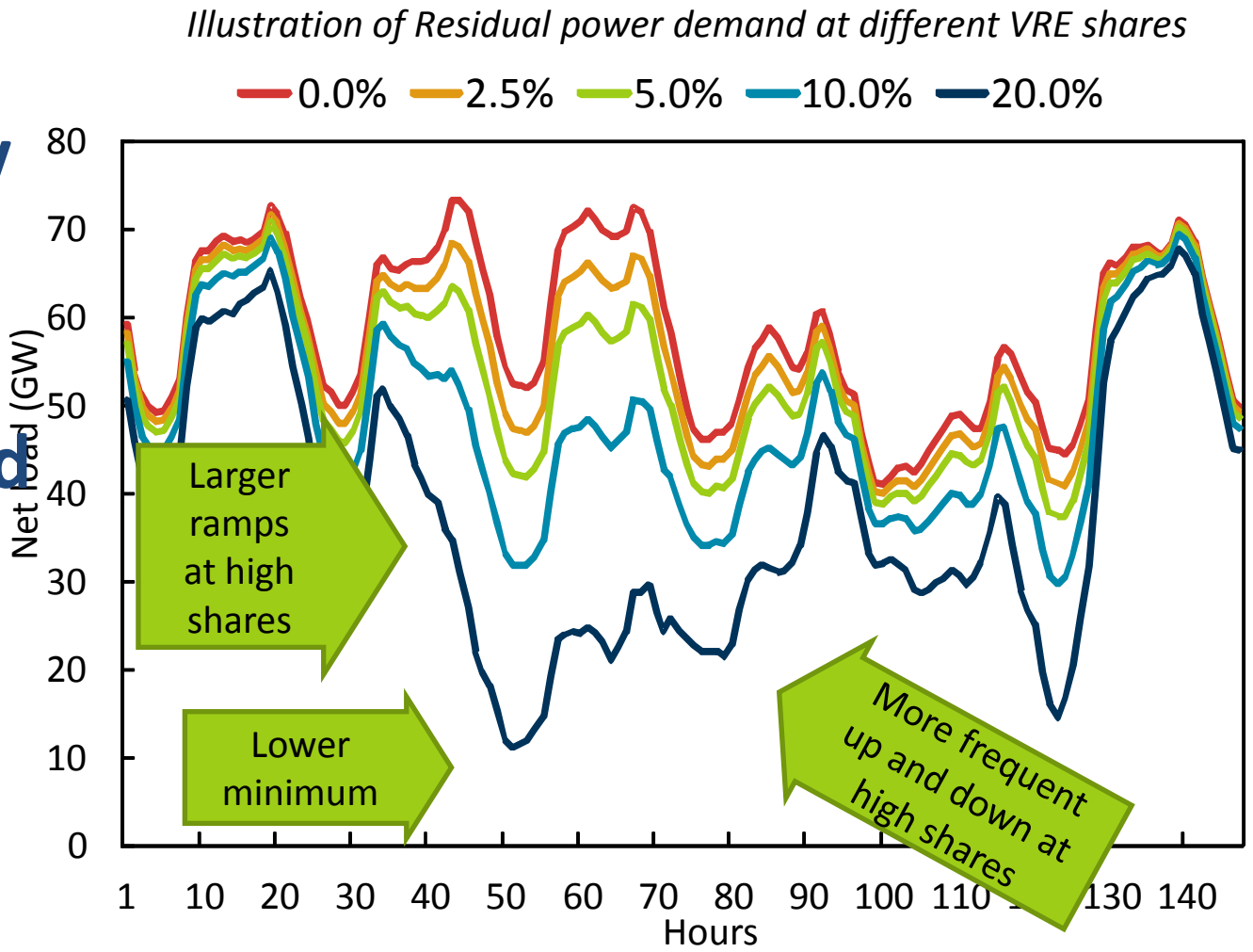
Exceptionally high variability in Brazil, 28 June 2010



- **No technical or economic challenges at low shares, if basic rules are followed:**
  - **Avoid uncontrolled, local 'hot spots' of deployment**
  - **Adapt basic system operation strategies, such as forecasts**
  - **Ensure that VRE power plants are state-of-the art and can stabilise the grid**

Integrating larger shares of VRE: the balancing challenge

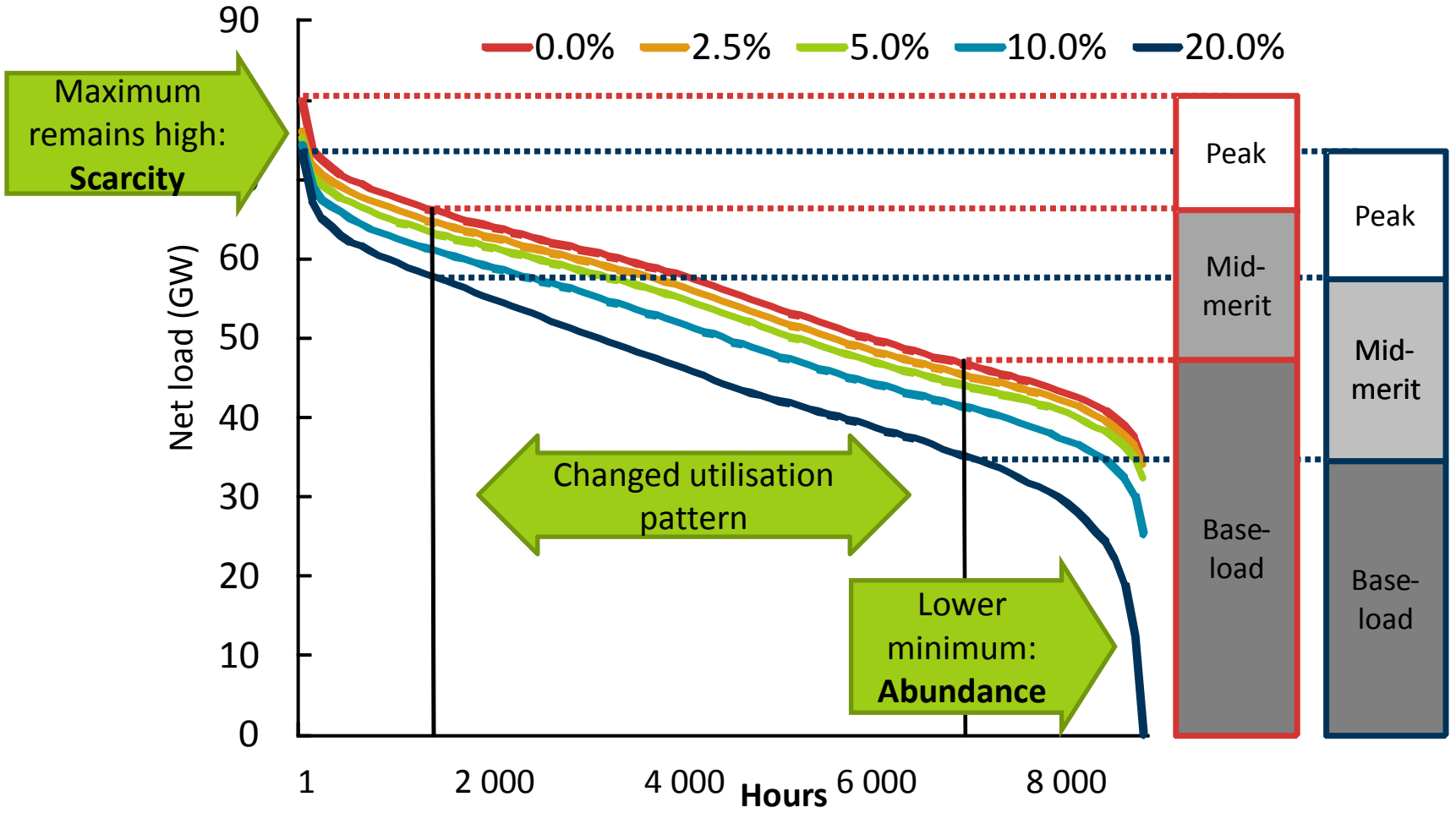
- Higher uncertainty
- Larger and more pronounced changes



Note: Load data and wind data from Germany 10 to 16 November 2010, wind generation scaled, actual share 7.3%. Scaling may overestimate the impact of variability; combined effect of wind and solar may be lower, illustration only.

Integrating larger shares of VRE: the utilisation challenge

- **Netload implies different utilisation for non-VRE system**



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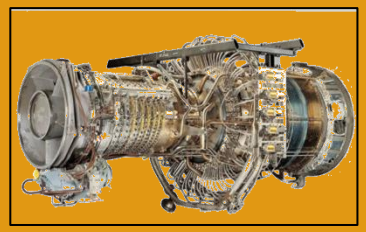
Three pillars of system transformation

Technology spread

Geographic spread

Design of power plants

System friendly VRE

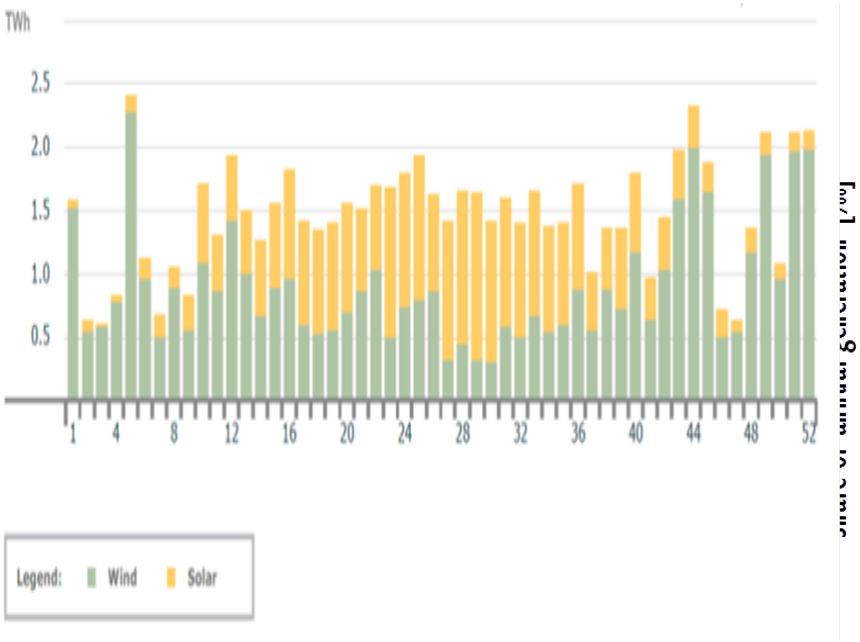


Investments

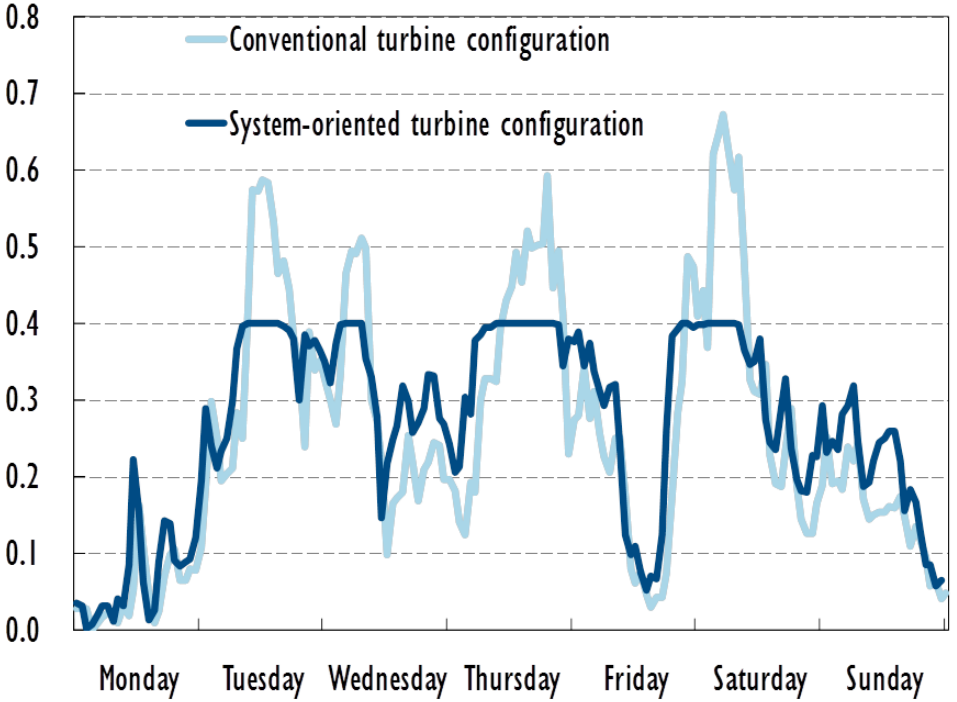
Operations

1) System-friendly VRE deployment

Example: Complementarity of wind and solar generation in Germany

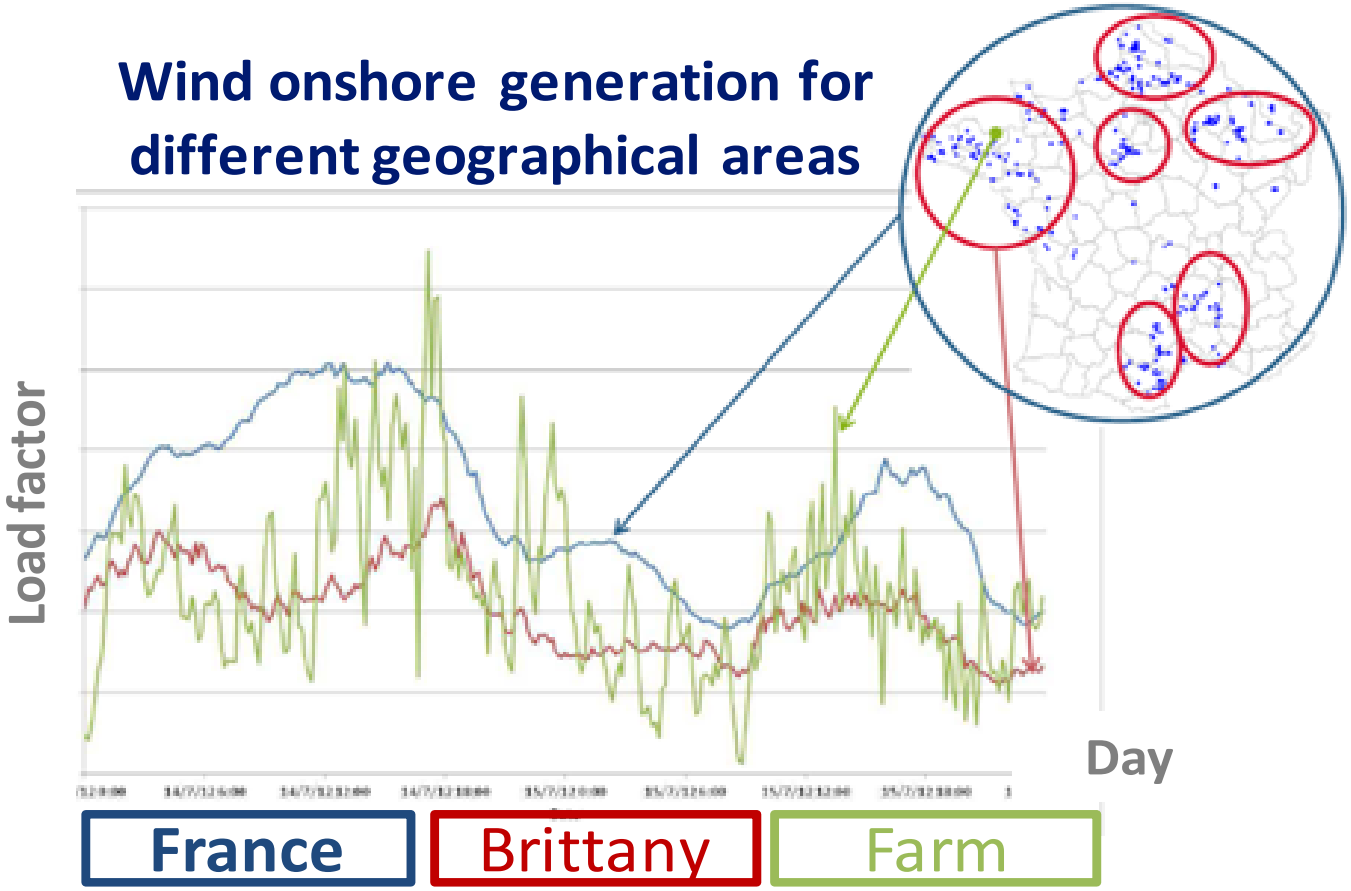


Example: System-friendly design of wind turbines reduces variability



Source: adapted from Agora, 2013

Geographic spread smooths out variability somewhat

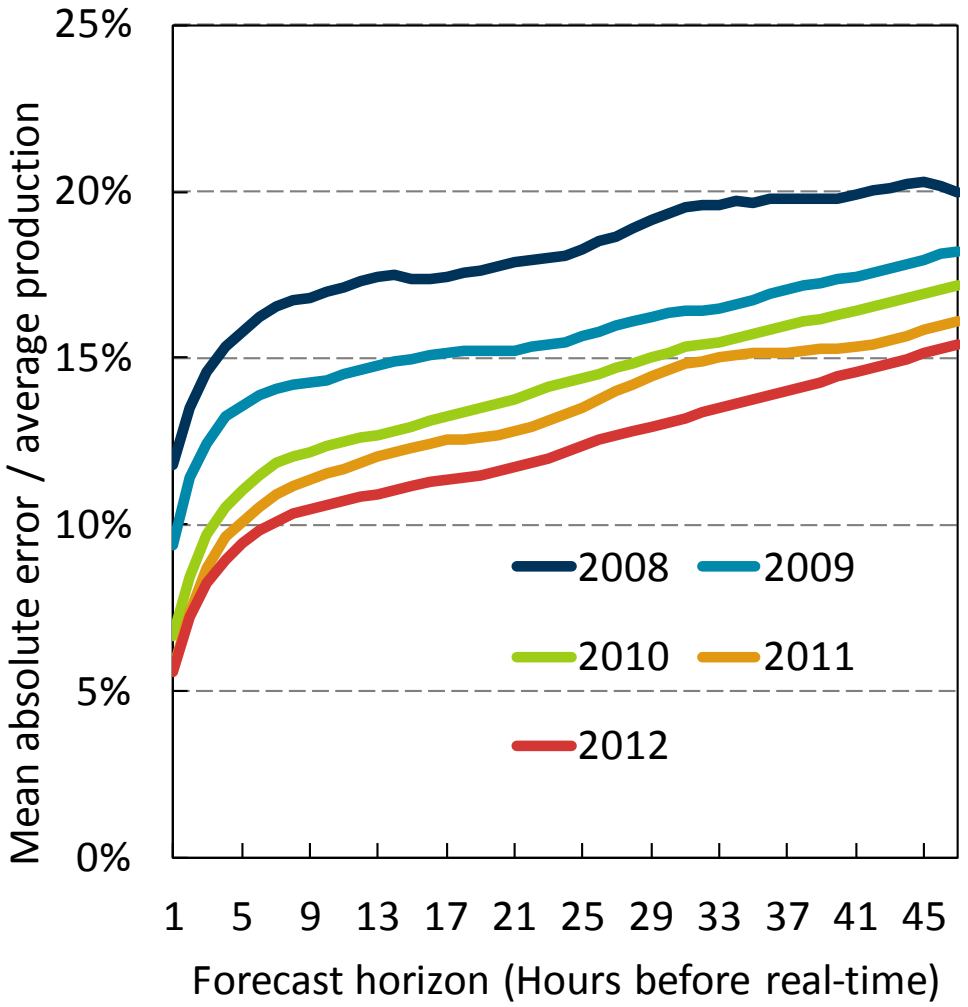


Source: EDF R&D after RTE

2) Better system & market operations

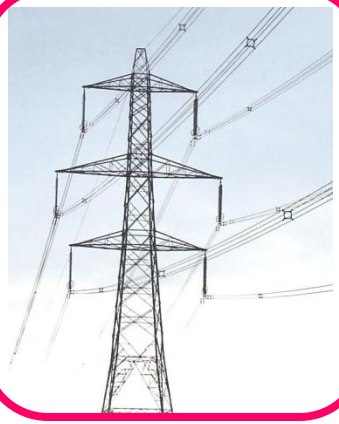
- **VRE forecasting**
- **Better market operations:**
  - **Fast trading**
    Best practice:
    ERCOT (Texas) – 5 minutes
  - **Price depending on location**
    Best practice: United States – Locational Marginal Prices
  - **Better flexibility markets**

Accuracy of wind forecasts in Spain

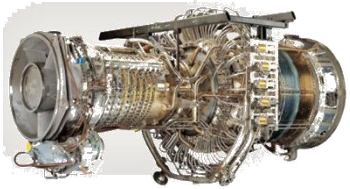


3) Invest in additional flexibility

Four sources of flexibility …



Grid infrastructure

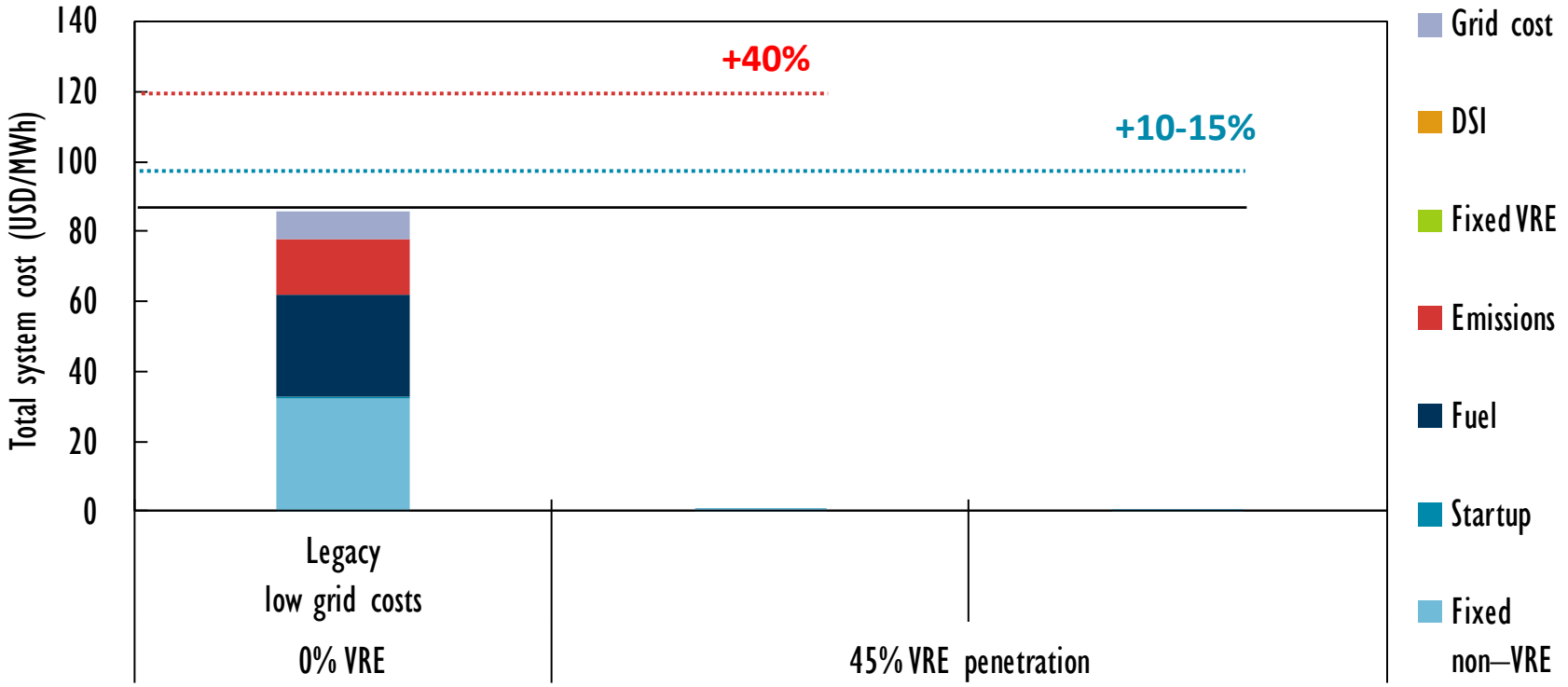


Dispatchable generation

Storage

Demand side integration

Cost-effective integration means transformation of power system



Test System / IMRES Model

- Large shares of VRE can be integrated cost-effectively
- But adding VRE rapidly without adapting the system is bound to increase costs

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Specific issues from distributed generation

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Commercial PV in the US

Residential PV in Australia

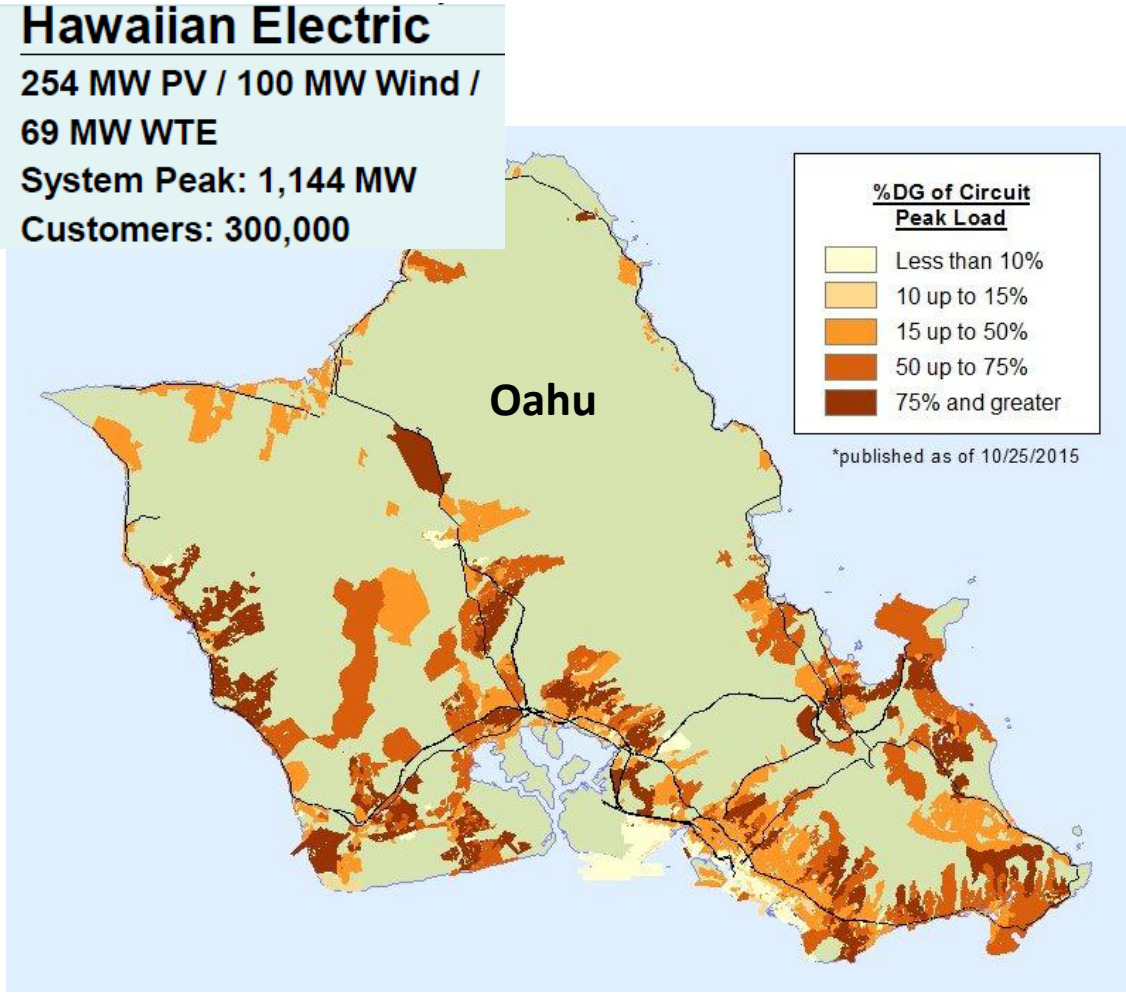
Grid cost issues with self-consumption and net-metering

- Depending on the time match demand vs. sunshine, grid costs may be reduced or increased
- T&D costs 30-50% of retail costs, but only 0-15% recovered through fixed payments for efficiency/equity reasons
- Self-consumers pay less but still benefit from the grid
- Net-energy metering only increases the size of the issue
- Recovering grid costs over lesser sales may require tariff increase, but this leads to cross-subsidies, and further incentivizes self-consumption

➔ "Load-defection" will not (likely) lead to "grid defection", but financing of grid development is a real issue. Grids have high value to integrate large shares of variable renewables

Hawaii at the forefront

- In 2013, Hawaii imported 91% of the energy it consumed leading to high electricity prices
- In 2014 electricity generation from solar more than doubled
- 381 MW of small-scale solar capacity were installed
- Overall 21% of electricity from renewables in 2014, of which 62% have been distributed sources
- First State to set goal of 100% RE, to be reached by 2045
- State is at the forefront of the integration challenges associated with high shares of distributed energy generation



Source: Hawaïan Electric

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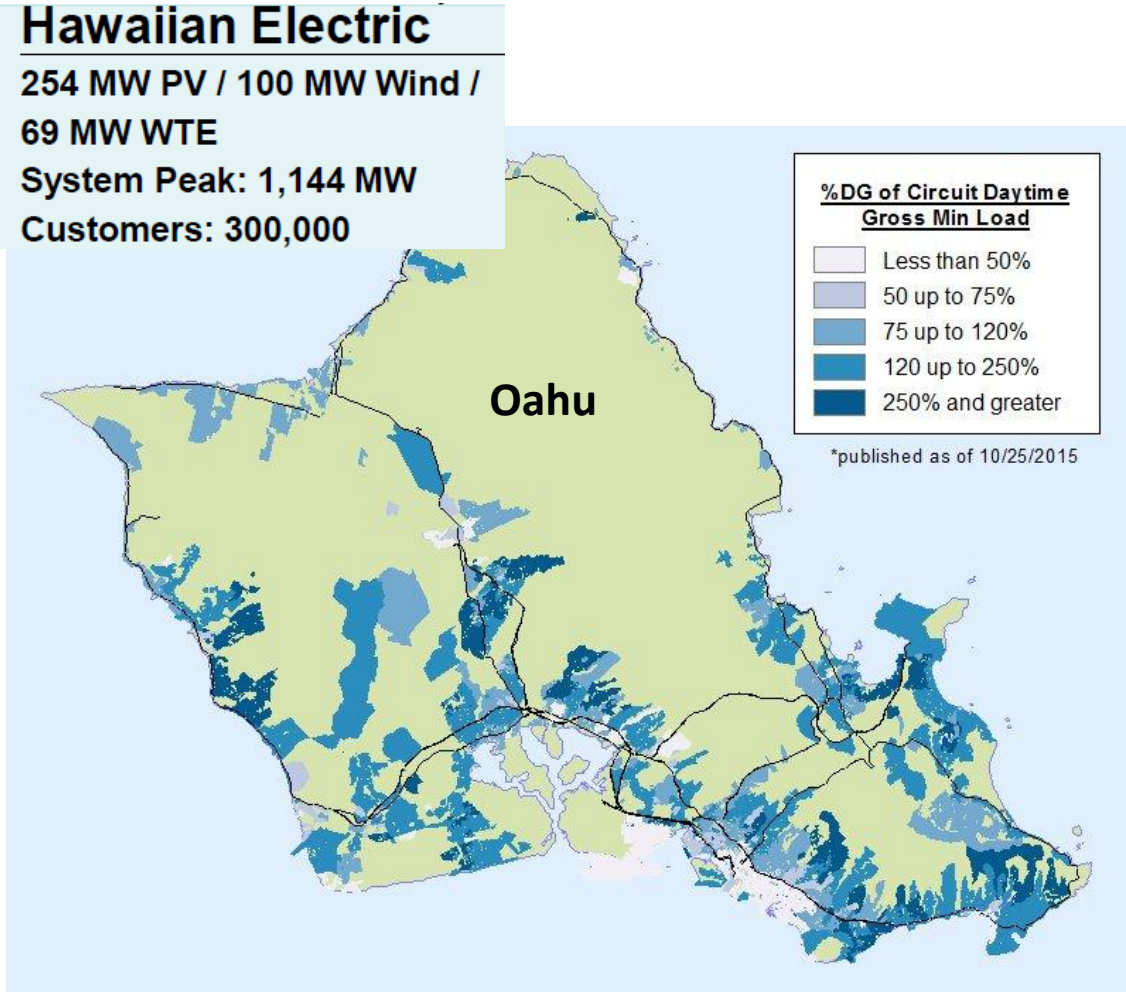
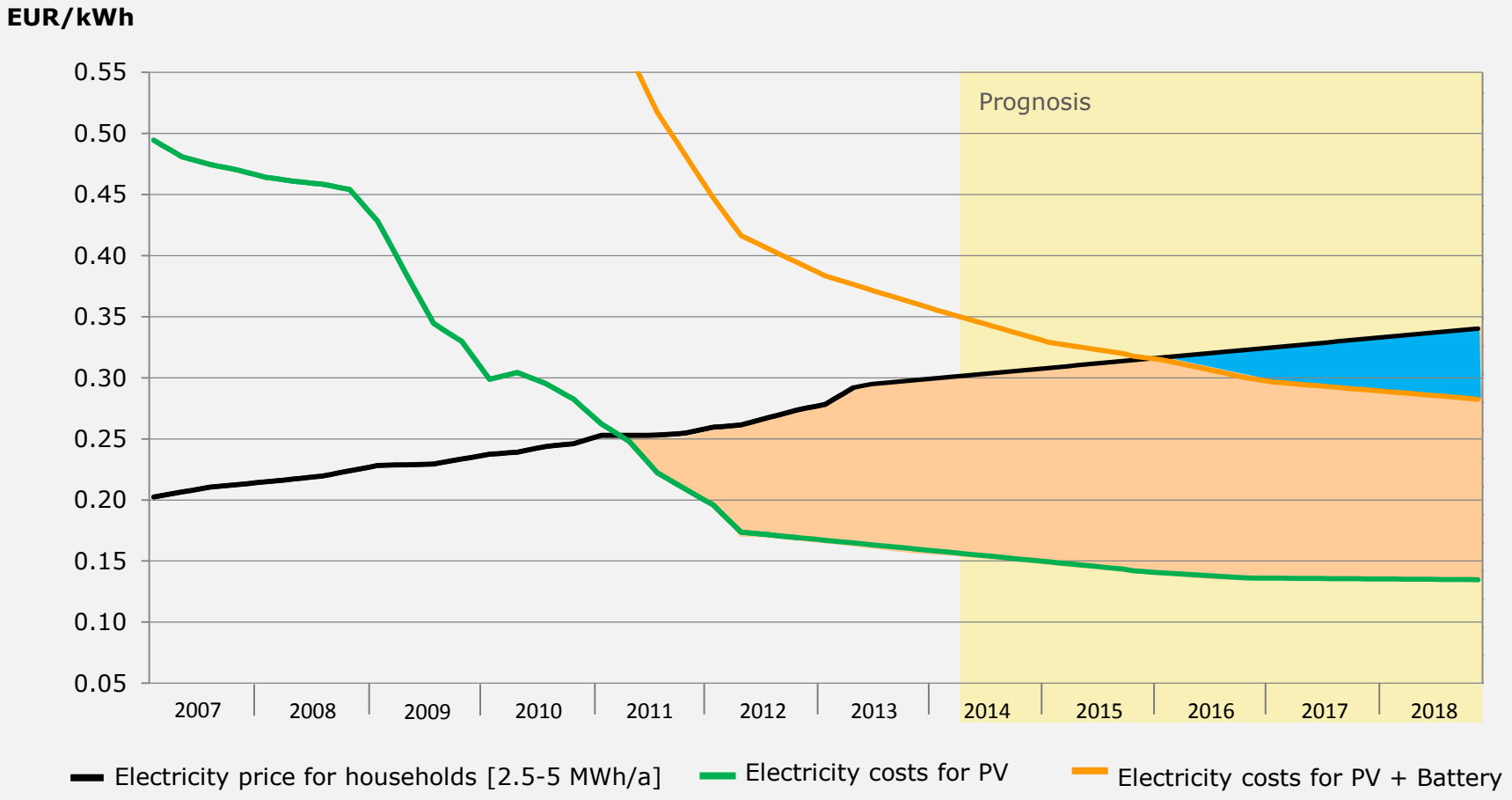


Source: Hawaïan Electric

Battery storage, the next big thing?



PV+battery socket parity might be around the corner in Germany

* SOURCE: **Trade and Invest, Germany.** Model calculation for rooftop systems, based on 802 kWh/kWp (Frankfurt/Main), 100% financing, 6% interest rate, 20 year term, 2% p.a. O&M costs. Sources: FiTs: BMU 2013; System Prices: BSW 2013; Model Calculation: Deutsche Bank 2010; Electricity Prices 2007-2013: Eurostat 2013.

Conclusions and recommendations

- **Variability is not new to grid managers, reaching 5-10% energy from wind and solar is no problem if well-managed:**
  - **Optimise system and market operations**
  - **Deploy VRE in a system-friendly manner – giving the right incentives to developpers**
  - **Develop state-of-art forecasting**
- **Going to larger shares**
  - **Approach VRE integration as a question of holistic, long-term system transformation from the onset, seeking for flexibility from all sources**
- **Building upon the dynamism of distributed generation**
  - **Avoiding uncontrolled concentrations (hot spots)**
  - **Ensuring grid cost recovery**