International Energy Agency
Secure Sustainable Together

Decarbonisation at high shares of variable generation

IEA-EPRI Workshop
Third Annual Expert Workshop: Challenges in Electricity Decarbonisation
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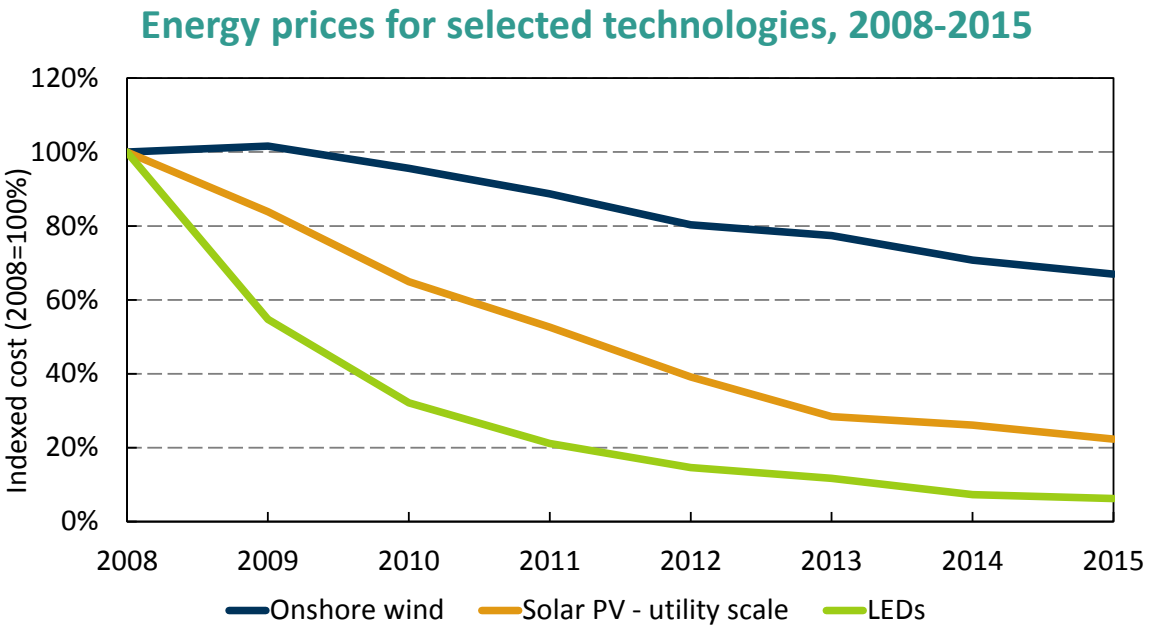
Significant cost reductions



Key point: *PV and wind costs have fallen dramatically in recent years*

The 6 relevant VRE properties

Uncertainty

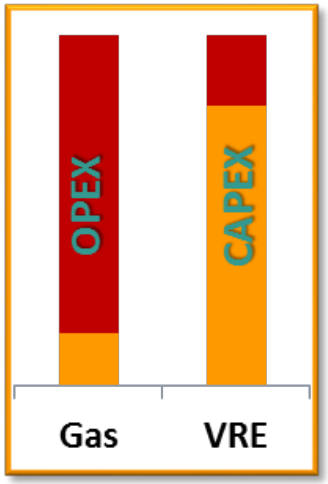
Variability

Non-synchronous technologies

Location constraints

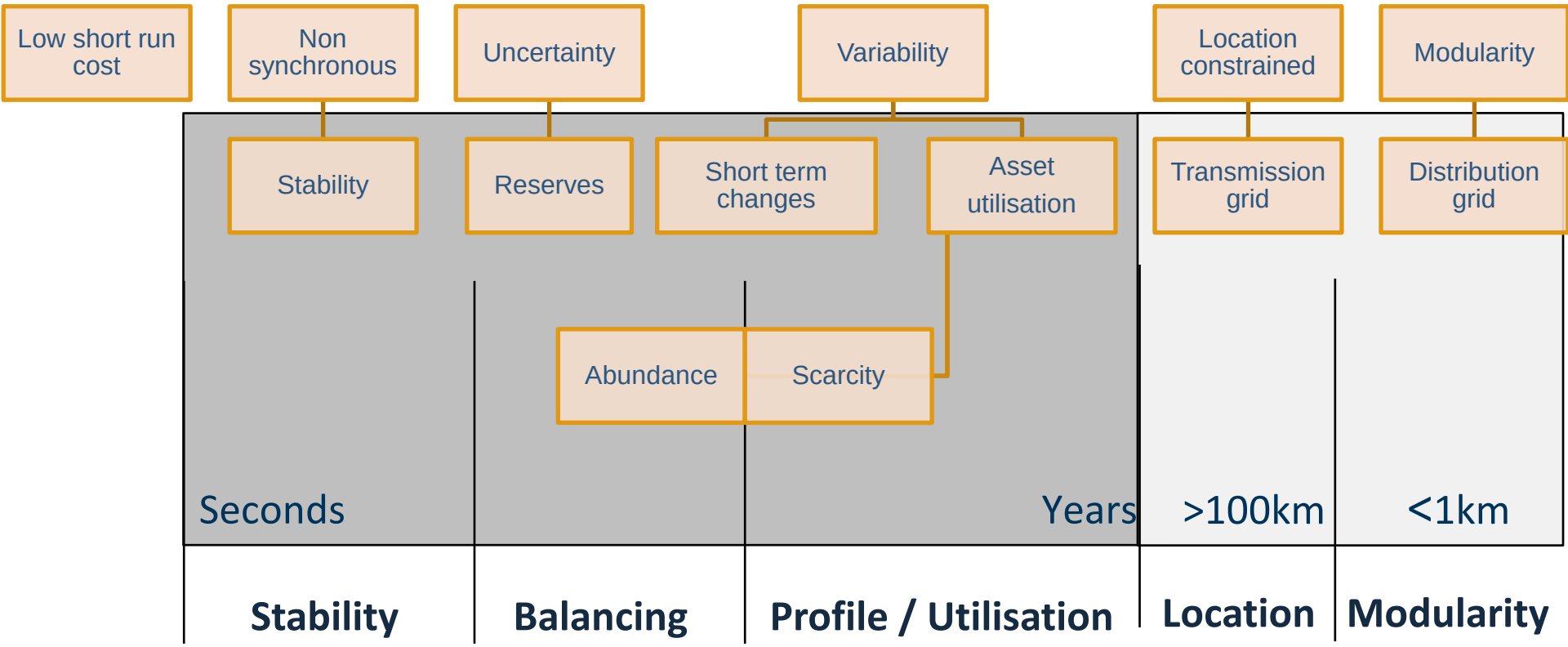
Modularity

Low short-run cost



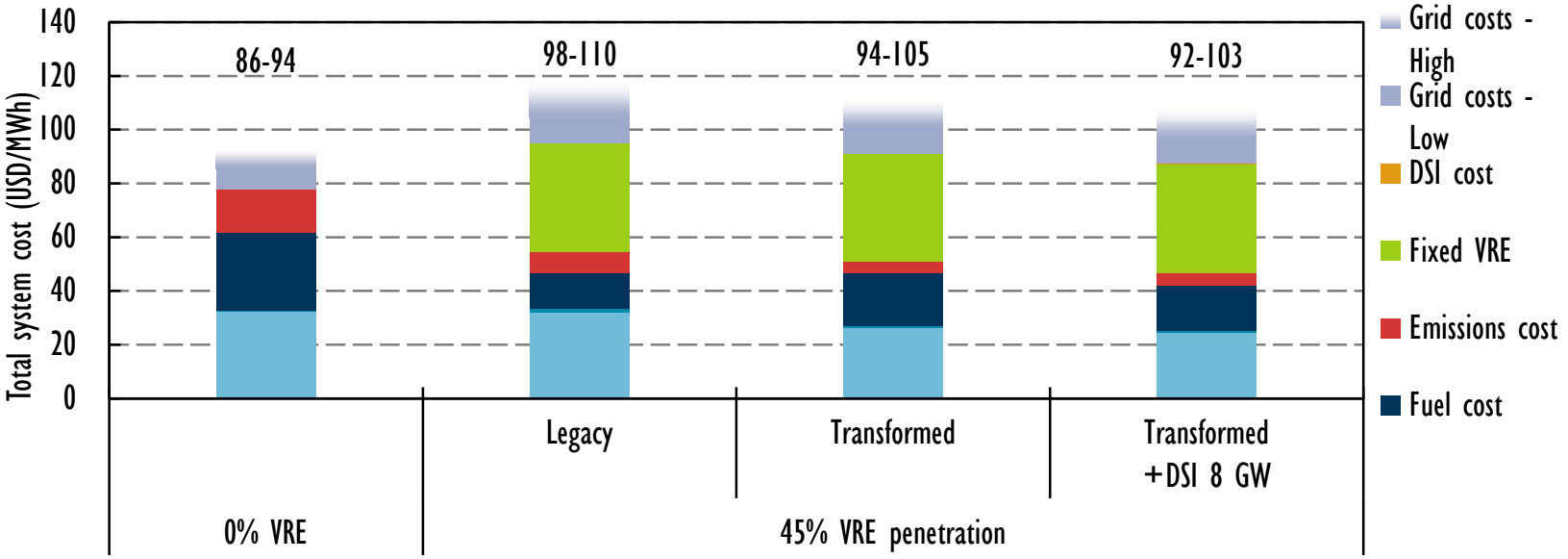
Properties of variable renewables and impact groups

- Systems are different – impacts will vary too
- But common groups of effects



IEA GIVAR analysis – reaching 45%

Total system costs for GIVAR test system, USD/MWh



- **2014:**
  - Depending on degree of system transformation, 45% VRE come at a cost increase of 10-40% (onshore wind at USD 87/MWh, solar PV at USD 150/MWh)
- **2016:**
  - Cost increase ranges from 20% to -6%
    (onshore wind at USD 60/MWh, solar at USD 70/MWh)

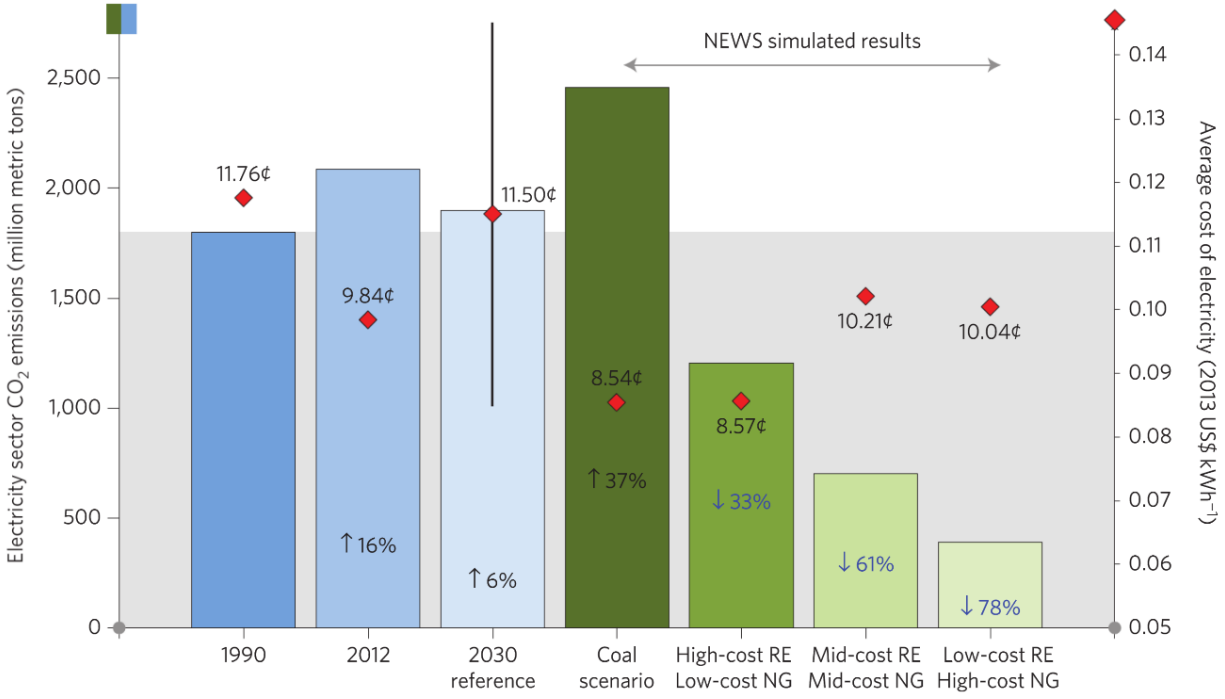
Towards deep decarbonisation

- **Relevant challenges for high shares in electricity:**
  - Possible mismatch in timing between VRE supply and demand
    - *Seasonal mismatches depend on latitude (solar PV) and local climate*
  - Resulting requirement of building complementary infrastructure
  - Diminishing returns on additional VRE due to auto-correlation
- **But …**
  - Many options to better match demand to supply
  - Reginal aggregation often effective at smoothing much variability
  - Decarbonisation is an energy systems issues; it goes beyond the boundary of the current power system
- **And …**
  - No credible decarbonisation scenario is built only on wind and solar power

Key point:	***Credible analysis of VRE's role for decarbonisation needs to capture all available integration options, including grid expansion and energy sector coupling.***

Example: US 2030, -78% CO2 power sector emissions

US electricity sector CO2emissions (left axis) and levelised cost of electricity (right axis)



Cost of capital and O&M of technologies (2013$ / W), natural gas fuel (2013$ / MMBtu)

	Onshore	Offshore	PV	CCGT	NG Fuel
LRHG Scenario	$2.16	$3.41	$1.19	$1.24	$11.10
MRMG Scenario	$2.25	$5.53	$2.57	$1.24	$8.82
HRLG Scenario	$2.36	$7.64	$3.94	$1.24	$5.40

2030 LRHG scenario

- **Total: 1529 GW**
- **Wind offshore 22 GW (8% of generation)**
- **Wind onshore 501 GW (38% of generation)**
- **Photovoltaics 371GW (17% of generation)**
- **461 GW CCGT (21%)**
- **100 GW nuclear (16%)**
- **74 GW hydro (8%)**

Key measures include

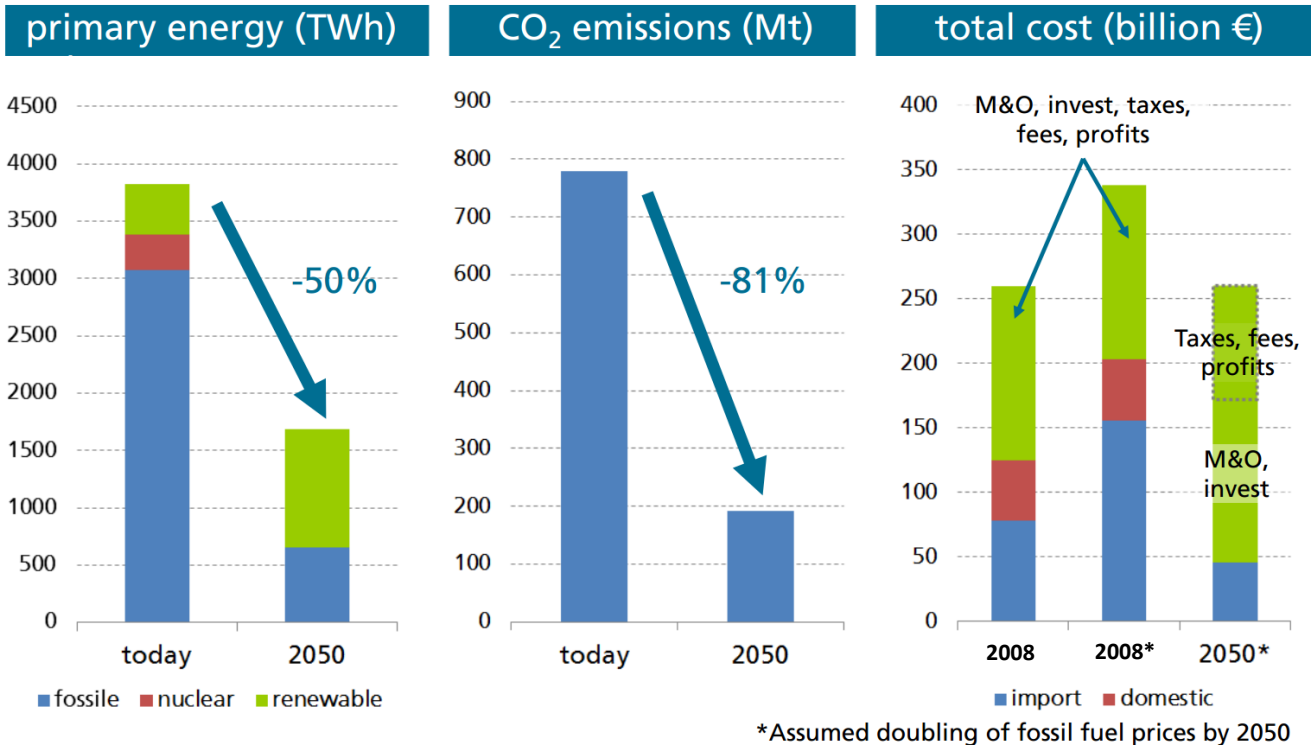
- **Construction of HVDC grid**

Key point: ***At moderate natural gas prices, regulation limiting coal use, maintaining nuclear at current levels, and building an HVDC grid, a least cost power mix features 63%VRE in annual generation and -78% of CO2 emissions (vs. 1990).***

Source: Future cost-competitive electricity systems and their impact on US CO2 emissions, MacDonald *et al*, Nature Climate Change, DOI: 10.1038/nclimate2921

Example: Germany 2050, -81% CO_2 energy related emissions

Energy demand, CO2 emissions and cost for a 2050 energy system in Germany



*Assumed doubling of fossil fuel prices by 2050

VRE in 2050 scenario

- **Peak demand: 60 GW**
- **Wind offshore 32 GW (17.6% of generation)**
- **Wind onshore 120 GW (34.2% of generation)**
- **Photovoltaics 147 GW (22.5% of generation)**

Key measures include

- **Refurbishment of buildings (main cost driver)**
- **Electrification of heating and transport, power-to-gas**

Key point: ***Combining aggressive energy efficiency measures and energy sector coupling, deep decarbonisation at high shares of VRE yields energy system costs comparable to those already observed.***

Source: Pathways towards transformation of the German energy system until 2050 – *A. Palzer, H.-M. Henning*

Conclusions

- **No scenarios that attempt decarbonisation with VRE only, 100% renewables is not 100% wind and solar**
- **Rapid cost reductions are quickly increasing cost-optimal share of VRE, but flexibility options key to reach high shares**
- **Achieving ambition of Paris Agreement requires effort beyond current electricity sector**
- **Electrification and energy sector coupling helps both VRE integration and decarbonisation**
  - Widening access of electricity system to heating and transport mitigates effects of variability
  - Electrification of heating and transport using clean power curbs emissions
- **Depending on latitude and climate, dealing with imbalances in systems dominated by VRE requires seasonal storage options**
  - If well implemented, such systems can be affordable

Thanks

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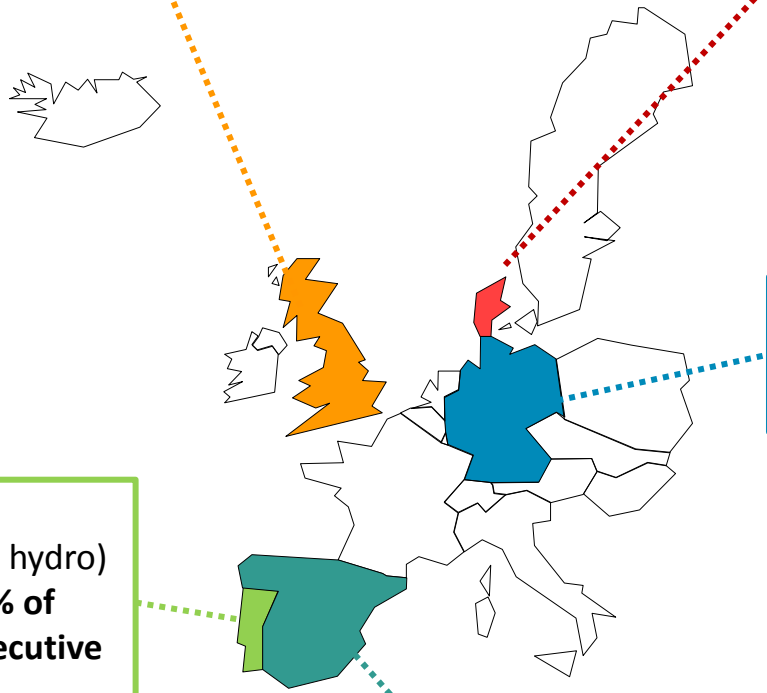
Recent RE integration milestones

Scotland, 14 August 2016 : Daily **wind power production exceeded demand**

Denmark, 2 September 2015: The Western Danish power **system runs without centralised power generation** for the first time



Germany, 8 May 2016: **Wind and solar PV** cover the equivalent of **90% of power demand**

Portugal, 7-11 May 2016: **Renewable energy** (including hydro) covers the equivalent of **100% of power demand for 107 consecutive hours**

Spain, 28 February 2016: For the first time, **wind power provides upward balancing reserves**