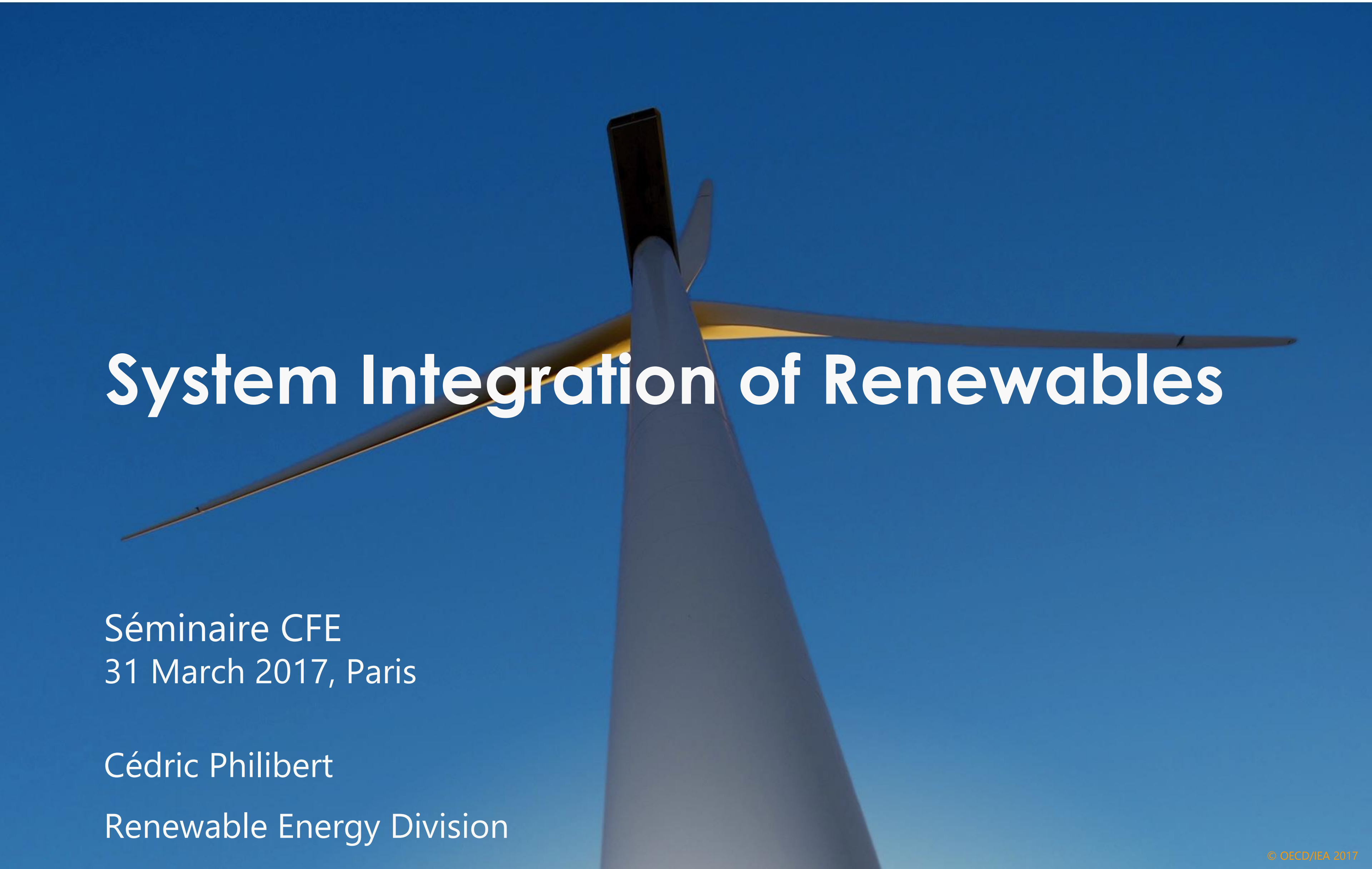


System Integration of Renewables

Séminaire CFE
31 March 2017, Paris

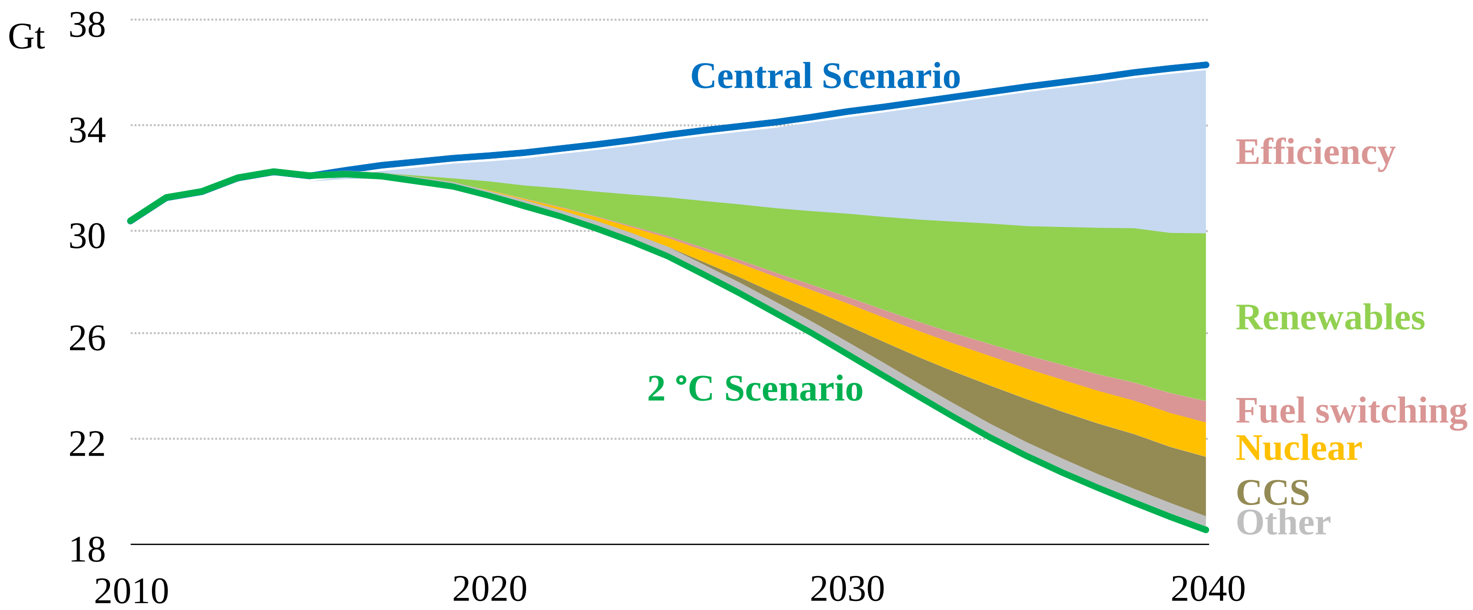
Cédric Philibert

Renewable Energy Division

Efficiency and renewables key to climate change mitigation

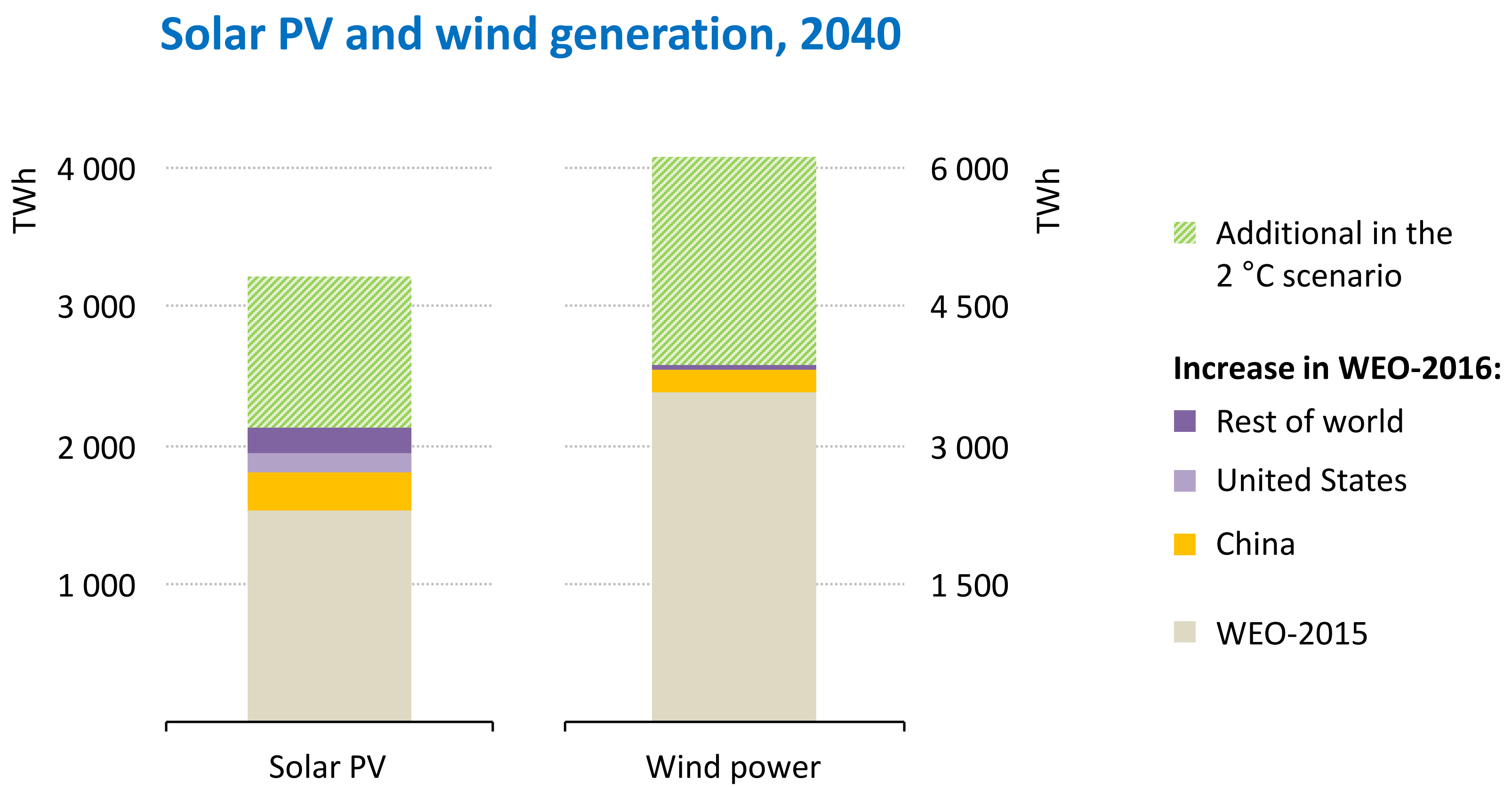
World Energy Outlook 2016

Global CO_2 emissions reductions in the Central & 2 °C Scenario by technology



Aligning policies for energy efficiency and renewables become critical to achieving climate goals

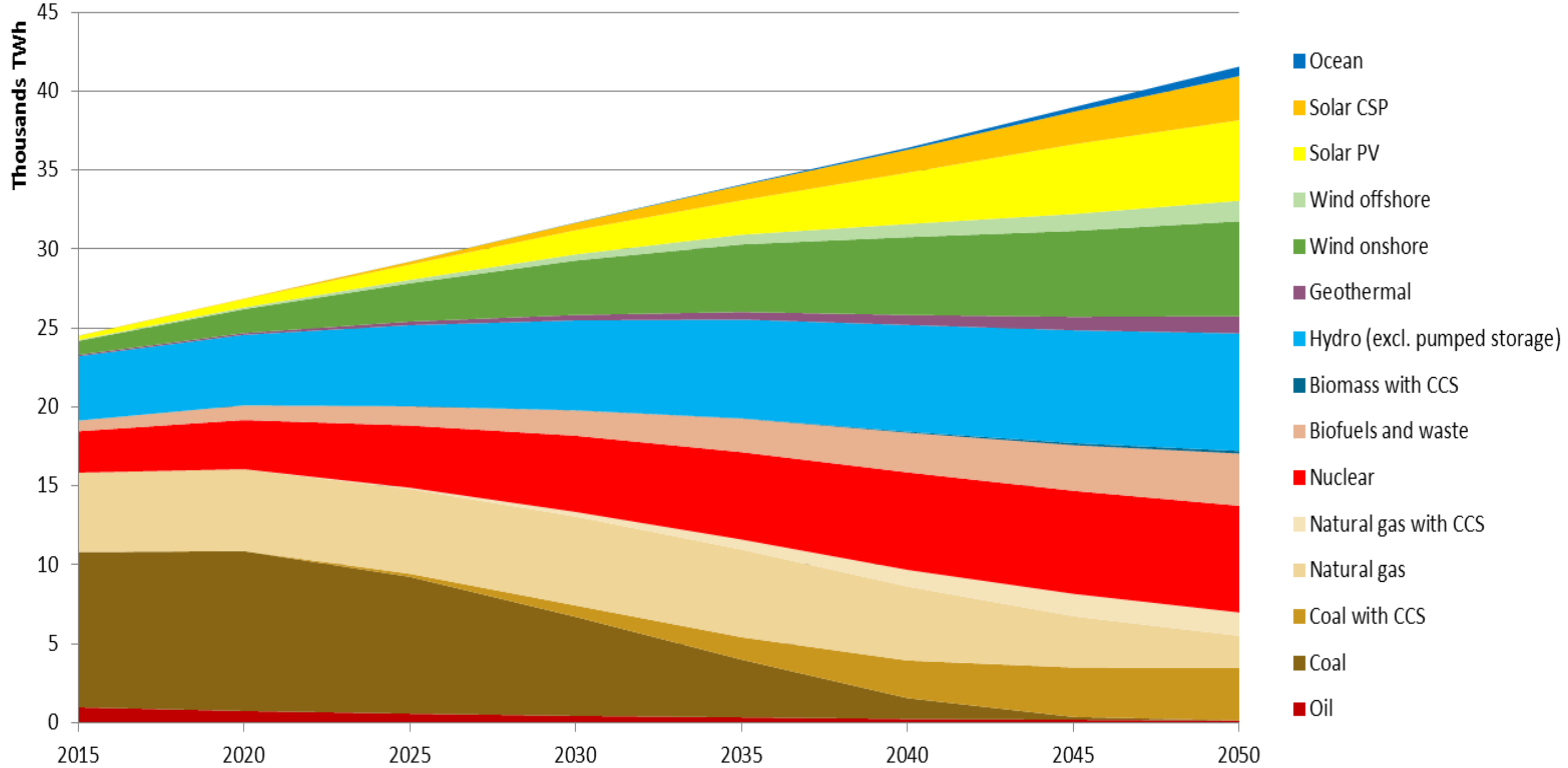
Greater policy support boosts prospects for solar PV and wind



Stronger policies on solar PV and wind help renewables make up 37% of electricity generation in 2040 in our main scenario – & nearly 60% in the 2 °C scenario

Global electricity mix changes in the 2DS

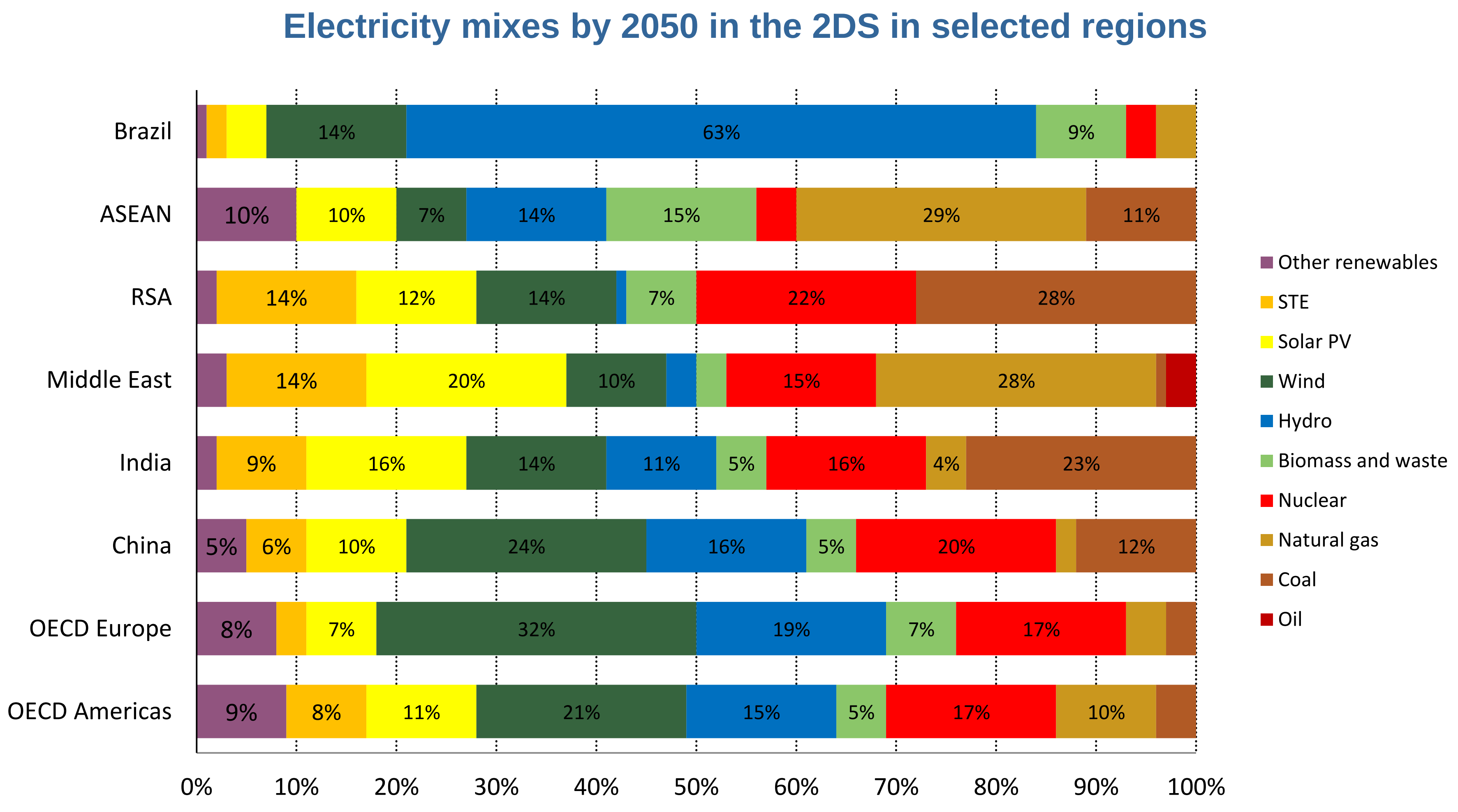
ETP 2016



A shift reversal is needed with renewables providing over 60% of global electricity by 2050 or before

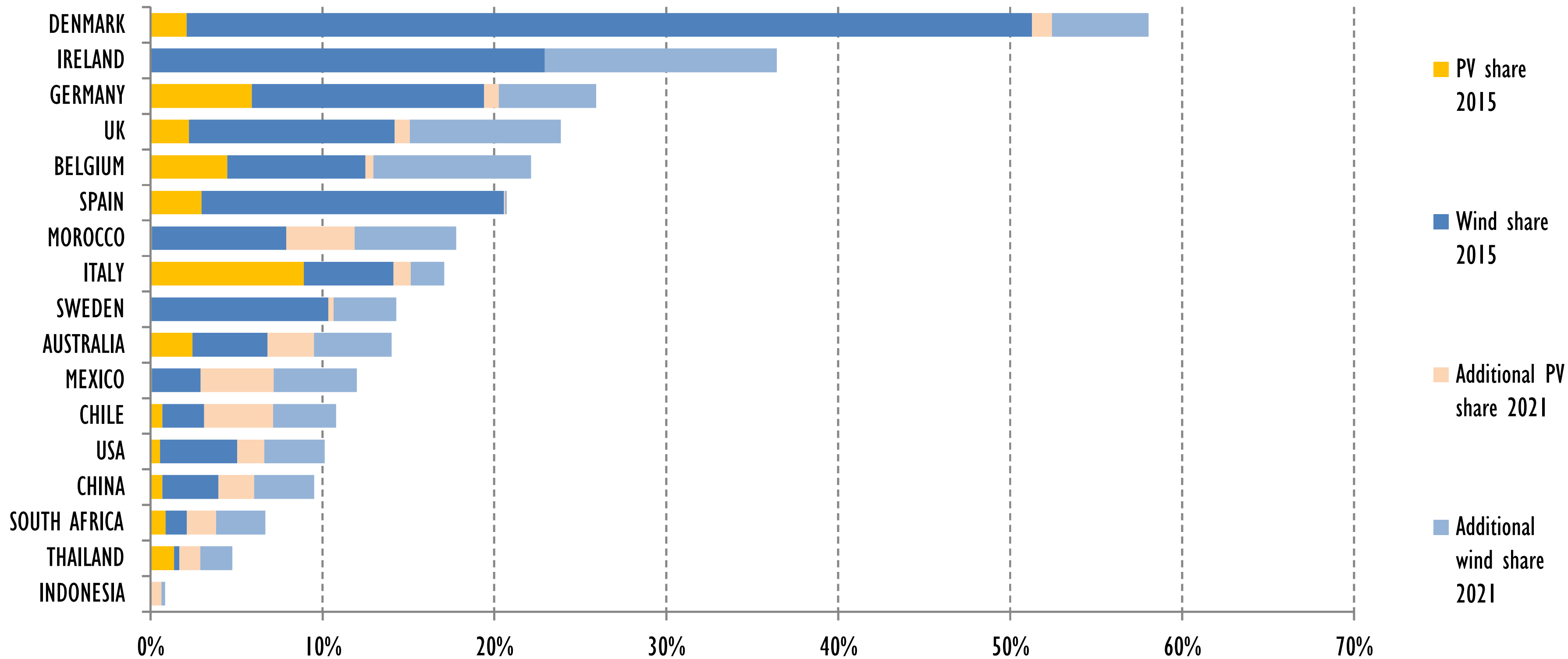
Electricity mixes by 2050 in the 2DS vary widely

ETP 2016



Resources and shape of the demand explains the variations

Large shares of VRE in some countries

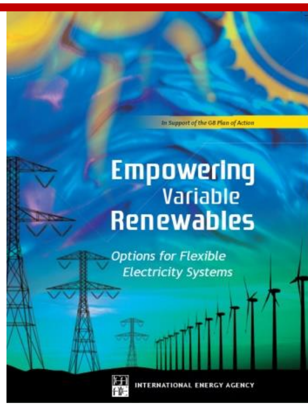


- **Experience in a number of countries available how to integrate significant shares of VRE**
- **According to latest available forecasts in 2021:**
  - VRE is forecasted to exceed 20 % of annual generation in at least 6 countries
  - Double-digit shares becoming new normal for many power systems

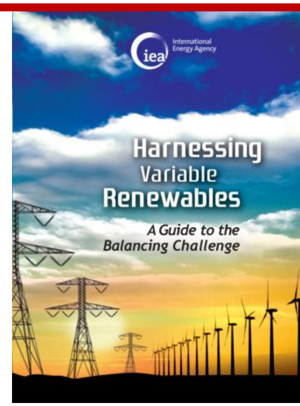
Source: Medium Term Renewable Energy Market Report 2016

IEA GIVAR: to date

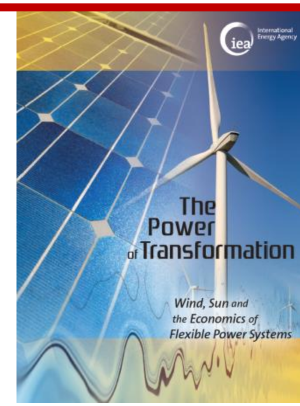
2008 | 2011 | 2014 | 2016



Fundamentals



Technical



Economic

Link to policy

- **Grid Integration of Variable Renewables (GIVAR) programme**
- **Global expert network covering policy making, engineering and modelling analysis, including IEA Technology Collaboration Programmes (TCPs)**
- **Analysis based on extensive research on current global state of play and sophisticated modelling tools**
- **System Integration of Renewables unit created within RED, June 2016**

Phases of VRE system integration

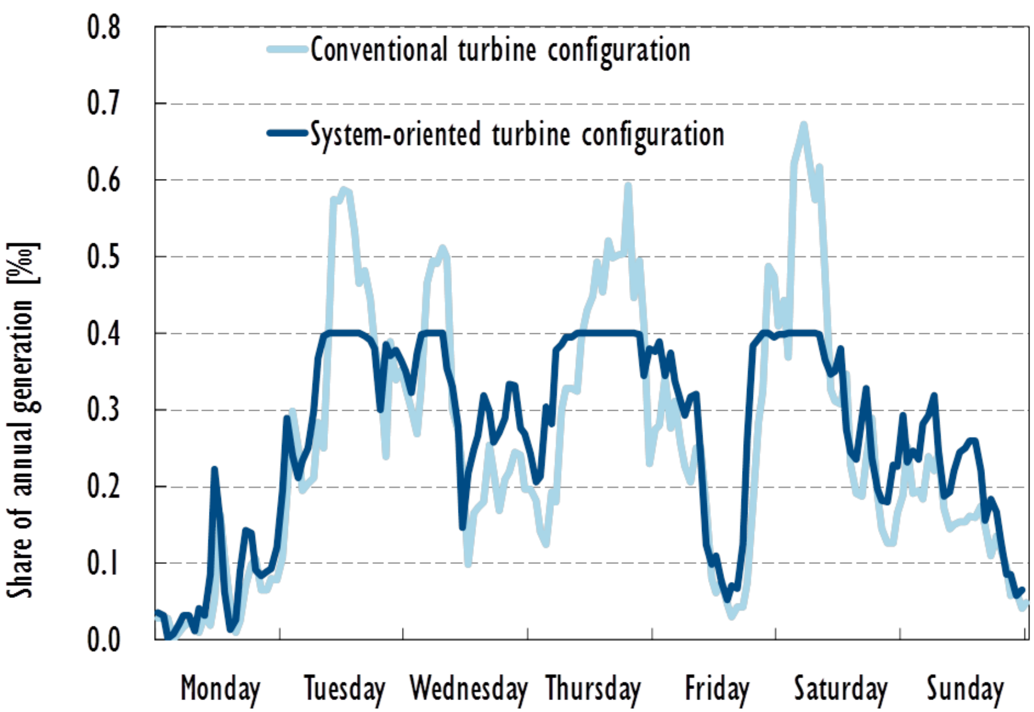
Phase	Description
1	VRE capacity is not relevant at the all-system level
2	VRE capacity becomes noticeable to the system operator
3	Flexibility becomes relevant with greater swings in the supply/demand balance
4	Stability becomes relevant. VRE capacity covers nearly 100% of demand at certain times
5	Structural surpluses emerge; electrification of other sectors becomes relevant
6	Bridging seasonal deficit periods and supplying non-electricity applications; seasonal storage and synthetic fuels

Increasing variable RE will need more system flexibility

1) Foster System-friendly RE

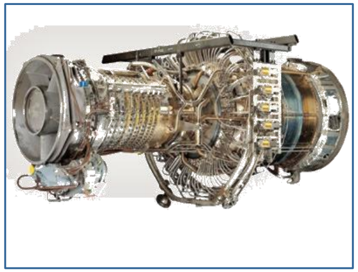
2) Better market design & operation

3) Increase flexibility of other power system components



Grids

Generation



Storage

Demand Side

Next Generation Wind and Solar Power

- **New phase of wind and solar deployment:**
  - Low-cost
  - Technologically mature
- **Requires new policies to achieve integration:**
  - Focus on generation cost no longer enough
  - Policies need to consider system-wide impact
- **Case studies with specific recommendations:**
  - Brazil, China, Indonesia, Mexico, South Africa
- **Strong focus on country implementation**

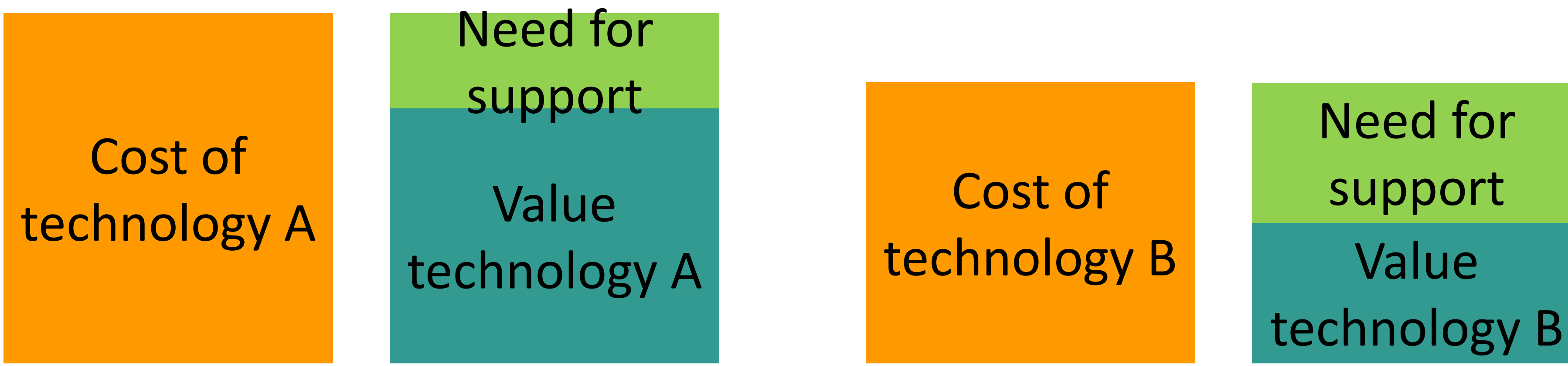
Key point

Next-generation wind and solar PV need 'next-generation policies' focusing on system value and not just costs.

Next generation policies

- **Policy and market frameworks must seek to maximise the net benefit of wind and solar power to the overall power system.**
  - A more expensive project may be preferable if it provides a higher value to the system.

Despite its lower cost, technology B will need more support payments than technology A

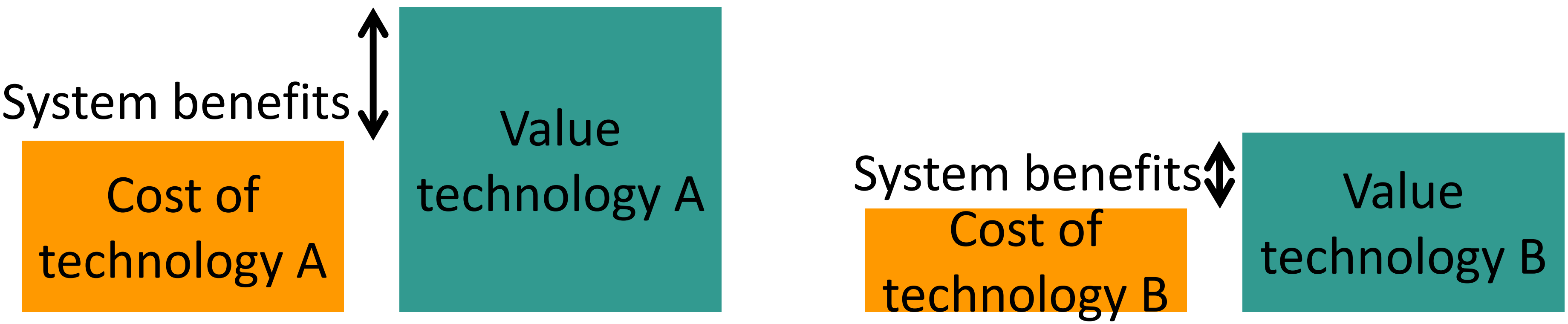


Key point: ***Next generation wind and solar power calls for next generation policies. These must focus on maximising value in addition to reducing cost.***

Next generation policies

- **Policy and market frameworks must seek to maximise the net benefit of wind and solar power to the overall power system.**
  - A more expensive project may be preferable if it provides a higher value to the system.

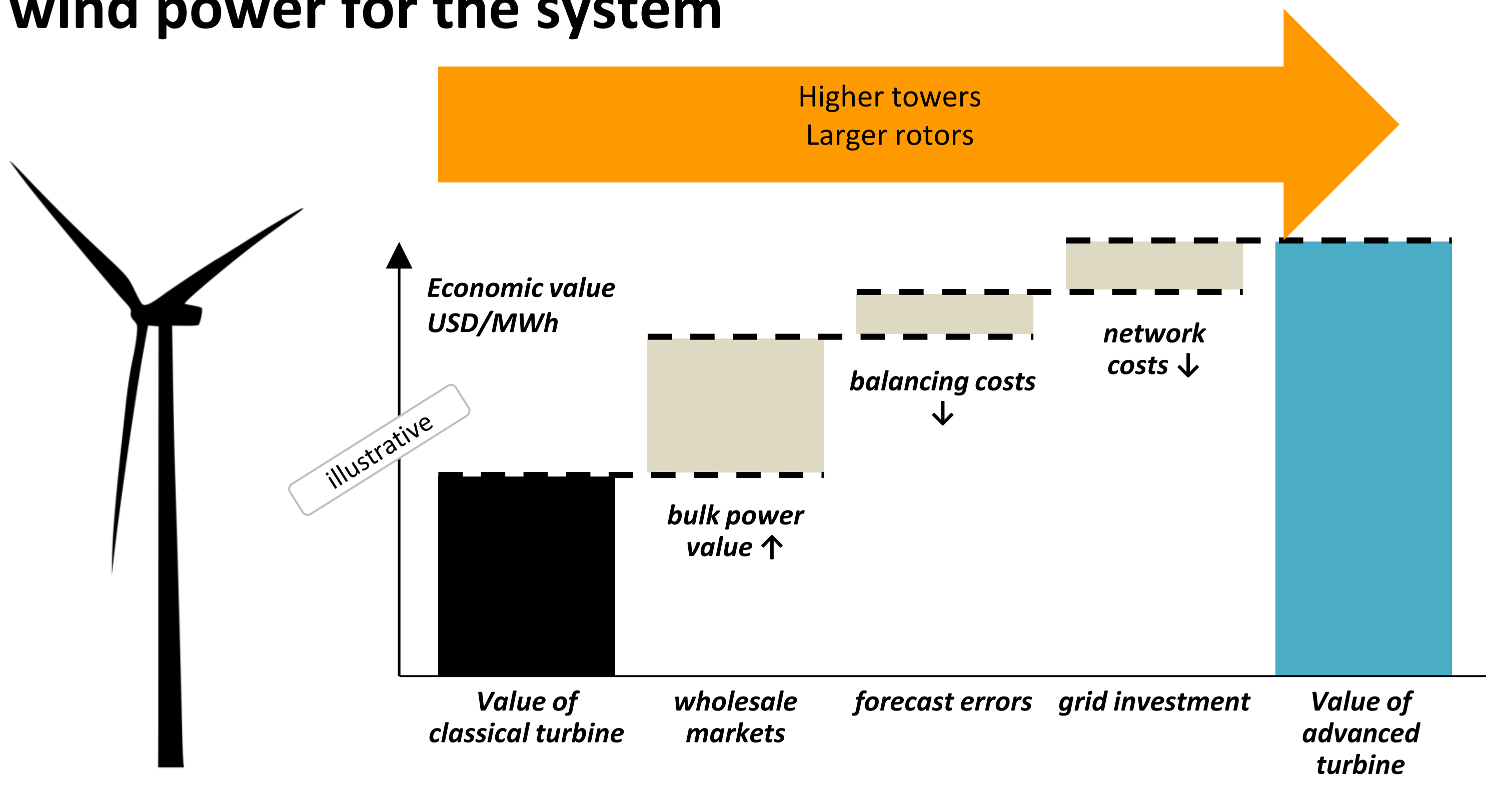
Despite its lower cost, technology B will deliver lesser benefits than technology A



Key point: ***Next generation wind and solar power calls for next generation policies. These must focus on maximising value in addition to reducing cost.***

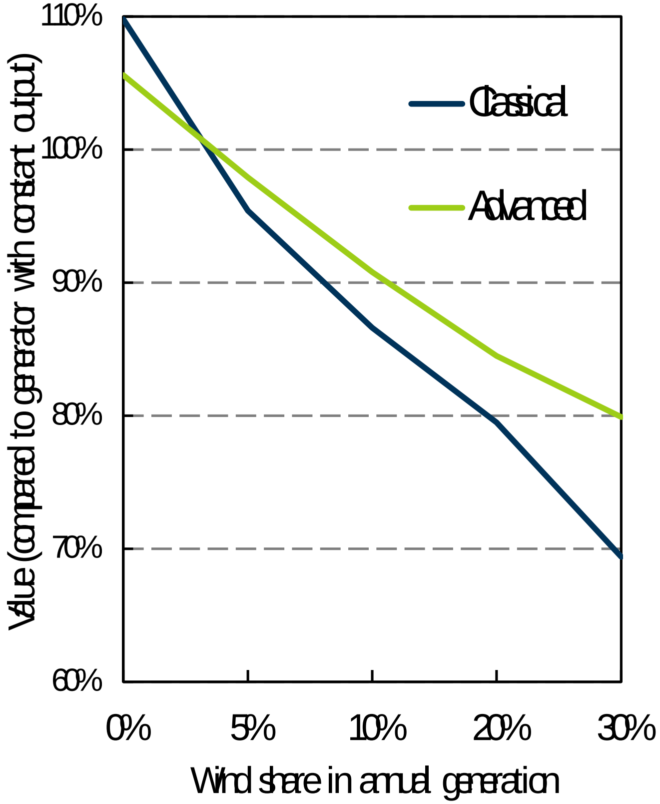
Modelling study of North-West Europe: Value of onshore wind

- Increased rotor size (at the same nameplate capacity) and larger towers makes output less variable
- This advanced technology can increase the value of wind power for the system

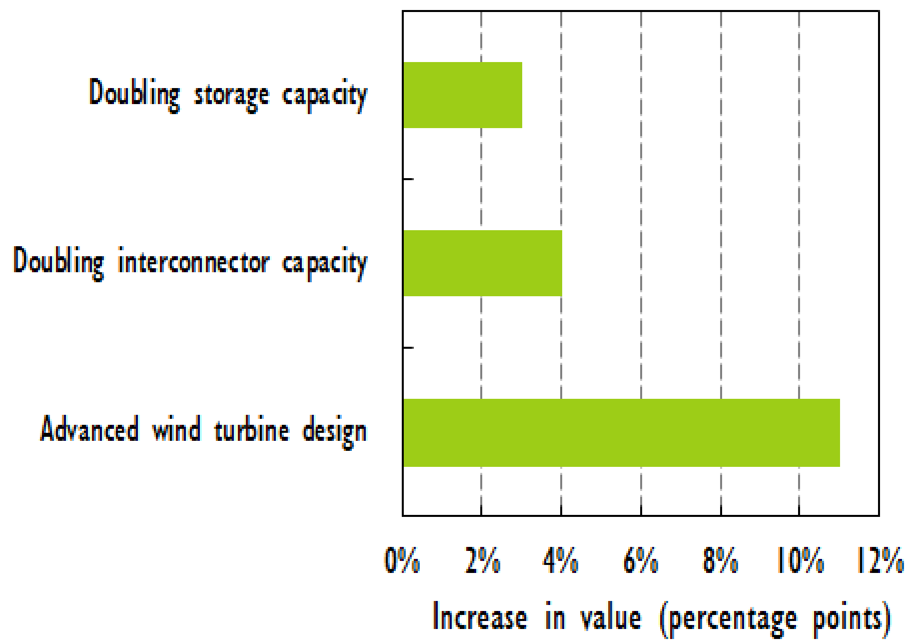


Main results

Value of wind power at different shares



Effect of different flexibility options on value of wind power

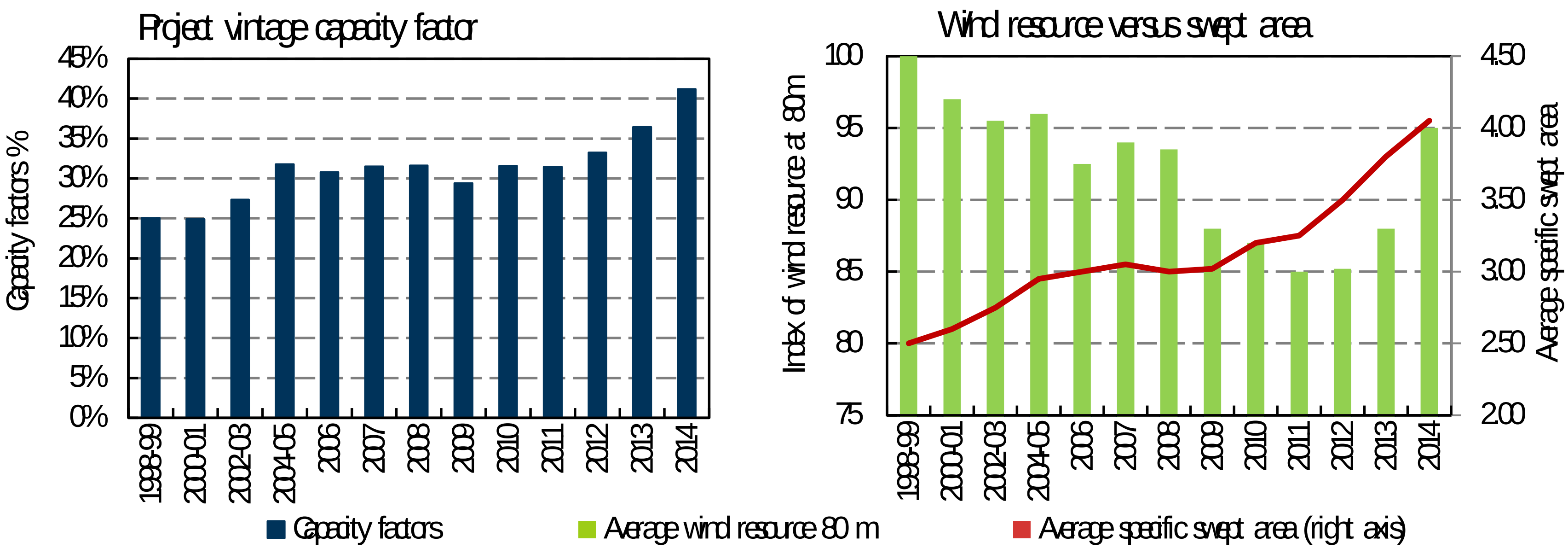


Key point: *Using advanced wind turbine technology has a large, positive impact on system value compared to other flexible resources; gross annual savings in simulation for North-West Europe at 30% wind range between 19-44 bn USD.*

Source: Hirth L. and Mueller S. (2016), "System-friendly wind power: How advanced wind turbine design can increase the economic value of electricity generated through wind power", Energy Economics, Vol. 56, Elsevier, pp. 51-63

Onshore wind: increased resource base and growing capacity factors

Capacity factor, wind resource and swept area, USA

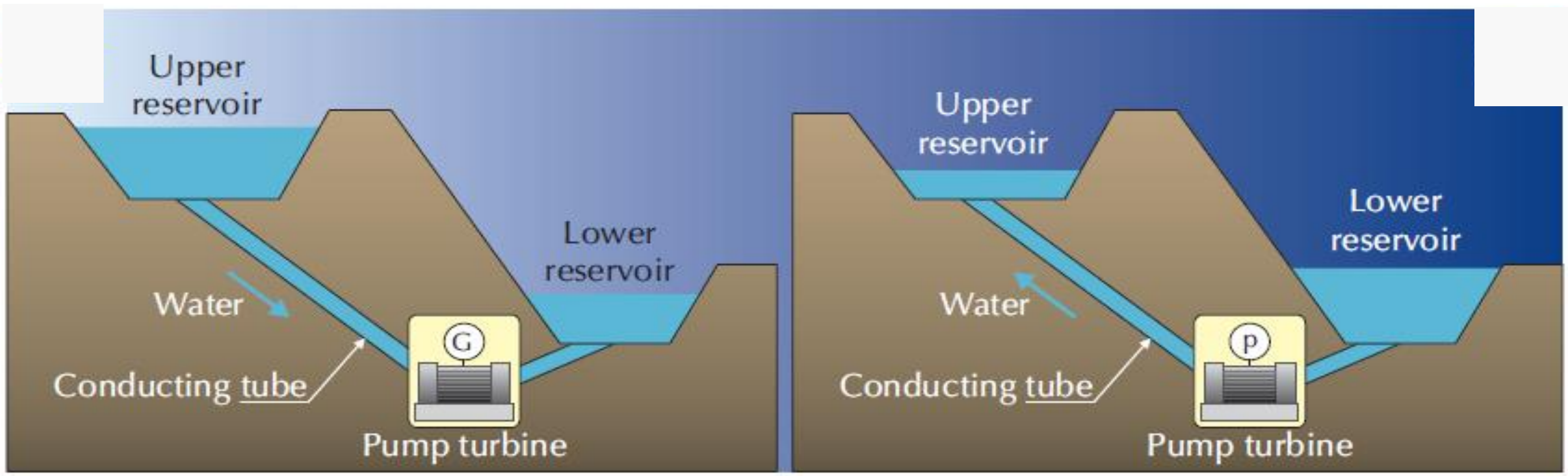


Key point:	***Modern wind turbine technology in the United States has supported deployment in lower-resource areas and increased capacity factors.***

Source: Wiser and Bolinger, 2016

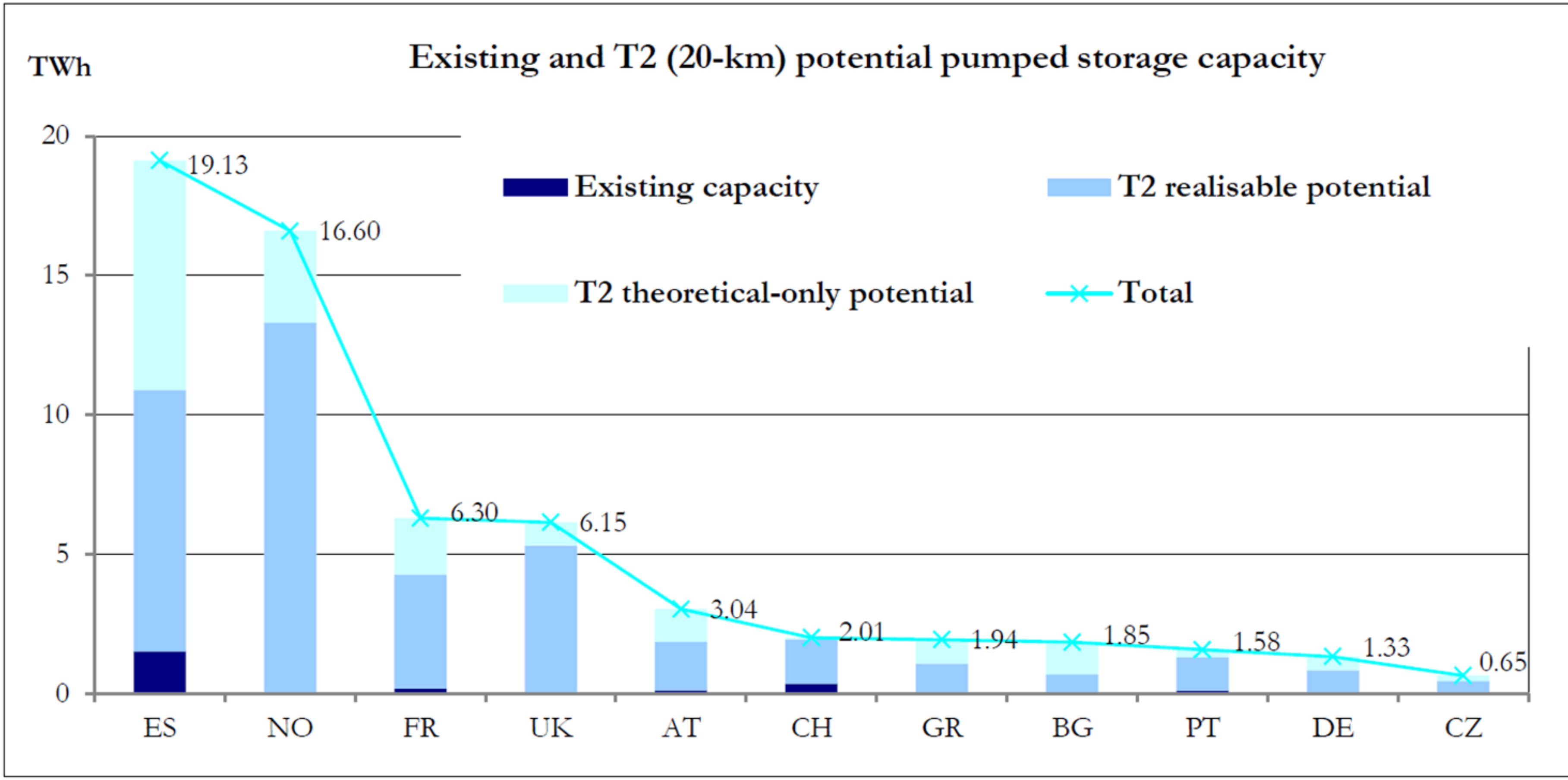
PSP: >90% of current on-grid storage

- Pumped-hydro plants the reference solution
  - 140 GW in service, 50 GW in development
- PSP developed from existing hydro plants
  - “off-stream” or “pumped-back” schemes
  - Small energy volumes but large power capacities
  - Daily/weekly storage does not require large areas

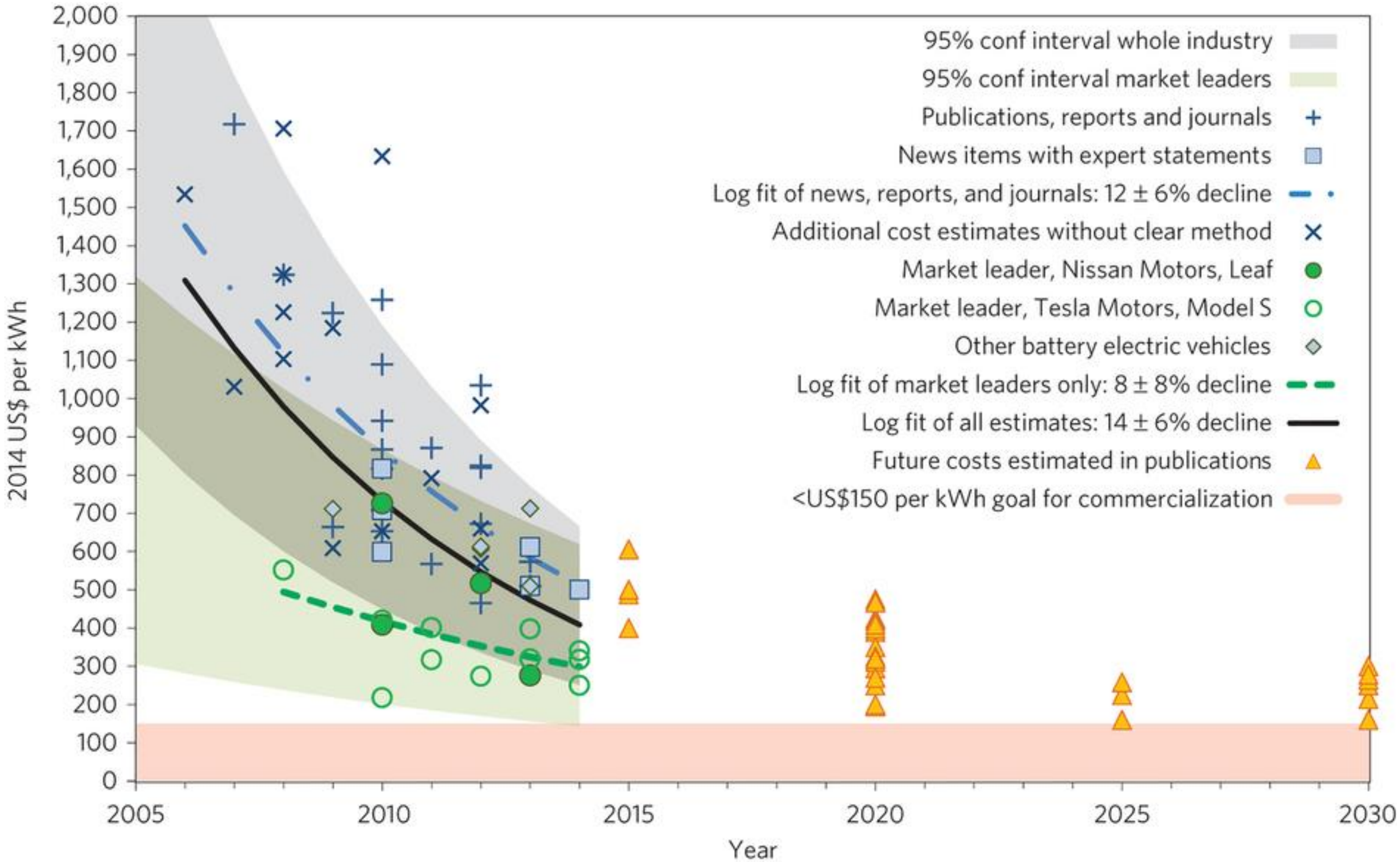


Source: Inage 2009.

Still large potential for new-built PSH plants

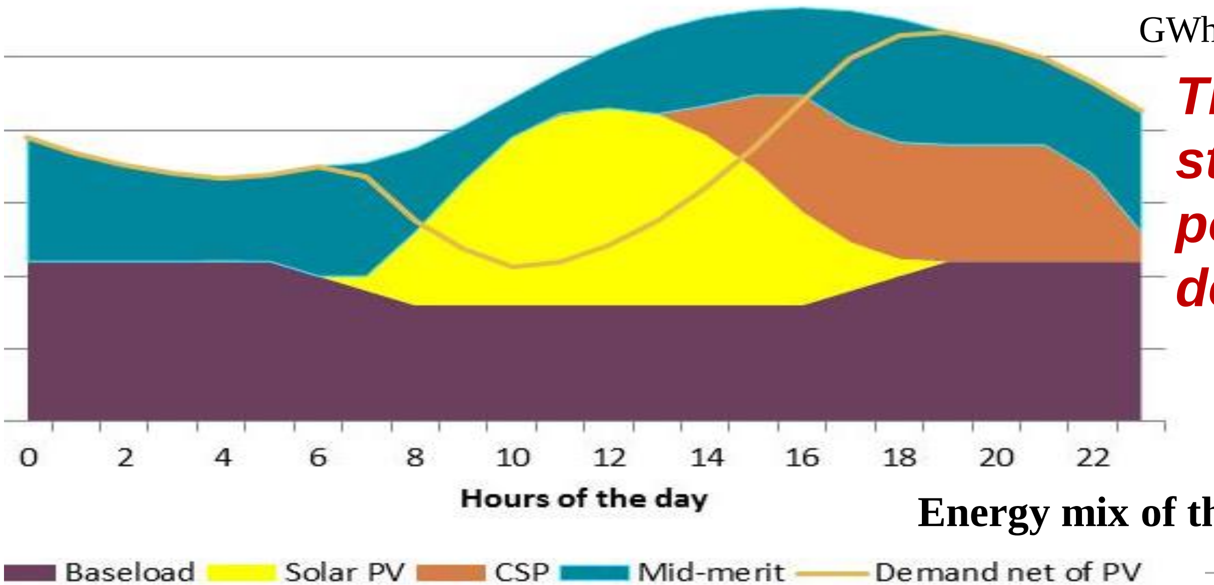


Battery cost trends – a breakthrough in sight?



PV et CSP complement each other

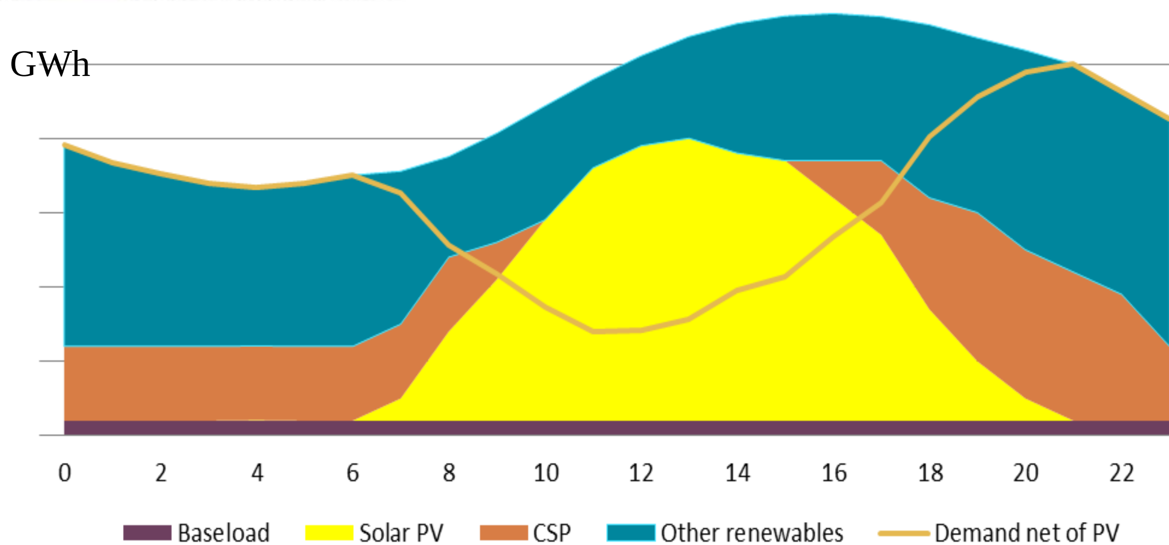
Energy mix of the power sector in a sunny country, 2030



Thanks to built-in thermal storage CSP plants generate power after sunset as demand peaks

Energy mix of the power sector in a sunny country, 205

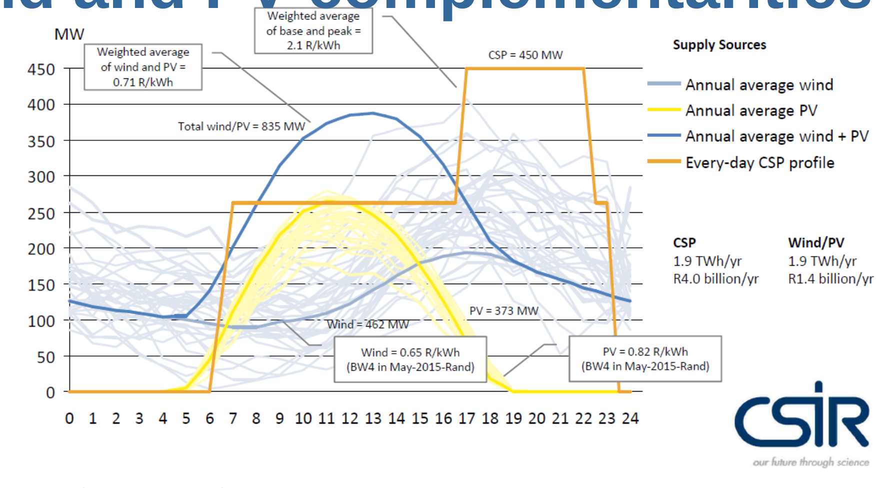
As PV saturates diurnal power demand and emissions must be further reduce, CSP plants generate during all hours… when the sun does not shine



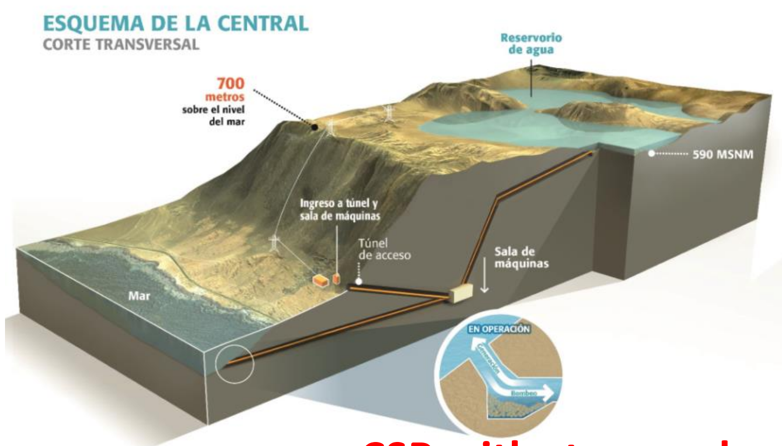
Multiple competing options

East-West orientation of PV

Wind and PV complementarities



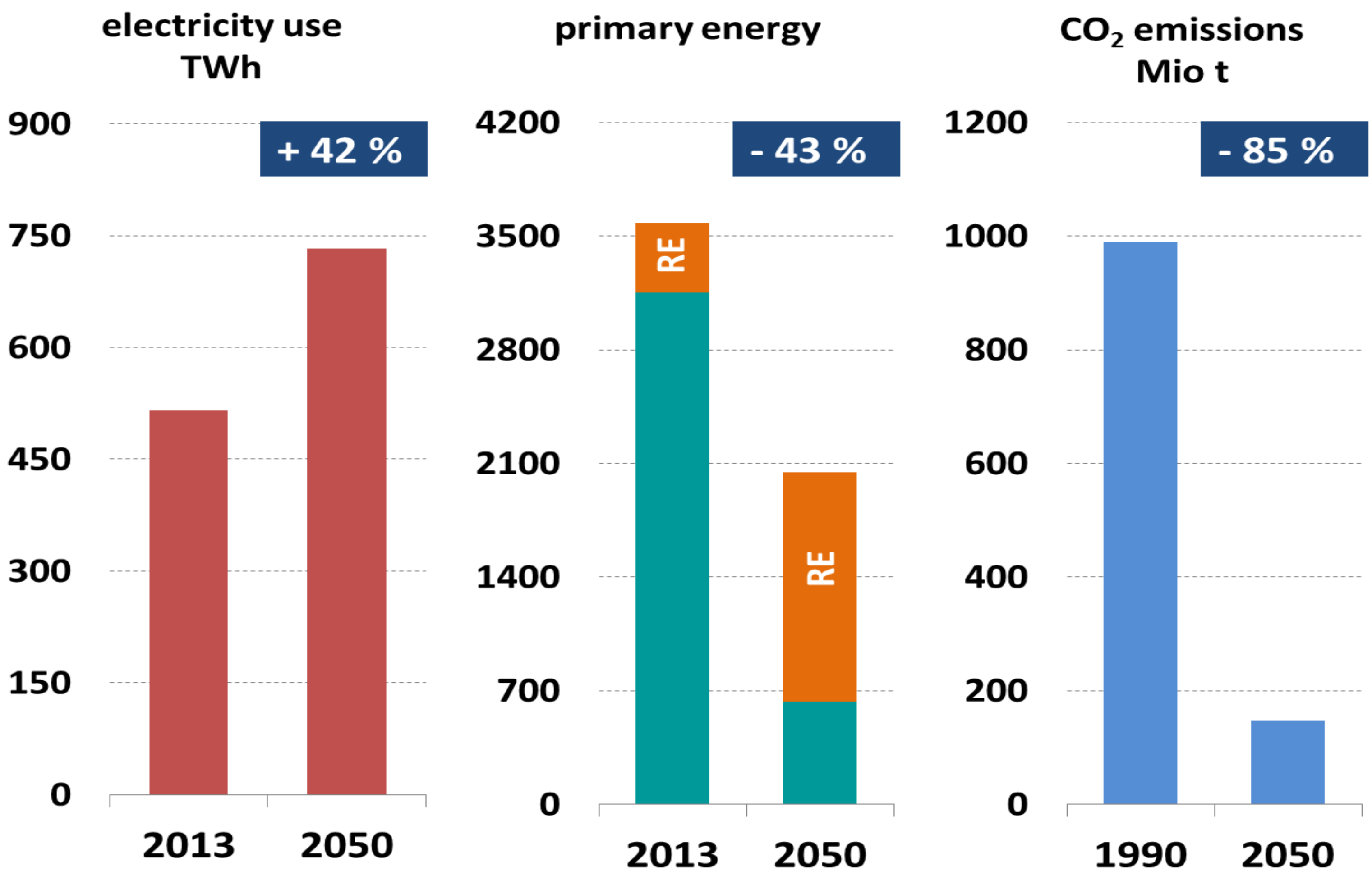
Hydro and pumped-hydro power



Demand-side response

CSP with storage does not offer the only way to mitigate the variability of the solar resource

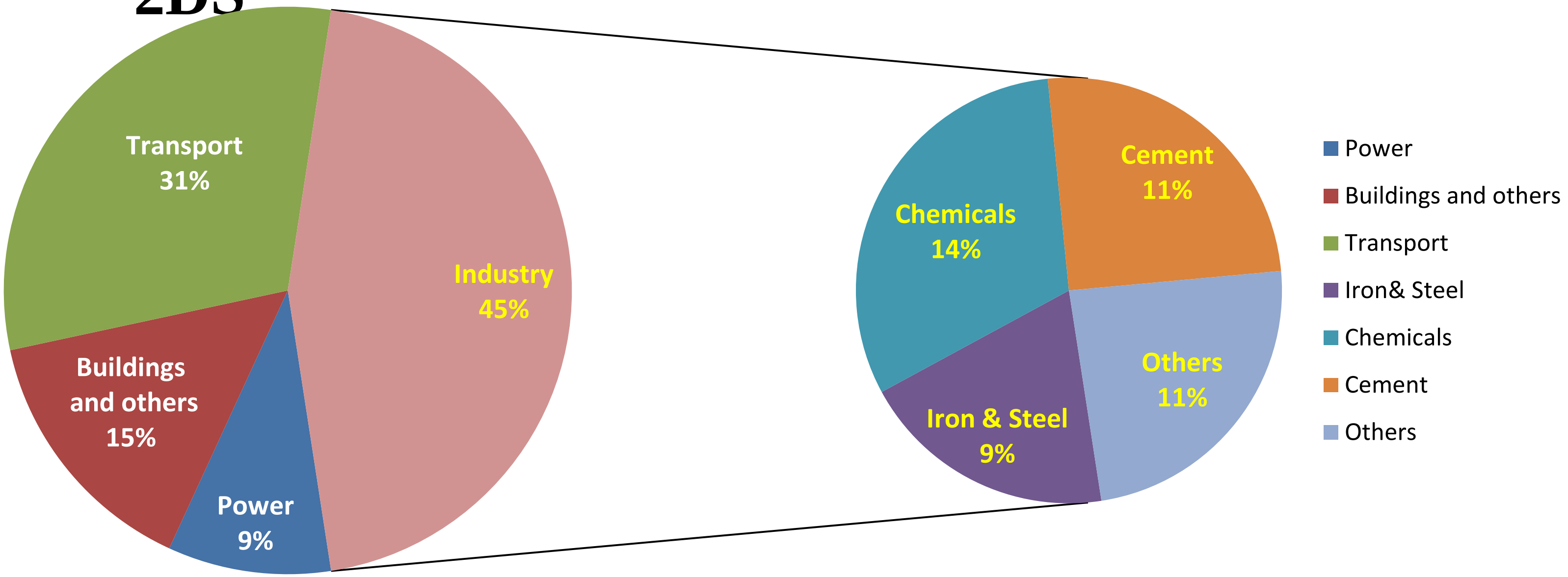
Massive electrification is an option



Modelling by Fraunhofer ISE suggests deep decarbonisation of Germany based on massive electrification of end-use sectors

Materials represent a major issue

Direct CO_2 emissions from industry by 2050 in the 2DS

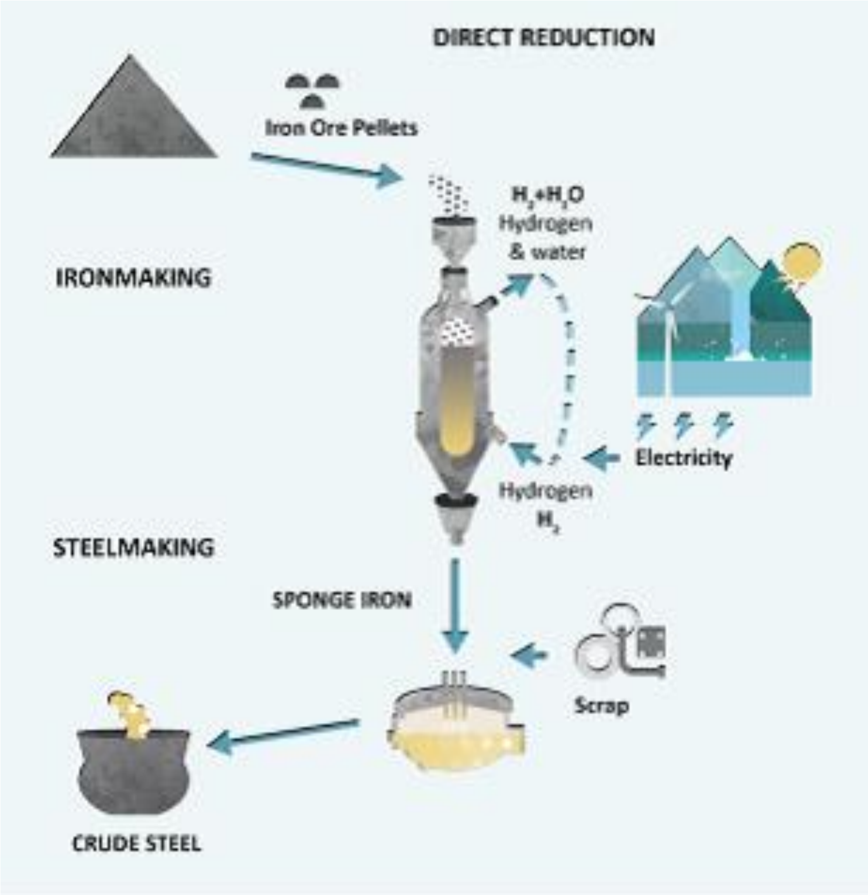


Iron and steel, chemicals and cement manufacturing responsible for the bulk of remaining emissions in 2050

Electricity – and hydrogen

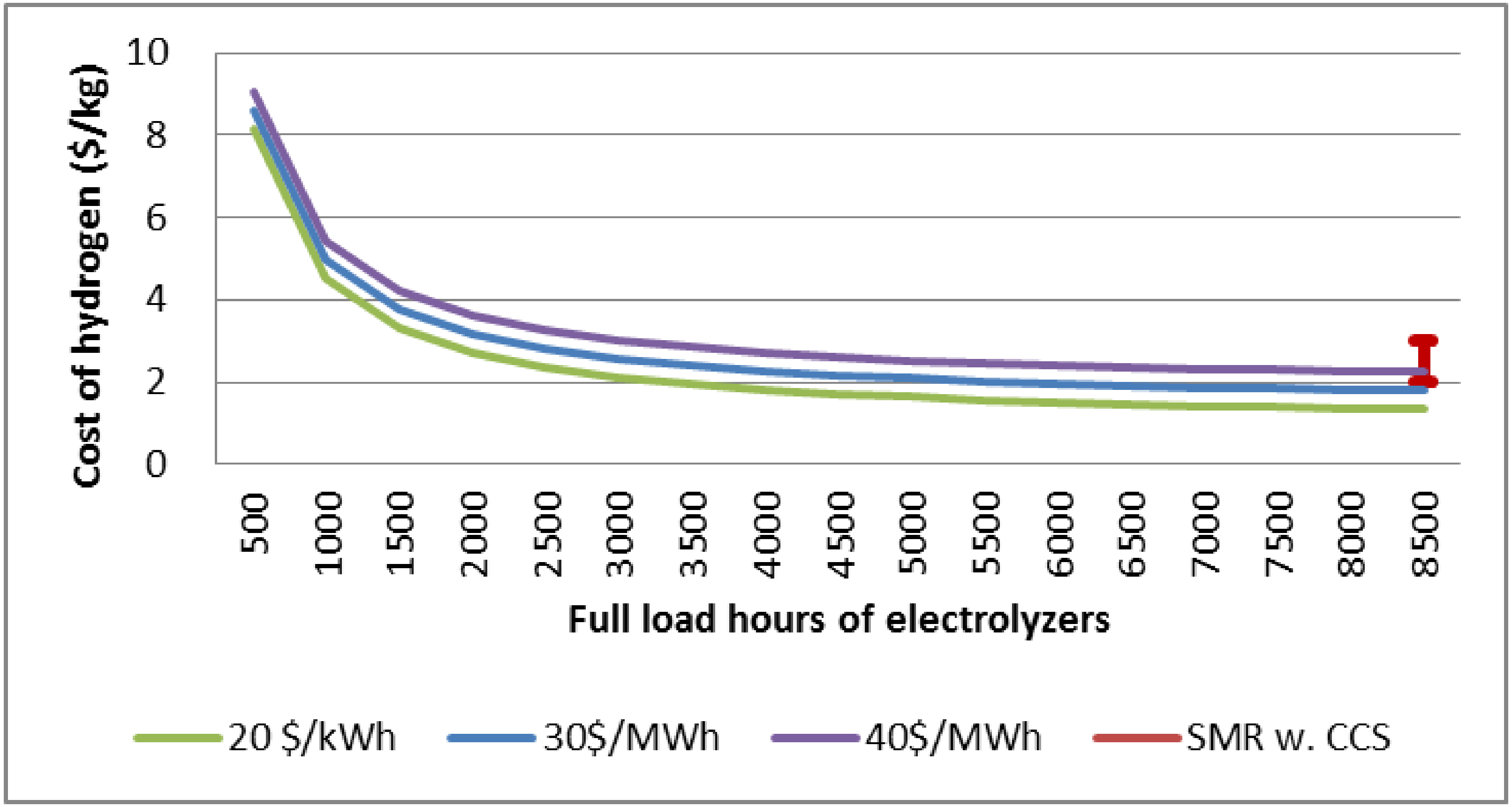
CO2-free steel making options:

- Direct iron reduction with hydrogen from renewables and electric arcs (Hybrit Projekt)
- Electrolysis/electrowinning (ULCOwin/ULCOlysis)



Hydrogen may play multiple roles as energy vector and as processing agent

Renewables-based hydrogen



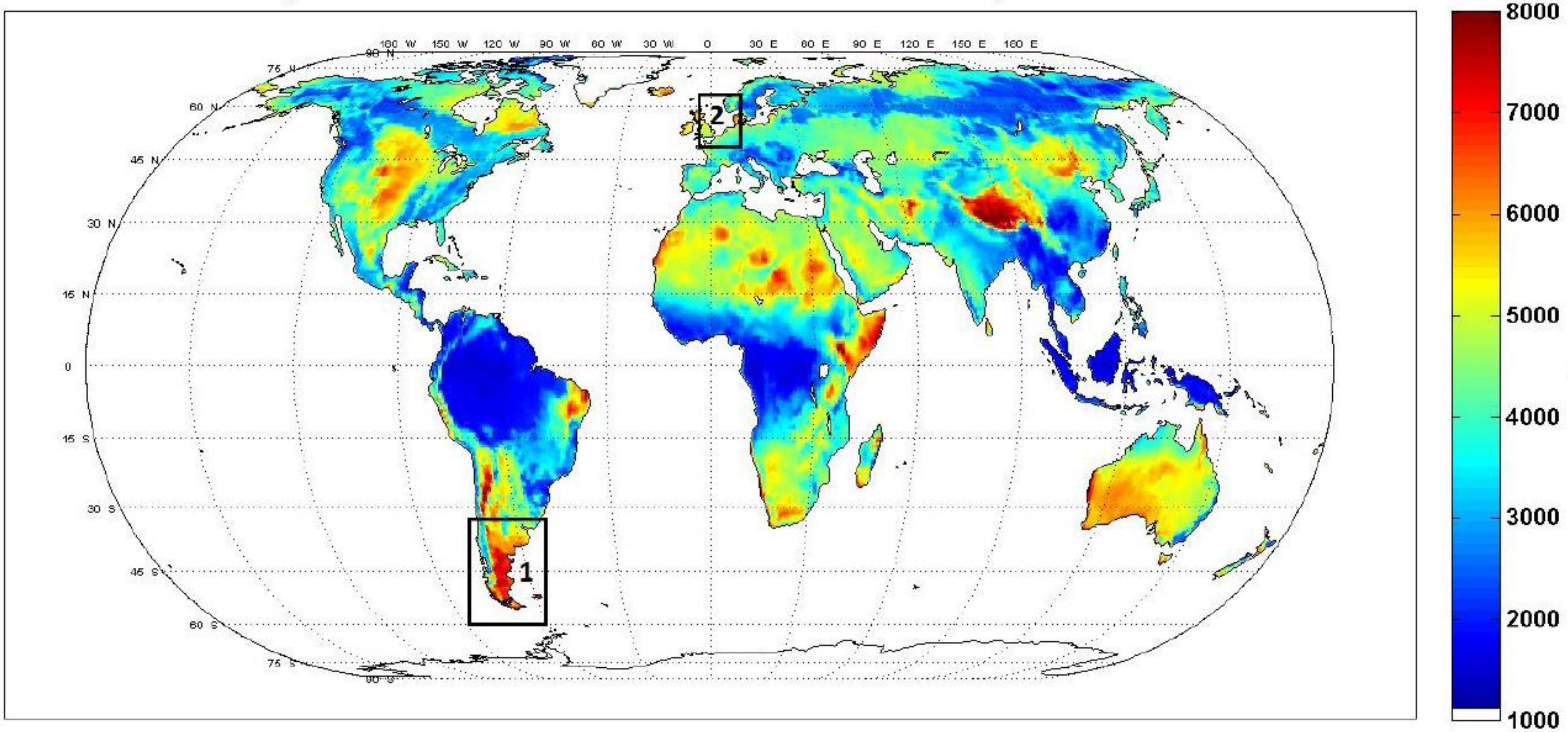
Renewables-based water electrolysis can compete with steam reforming of fossil fuels in areas with excellent solar and wind (or HP) resources

Data

Plants' Location (case study)

Open your mind. LUT.
Lappeenranta University of Technology

Hybrid PV1-Wind cumulative FLh for cost year 2030



1) Patagonia, Argentina:

- Hybrid PV-Wind Power Plant
- CO_2 capture Plant
- Desalination Plant
- PtL Plant

2) Rotterdam, the Netherlands

Marine distance

- Patagonia – Rotterdam: 13,500 km

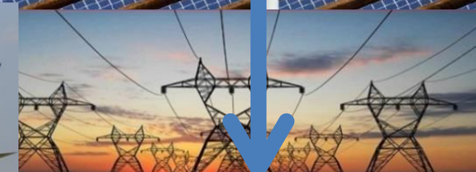
NEO CARBON ENERGY

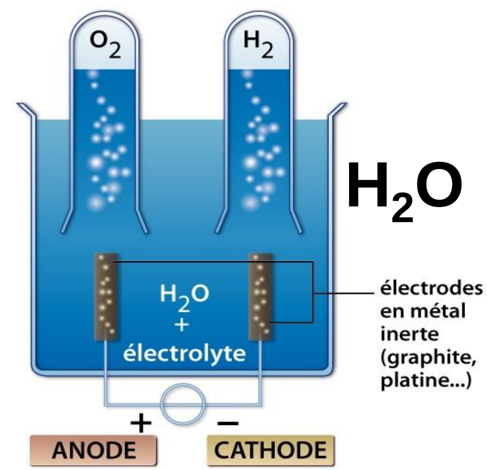
Ammonia, the other hydrogen

- 60 Mt H_2 is produced annually for industrial uses; half is for ammonia, input to fertilizers
- Current hydrogen production is 95% from NG or coal; manufacturing 1 t H_2 emits 10 t CO2!
- Clean hydrogen requires CCS or renewables-based electrolysis
- Clean ammonia, however, could serve as an energy carrier and store, and be directed to some end-use applications, e.g. balancing power plants

Re-energising CO_2 to prevent more emissions from bioenergy

CO_2





H_2O

$xCO_2 + yH_2 = C_xH_{2y} + xO_2$

1 CO_2 unit from atmosphere avoiding 2 CO_2 from fossil fuel use before it returns to the atmosphere