27 September 2016 | Algiers

Enhancing energy security: The role of technology

Parallel Roundtable 2

Introduction and roundtable themes

Context

- Technology has continuously transformed the energy sector in both supply and demand
- Innovations in production and transport technologies technology have driven substantial increase in both volume and trade flows in the last 10 years
- Innovations in solar and wind are moving towards grid parity in many markets, carbon capture use and storage and other technologies move more slowly.
- Upcoming technologies will play a large part in achieving the COP21 objectives

Session objectives

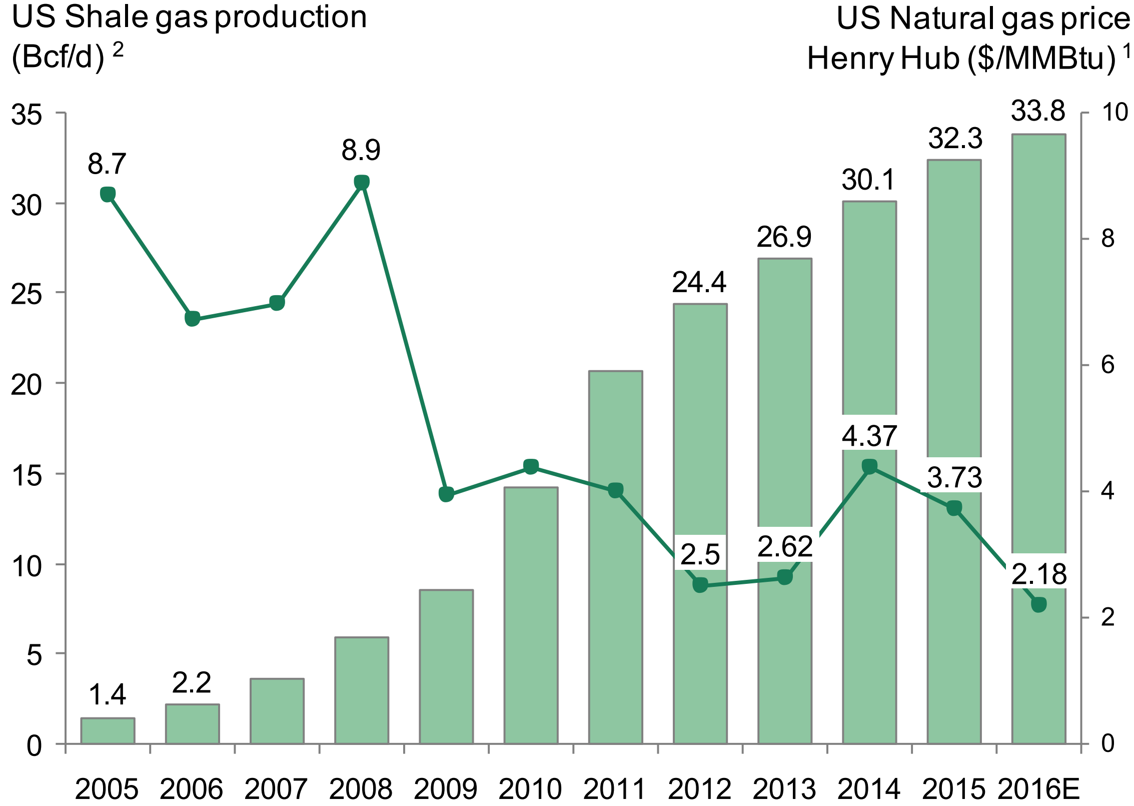
- To understand the recent impact and potential future impact of technology on the energy sector
- To exchange views on how to promote innovation and technology transfer
- To discuss how innovation and technology transfer across all sectors improves energy security and 21st century demands

Key Question: In which areas can Ministers most usefully support the deployement and transfer of new technologies to enhance energy security?

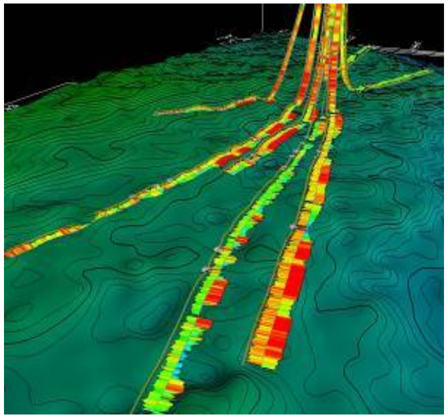
Technology can rapidly transform the energy landscape

Case Study: Explosive growth in US shale driven by horizontal drilling and hydraulic fracturing

US Shale gas production and impact on US natural gas price



Horizontal drilling...



...and hydraulic fracturing

1.MMBtu: million British Thermal Unit, 1BTU = 1.055 kjoules. 2016 Henry Hub gas price is YTD average (Jan-Jul)
2.bcf/d: billion cubic feet per day
Source: EIA; Rystad, LCI Energy Insight

Leading institutions have high expectations for CCUS

CCUS seen as a critical enabler of global carbon dioxide goals

"CCS identified as an **essential technology in limiting temperature increase to 2ºC"**
International Energy Agency

"Wide adoption of CCS part of the scenario that achieves 450 ppm atmospheric stabilization level for CO2"
World Energy Council

"Availability of CCS is **critical for producing 450 ppm"**
Energy modeling forum 27 study

Meeting GHG reduction goals depends on global CCUS

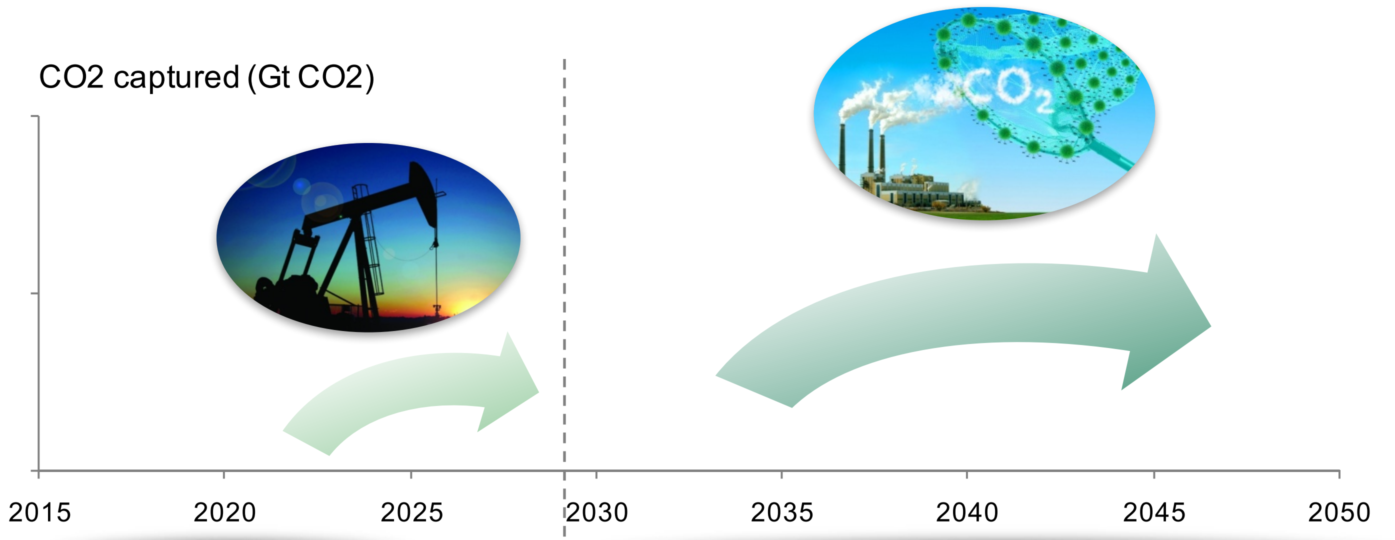
"CCS is an important technology in the long run… deployment to drive down costs is desirable"
UK Committee On Climate Change

"Commercial demonstration of CCS essential for **deployment in the 2030 timeframe"**
European Commission

"CCS to be cost effective when transformational technologies emerge"
US Climate Action Report 2014

Despite the undisputed relevance of CCUS, limited action is leading to loss of momentum in technology development

CCUS technology is expected to develop in 2 waves



1st wave: 10 - 15 yrs → | **2nd wave: 20 - 25 yrs** →

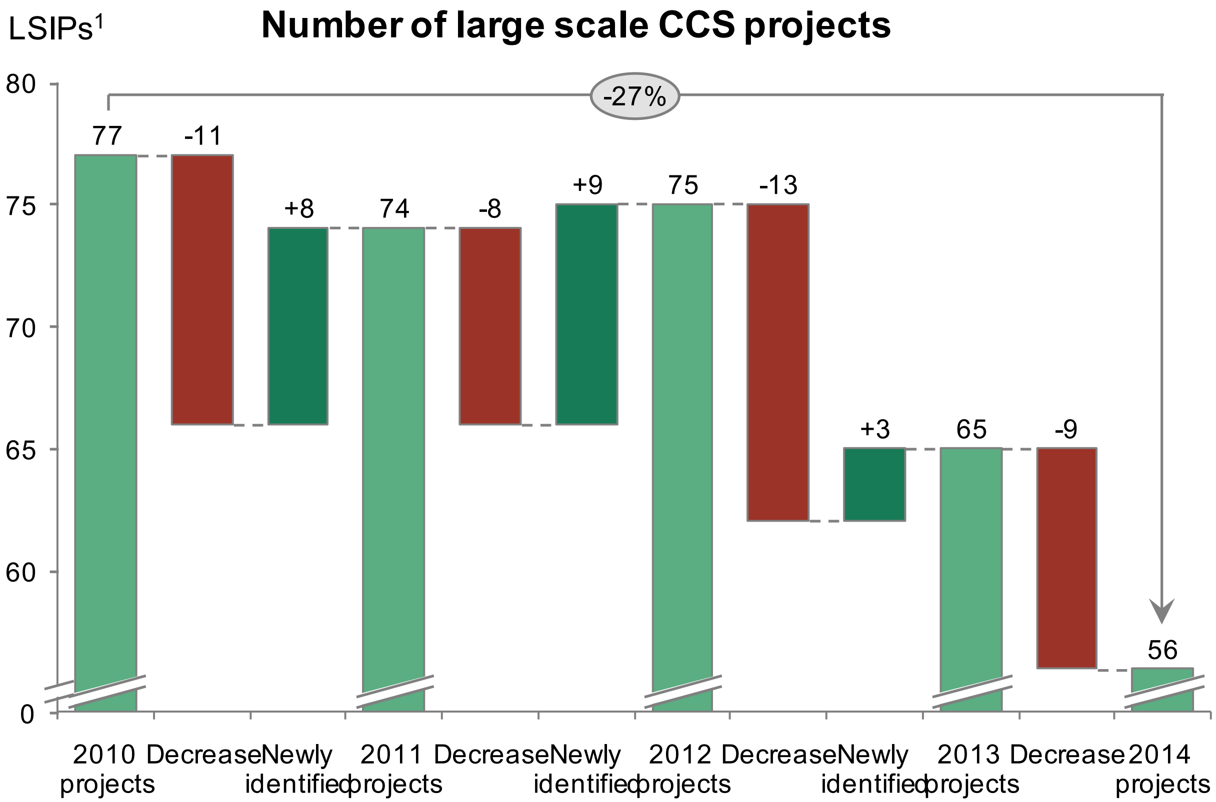
	1st wave	2nd wave
Enabler	**Deployment of CCS with EOR storage Research on CO2 utilization technology**	**Large scale development of utilization of CO2 as alternative to geological storage**
Challenge	**High cost of carbon capture technologies**	**Limited geological storage** • Saturated EOR capacity • Deep saline aquifers difficult to exploit

Regulation as complementary enabler to push further CCUS deployment

Source: Energy Technology Perspectives 2016 IEA

Yet a lack of incentives can lead a Technology to stutter

Case Study: A lack of incentives for CCS has led to a 27% reduction in CSS projects 2010-14



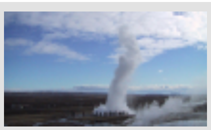
Drivers in reduction in CSS investment

- No incentive to pay for CSS
  - CO_2 prices / carbon taxes are not high enough
  - "In the European quota system a ton of CO_2 costs ~8-10$ – while typical purification costs lies in the area of 80-165 $/ton"
- Shale gas revolution in the US - reduced CO_2 emissions a positive byproduct
  - Reduced pressure for funding for CO_2 avoidance projects
- Costly when solely for CO_2 avoidance
  - Large (~$1Bn) capex investment
  - Renewables investment additionally generates energy and efficiency measures

1. LSIP - Large-Scale Integrated Projects - LSIP defined as projects involving CCS at a scale of: 1) at least 800k tonnes of Co2 annually for coal-based plant or 2) at least 400k tonnes of Co2 annually for other emissions-intensive industrial facilities & "CCS projects considered to be at a sufficiently large scale to be representative of commercial-scale process streams"
Source: Global CCS Institute

Renewable technology is continuing to develop and mature

Significant growth in last 5 years in core technologies; Wind and Solar PV

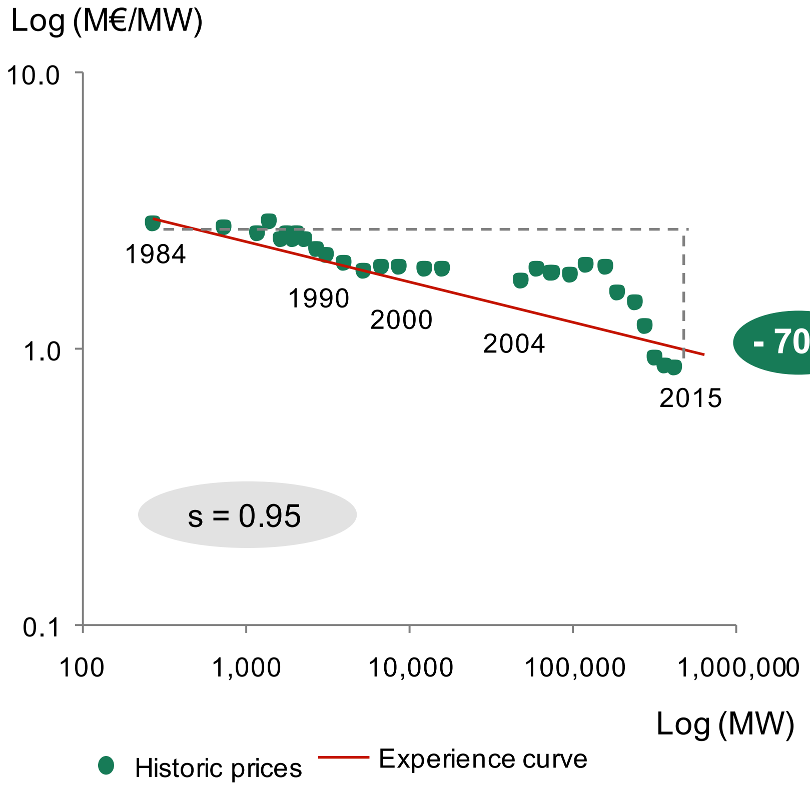
	Type	Installed[1] by 2015	CAGR[2] '15-'20	Cost 2015[3]	Project size	Comments
	Wind on-shore	~ 419 GW	6-7%	1.200-1.800 €/kW	10-400 MW	• Wind on-shore is a mature technology with cost reduction potential • Feed-in tariffs schemes are gradually substituted by public competitive auctions
	Wind off-shore	12 GW	22-24%	3.500-4.000 €/kW	100-600 MW	• Technology slowly maturing with a 40% cost reduction target by '23 • Higher availability and less variability compared to on-shore
	Solar PV	~222 GW	10-12%	800-1.800 €/kW	1-300 MW	• Mature technology with substantial cost reduction experienced • Feed-in tariffs schemes are gradually substituted by public competitive auctions • Grid parity increasingly driving future market adoption
	Solar CSP	~ 5 GW	10-12%	3.500-4.500 €/kW	50-200 MW	• 2nd gen. technologies being commercialized by a few companies • Solar PV with substantial cost advantage in most geographies
	Biomass/ Biogas	~ 117 GW	5-6%	2.200-3.500 €/kW	1-300 MW	• Primarily used for heat and gas; 7% electricity production • Biogas with about 60 TWh electricity production • Profitability depends on biomass price and availability
	Small Hydro	~ 145GW	2-4%	2.000-4.000 €/kW	1-10 MW	• Contributing to rural electrification • Established mature technology but high capital cost
	Geo-thermal	~ 13 GW	6-7%	2000-3.000 €/kW	2-100 MW	• Long term high growth potential in "Hot dry rock" and other resources • Substantial exploration risks (i.e. triggering of earth quakes)

1. Cumulated installed capacity by end of year 2. Growth rate for annually installed capacity 3. Cost for adding new capacity
Source: IEA; BTM; Research firms: BCG market models; Bloomberg , United Nations, BCG analysis

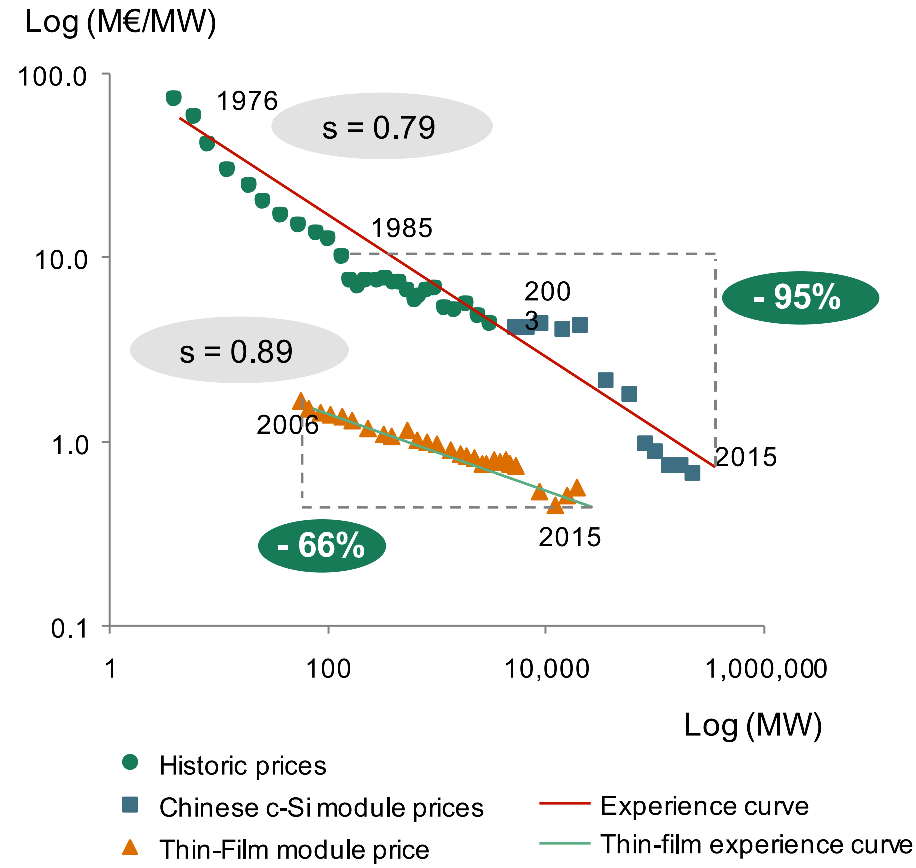
Solar and wind have seen rapid technology improvements

Technology improvements have lead to an aggressive reduction in price

Wind turbine price index 1984–2015



Solar PV module experience curve 1976–2015

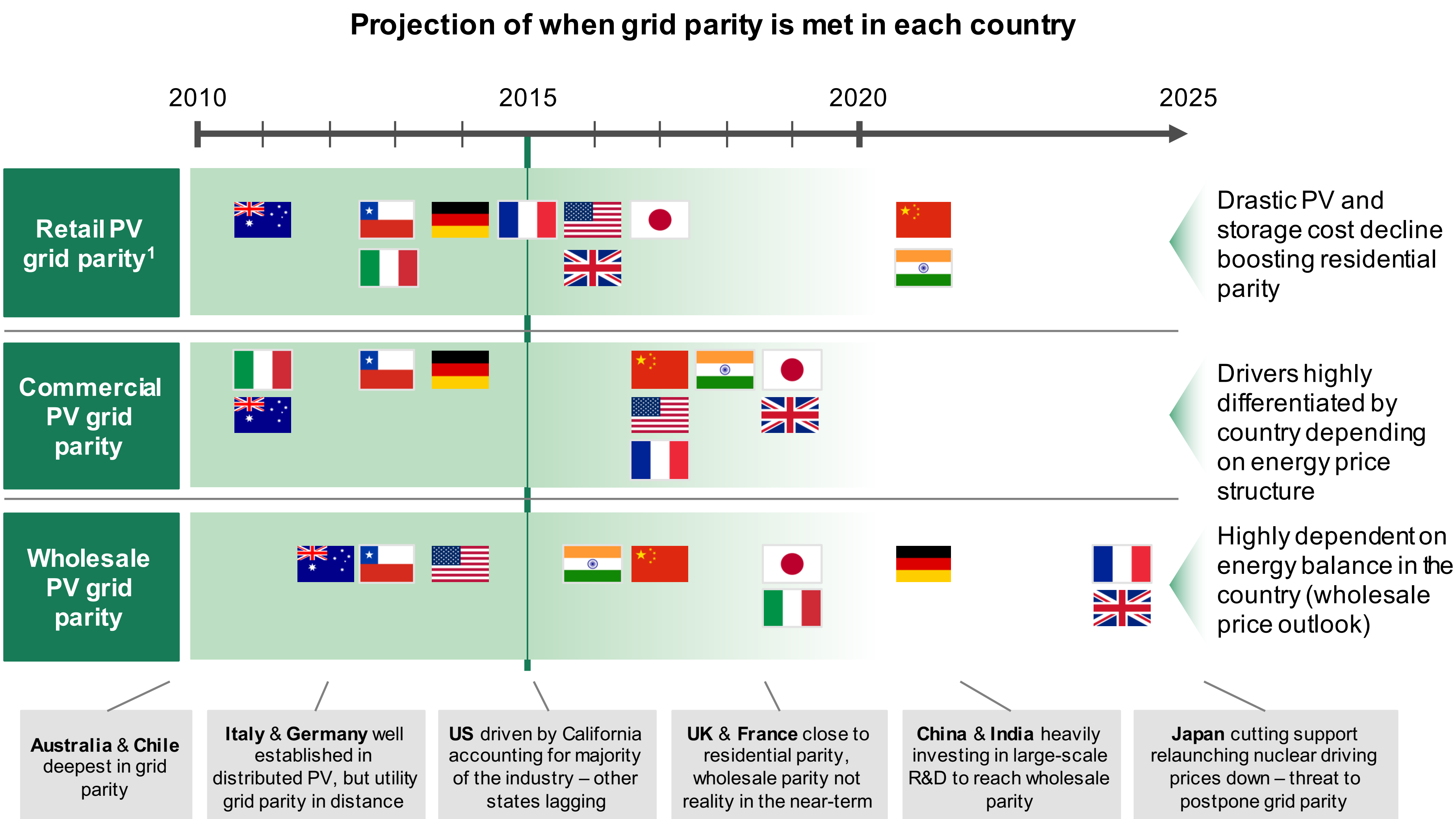


1. S: price index as cumulative volume doubles; S= 0.95 means as cumulative volume doubles, price drops to 95% of before

Source: Bloomberg new energy finance; Lawrence Berkeley laboratory

Solar is approaching grid parity[1] in many markets

Technology investment is needed to obtain Grid parity for wholesale energy use



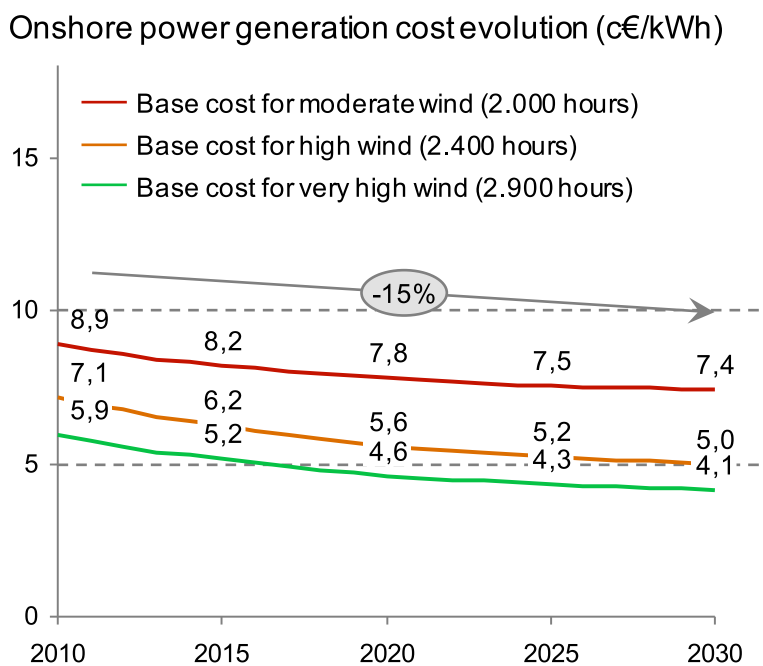
1. Grid parity (or socket parity) occurs when an alternative energy source can generate power at a levelized cost of electricity (LCOE) that is less than or equal to the price of purchasing power from the electricity grid.

Source: Expert interviews; BCG PV market model; IHS (2015); Banking analyst forecasts and market reports; BCG analysis

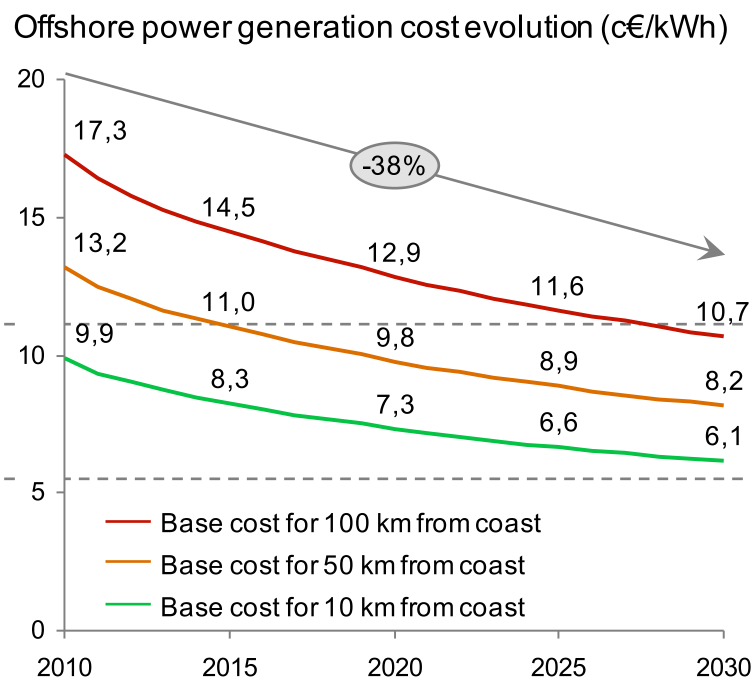
Technology improvements continue to reduce cost of wind

~40% reduction in offshore cost, with onshore technology maturing

Onshore wind power generation cost evolution until 2030 for 50 MW farms



Offshore wind power generation cost evolution until 2030 for 150 MW farms



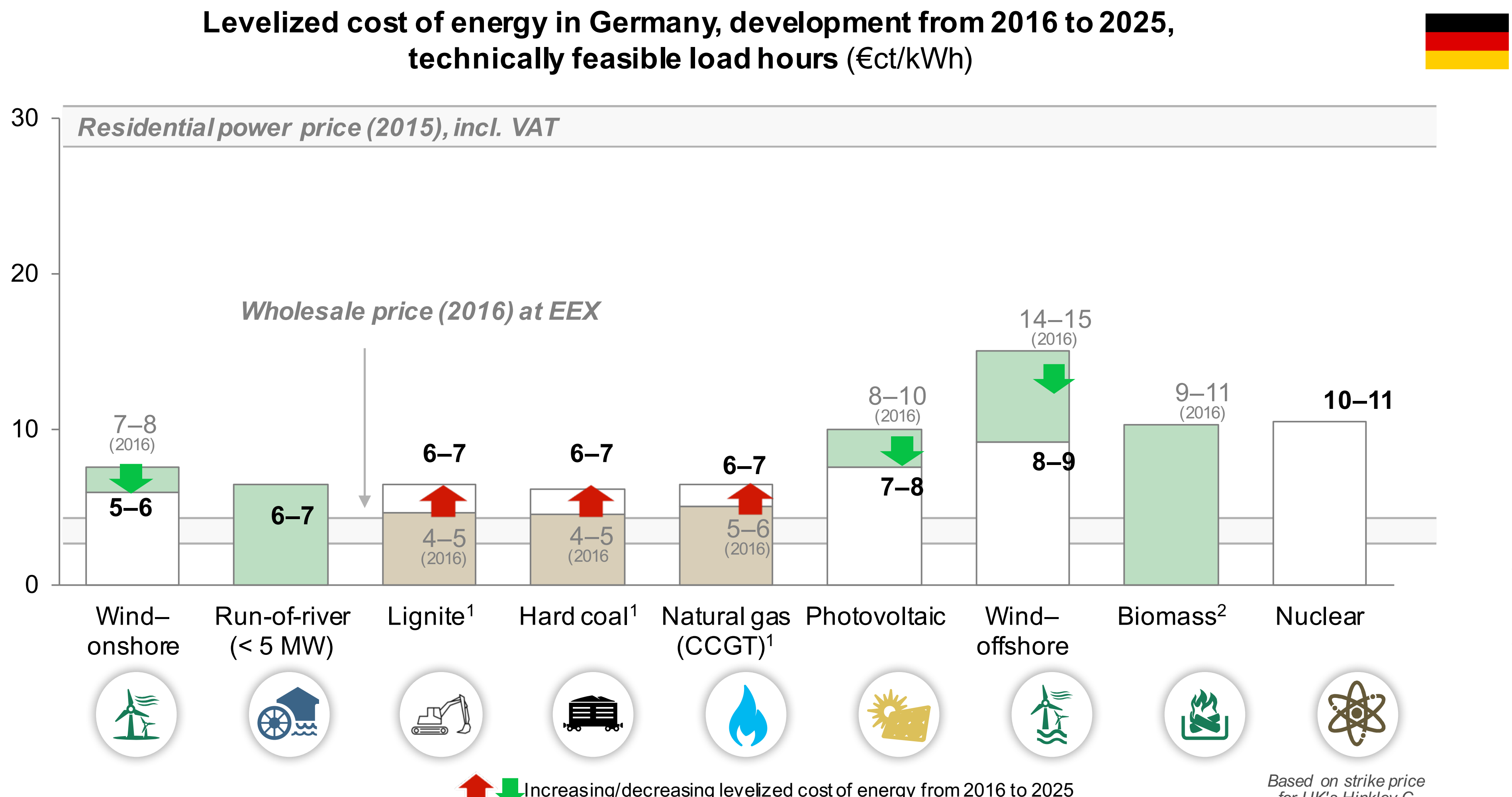
In ~2020, some offshore farms could be competitive in cost terms with lowest profitability onshore farms

% - average annual cost reduction 2015-2030

Note: 7,8% discount rate assumed (nominal and after taxes)

The costs of technology-led energy sources are falling

...whilst mature hydrocarbon sources are increasing



1. Assumed CO_2 prices: ~ 5 €/t in 2016, ~ 25 €/t in 2025. Lignite full cost including mining.
2. Based on large scale generation. Assumed to remain relatively constant at current woodchip price ~25 €/MWh.

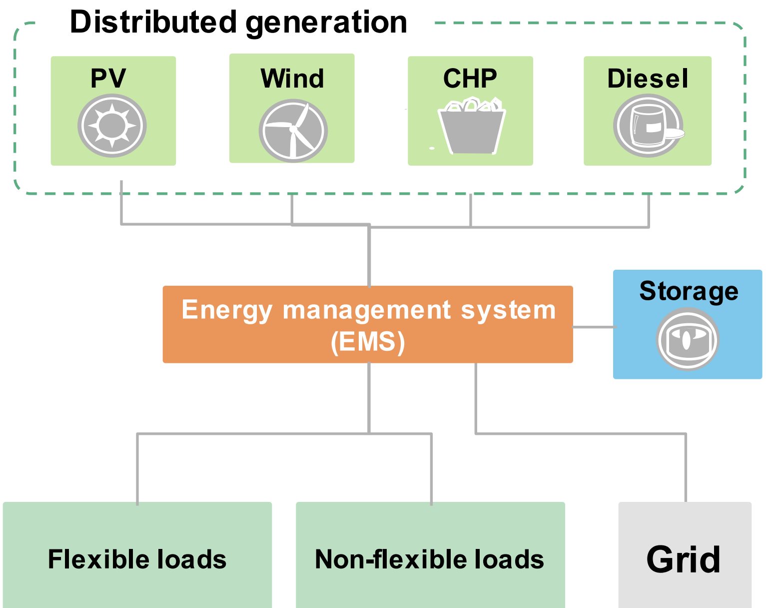
Note: LCOE = levelized cost of energy. All WACC = 8%. Residential Power price = 29,2 €ct/kWh. Dong Ref.: LINK

Source: IRENA; 4C Offshore; Bloomberg; EC - 2050 Energy trends; BCG coal fuel price forecast; BCG analysis.

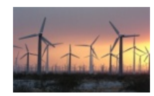
Integration of multiple technologies is key for the future

This is more technically intensive than historically due to intermittent supply

De-centralised technologies consist of generation, storage, and load ...



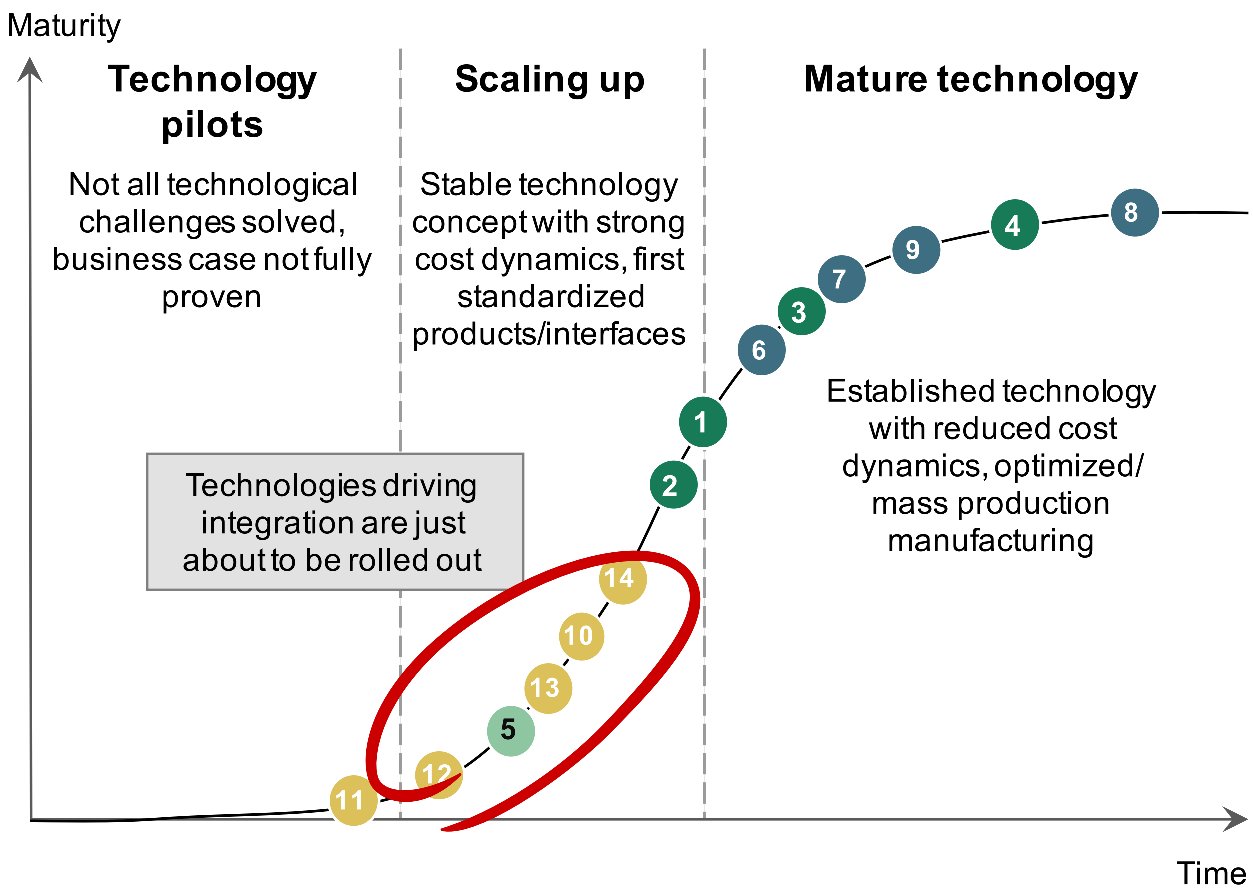
... and are applied across key customer segments

Segment		Example
Small utility		• IPPs , yieldcos, and / small utilities
Off-grid		• Mines in remote regions e.g. in Africa
Community		• Small cities, universities, military
Industrial		• Heavy industries e.g. a large steel plant
Commercial		• Retail stores e.g. IKEA
Residential		• One- or two-family homes

Supporting technologies have different maturity levels

Distributed generation and energy efficiency most advanced

Development of technology maturity



Technologies

Generation	1	PV
	2	Residential CHP
	3	Commercial CHP
	4	Industrial CHP
Storage	5	Li-ion battery storage
Energy Efficiency	6	Heat pumps[1]
	7	LED
	8	HVAC[2]
	9	Heat recovery
Optimization/ coordination [EMS]	10	Demand Response
	11	Virtual Power Plants
	12	Residential EMS[3]
	13	Commercial EMS[3]
	14	Industrial EMS[3]

1. Incl. thermal storage 2. Heating, Ventilation, Air Conditioning 3. Energy Management System able to optimize both generation and load
Source: BCG

Key questions for our discussion

1. What roles governments and industry should play to promote, deploy and transfer cleaner energy technologies?
2. How can the existing mechanisms (international collaboration, public/private) be improved to meet the challenges set by the Paris Agreement?
3. What are the technologies most likely to be the focus of support?
4. Should energy targets or specific technologies be the focus of government policy, or should the latter be technology-neutral?
5. How can the transfer of cleaner technologies to developing countries be accelerated?

Disclaimer

The observations presented herein are meant as background for the dialogue at the 15th International Energy Forum Ministerial Meeting. They have been prepared in collaboration with the Boston Consulting Group, and should not be interpreted as the opinion of the International Energy Forum or the Boston Consulting Group on any given subject.

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