Innovating Green Transitions

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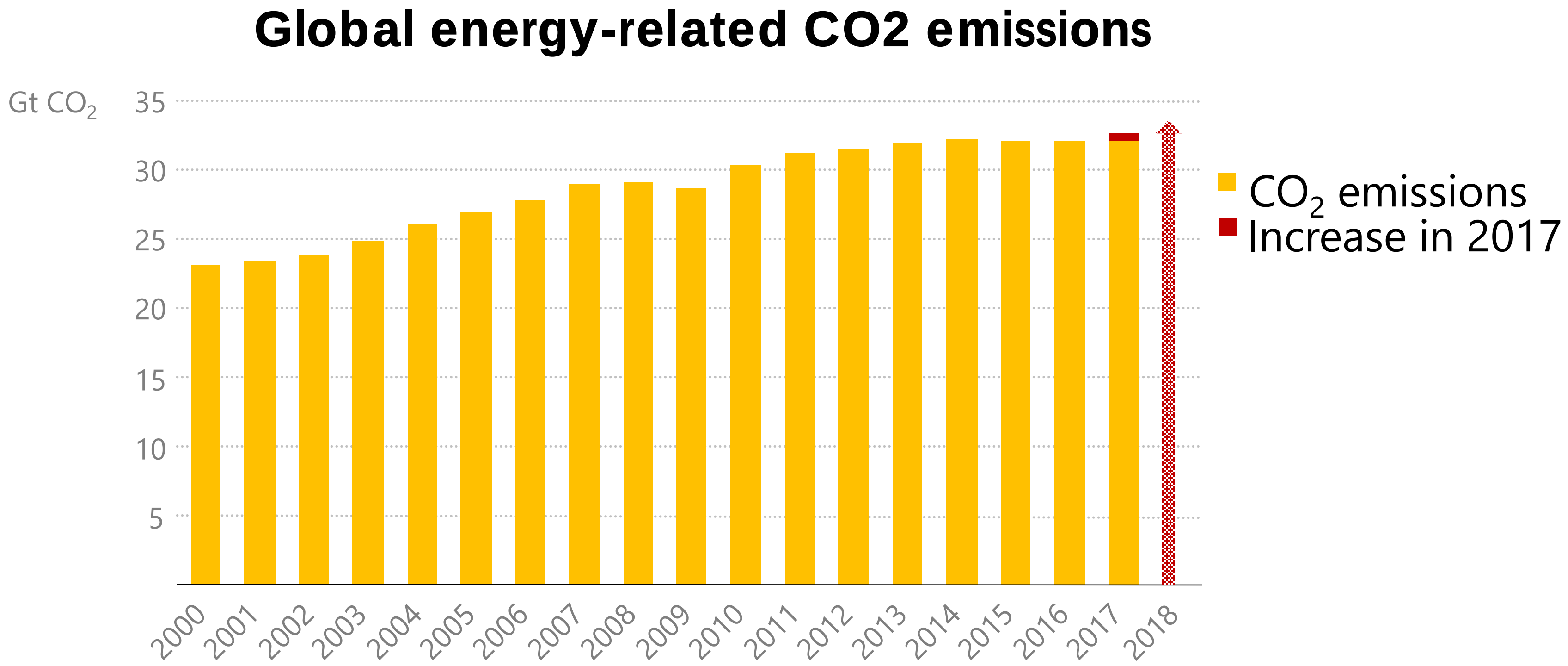
Oslo, Norway, 15 January 2019

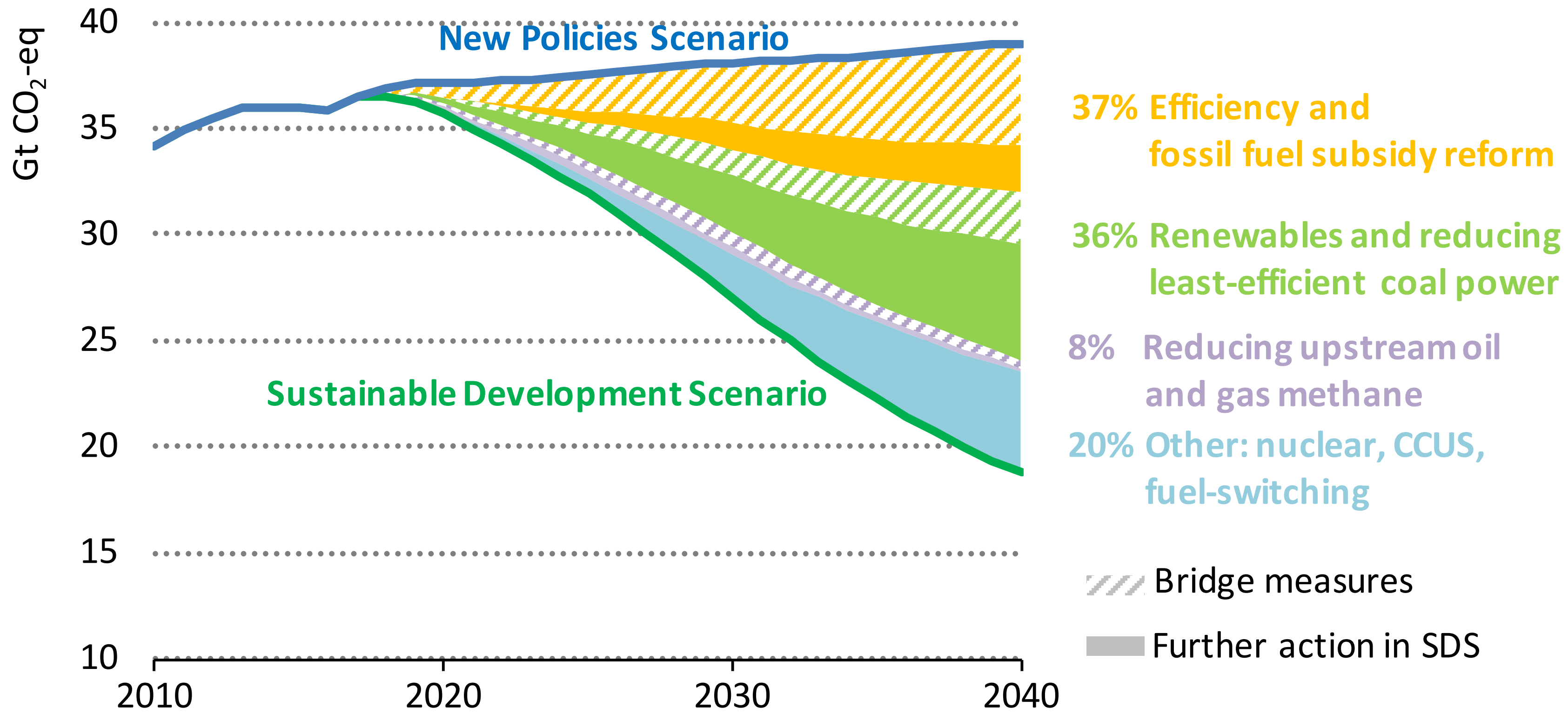
IEA

Latest snapshot of global emissions…



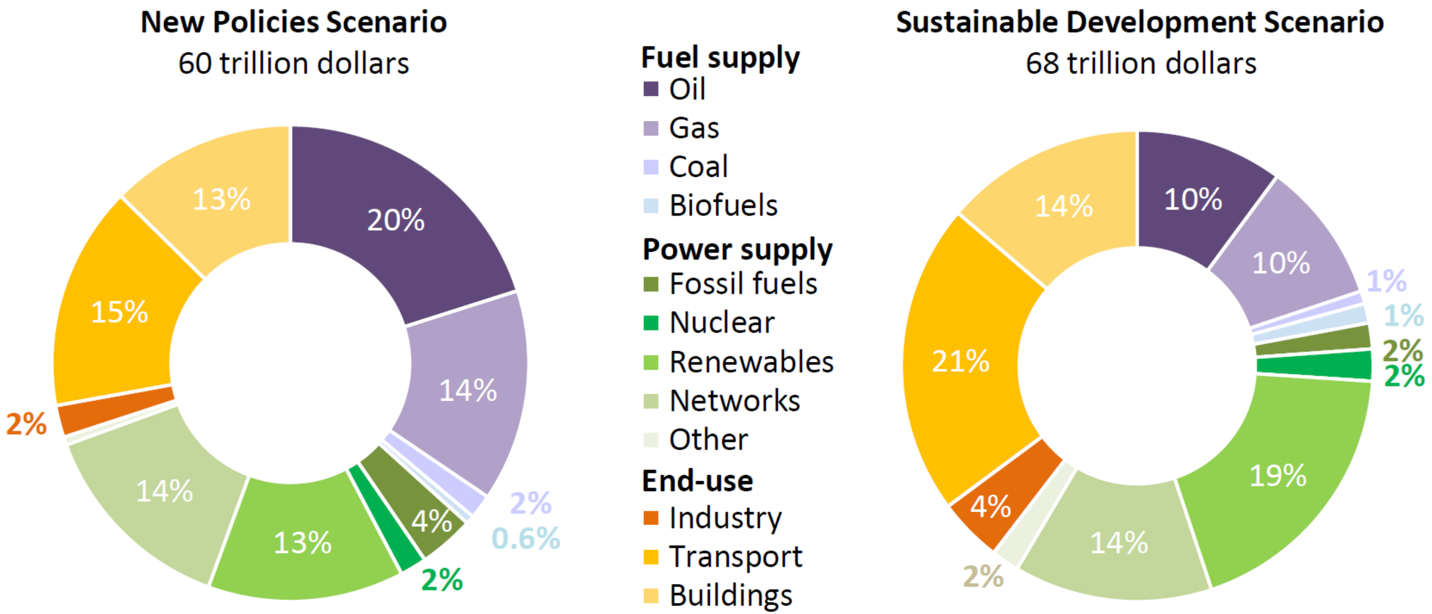
Global emissions are set to increase in 2018…again

Where do we need to go?



Achieving goals require early emissions peak & sharp decline;
CO_2 needs to fall to 1960 levels (with global economy 20 times larger); innovation absolutely critical

Cumulative investment needs in NPS and SDS, 2018-2040



Total investment in the Sustainable Development Scenario is only about 15% higher than in the New Policies Scenario, but there is a marked difference in capital allocation

Tracking Clean Energy Progress (TCEP) – www.iea.org/tcep

Power

- Renewable power
  - Solar PV
  - Onshore wind
  - Offshore wind
  - Hydropower
  - Bioenergy
  - Geothermal
  - Concentrating solar power
  - Ocean
- Nuclear power
- Natural gas-fired power
- Coal-fired power
- CCS in power

Industry

- Cement
- Chemicals
- Steel
- Aluminum
- Pulp and paper
- CCS in industry

Transport

- Electric vehicles
- International shipping
- Fuel economy
- Trucks
- Transport biofuels
- Aviation
- Rail

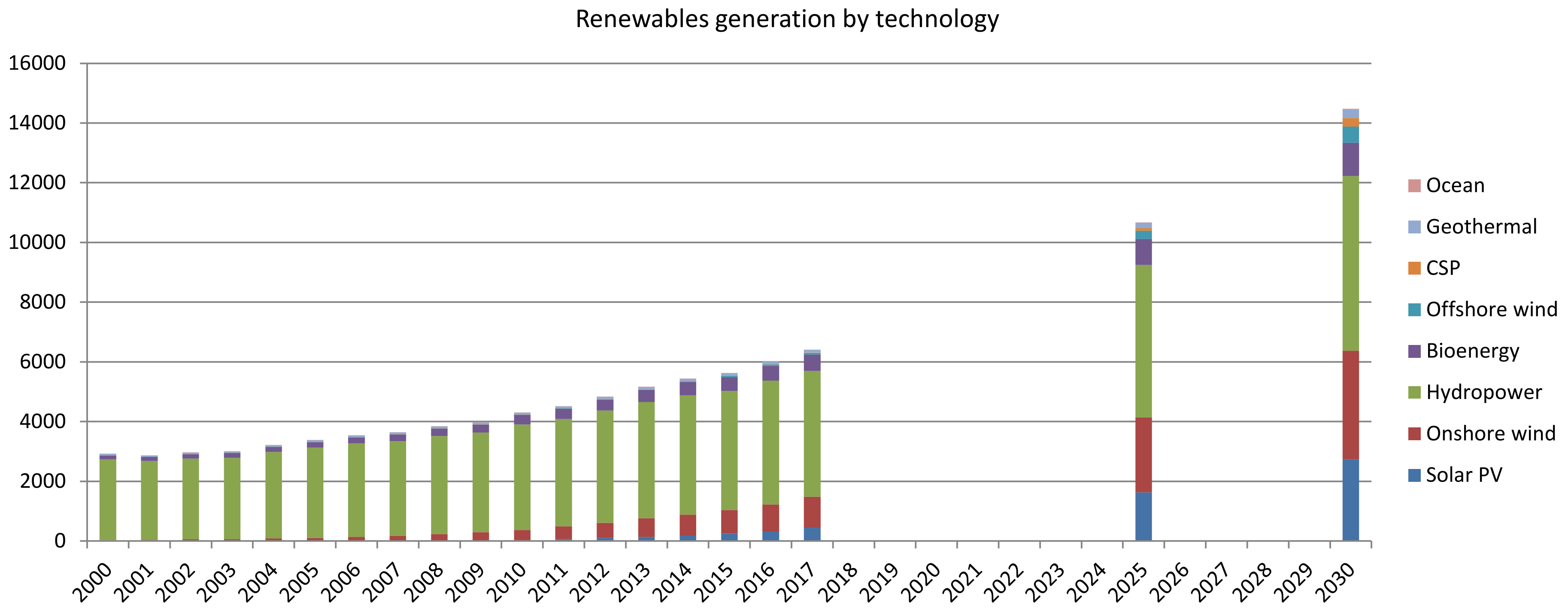
Buildings

- Building codes
- Heating
- Cooling
- Lighting
- Appliances & equipment
- Data centres and networks

Energy Integration

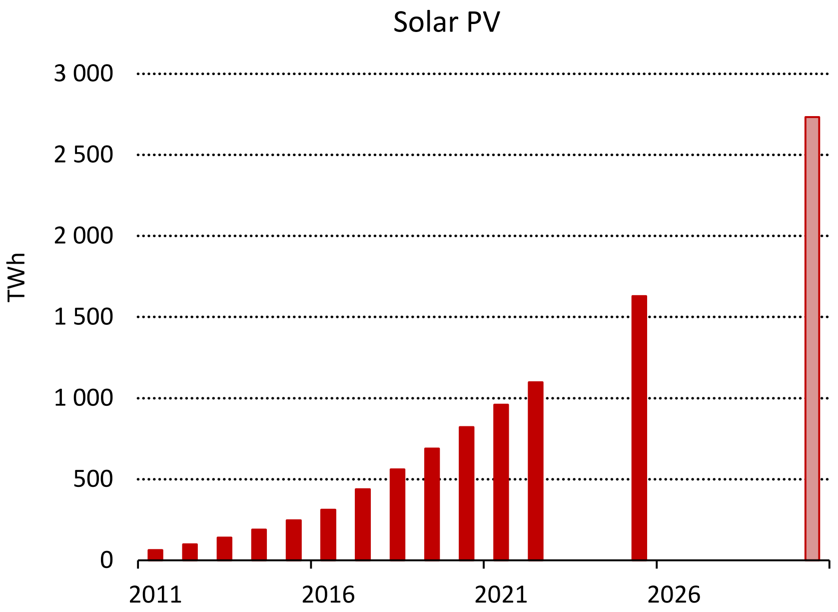
- Energy storage
- Smart grids
- Demand response
- Digitalization
- Hydrogen
- Renewable heat

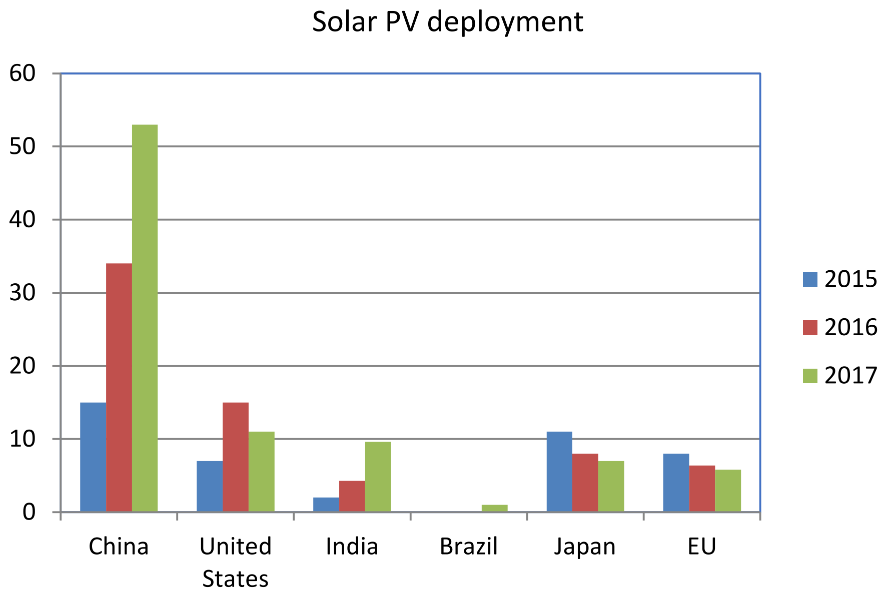
Renewables growth is not fully on track for what is needed



Renewables saw highest rate of generation growth among all energy sources in 2017, but deployment must further speed up to meet 2030 targets

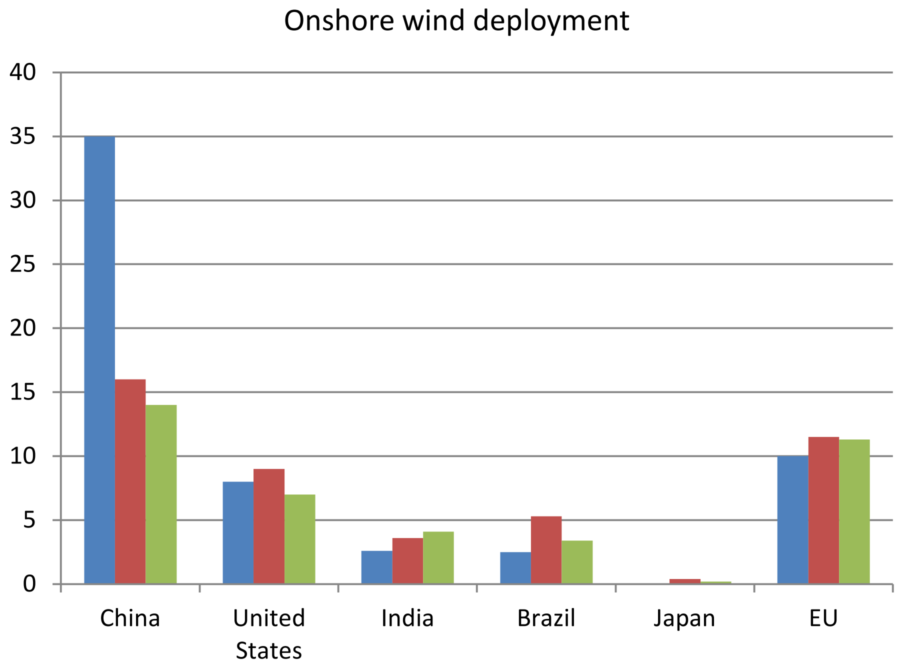
Solar PV is the only renewable technology on track

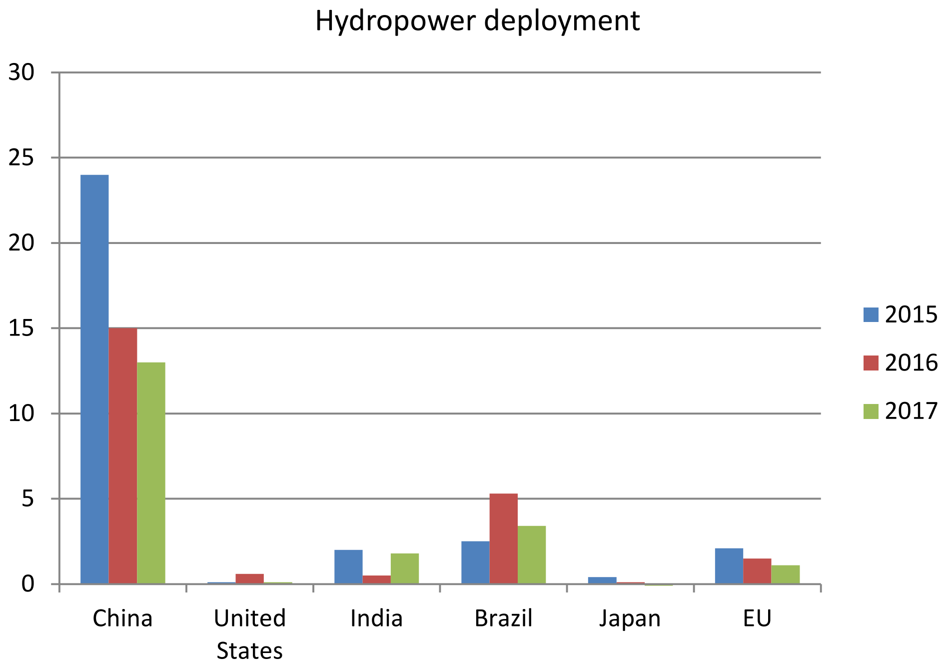




Solar PV has shown record growth in 2017; it is well on track to meet its SDS target

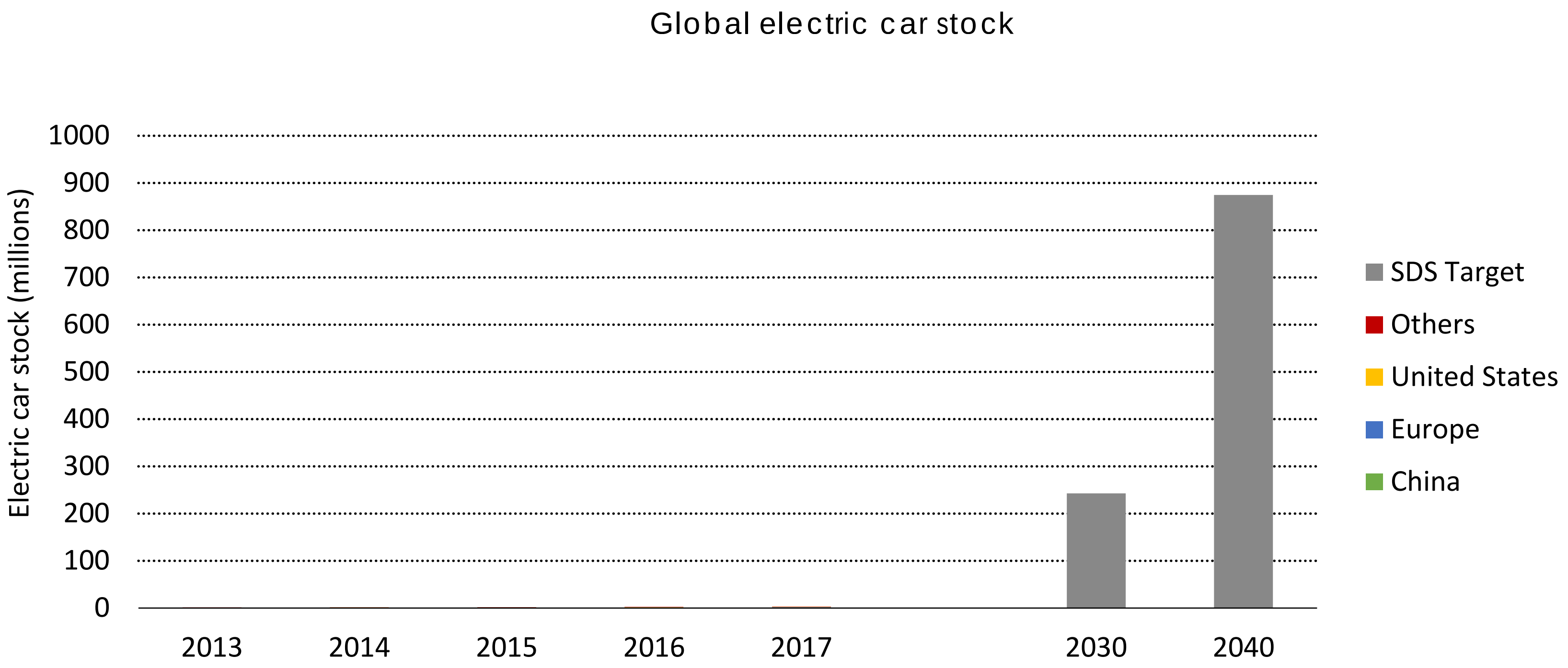
Onshore wind and hydro need more improvement





Onshore wind capacity additions declined by 10% in 2017, marking the second year of decline; hydropower additions have also decreased for fourth consecutive year

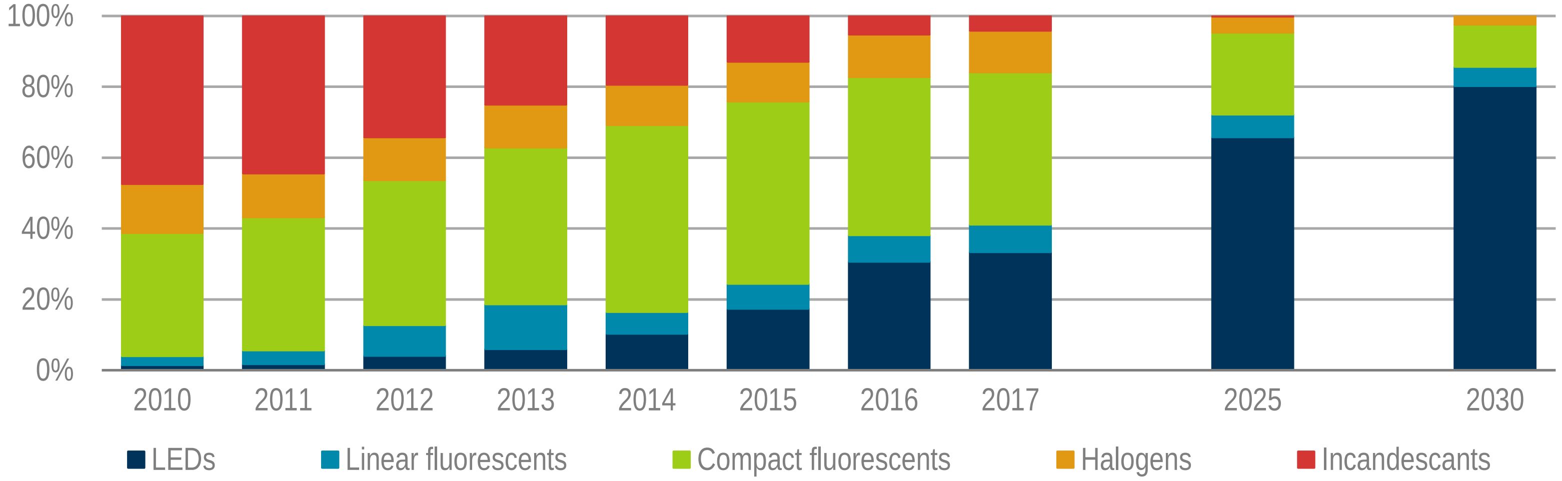
EV growth has grown rapidly; strong momentum needs to continue



The number of passenger electric cars on the road passed 3 million in 2017, but it needs to grow to 240 million by 2030 in SDS

LED sales on track to reach 80% of total by 2030

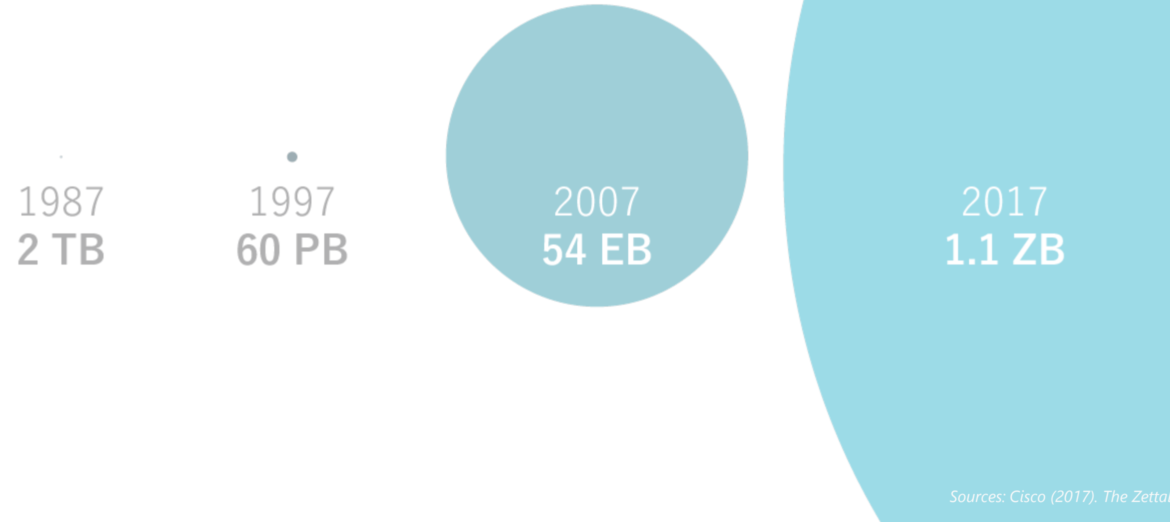
Shares of global residential lighting sales by type

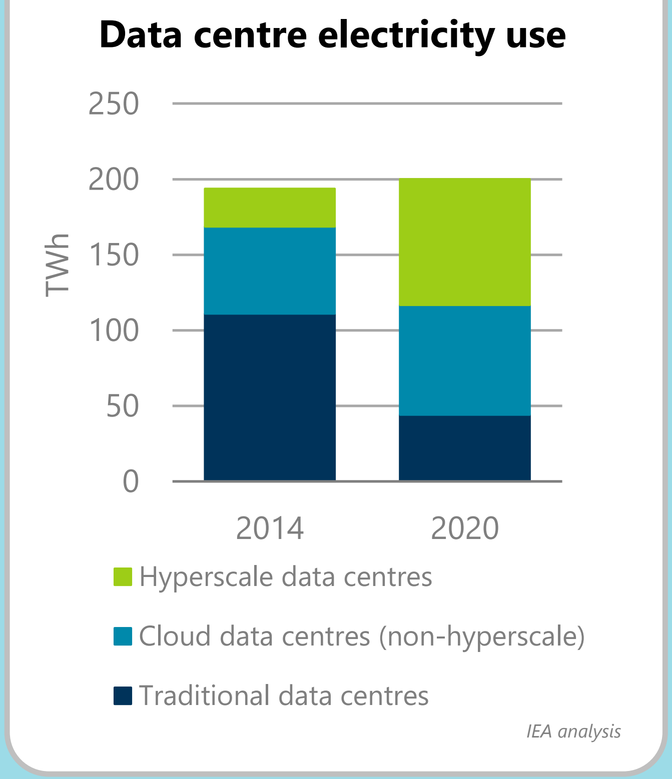


LEDs are on track to dominate residential lighting by around 2020;
3.3 billion LEDs were installed in 2017, underpinned by falling costs & government policy

Digitalization trends are truly astounding

KB	kilobyte	10^3 bytes
MB	megabyte	10^6 bytes
GB	gigabyte	10^9 bytes
TB	terabyte	10^{12} bytes
PB	petabyte	10^{15} bytes
EB	exabyte	10^{18} bytes
ZB	zettabyte	10^{21} bytes
YB	yottabyte	10^{24} bytes





Sources: Cisco (2017). The Zettabyte Era: Trends and Analysis June 2017; Cisco (2015). The History and Future of Internet Traffic.

Sustained efficiency gains could keep energy demand largely in check over the next five years, despite exponential growth in demand for data centre and network services

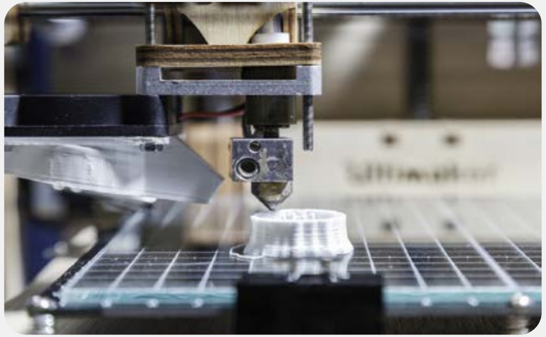
Digitalization impacts across energy sectors, esp. electricity

Transport

- Key digital trends across all modes: connectivity, sharing, and automation
- Digital solutions for trucks and logistics could reduce energy use for road freight by 20-25%

Buildings

- Smart building controls will improve comfort and transform building energy use
- Energy use could be reduced by 10% to 2040, but rebound effects are uncertain

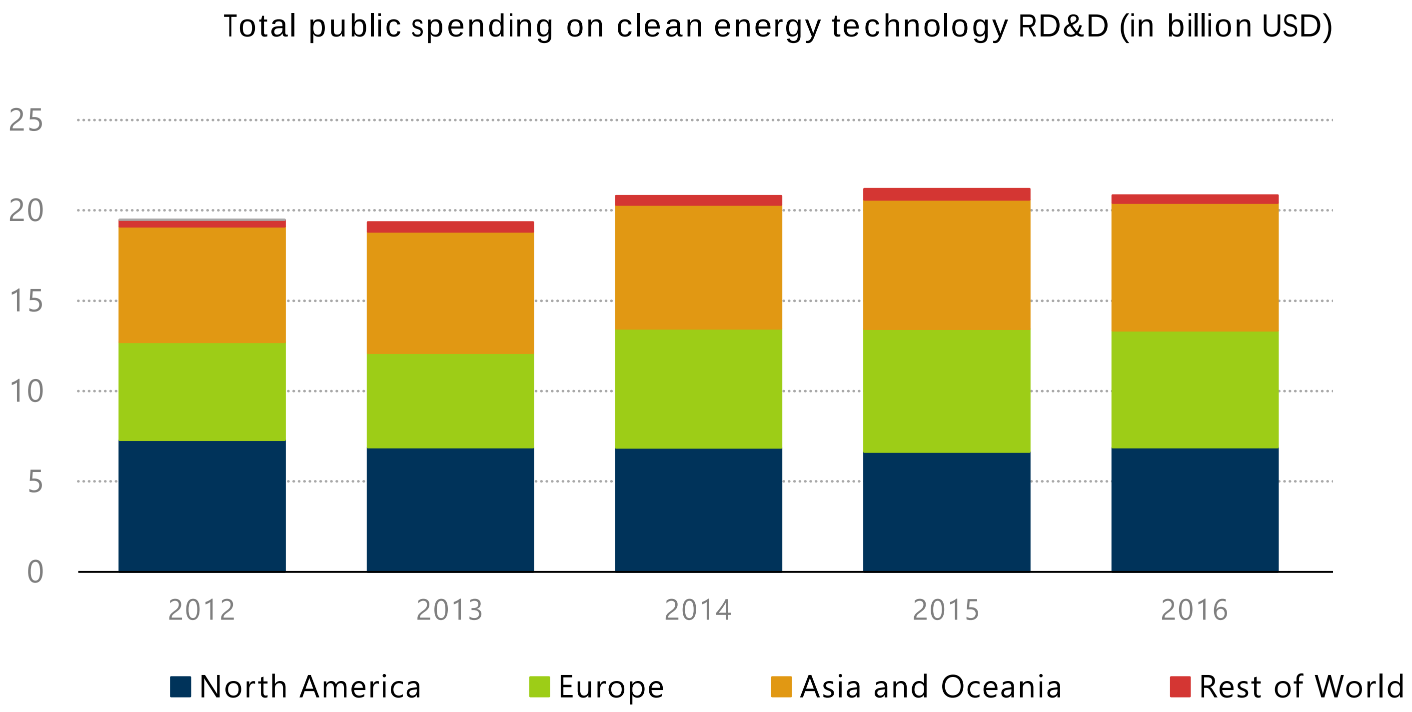


Industry

- Industry will witness increased productivity, reduced costs and improved safety
- Energy use can be incrementally reduced at plant level but broader impacts remain uncertain

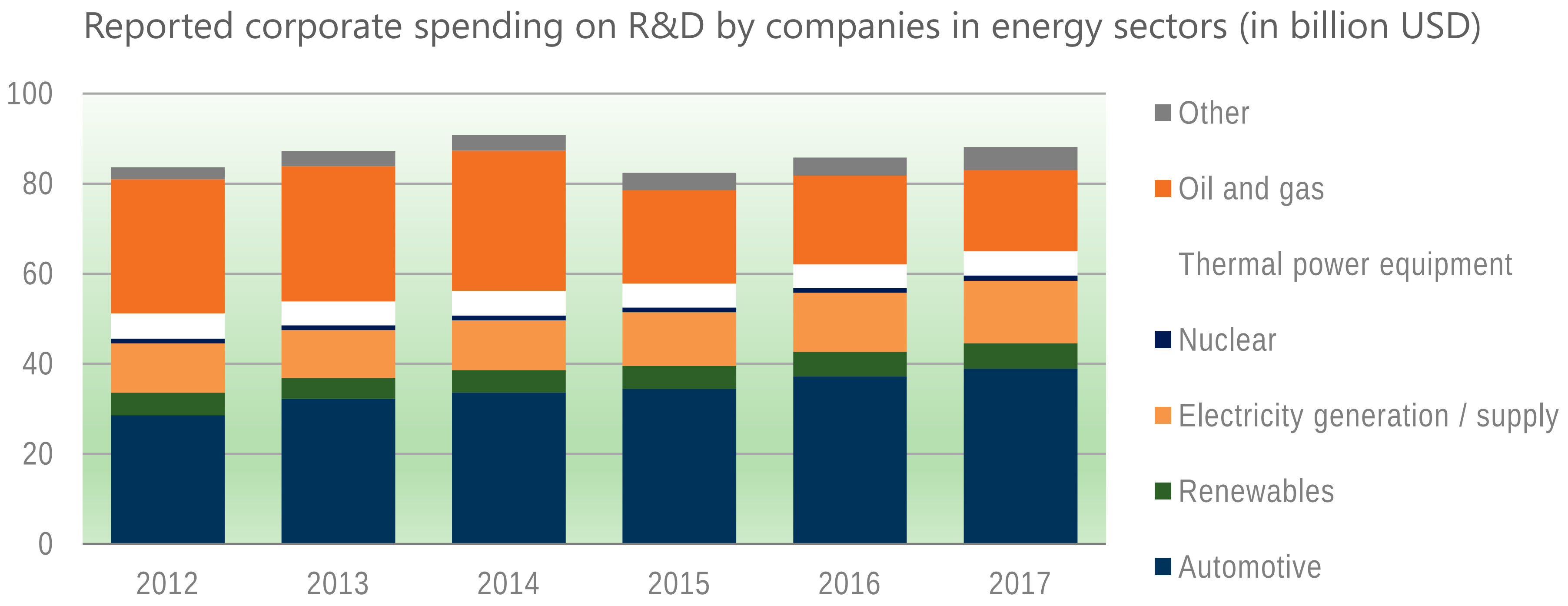
Digitalization has the potential to reshape, modernise, transform demand-side sectors;
policies are needed to maximise benefits and reap energy saving opportunities

Public innovation investment in clean energy technologies



Investment in clean energy R&D rose in 2017, but more is needed; Mission Innovation is having an impact

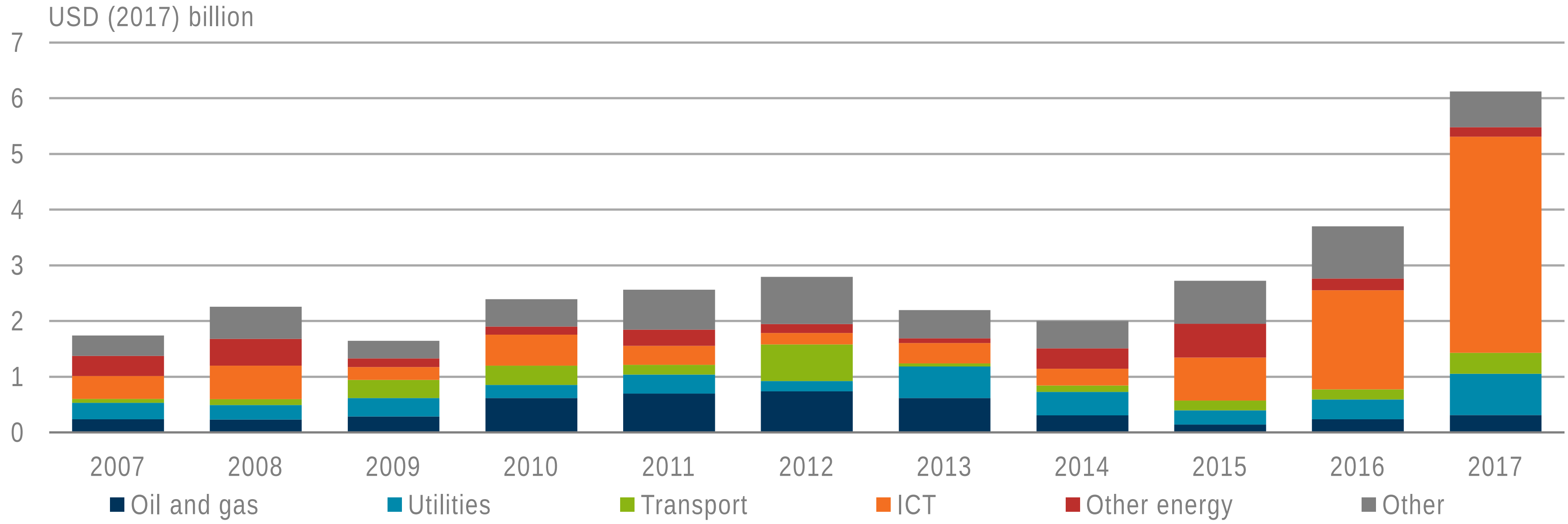
Corporate energy innovation investment



Private energy R&D spending has risen by around 4% per year, except in 2015 when oil & gas firms dropped one-third. It is rising faster in clean energy sectors, in which automotive is a big contributor.

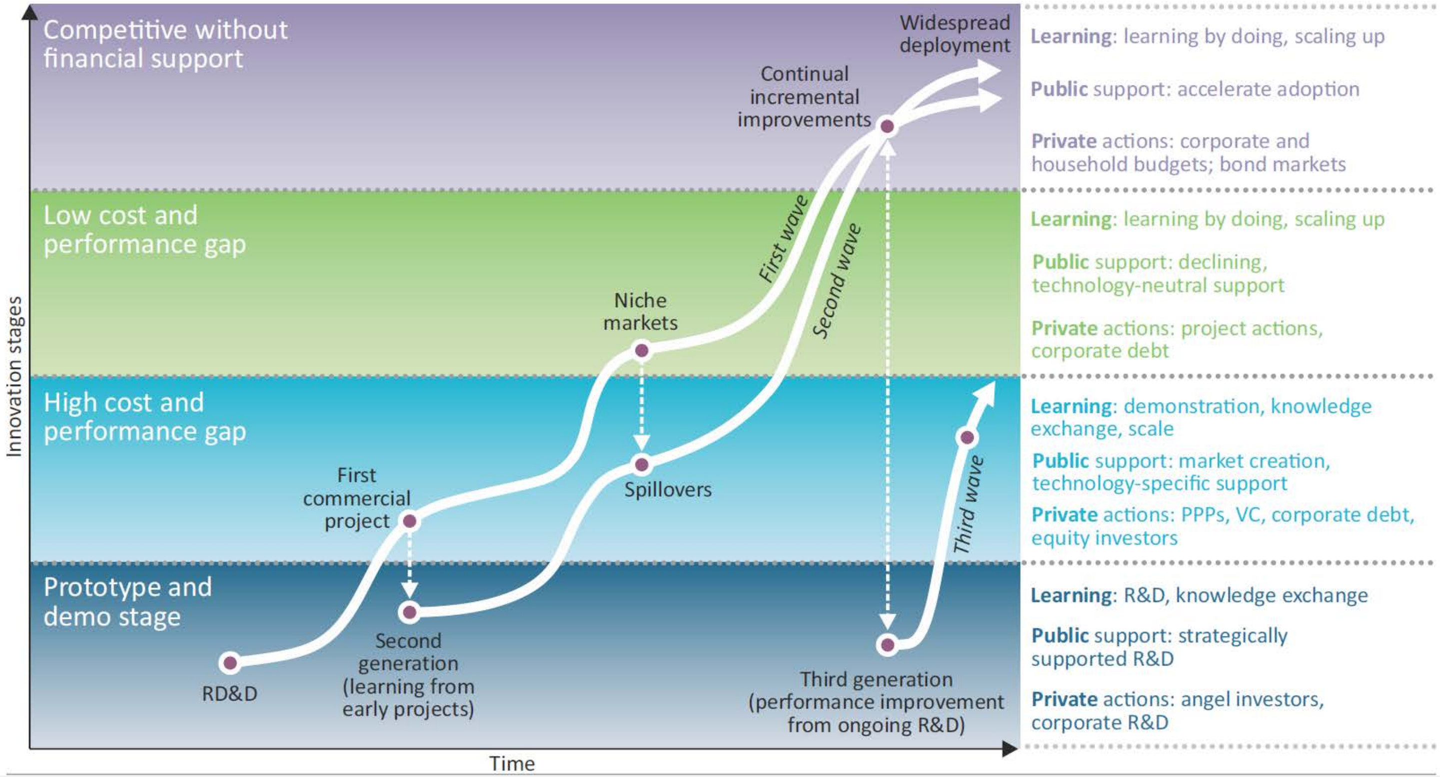
Companies invest more in energy tech startups, led by ICT sector

Corporate investments in new energy technology companies, by sector of investing company



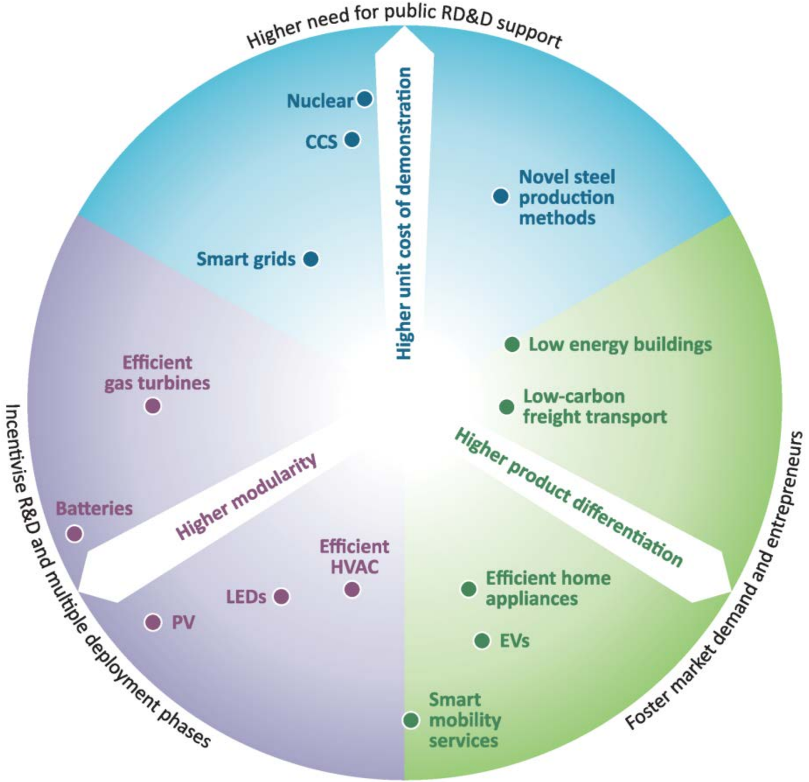
Corporate venture capital and growth equity for energy tech startups reached USD 6 billion in 2017; companies are taking strategic positions in a changing energy system, digital firms above all others.

Innovation stages require different public and private models



Innovation is an evolutionary process; today's commercial technologies – whether low- or high-carbon – can be out-competed by solutions that are currently at the prototype stage if conditions are right

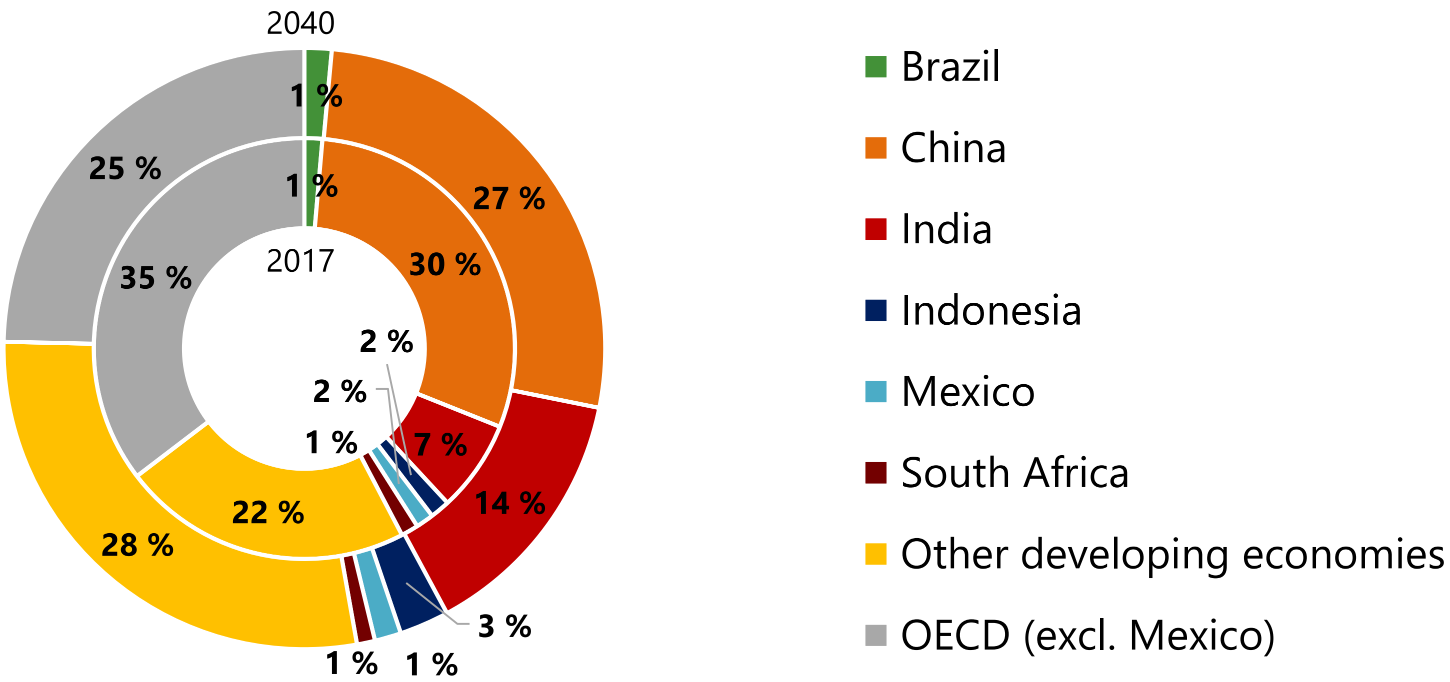
Technology characteristics influence public support needs



Different product types and business models have different support needs, ranging from direct public funding for the R&D to developing enabling environment for innovation.

Globally-relevant innovation...

CO_2 emissions: 2017 vs 2040



Developing economies are becoming the main source of CO2 emissions

Technology Collaboration Programmes

- **TCPs: a main pillar of IEA's innovation enhancement efforts**

- **National TCP Coordination Days**: a best practice across IEA Members – Austria, Italy, Norway, Switzerland, UK and the Czech Republic

  - Gain better understanding of broad range of activities under IEA TCPs
  - Raise awareness of national strategic vision and inform all about key priorities
  - Exchange experiences / lessons learned across stakeholders; enhance communication
  - Consider benefits of participating in each TCP and identify opportunities for further engagement; seek to steer TCP activities toward national priorities

IEA Technology Roadmaps

- Since 2009, 22 Technology Roadmaps and How2Guides (33 total)

- Re-endorsed at G7 Energy Ministerial Meetings in 2016 (Japan) and 2017 (Italy) – "*(G7 Ministers) welcomed the progress report on the Second Phase of IEA's Technology Roadmaps, focused on viable and high impact technologies*"

2009 2010 2011 2012 2013 2014 2015 2016 2017

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Tracking Innovation – IEA Innovation Gaps 2.0

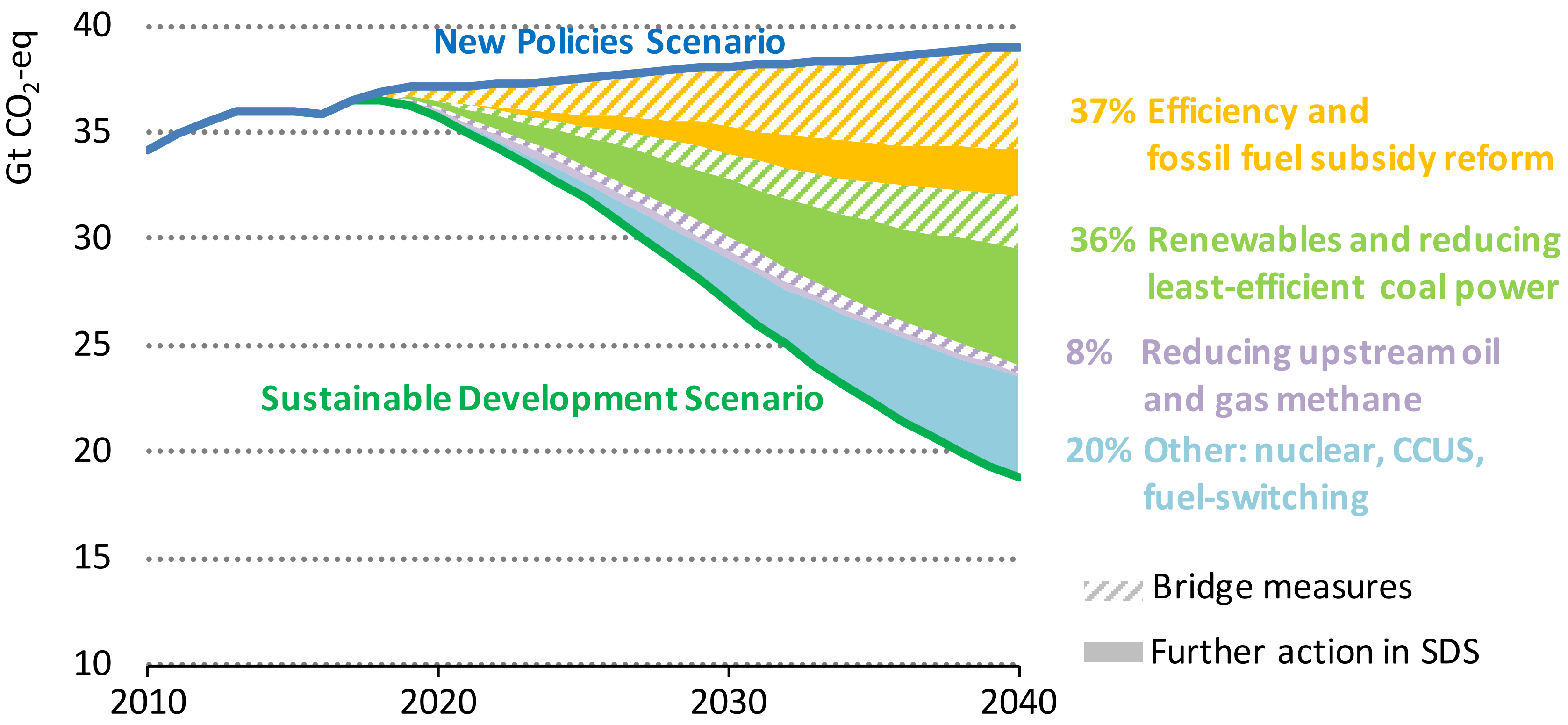
1. **Identify key global innovation 'gaps':** The most important technology innovation challenges that need to be overcome based on IEA modelling

2. **Tracking progress:** At what level of development are the solutions to the gap today? What has the recent progress been?

3. **Mapping of innovation landscape:** Who is involved in technology development for each gap – public/private/academia? How do they select and fund research?

4. **Key actions and milestones:** What needs to be done by each to achieve solutions (e.g. various ministries / agencies, companies, research institutes, NGOs, IGOs, etc.)?

Where do we need to go?



Innovation absolutely critical to help us get where we need to go...

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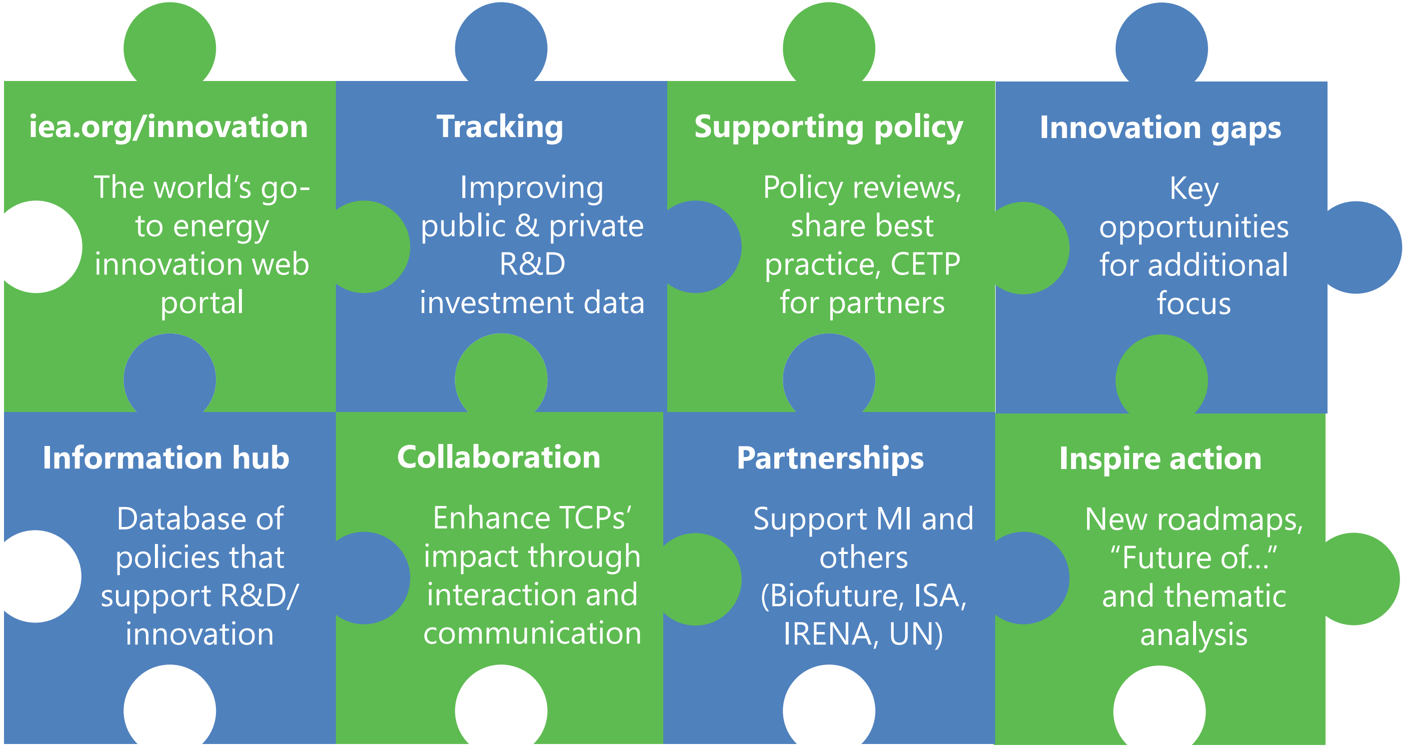
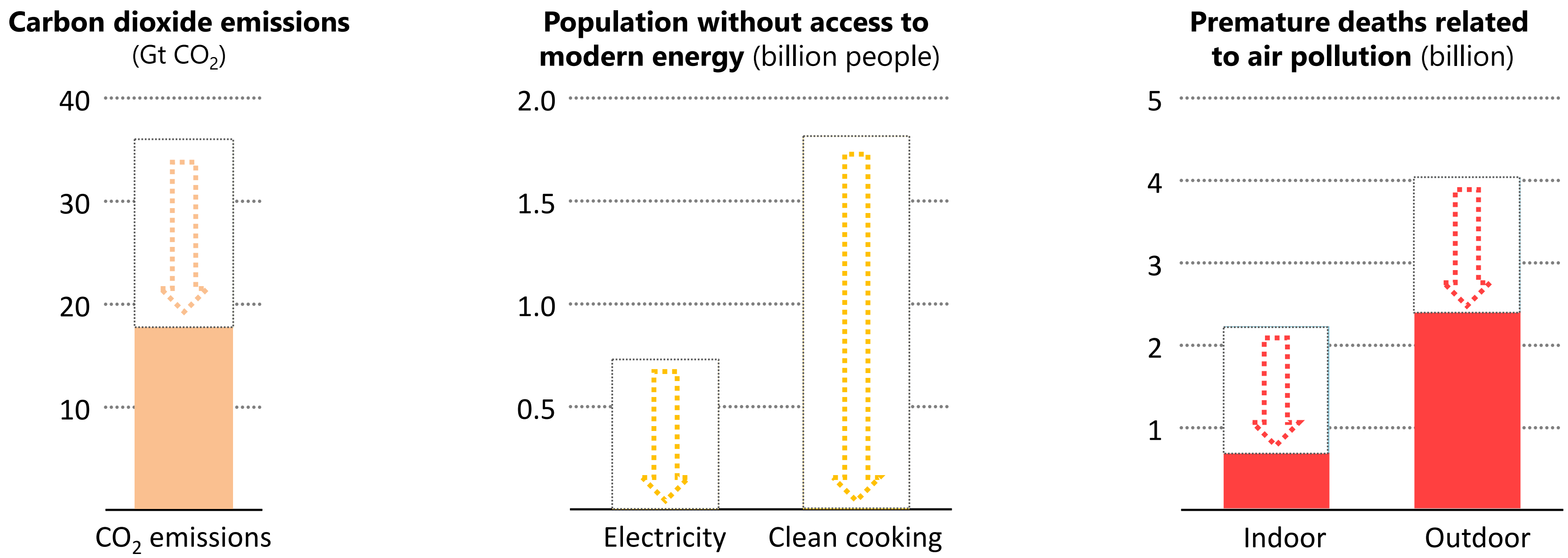
Bringing the pieces of the puzzle together...



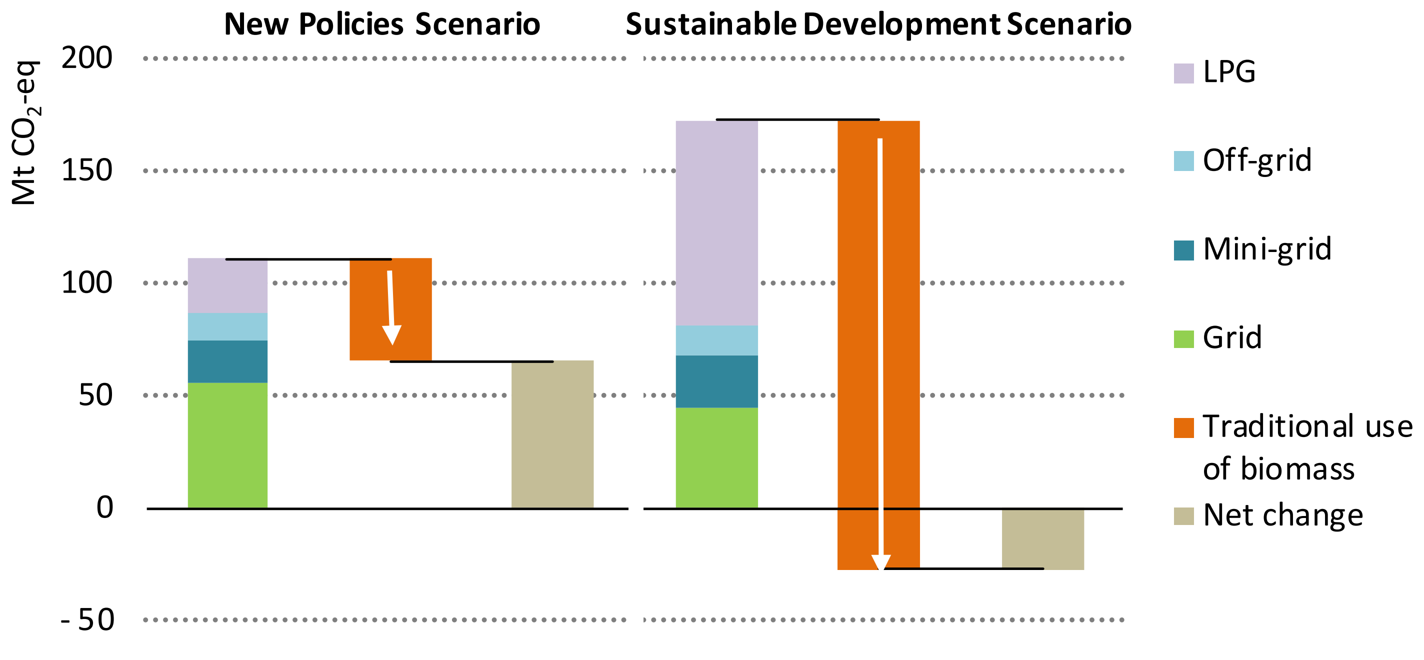
Enhancing IEA work on energy innovation can build on an impressive range of existing work and advance it in exciting new directions in support of global efforts

Outcomes of the Sustainable Development Scenario vs. New Policies Scenario, 2040



In an integrated approach, universal energy access can be reached while also achieving climate goals and reducing air pollutant emissions, at little extra cost

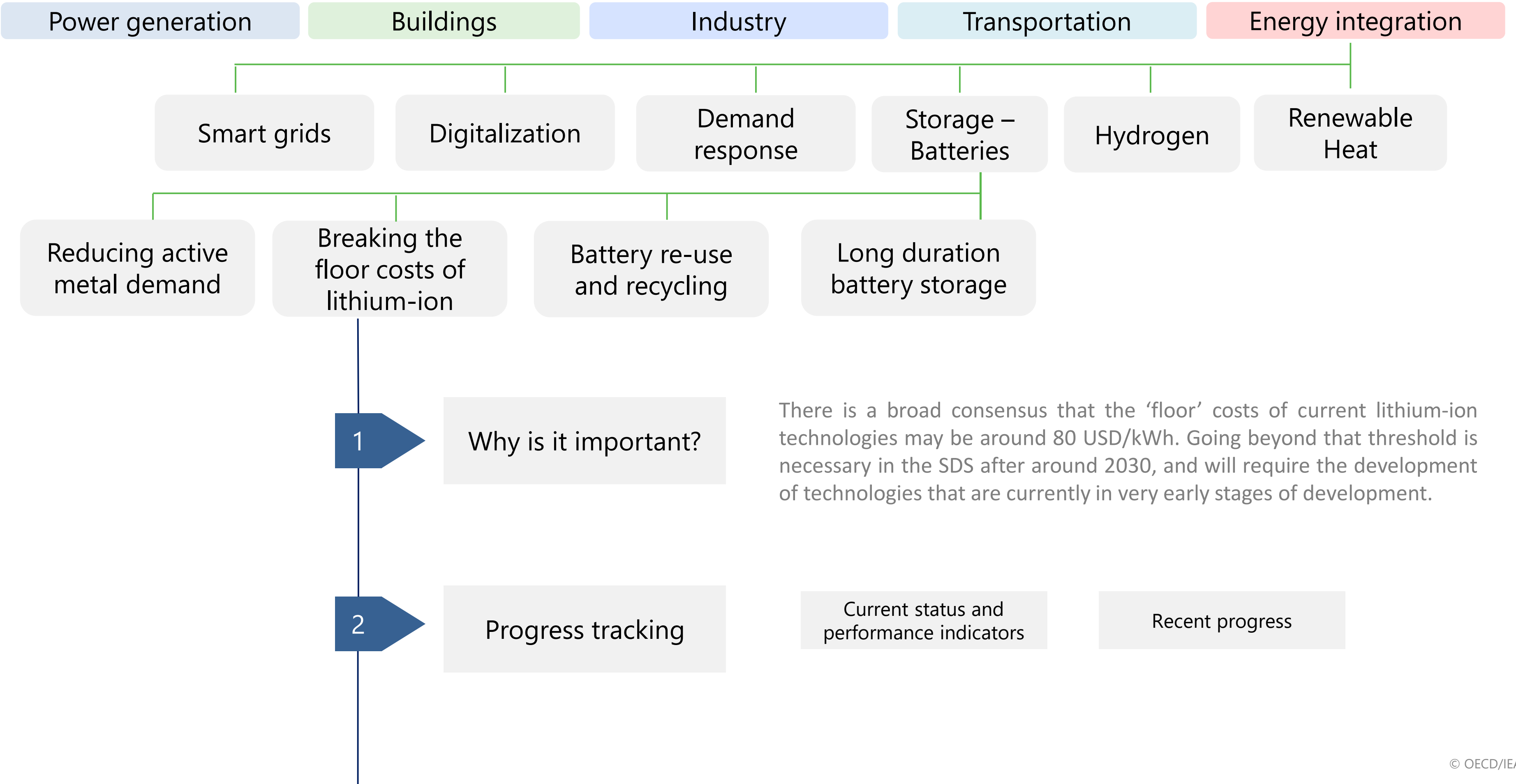
Energy access-related GHG emissions from electricity and clean cooking access by scenario



Higher CO_2 emissions from increased fossil fuel consumption for access are more than offset by a reduction in other GHGs, notably methane, from traditional use of biomass

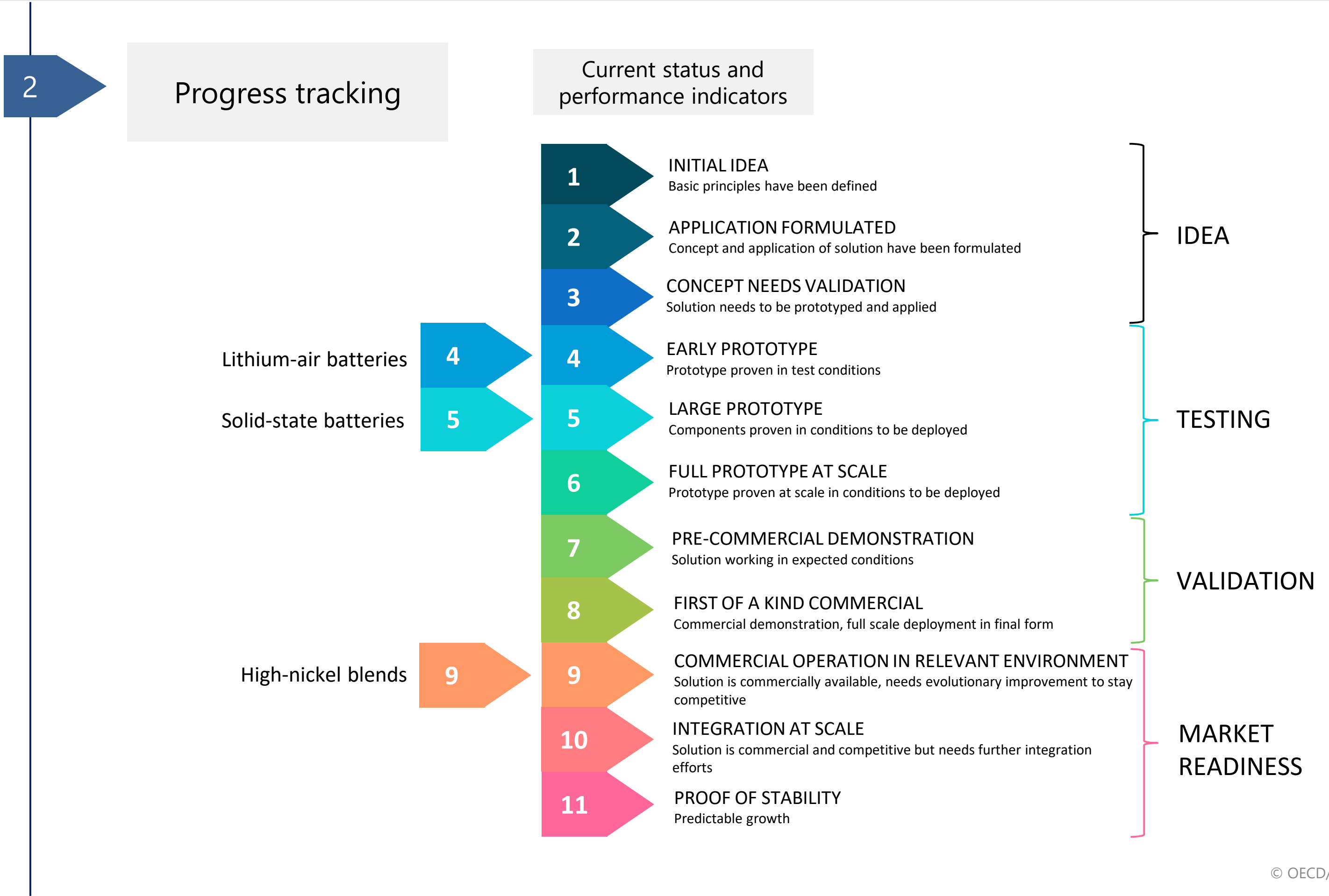
Source: World Energy Outlook 2018

Innovation Gaps 2.0 – a storage example



There is a broad consensus that the 'floor' costs of current lithium-ion technologies may be around 80 USD/kWh. Going beyond that threshold is necessary in the SDS after around 2030, and will require the development of technologies that are currently in very early stages of development.

Innovation Gaps 2.0 – a storage example



Innovation Gaps 2.0 – a storage example

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Innovation ecosystem today

Supply chain ready for scaling the innovation up?

No: Poorly developed supply chains for novel materials and components of next-generation batteries. In current generation, shortages in Li-ion and gaps in control software need strengthening. However R&D activities are rapidly evolving within big companies which could be positive for scale-up – a recent survey identified 54 involved in solid-state R&D.

Who is involved?
Leading countries and institutions

Joint initiatives:

- Much of the work in solid-state done by partnerships. EU: EASE is facilitating awareness; JRC has assessed advanced battery chemistries.

Private sector:

- Technology providers:
    - Japan: Toyota has a solid-state battery R&D programme and has oriented its battery development around the technology.
    - Korea: Hyundai is working with Ionic Materials
- Battery and vehicle manufacturers:
    - US: Tesla reportedly looking at Li-air
    - Japan: Panasonic focusing on NMC and liquid electrolytes
    - EU: Volkswagen has a stake in QuantumScape

Public sector:

- US: Battery500 Consortium, Computer-Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) project. EC H2020 special thematic area on early stage storage technologies

Research institutions:

- NREL (CAEBAT programme); EU: Horizon Europe thematic area (yet to be defined), ERA-NET on Smart Energy Systems

Innovation Gaps 2.0 – a storage example

4

Key actions and milestones Who needs to do what?	Next 5 years	By 2030
Overall technology development needs	1. High conductive solids, and lithium protection (catastrophic failure issues in current lithium-metal generation) 2. High voltage cathodes, including nano-structured lithium-ion cathode materials, novel carbon materials for air cathodes, minimising anode and O2 interaction. 3. Li-anode passivation to avoid dendrite formation could dramatically improve total life-cycle costs. 4. Optimize operation, lifetime and degradation issues to find a path to market	
Environmental, energy or resource ministries	Facilitate exploratory research, developing e.g. combinatorial materials for radically novel systems, including metal-air, solid-state, magnesium-based, fluoride or chloride-ion, etc. Develop awareness in research and development strategies towards utilising raw materials which will not be foreseen as scarce or environmentally problematic.	Help create platforms for assessing the critical impacts of new generation Li-ion and other battery technologies, which might have unforeseen environmental impacts (e.g. lithium or nanomaterial dispersion)
	Develop and expand strategies for research and demonstration on the use of second hand batteries provided by the transport sector for stationary storage, which could alleviate some of the pressures of reaching lower cost targets for the power sector	
Multilateral development agencies	Promote alternative sources of funding for innovative low-carbon technologies in the storage industry	
Nongovernmental organisations and think tanks	Raise awareness of the longer-term need for low cost storage and other flexibility solutions, that decrease the environmental impact	
Industry	Join forces and increase international collaboration to identify and raise awareness of the key challenges in taking key early stage battery technologies to the market, particularly focusing on the long-term view beyond current Li-ion technology	Reduce balance of system and integration costs for the new generation of low cost batteries