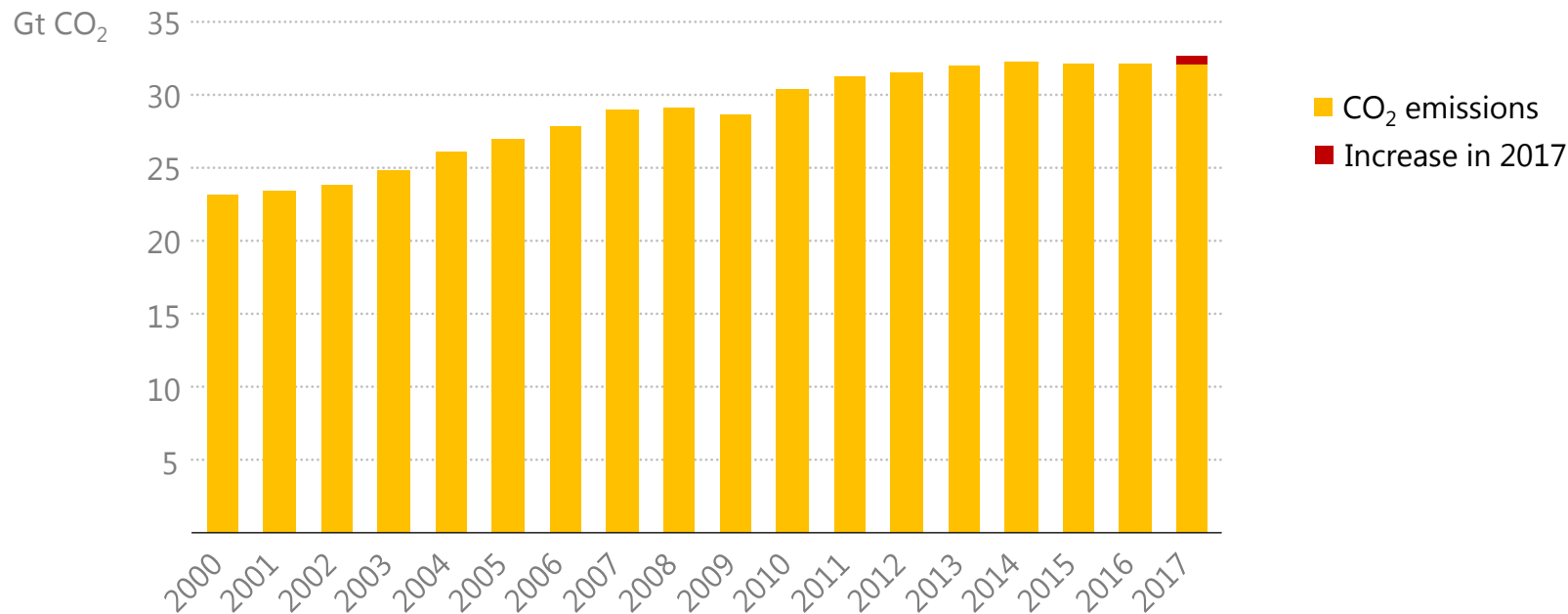




Tracking Clean Energy Progress

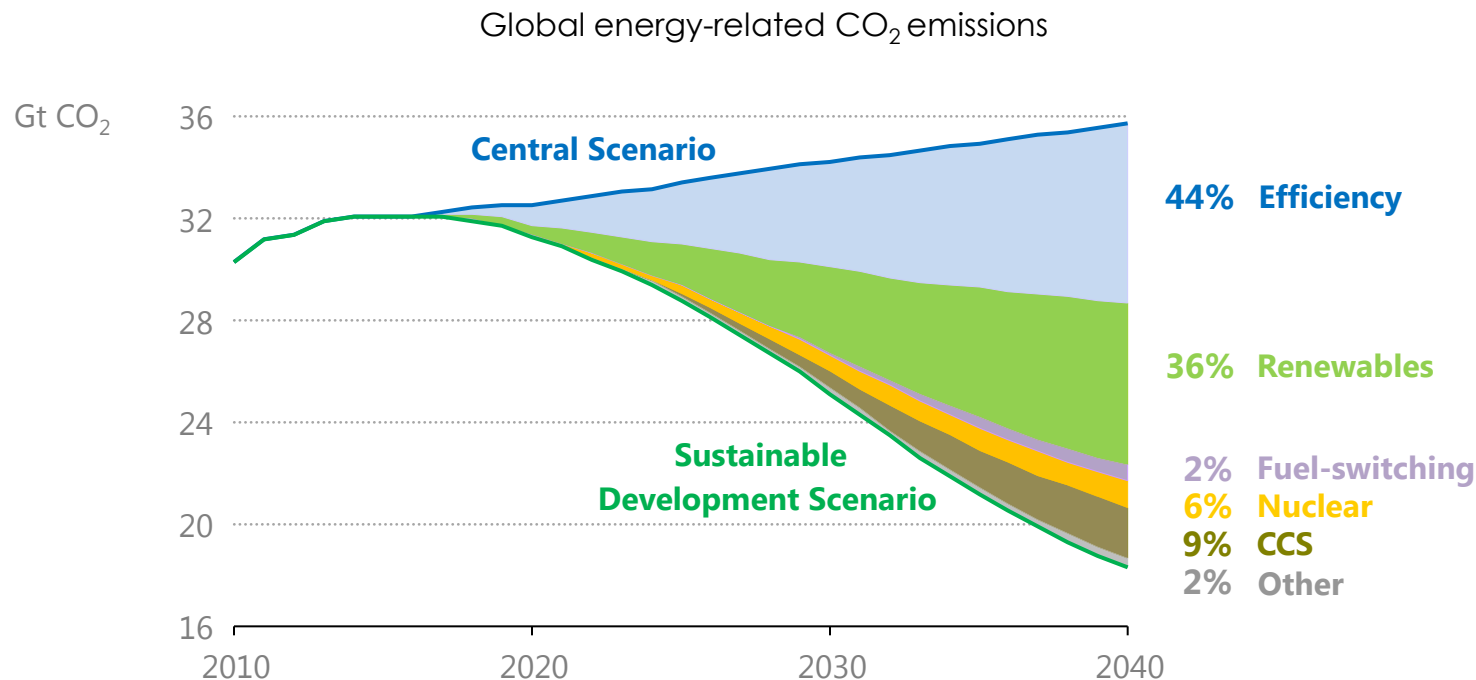
Keisuke SADAMORI, Director, Energy Markets and Security, IEA
Canon Institute for Global Studies, 14 June 2018

Global energy-related CO₂ emissions



After remaining flat for 3 years, global CO₂ emissions rose again in 2017, to an all-time high

What could the future look like?



A wide variety of technologies are necessary to meet sustainability goals, notably energy efficiency, renewables, CCUS and nuclear

How are clean energy technologies progressing?

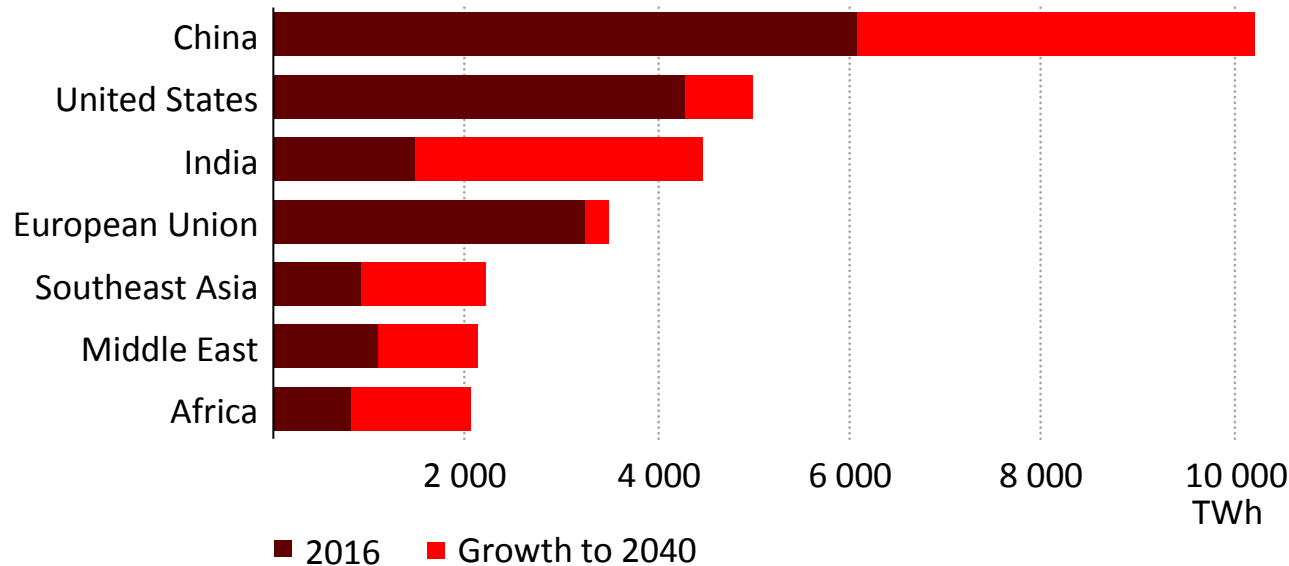
Power

- **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**

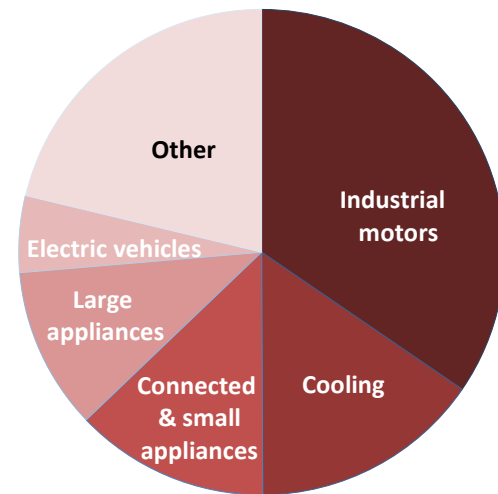
The future is electrifying

6

Electricity generation by selected region

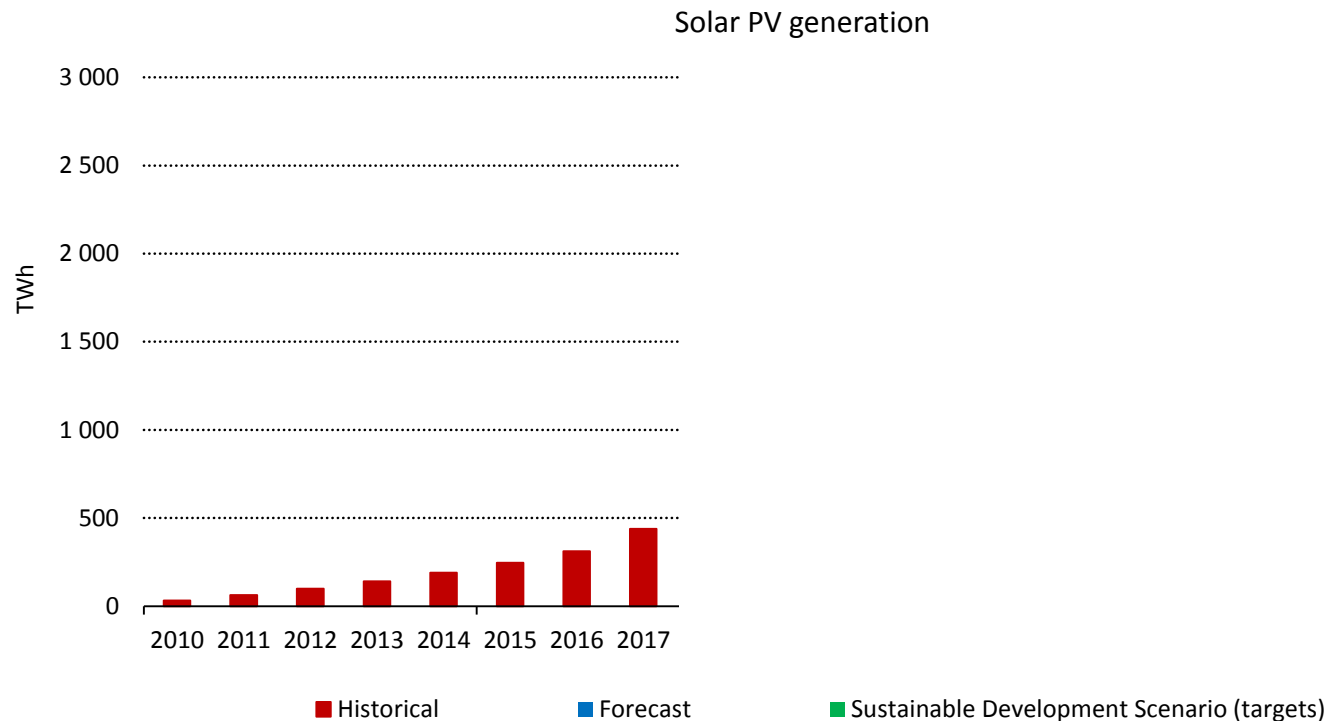


Sources of global electricity demand growth



India adds the equivalent of today's European Union to its electricity generation by 2040, while China adds the equivalent of today's United States

Solar PV is the only renewable technology that is on track



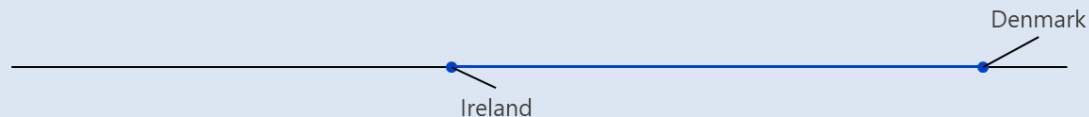
Following another record year in 2017, solar PV continues to drive the expansion in renewable power; All other renewable technologies – including wind – need to accelerate faster to be on track

Wind & solar making strong inroads, but new challenges may emerge

Four phases of wind and solar integration

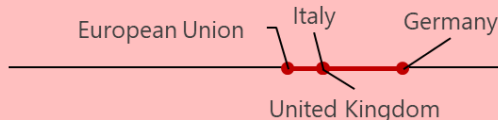
Phase 4

Require advanced technologies to ensure grid reliability



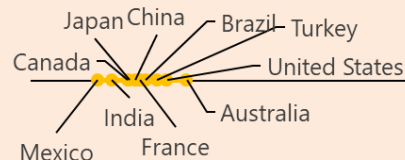
Phase 3

Flexibility investments: all power plants, demand side, storage, grids



Phase 2

Draw on existing flexibility in thermal & hydro plants, grids



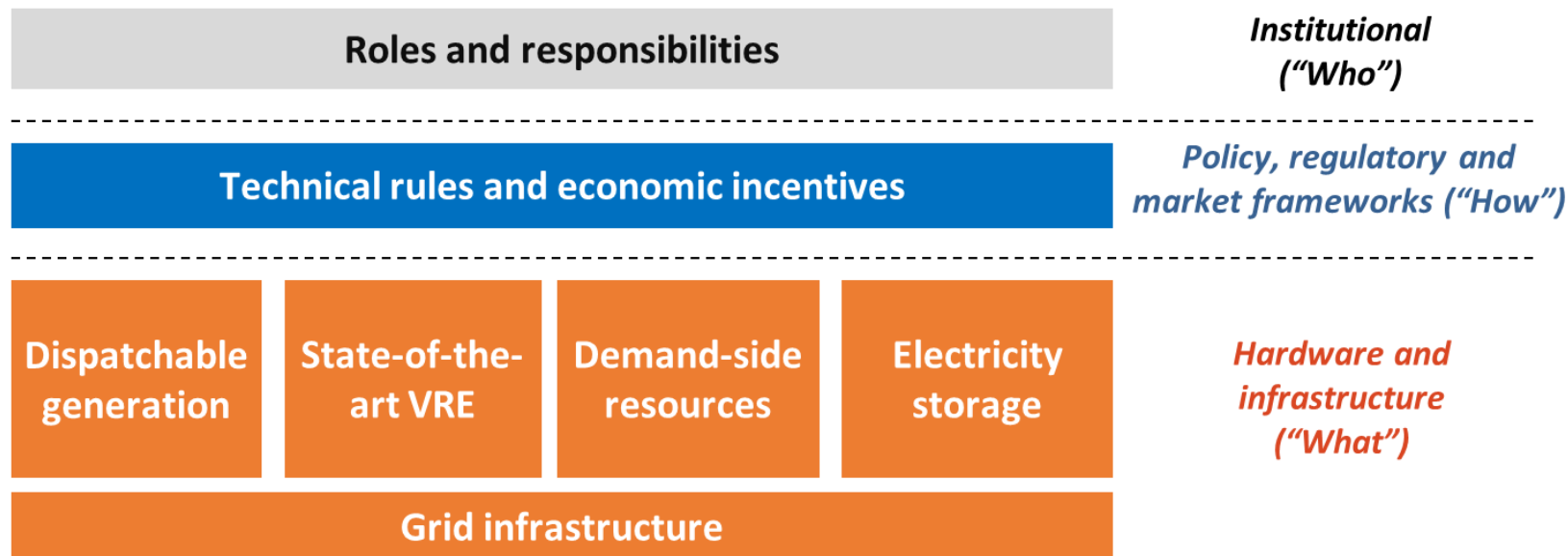
Phase 1

System integration currently no relevant issue



0% 5% 10% 15% 20% 25% 30% 35% 40% 45% 50%

share of wind, solar PV in power generation, 2016

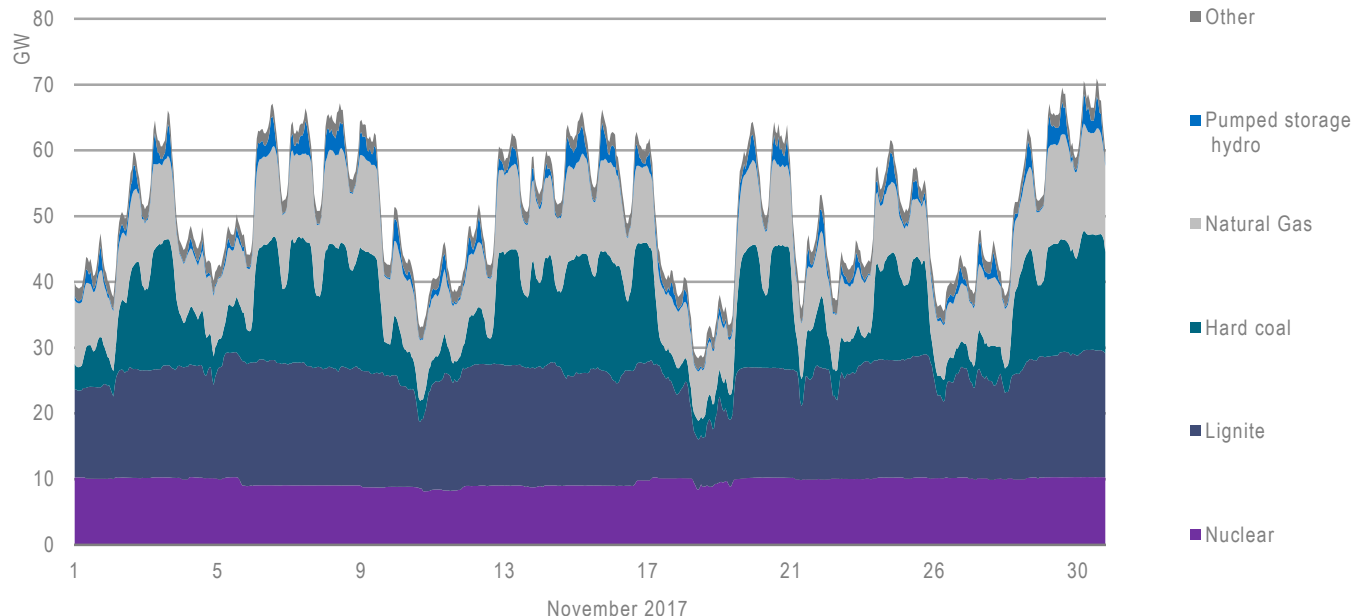


Technical, economic and institutional policy layers mutually influence each other and have to be addressed in consistent way to enhance power system flexibility.

Conventional electricity generation in Germany in November 2017

Advanced Power Flexibility

- Clean Energy Ministerial Campaign, 14 partner countries and 14 industry and NGO partners
- Results published at CEM9
- Continued with broader scope: Power System Flexibility



Significant system flexibility lies latent in many power plants; a range of strategies are available to unlock low-cost flexibility, many non-technical.

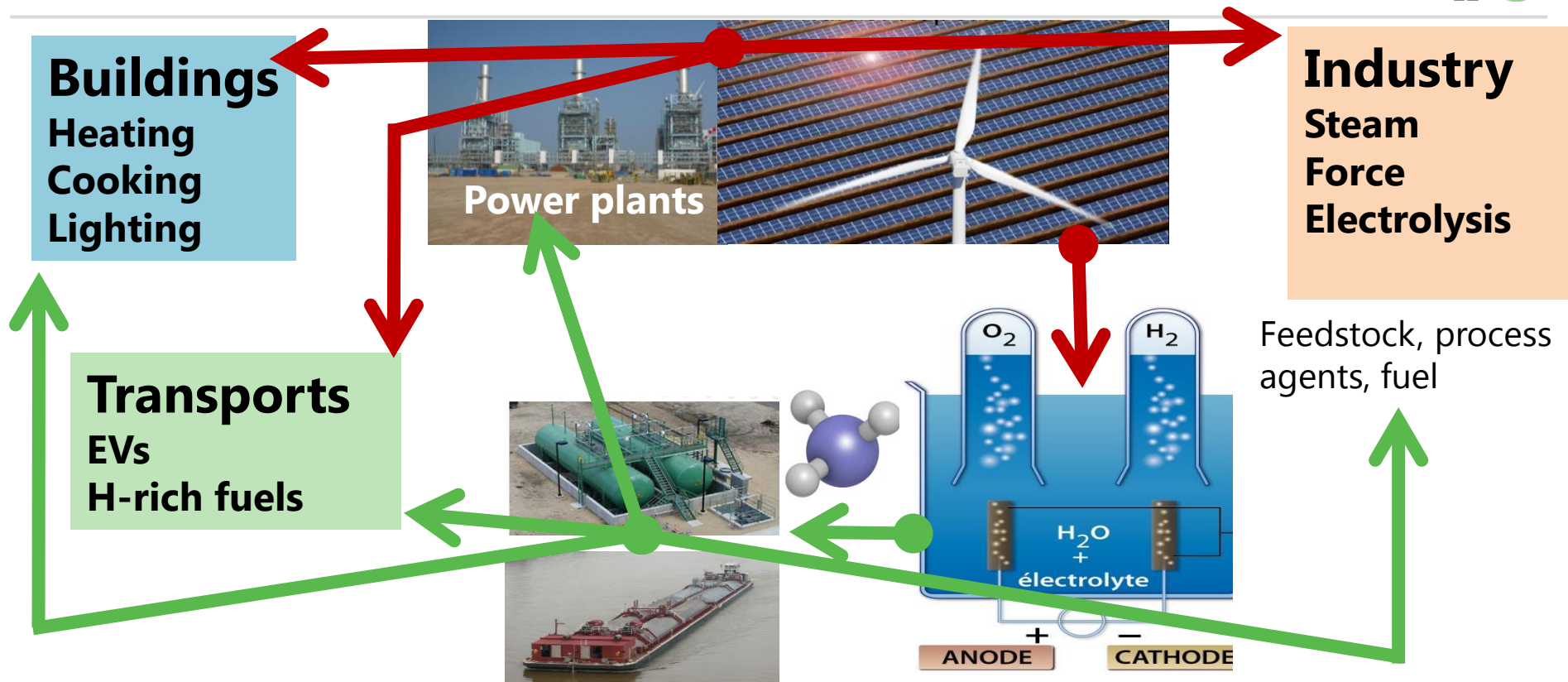
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- Coal-fired power
- CCS in power

Industry

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

Renewable power can replace fossil fuels in many uses

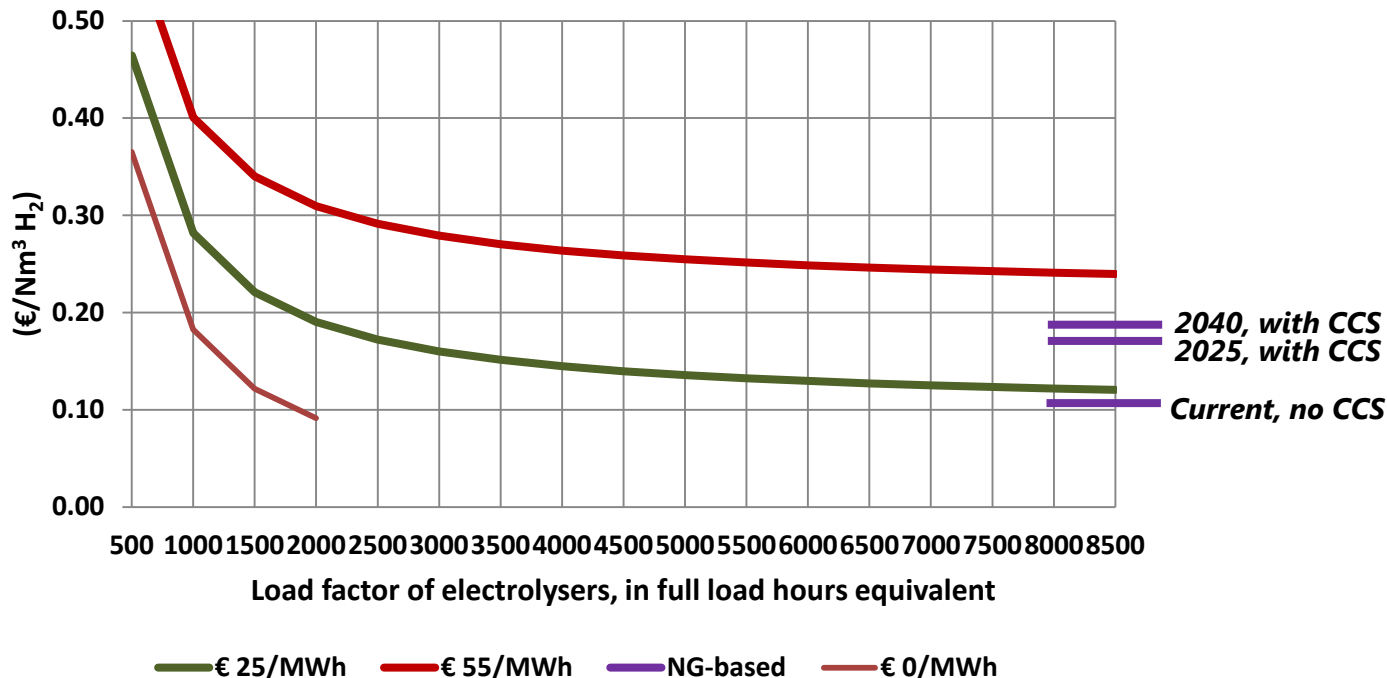


Beyond current uses, renewable electricity can replace fossil fuels in direct uses in buildings, industry and transports, directly or through electrochemistry/electrolysis

Green hydrogen from water electrolysis vs NG reforming

Cost of hydrogen from electrolysis for various electricity price and load factors

Assumptions: Capex
electrolysers
€ 400/kW_{in}
+ 30% install. +20%
Opex; lifetime 30 y;
WACC 7%; efficiency
70%;
H₂ from NG
reforming based on
gas prices in Europe
(SDS -WEO 2017)



**Beyond 50% capacity factor the cost of electricity dominates the cost of hydrogen from electrolysis;
With "surplus" electricity the cost of hydrogen increases rapidly if load factors fall below 3000 FLH**

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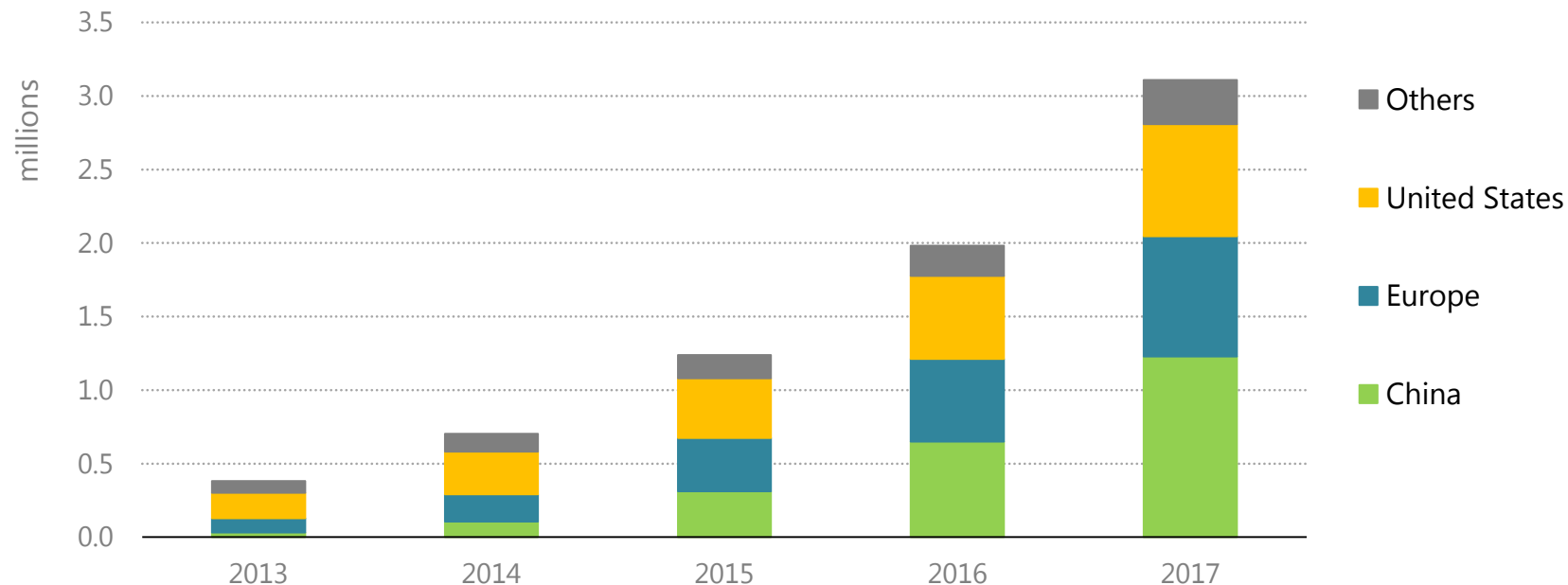
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Transport

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

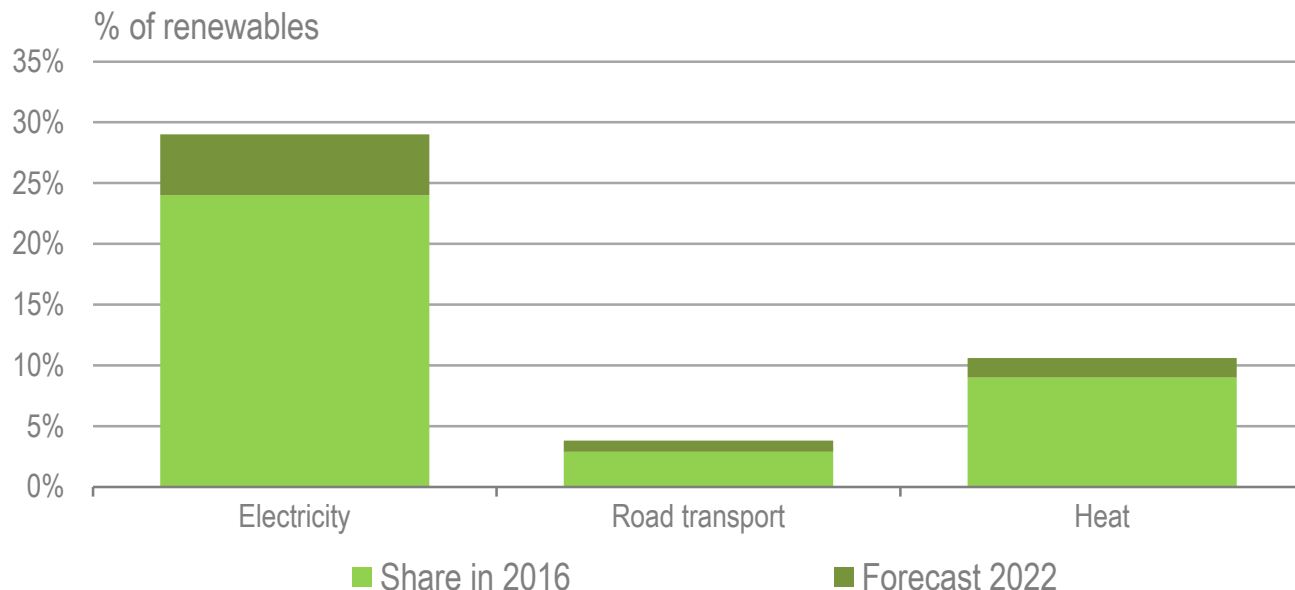
Global electric car stock



The number of passenger electric cars on the road passed 3 million in 2017, although they still represent just 1% of the global car sales

Transport remains the most challenging sector to decarbonise

Share of renewables in electricity, road transport and heat, 2016 and forecast for 2022



[Source: Adapted from Renewables Market Report 2017]

Transport lags behind the electricity and heat sectors in integrating renewables, and a limited increase in the renewable share of road transport fuel demand is forecast, remaining below 5% in 2022.

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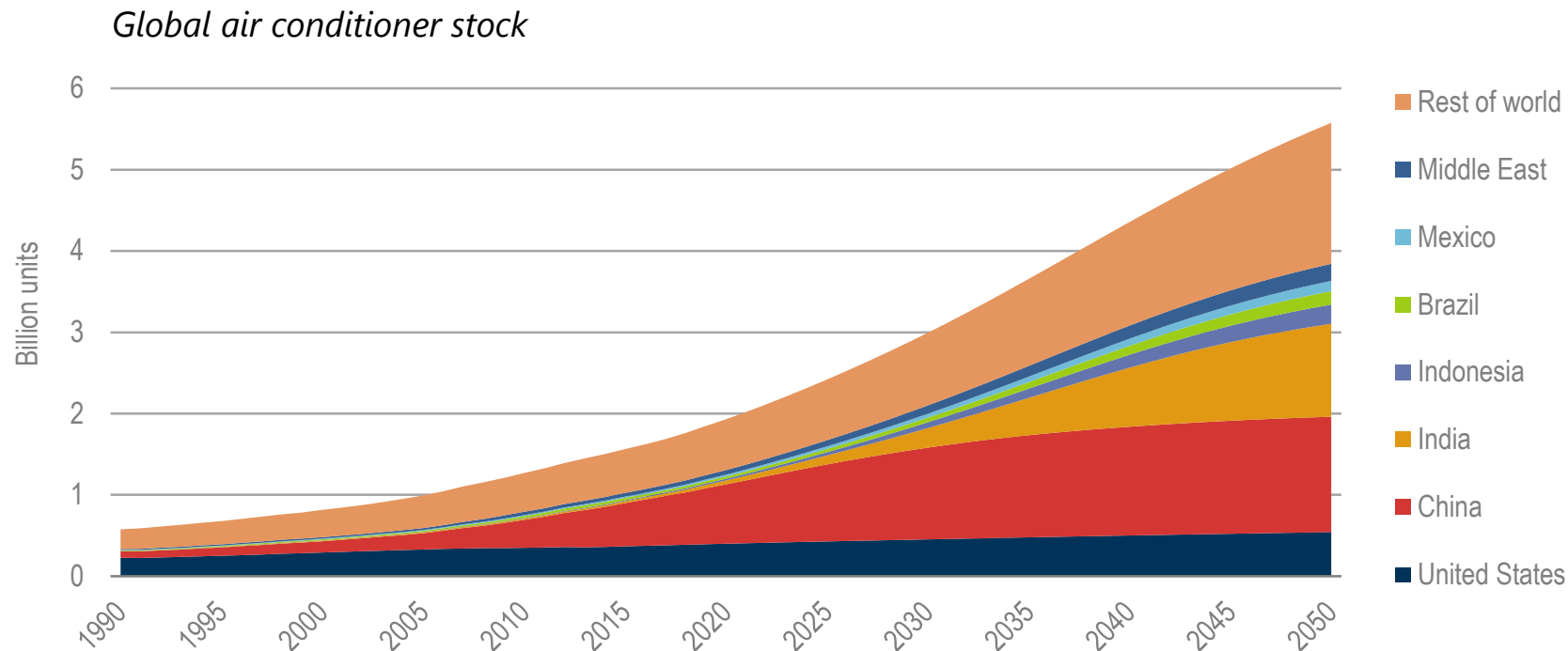
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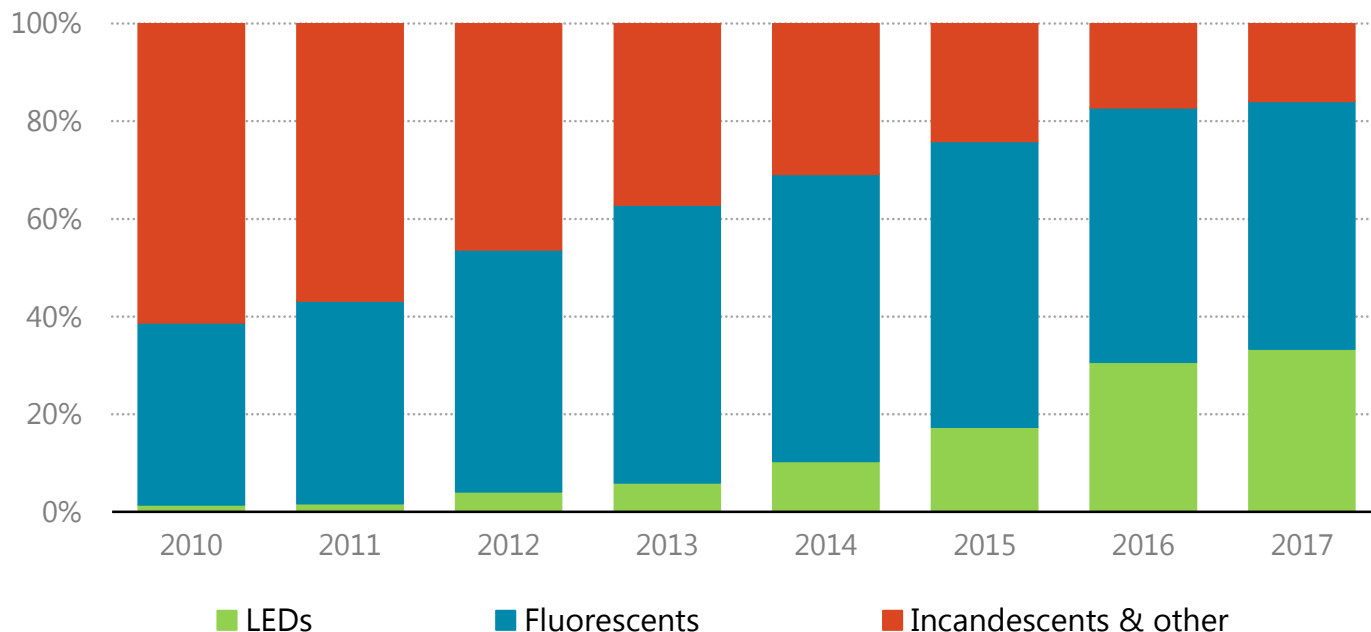
Buildings

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



By 2050, around 2/3 of the world's households could have an air conditioner. China, India and Indonesia will together account for half of the total number.

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**

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Buildings

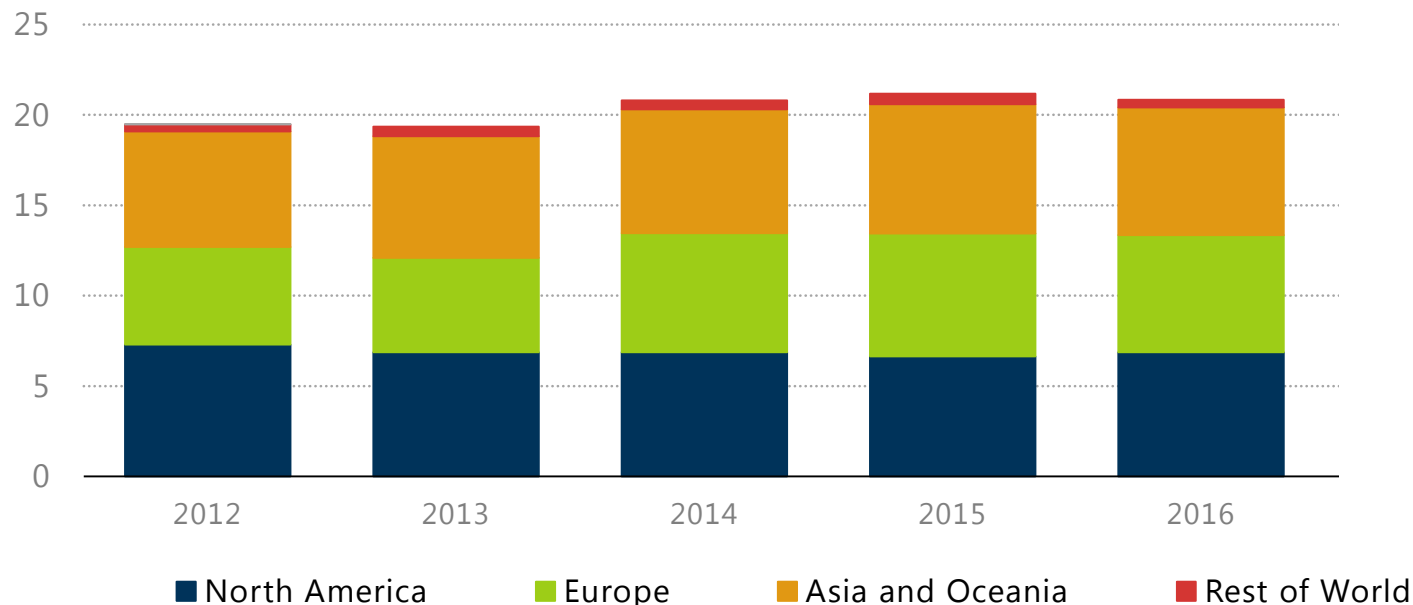
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- Data centres and networks

Energy Integration

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

Clean energy R&D investment is finally on the rise...

Total public spending on clean energy technology RD&D (in billion USD)



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

- Faster technological innovation can spur economic growth, while also improving energy security & sustainability
- Of 38 clean-energy technologies **4 are on track**, **23 need improvement** & **11 are off track**
- Need to focus on all technologies; lack of progress on some puts even more pressure on others
- Government policy & market design will be instrumental in spurring innovation, deployment and private investment



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