Improved energy efficiency and accelerated renewable deployment are the most important steps in the transition.
A clean energy revolution or a wind and solar revolution?

The clean energy portfolio is increasingly dominated by wind and solar PV requiring a deep system transformation.
Today’s mature renewables benefited from decades of public R&D

The soviet space program as an early PV competitor

A Boeing experimental wind turbine funded by the Reagan Administration

Public funding for innovation continues to play a key role to accelerate clean energy progress
While public energy RD&D spending rose modestly in 2018, led by the United States and China, most countries are not spending more of their economic output on energy research.
Building electrification generates more demand but transport represent a disruptive change in business models and system operation.

Additional electricity demand in the Future is Electric Scenario:

- **New Policies Scenario**
  - Transport: +2,310 TWh
  - Buildings: +2,690 TWh

- **Future is Electric Scenario**
  - Industry: +1,680 TWh
An emerging middle class in hot climates

Evolution of global air conditioner ownership

A strong effort on air conditioner efficiency will be essential to mitigate demand impacts
Bringing electricity to the transport sector

Electrification of cars

Hydrogen and electro fuels for heavy vehicles

Modal shift to electrified railways

China is leading transport electrification, but the current scale has only a minor impact on global oil demand
The OEM commitments will need to be followed through to put transport on a sustainable path.
Coordinated smart charging can save up to 300 GW generation capacity, bypass difficult network upgrades and ensure that the cars are fed low carbon electricity.
Renewables in building heating requires strong policy

Convert to electric heating and use renewable electricity directly

Keep the pipeline network for biogas and for hydrogen/PtG from renewable electricity

The two pathways have different advantages and barriers and policy choices can depend on regional characteristics
Low carbon generation deployment stagnates at 1.5% of global power demand, lower than average demand growth

Despite the success of wind and solar the slowdown of nuclear and hydro creates a powerful headwind for low carbon deployment
Investment policy will need to overcome value erosion

Increasing flexibility, grid expansion and storage investment will be needed to overcome correlation of especially solar production. Wind benefits from winter peak demand in Europe.
Decentralized renewables?

The large majority of wind and solar deployment is utility scale and grid connected.
The electricity network: a key area of technological and regulatory innovation

Grid investment expands by 50% in SDS with digitalization and better market design facilitating renewable integration
Efficient markets unlock the value of flexibility

Residential batteries aggregated to provide frequency response, Germany

Distributed storage solutions substituting for transmission upgrades, New York

Regulation and lack of price signals are more important barriers for smart energy systems than IT.
Even ultra cheap batteries don’t eliminate the need for dispatchable capacity.

With an average storage time of 4 hours the key application of batteries is frequency control and network bottleneck management.
100% renewables or 100% low carbon energy?

Nuclear
- Very efficient use of land and transmission capacity
- Baseload capacity especially for winter peak demand systems

CCUS
- Turning conventional dispatchable plants low carbon
- Energy intensive heavy industry
- Negative emissions

In countries that chose to use these technologies a diversified low carbon portfolio including nuclear and CCUS offers significant infrastructure and energy security benefits
What would it take to reach climate targets in Japan without nuclear?

- 25,000 wind turbines
- 4,000 km² of solar panels
- DC cables for Hokkaido wind and Kyushu solar to Honshu
- Internal interconnection reinforcement
- Cable connections for floating offshore wind

Together with distribution reinforcement to support small scale solar network investment needs reach 0.6% of GDP
Four key opportunities for scaling up hydrogen to 2030