New Energy + Energy Storage/ + (Hydrogen Production)

June, 2022

CONTENTS

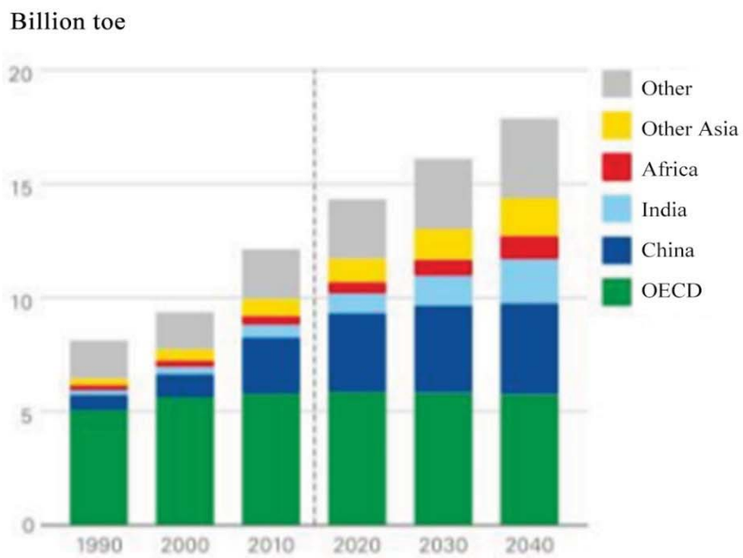
PART 01

Status Quo and Trend of Global Energy Development

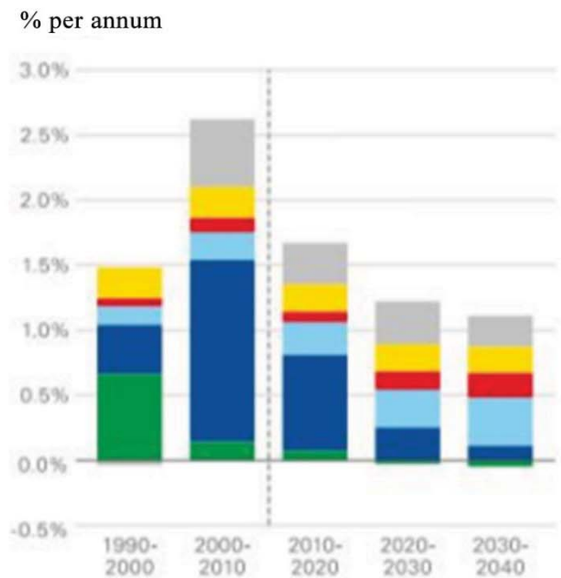
1.1 Global Energy Structure Transformation

Global oil and gas are basically stable, coal is decreasing, and clean energy represents the main component of the increase.

- The international energy supply and demand grew steadily, mostly concentrated in developing Asian countries. In 2019, Asian and the Pacific countries and regions contributed about 70% of the increase in global primary energy. The energy demand of developed countries continued to be saturated or decreased.
- China's economic growth is gradually changing toward a more sustainable model. By the mid-2020s, India will account for more than a quarter of the increase in global energy in the outlook period, but China will remain its position as the largest energy market.



Primary energy consumption by region



Primary energy growth and regional contributions

Data source: BP Energy Outlook (2019 edition)

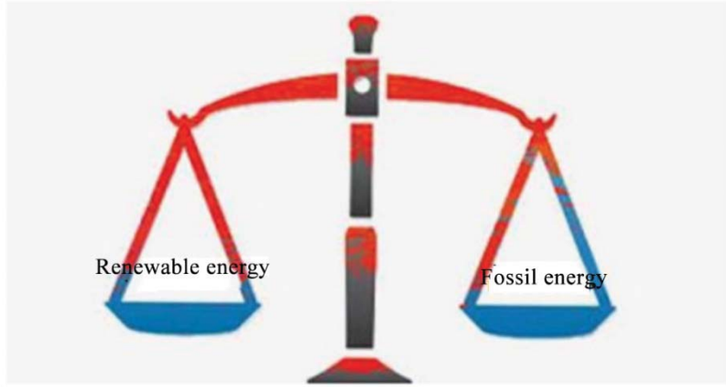
1.1 Global Energy Structure Transformation

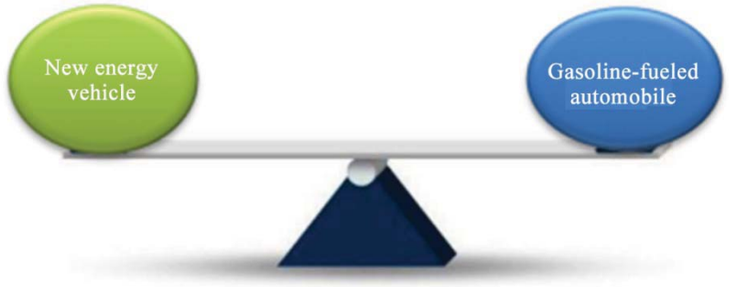
The global energy structure is subject to major changes, gradually getting rid of dependence on fossil fuels, and the following two fundamental factors are driving such changes:

- Rise of new technologies such as PV, wind power, and new energy vehicles
- Policies related to climate change

In the next five years, we are expected to witness two key parity turning points:

- Parity between renewable energy and fossil energy in power generation
- Parity between new energy vehicles and gasoline-fueled automobile



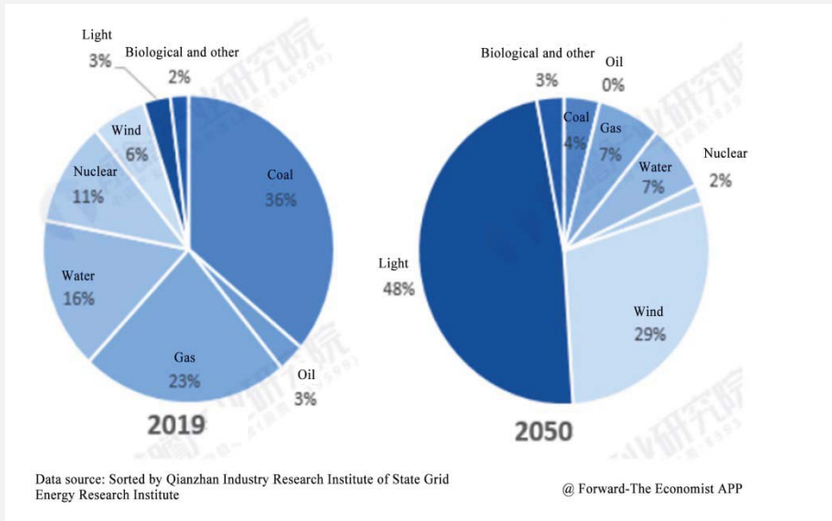


1.1 Global Energy Structure Transformation

Power generation structure is changed.

Decline of the global total installed capacity of coal-fired power for the first time

The coal-fired power installed capacity of 21.2 GW in the world (including 8.3 GW in the European Union and 5.4 GW in the United States) decommissioned, and the global total installed capacity descended to 2,047 GW in the first half of 2020 according to the latest tracking report of coal-fired power plants from the global energy monitoring agency. The global decommissioned coal-fired power installed capacity has surpassed those newly put into operation, recording the descending of the installed capacity of coal-fired power stations in the world for the first time.



Data source: Sorted by Qianzhan Industry Research Institute of State Grid Energy Research Institute

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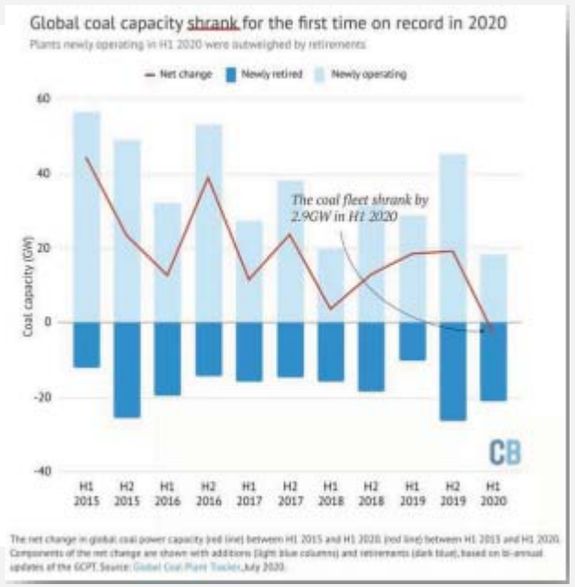


1.1 Global Energy Structure Transformation

Economical efficiency of power generation is reversed.

The International Energy Agency (IEA) recently launched the "World Energy Outlook Report 2020", which made a scenario analysis of the prospects of various types of energy generation:

①. All states fully implement the commitments in the *Paris Agreement* (State policies).

②. Global warming is controlled within 2° C at the end of this century (Below 2).

Thermal power output will be at its peak by 2025.

Relatively slow growth in nuclear and hydropower output

Renewable energy generation becomes the main power supply.

Wind and solar power gradually dominate.

State Policies Scenario: Renewable energy generation accounts for 77% in 2050.

Below 2 Scenario: Renewable energy generation accounts for 85% in 2050.

The LCOE (Levelized Cost of Energy) for PV + energy storage in the United States ($23-36/MW·h) is less than that of nuclear power and coal power and is close to that of gas-fired combined-cycle units.

Nuclear power: average ($105/MW·h) ($102-127/MW·h)

Coal power: average ($67/MW·h) ($56-84/MW·h)

Gas combined cycle: average ($39/MW·h) ($34-50/MW·h)

1.1 Global Energy Structure Transformation

New technologies such as energy storage and hydrogen energy become hot spots.

Hydrogen energy is a clean and flexible secondary energy, and an energy carrier that can exist in energy production, conveying, and consumption.

Promote the new energy integration

- Hydrogen production from renewable energy
- Hydrogen enriched and pure hydrogen conveying in natural gas pipeline

Improve the flexibility of electric power system

- Hydrogen storage, heat storage and energy storage
- Electricity-hydrogen-electricity or electricity-hydrogen-application

Clean, low-carbon, and environmentally friendly

- Combined heat and power, fuel cell, no pollution
- Hydrogen enriched combustion engine

Production

Electrolysis of water, fossil fuel, solar energy, etc.

Storage and conveying

Various storage and conveying methods, flexible configuration of power capacity

Application

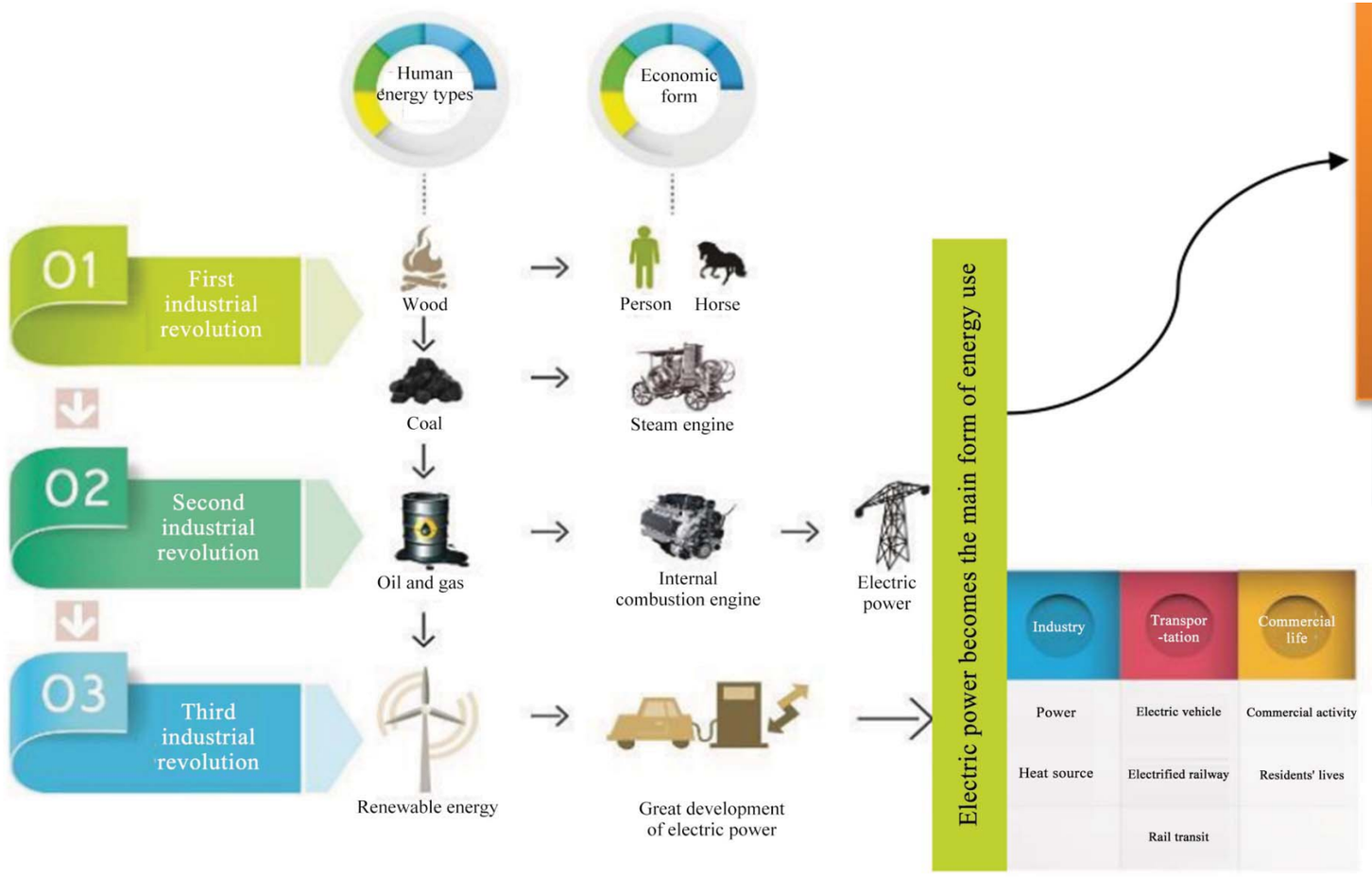
Argon-powered automobile, argon fuel cell, methane production, etc.

Hydrogen production method	Cost (RMB/kg)
Coal gasification	11.67
Natural gas hydrogen production	14.00
Methanol cracking	27.98
Electrolysis of water	36.40

- Now, hydrogen production from fossil energy remains the main means (accounting for about 96%) of hydrogen energy production
- Hydrogen, as a by-product of the coal chemical industry, has no additional environmental burden, and also helps to improve the overall industrial chain benefits.

1.2 Global Energy Transition Strategy

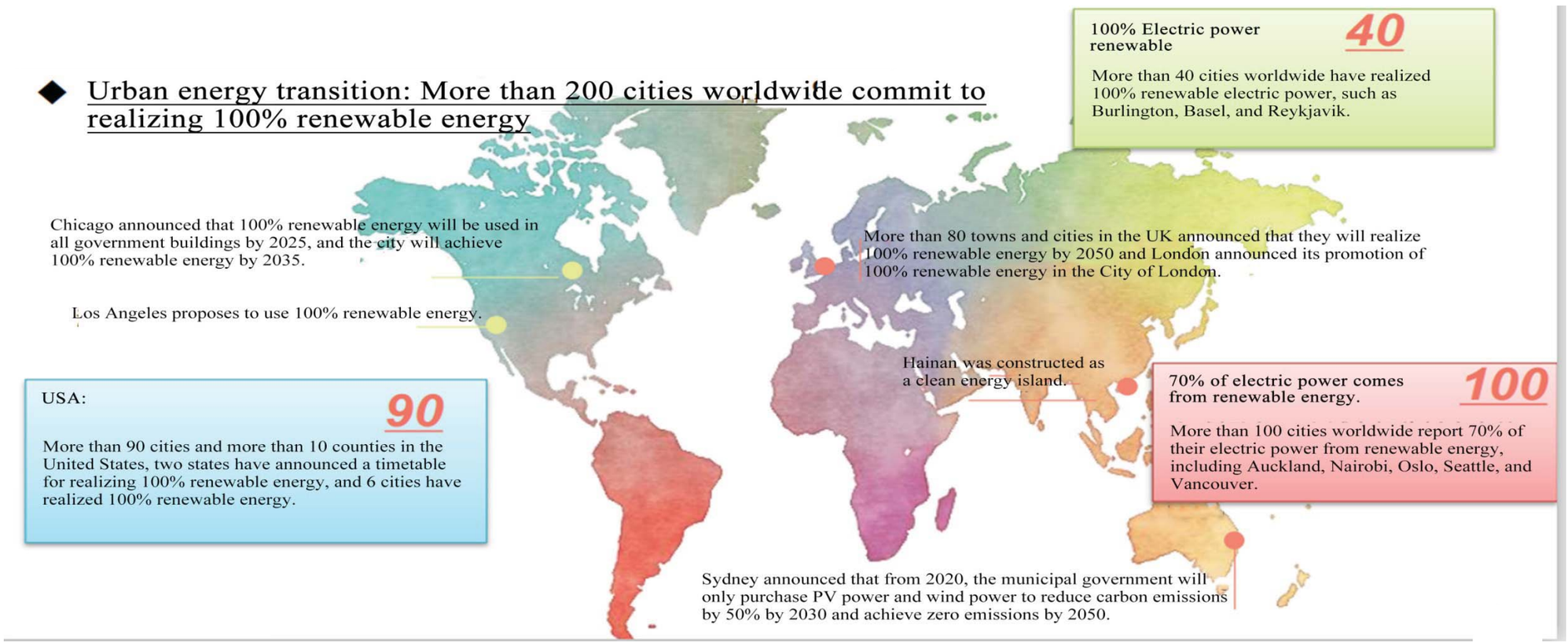
Three industrial revolutions and their economic forms



Consumption Revolution: Electricity will account for about 50% of end energy consumption in 2050, forming an end energy supply system with electricity as the core.

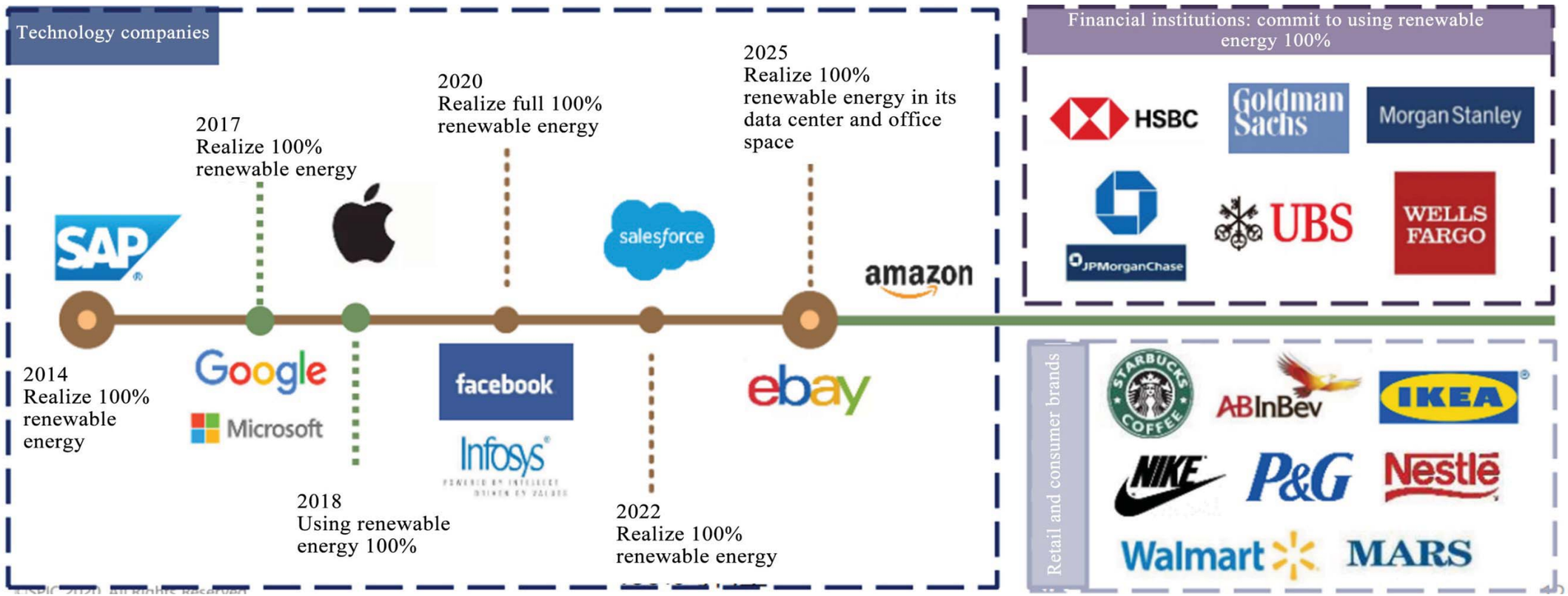
Production Revolution: clean, mainly sourced from wind, light, and other renewable energy.

1.2 Global Energy Transition Strategy



1.2 Global Energy Transition Strategy

Enterprise energy transition: Globally, 174 large enterprises have announced a clear timetable for commitment to 100% renewable energy consumption.



PART 02

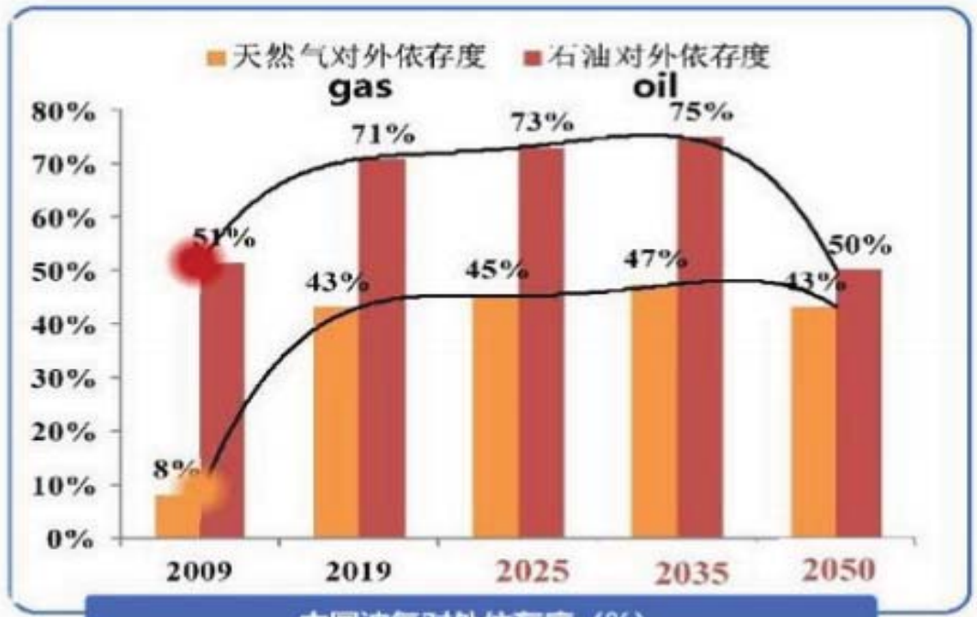
China's Energy Transition Strategy and Direction

2.1 Current Situations of China's Energy Development

China is the largest energy producer and consumer with coal as its main energy. It is highly dependent on external oil and gas and has prominent problems with food and energy security.

The energy consumption weight is 4.97 billion tons of standard coal, and coal consumption accounts for 57.7%. The dependence of crude oil and natural gas is 73.5% and 42% in 2020.

中国一次能源消费结构（%）Constitutes of China's Primary energy consumption（%）



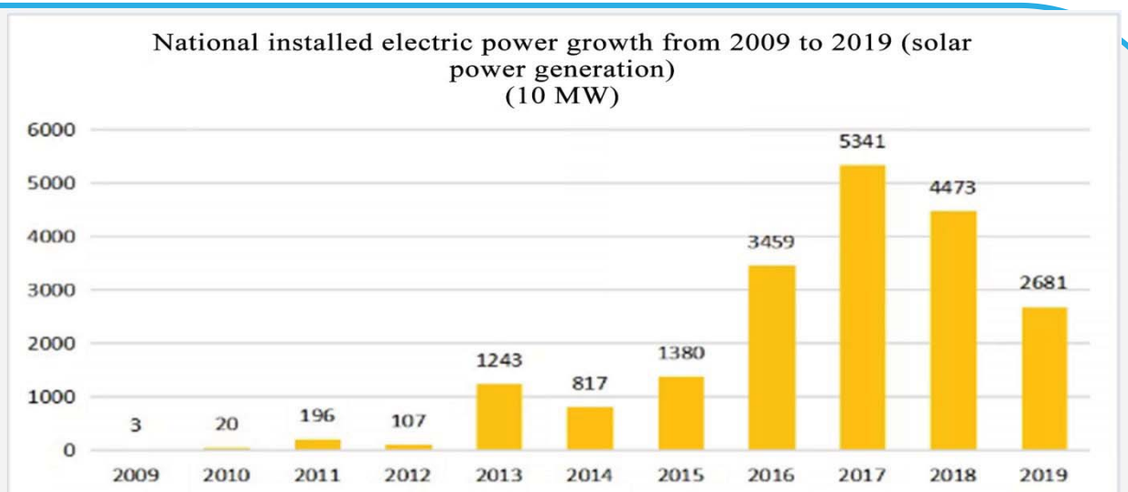
中国油气对外依存度（%）
Oil and gas dependency（%）

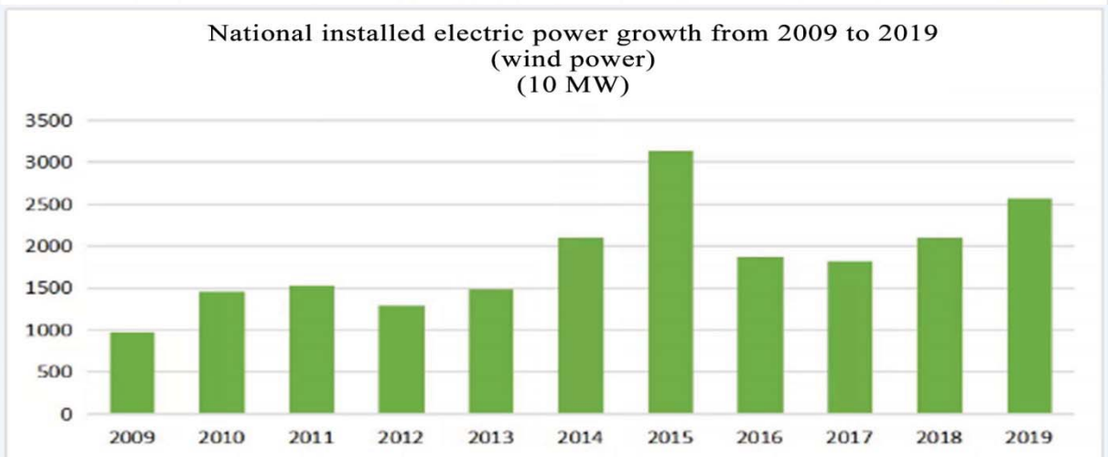
2.1 Current Situations of China's Energy Development

Energy production

The high-quality development momentum of China's power industry continues, but as the world's largest carbon emitter, the pressure of energy conservation and emission reduction is highlighted.

- The installed capacity of power generation has grown steadily, and non-fossil energy power generation has maintained rapid growth;
- Power investment has risen steadily, and UHV investment has risen significantly;
- The reform of the power system has continued to advance, and the overall efficiency of the industry has improved.



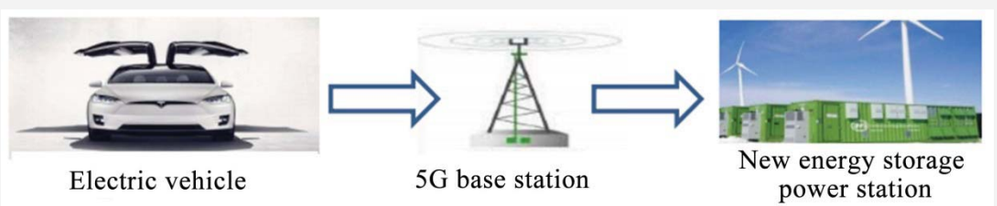


2.1 Current Situations of China's Energy Development

Energy consumption Steady grew energy consumption, increased proportion of electric energy, high energy consumption per unit GDP, and large space for energy efficiency improvement

☐ **Electricity replaces oil in the transportation field** ☐ **Electricity replaces coal and gas in the construction field**
☐ **Distributed green electricity replaces coal power and state grid power in the information field**

- Replacing the consumed electric quantity with electric energy in the fields of transportation, construction and information are equivalent to rebuilding a new power system, which can effectively replace oil and gas imports. It is estimated that the proportion of electricity in end energy consumption during the 14th Five-Year Plan period will increase by 7 percentage points;
- Combine the application methods in the fields of transportation, construction, and information in pairs to form a number of small new energy microgrids, which are applied to schools, hospitals, and other scenarios, and finally, the transition to smart energy on the user side will be realized;
- Maximize the value through the cascade utilization of energy storage and give full play to the marginal effectiveness in the whole life cycle;
- The energy storage will be widely used in three basic elements: electric vehicles, buildings, and 5G+ data centers. It is estimated that the three fields will provide about 330 million kilowatts of flexible load in 2025 to enhance the flexible adjustment ability of the power system.



2.1 Current Situations of China's Energy Development

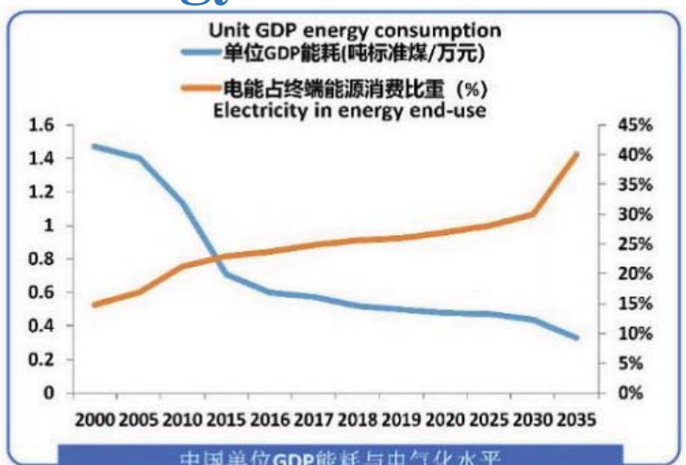
Energy technology Faster evolution of energy technology, greatly reduced costs and breakthroughs by cross-border applications

- Constantly improved **proportion of electric energy in end energy consumption**, and widely accepted green production and green consumption of energy;
- Reconstruction of energy production and supply mode driven by distributed energy supply technology;
- Reconstruction of distribution network caused by the rapid growth of electric vehicle load;
- Reconstruction of the business model and transaction model caused by internet technology.

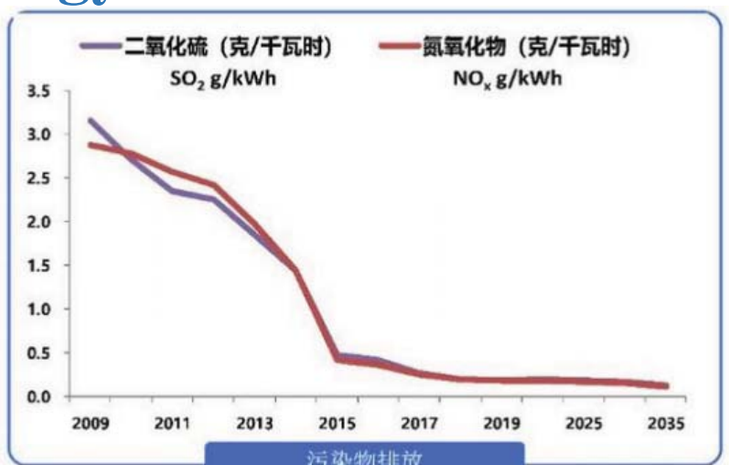
Many new participants emerged in the energy field, and so did user-side innovations one after another
The popularity of energy storage and electric vehicles will subvert the existing energy supply and demand structure.

2.2 China's Energy Transition Strategy

Boost the development of renewable energy, strengthen the electric energy proportion of energy supply and consumption, and realize the deep substitution of clean energy for fossil energy



中国单位GDP能耗与电气化水平
Unit GDP energy consumption and electrification level

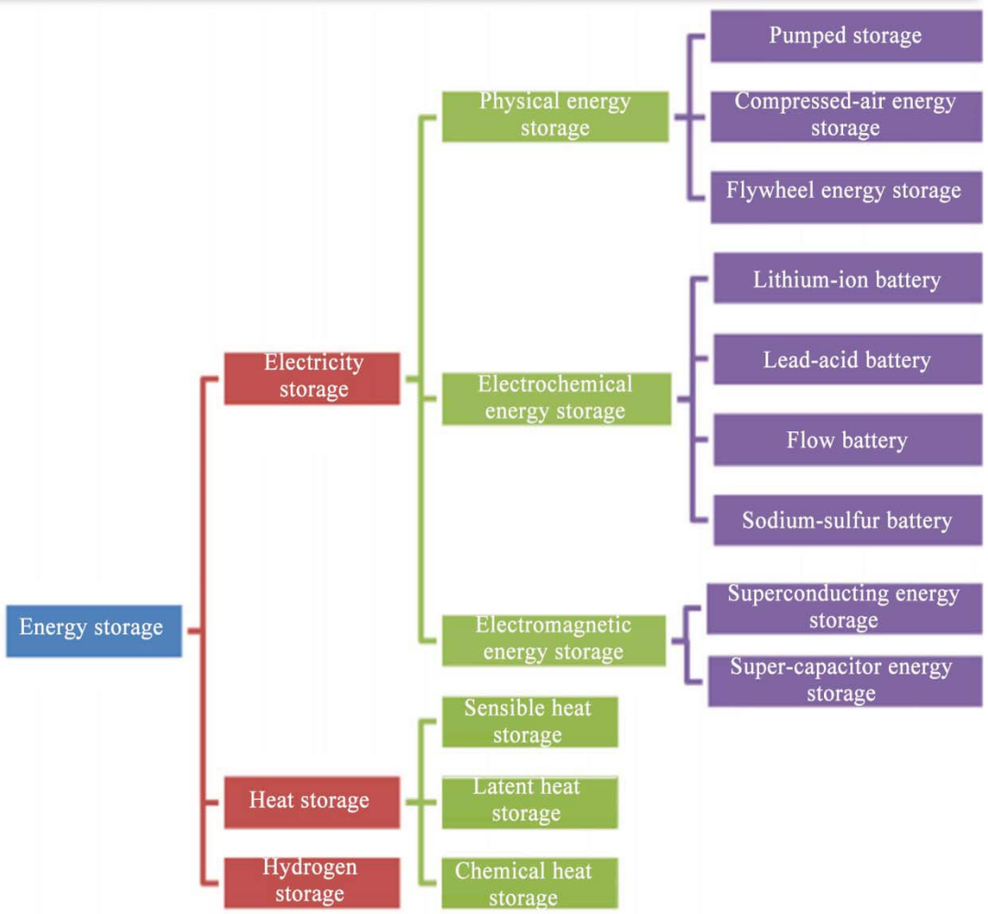


污染物排放
Emissions

Newly add 1.6-3.2 billion kilowatts of clean energy in the next 15-30 years;
Develop low carbon transition and digital economy.

2.2 China's Energy Transition Strategy

2.2 China's Energy Transition Strategy

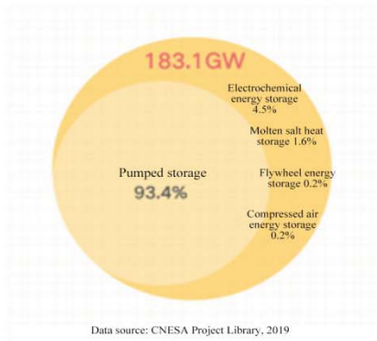


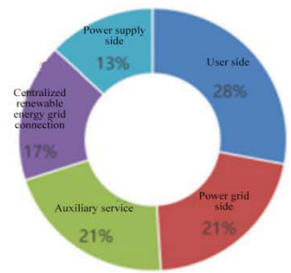
- Pumped storage and electrochemical storage are the leading energy storage means, with the former accounting for the largest proportion and the latter developing the fastest. The main application scenario from pumped storage to electrochemical energy storage is on the user side.
- In electrochemical energy storage, lithium-ion batteries account for the largest number of items and installed capacity, with the fastest growth speed, and have become the fastest-growing electrochemical energy storage technology. The cost of lithium batteries reduced to 1,000-1,500 RMB/kWh in 2020, indicating the attainment of the break-even point of application, laying the foundation for commercial development.
- In view of the cost performance, the lithium iron phosphate battery is the most widely used at present, but solid-state lithium battery is the hot spot of R&D.

2.2 China's Energy Transition Strategy

With the rapid development of lithium battery production in recent ten years, its price has been reduced by nearly 90%, making electric vehicles and electrochemical energy storage commercially feasible for the first time in history. Research from the National Renewable Energy Laboratory (NREL) shows that the investment cost of a 4-hour battery energy storage system will drop to $208/kWh by 2030 and further to $156/kWh by 2050.

Global market size

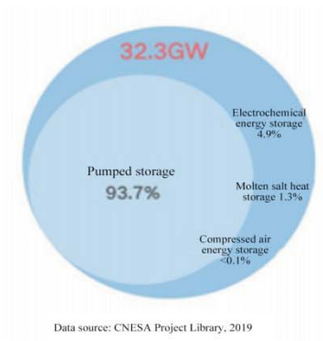


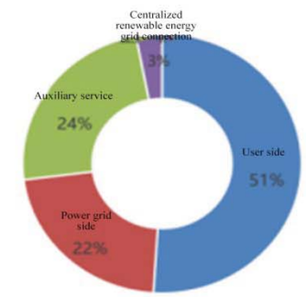


Data source: CNESA Project Library, 2019

Global market forecast: According to RENA data, by 2030, the capacity of fixed energy storage power stations will reach 100-167 GWh. According to IEA data, by 2030, the capacity (excluding pumped storage) of power grid-scale energy storage stations will reach 106 GW, and by 2040, it will reach 218 GW.

China market size





Data source: CNESA Project Library, 2019

China market forecast: According to the forecast of CNESA, by the end of 2020, the installed capacity of electrochemical energy storage in China will reach 2,833.70 MW, and by the end of 2023, the scale will reach 19,319.7 MW. In the next three years, the electrochemical energy storage market will grow by seven times and enter a period of rapid development.

2.2 China's Energy Transition Strategy

Hydrogen industry

China's hydrogen production exceeded 20 million tons in 2019. With the promotion of fuel cell technology, the consumption of hydrogen in the energy field will gradually raise. It is estimated that China's hydrogen production will exceed **45 million tons** in 2030 and exceed **76 million tons** in 2035, and the corresponding proportion of hydrogen production by electrolysis of water will be up to 25% and 30%, respectively.

Hydrogen industry condition: At present, a certain hydrogen industry foundation is established, with an annual output of 20 million tons, ranking first in the world.

Hydrogen industry policies: **Hydrogen energy is included in the *Report on the Work of the Government*, and the *Energy Technology Innovation Plan of Action (2016- 2030)*, *Made in China-Equipment Manufacturing*, the *National Development Plan for Strategic Emerging Industries during the 13th Five-Year Plan Period*, and the *Special Plan for Science and Technology Innovation in Transportation Field in the 13th Five-Year Plan* are released.**

Industry standard system: There are 122 standards in total, including 77 national standards, 40 industry standards, and 5 local standards.

Hydrogen energy regional demonstration: Twenty-three (23) hydrogen refueling stations are built and regional hydrogen industry demonstration projects are established.

2.2 China's Energy Transition Strategy

Hydrogen industry

According to the prediction of the China Hydrogen Energy and Fuel Cell Industry Alliance (CHA):
China's hydrogen demand will be 35 million tons in 2030, accounting for 5% of the end energy system. The demand for hydrogen will be close to 60 million tons in 2050, and its proportion in the end energy system will increase to 10%.

Industrial target		Current situation (2019)	Short-term objective (2020-2025)	Medium-term objective (2026-2035)	Long-term objective (2036-2050)
Proportion of hydrogen industry (%)		2.7%	4%	5.9%	10%
Industrial output value (RMB 100 million)		3,000	10,000	50,000	120,000
Equipment fabrication scale	Hydrogen refueling stations (Nr.)	23	200	1,500	10,000
	Fuel cell vehicles (10,000 Nr.)	0.2	5	130	500
	Fixed power stations (Nr.)	200	1,000	5,000	20,000
	Fuel cell system (10,000 sets)	1	6	150	550

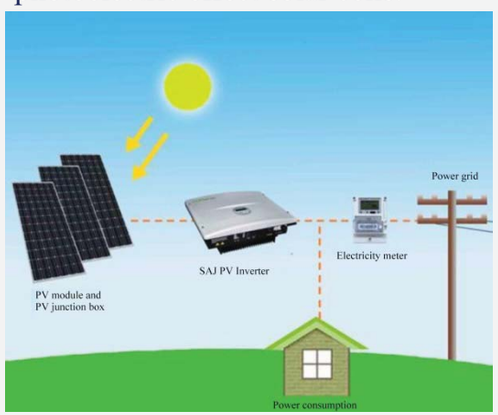
PART 03

Application of New Energy + Energy Storage + (Hydrogen Production)

3.1 PV (Wind Power)/Energy Storage/Hydrogen Production Principle

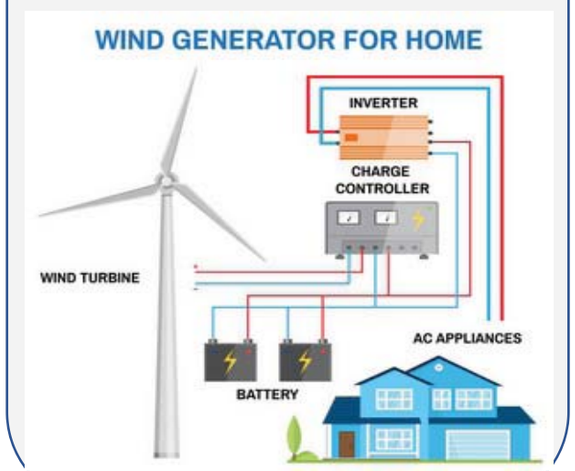
Principle of PV power generation

When the sunlight throws light upon p-n junction of a semiconductor, new hole-electron pair will be formed. Under the effect of p-n junction built-in electric field, the hole moves from n zone to p zone while the electron moves from p zone to n zone. The current will be generated when the circuit is closed. This is the working principle of photoelectric effect solar cells.



Principle of wind power generation

The wind power drives the windmill chips to rotate, and the rotary speed is boosted by a booster engine, thus promoting the generator to generate power. Converting wind energy into electricity is the most basic way of wind energy utilization.

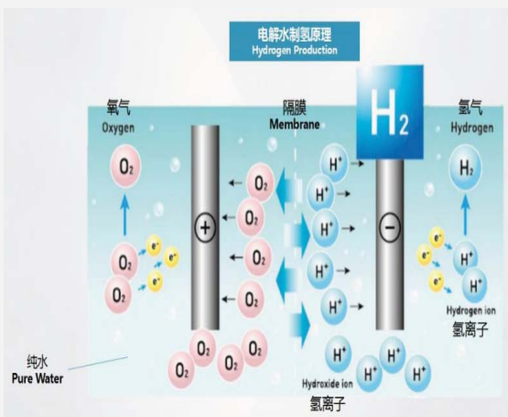


Energy storage principle

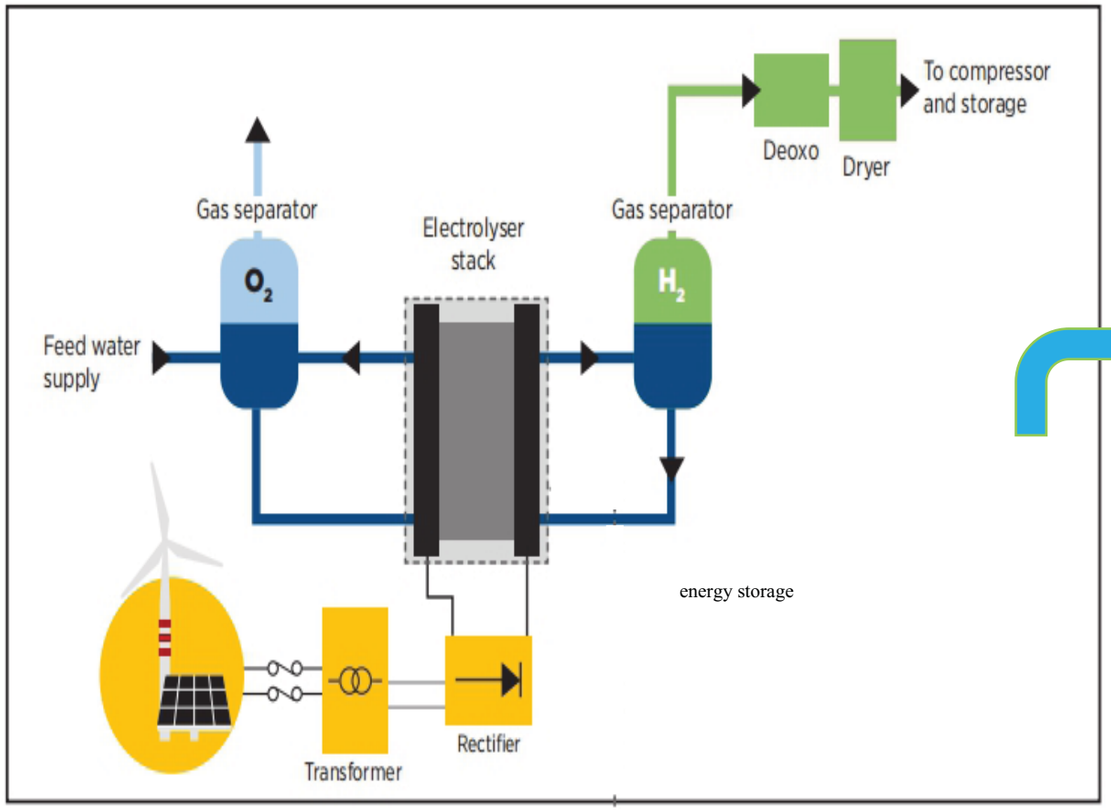
Energy storage is a process in which energy is converted into a relatively stable existing form under natural conditions. The energy storage device composed of energy storage elements and the power grid access device composed of power electronic devices jointly form the energy storage system.

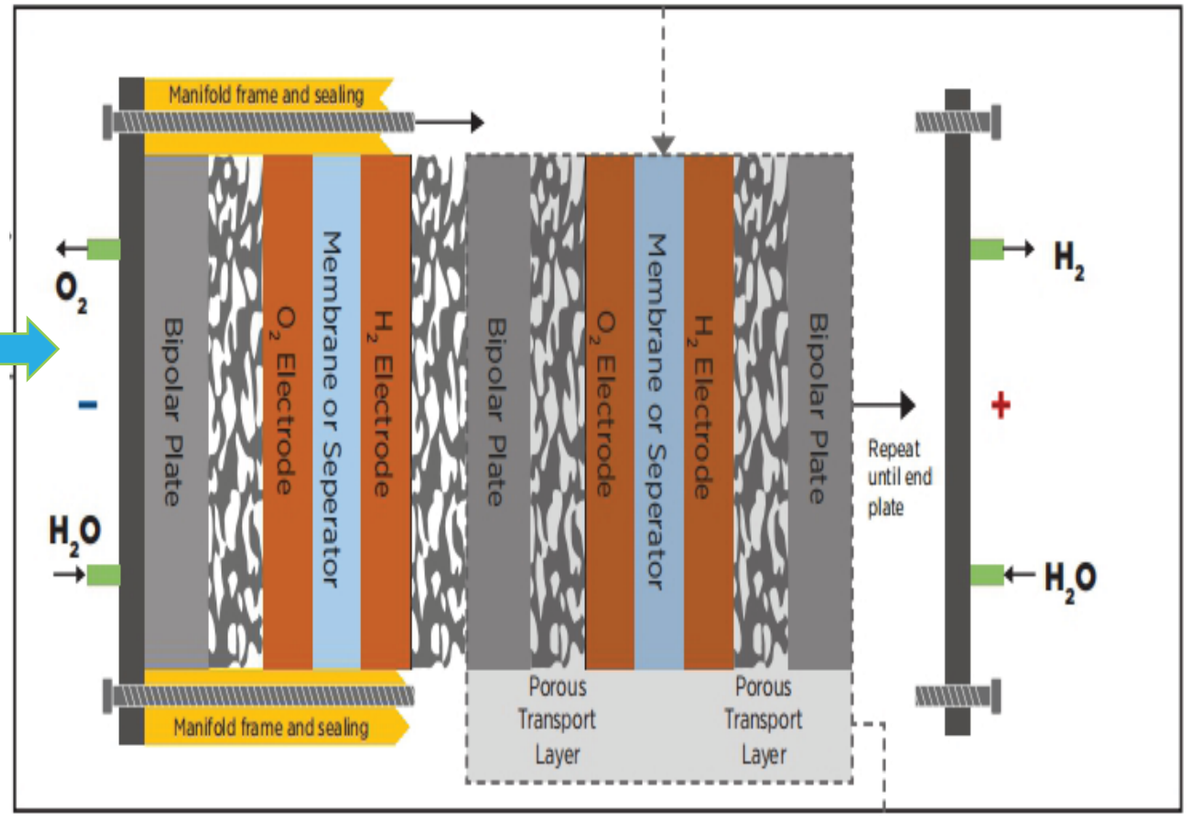
Principle of PEM hydrogen production

Principle of hydrogen production by electrolysis of water: $2H_2O$=(energized) $2H_2\uparrow+O_2\uparrow$.



Application of New Energy + Energy Storage + (Hydrogen Production)





Application of New Energy + Energy Storage + (Hydrogen Production)

Different types of commercially available electrolysis technologies.

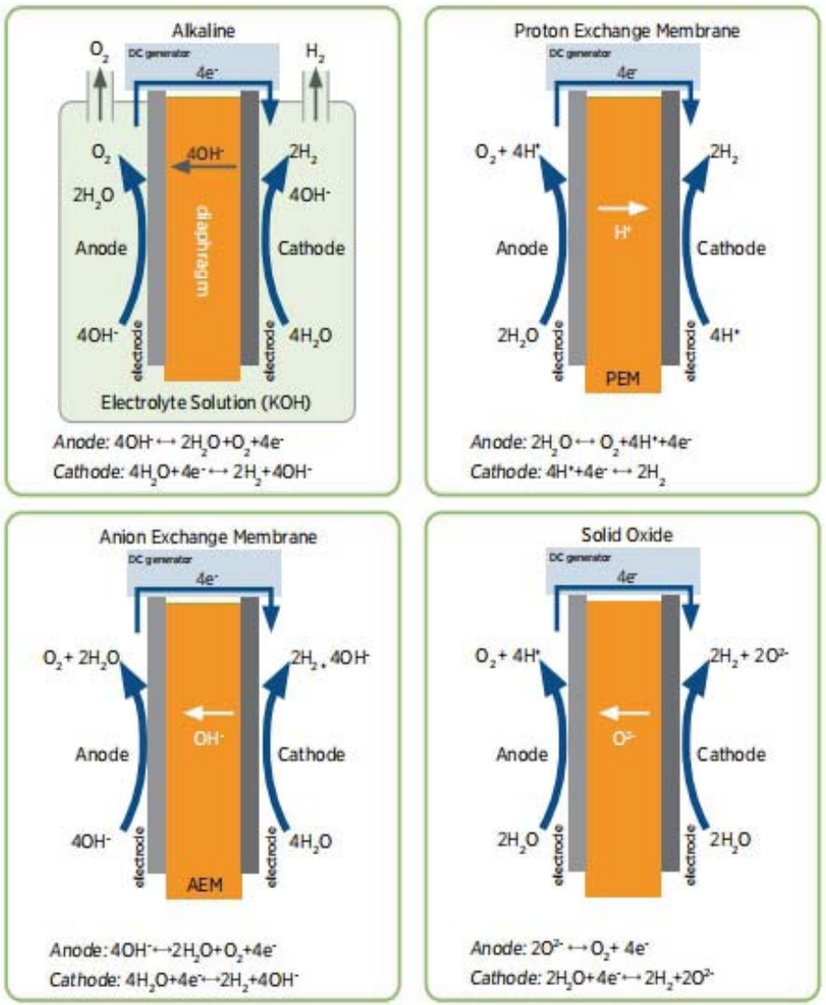
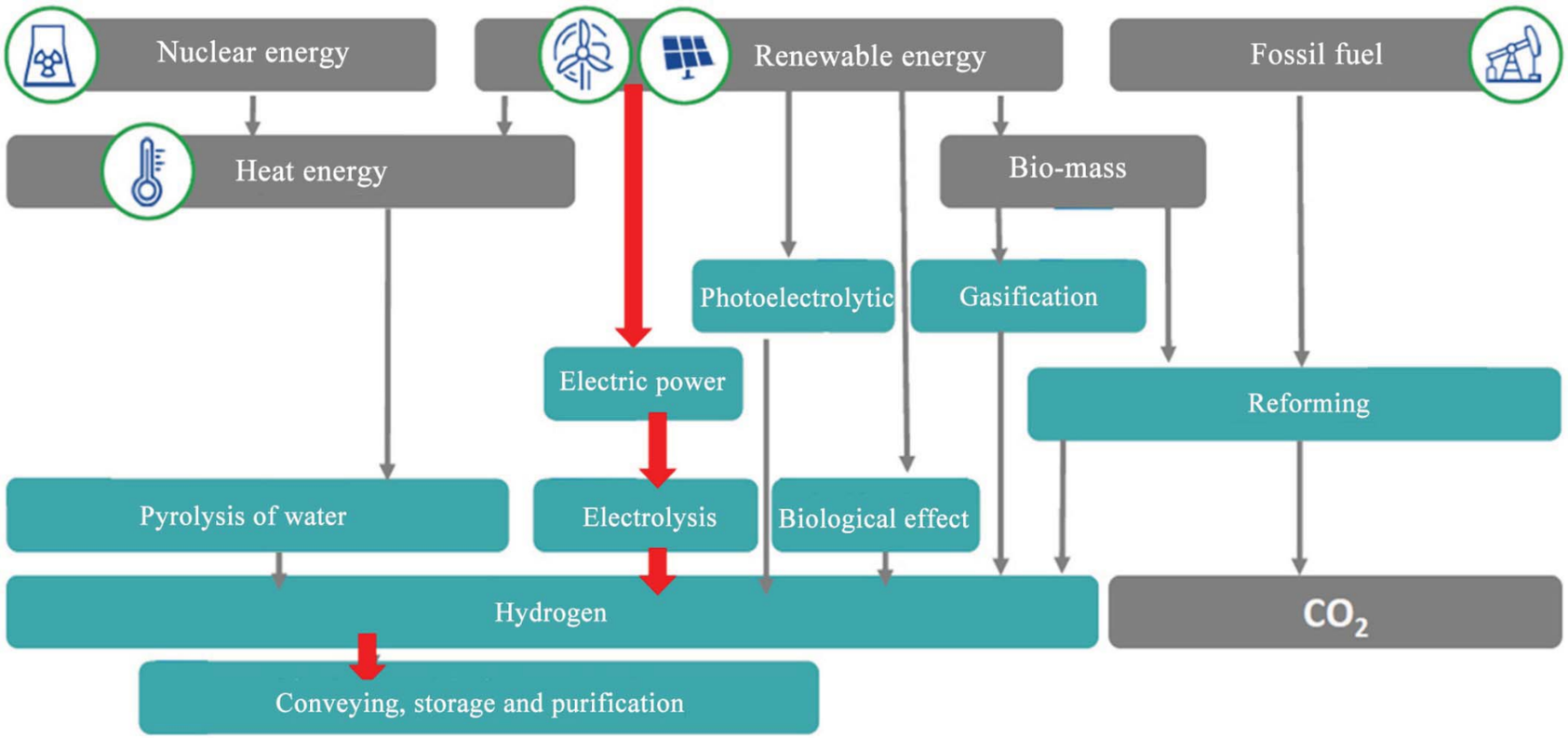


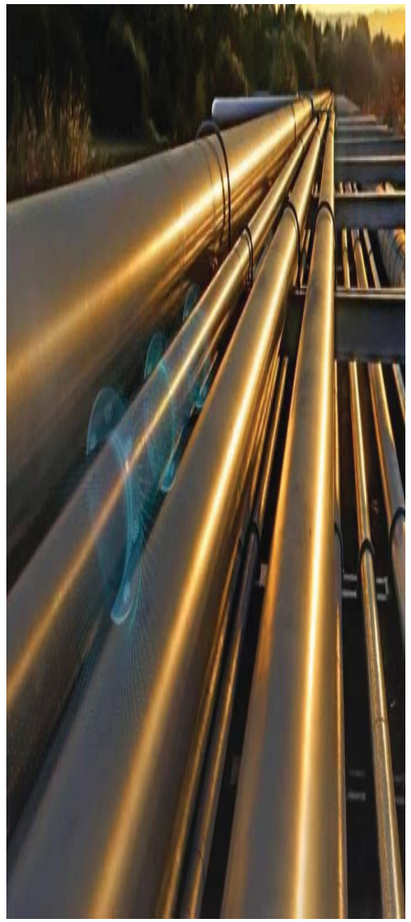
Table 1. Characterisation of the four types of water electrolysers.

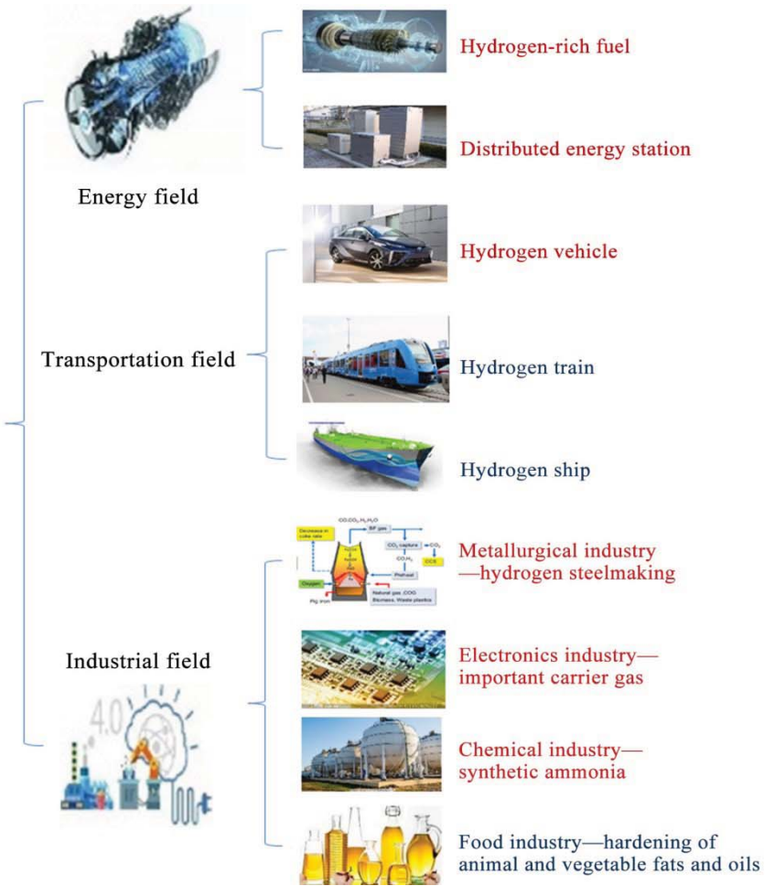
	Alkaline	PEM	AEM	Solid Oxide
Operating temperature	70-90 °C	50-80 °C	40-60 °C	700-850 °C
Operating pressure	1-30 bar	< 70 bar	< 35 bar	1 bar
Electrolyte	Potassium hydroxide (KOH) 5-7 molL^{-1}	PFSA membranes	DVB polymer support with KOH or NaHCO3 1molL^{-1}	Yttria-stabilized Zirconia (YSZ)
Separator	ZrO_2 stabilized with PPS mesh	Solid electrolyte (above)	Solid electrolyte (above)	Solid electrolyte (above)
Electrode / catalyst (oxygen side)	Nickel coated perforated stainless steel	Iridium oxide	High surface area Nickel or NiFeCo alloys	Perovskite-type (*e.g.* LSCF, LSM)
Electrode / catalyst (hydrogen side)	Nickel coated perforated stainless steel	Platinum nanoparticles on carbon black	High surface area nickel	Ni/YSZ
Porous transport layer anode	Nickel mesh (not always present)	Platinum coated sintered porous titanium	Nickel foam	Coarse Nickel-mesh or foam
Porous transport layer cathode	Nickel mesh	Sintered porous titanium or carbon cloth	Nickel foam or carbon Cloth	None
Bipolar plate anode	Nickel-coated stainless steel	Platinum-coated titanium	Nickel-coated stainless steel	None
Bipolar plate cathode	Nickel-coated stainless steel	Gold-coated titanium	Nickel-coated Stainless steel	Cobalt-coated stainless steel
Frames and sealing	PSU, PTFE, EPDM	PTFE, PSU, ETFE	PTFE, Silicon	Ceramic glass

3.2 New Energy/Energy Storage/Hydrogen Production Application Scenario



3.3 Characteristics of New Energy + Energy Storage + Hydrogen Production





$$N_{2\,(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

3.4 New Energy + Energy Storage + Hydrogen Production Simulation Case

Simulation case of PV + Energy Storage + Hydrogen Production Item		
S/N	**Item**	**Scale/cost/specification**
1	PV installed capacity	100 MW AC, DC side 120MWp
2	Full-load hours	2200h
3	Energy storage scale	20MWh
4	Power output	227300MWh
5	Hydrogen production technology	PEM hydrogen production
6	Energy consumption of hydrogen production	1 Nm^3 hydrogen/6.5 kWh electric energy
7	Annual hydrogen production	34.97 million m^3
8	Price of selling hydrogen	The energy hydrogen price above 35 MPa is 4.5-5.0 RMB/Nm^3.
9	PV cost	3,500 RMB/kWh, totaling 420 million RMB
10	Energy storage cost	1,200 RMB/kwh, totaling 24 million RMB
11	Hydrogen production cost	4 sets of 4,000 Nm^3/day hydrogen production equipment, totaling 400 million RMB
12	Business turnover	The annual business turnover is 157.365-174.85 million RMB.

PART 04

Business Model of New Energy + Energy Storage + (Hydrogen Production)

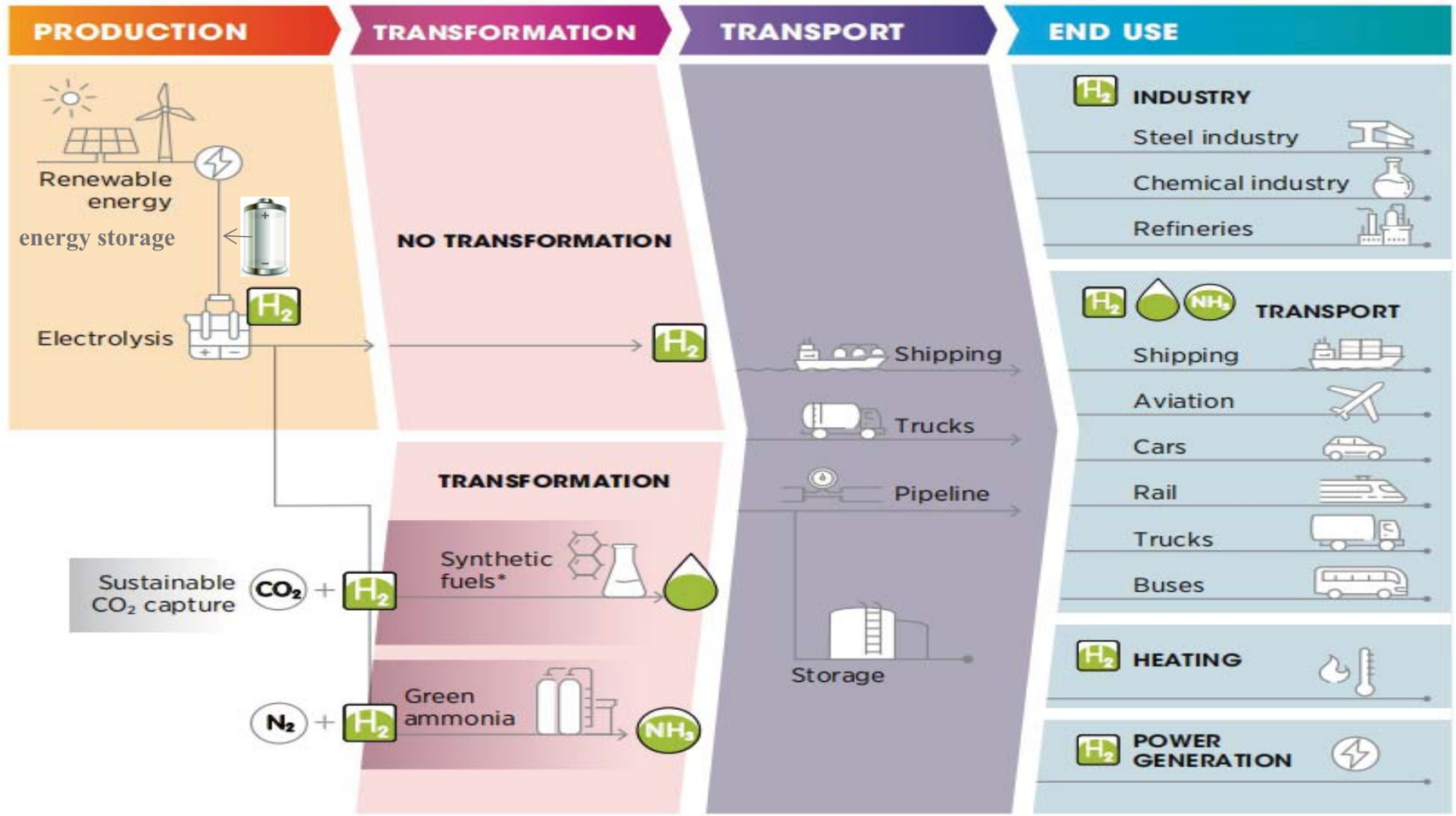
4.1 Business Mode Architecture

Electricity selling

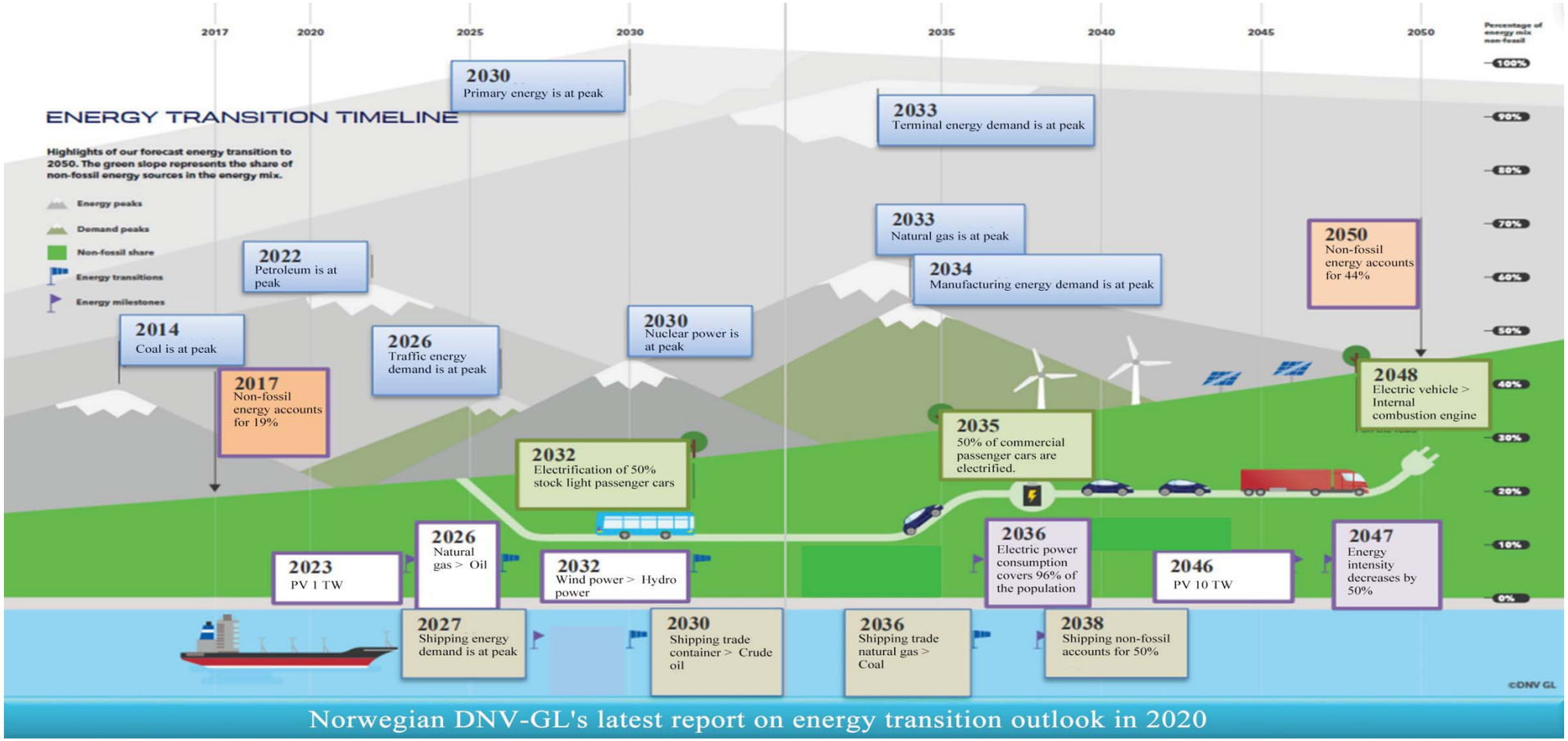
Stabilized electric energy
Continuous power supply

Hydrogen and oxygen selling

4.2 General Idea



4.3 Development Direction



PART 05

Bottleneck of New Energy + Energy Storage + (Hydrogen Production) Development

5.1 Bottleneck of Commercial Development

Bottleneck of New Energy + Energy Storage + (Hydrogen Production) Commercial Development:

- High cost of hydrogen production;
- Un-popularized hydrogen sales and integration;
- Lack of supporting policies and industry standards for new energy + energy storage + hydrogen production;
- High cost of water resources for electrolysis in Middle East

5.2 Bottleneck of Technological Development

Bottleneck of New Energy + Energy Storage + (Hydrogen Production) Technological Development:

- Intermittent and fluctuating new energy, and the allocation of energy storage may alleviate the power quality; the high cost of energy storage remains a problem;
- Difficult storage technology of hydrogen;
- Technical uncertainties exist in hydrogen transportation (pipeline transportation/hydrogen-ammonia-hydrogen/liquid hydrogen transportation).

Thank you for your guidance and support!