A road toward zero emission society

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Paris agreement
- Article 4 -

Parties aim

to achieve a balance between

anthropogenic emissions by sources and

removal by sinks

of greenhouse gases

in the second half of this century

= to achieve net zero emission of GHGs

by the end of 21^{st} century

Fig. Relation between cumulative CO2 emission and the rise in global surface temperature

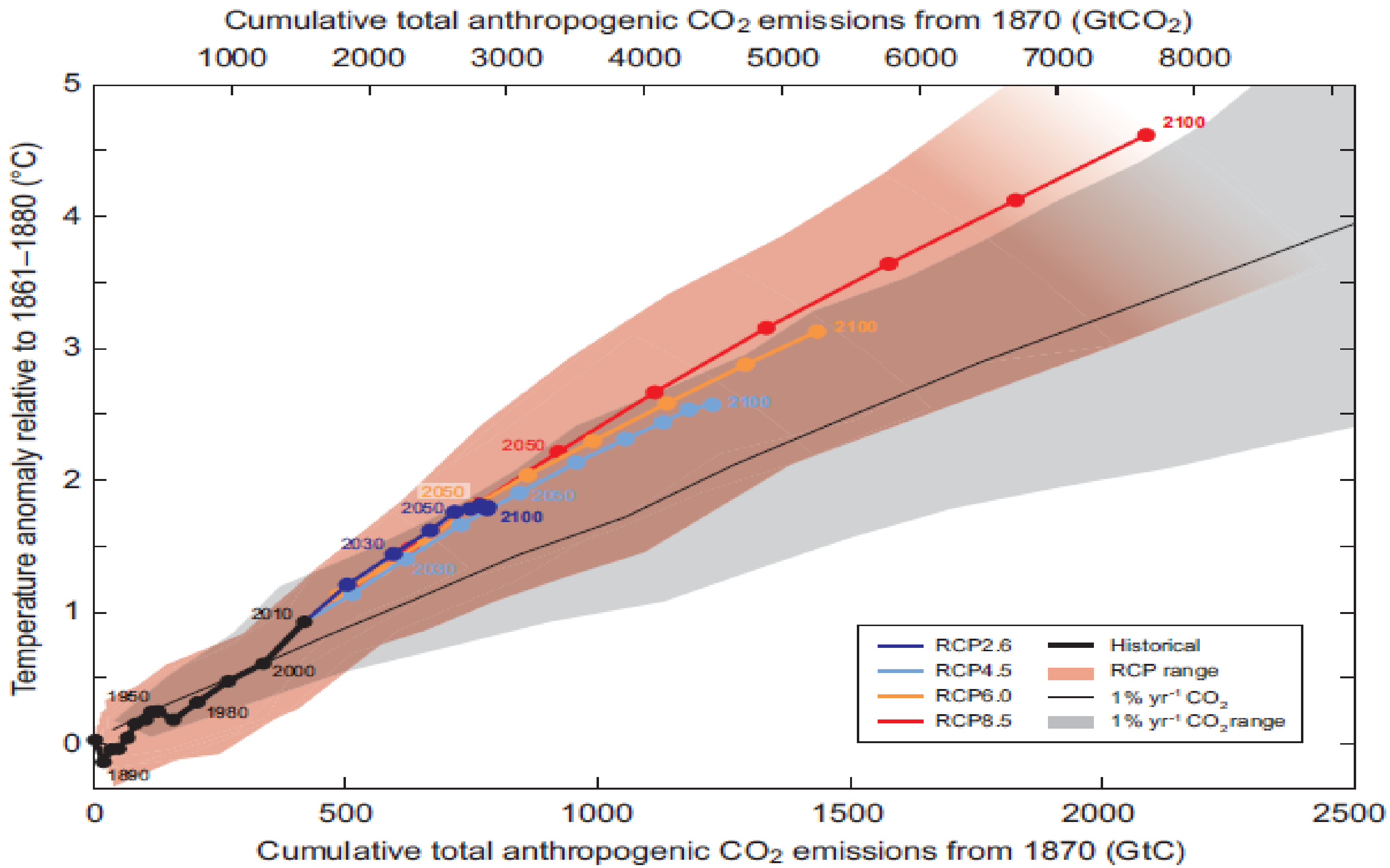


Figure SPM.10 | Global mean surface temperature increase as a function of cumulative total global CO_2 emissions from various lines of evidence. Multi-model results from a hierarchy of climate-carbon cycle models for each RCP until 2100 are shown with coloured lines and decadal means (dots). Some decadal means are labeled for clarity (e.g., 2050 indicating the decade 2040–2049). Model results over the historical period (1860 to 2010) are indicated in black. The coloured plume illustrates the multi-model spread over the four RCP scenarios and fades with the decreasing number of available models in RCP8.5. The multi-model mean and range simulated by CMIP5 models, forced by a CO_2 increase of 1% per year (1% yr^{-1} CO_2 simulations), is given by the thin black line and grey area. For a specific amount of cumulative CO_2 emissions, the 1% per year CO_2 simulations exhibit lower warming than those driven by RCPs, which include additional non-CO_2 forcings. Temperature values are given relative to the 1861–1880 base period, emissions relative to 1870. Decadal averages are connected by straight lines. For further technical details see the Technical Summary Supplementary Material. {Figure 12.45; TS TFE.8, Figure 1}

Source:IPCC AR5 WG1, SPM、2013

Stabilization of the global surface temperature and zero emission - suggestion by IPCC -

Cumulative total anthropogenic emission of CO2 and global mean surface temperature response are approximately linearly related

(IPCC AR5 WG1 SPM p.27)

⇒ To Stabilize the temperature requires to make CO2 emission approximately zero.

Note: In the past anthropogenic absorption of CO2 was almost zero, so only CO2 emission was mentioned here. If CO2 absorption is taken into account the target is to make net anthropogenic emission of CO2 to be zero.

About 3 main GHGs

1. Life time in the air

   CO_2 20~30% several thousand years

   CH_4 12 years

   N_2O 114 years

2. Their impacts on the global temperature

   impacts of CH_4, N_2O: <u>become zero</u>
   <u>if the increase in their emissions will be slow</u>

   impacts of CO_2: <u>keeps the temperature increase</u>
   <u>in the long run unless no emission</u>

→ CO2 zero emission is indipensable
for stabilization of the global temperature in the long run

Generality of CO_2 zero emission requirement

The condition of net zero anthropogenic emission of CO_2 is needed for stabilization of the global surface temperature (GST)

regardless of

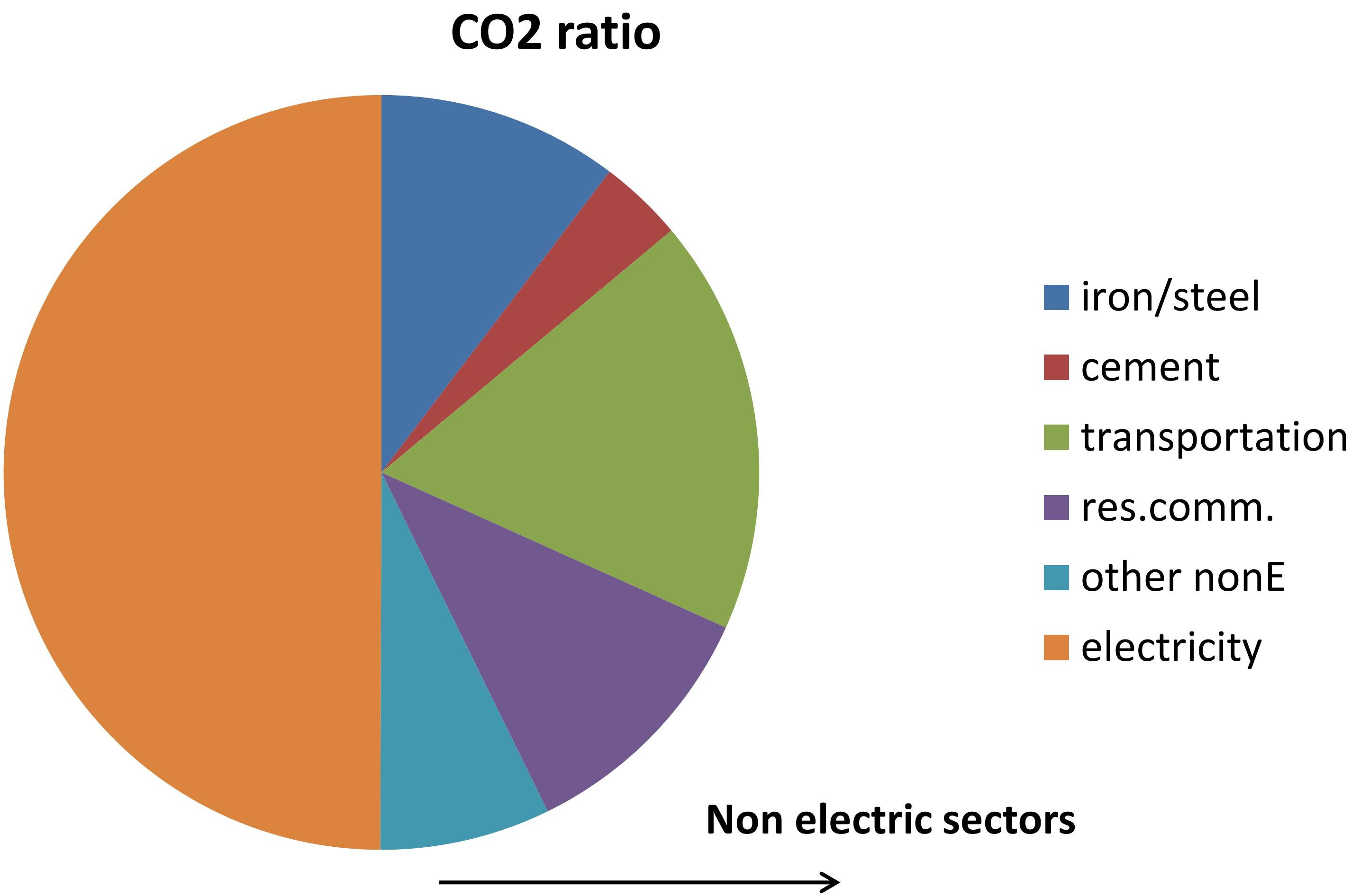
1) when (ex. 2100)
2) at which level (ex. 2℃ higher than pre-ind.era)

GST will be stabilized.

Difficulties in anthropogenic absorption of CO2

1. CCS （CO2 Capture and Storage)
   1)public acceptance of onshore CCS
   2) high cost
      Ex. RITE estimate: ～100 $ /ton CO2
2. BECCS (Bio Energy CCS)
   1) public acceptance of onshore CCS
   2) requirement of large land area
      Ex. 10Gton CO2 for BECCS ～ the whole USA
3. DAC (Direct Air Capture)
   1) very high cost

CO2 share of Japan（2013)



Decarbonization of iron& steel sector

1. In recent years Japanese iron & steel group has been doing R&D under the name of COURSE 2050.
2. It includes
    1) reduction of iron ores by hydrogen
    2) application of CCS to blast furnace gases

   CO_2 will be reduced by 30 %.
3. More reduction of CO_2 emission requires some drastic efforts.

Decarbonization of cement production

1. Theoretically almost 100% reduction of CO_2 emission is possible by applying CCS to exaust gas from cement rotary kiln.
2. There are two barriers for CCS to be introduced.
   1) Many factories are located inland so that CCS have to be introduced on shore --- hard to be accepted by the public.
   2) Prices of cement are so low that introduction of CCS may be economically hard to be accepted.

Decarbonization of other industrial processes

1. Most energy are used for heating and steam reforming for which possible fuels are, except fossil fuels,
   1) electric power
   2) hydrogen or CH_4 from hydrogen.
   3) biofuels
2. 1) and 2) are produced from electric power
   → <u>electric power may occupy the main part of alternative fuels</u>.

Decarbonization of future non-electric transportation fuels

1. Automobiles

Electric power（EV)、hydrogen（FCV) are applicable to automobiles.

First generation biofuels are already utilized . (Their neat use is still a matter of investigation)

Fuels both for EV and FCV will be made from electricity.

.2. Airplanes

1) Application of second generation biofuels are now at the stage of R&D.

2) Possibility of hydrogen based fluid fuels are to be investigated.

It seems not so easy to fully decarbonize airplane fuels.

3. Ships

1) Biofuels: may be utilized but to be investigated.

2) Possibility of hydrogen based liquid fuels are to be investigated.

It seems not so easy to fully decarbonize ship fuels.

Future of non-electric residential and commercial demands

1. Non-electric demands in these sectors are mostly the following types.

1)air conditioning 2)water heating 3) cooking

2. These demands can be covered mostly by electric power.

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High possibility of increase in future electric power demand

The survey of possible fuels for presently non-electric power demands indicates that most of them will be covered by electric power, hydrogen or hydrogen based liquid fuels like CH_4.

Taking into account that hydrogen will be mostly produced by electrolysis of water in future,

we believe

expansion of production of electric power from non-carbon sources should be highly promoted in the coming years.

Present and future structure of Power generation of Japan

Kind of fuels	2010	2030 Government plan	2050 ～2100 zero E oriented plan
PV/ wind	0 %	9 %	30 %
Hydro/biomass/ geothermal	7	15	15
nulear	22	20	20~30?
Fossil fuels	71	56	25~35

Innovative technologies required for future power systems

1. Storage technologies
2. Control technologies for system stabilization
3. Large scale non-carbon power generation technologies

Power storage technologies

0. Conventional pumping up stations
1. Batteries
   NAS batteries, Li ion batteries and other electrochemical storages
2. Flywheel
3. Hydrogen conversion
   Hydrogen will be utilized in transportation and industry areas.

Hydrogen related technologies
- for non electric demands -

1. Direct use of hydrogen
   1) Fuel cells for automobiles
   2) Fuel cells for residential energy use
   3) Direct use for heating in industries
2. Transform hydrogen into liquid fuels
   1) transformation into NH_3
   2) transformation into CH_4: methanation
      mainly for industrial use?

Innovative control technologies for system stabilization

1. The issue

Power systems have been operated as those occupied by AC machines such as synchronous machines, of which inertia and synchronous torques play key roles for system stabilization, particularly for stabilization of the frequency.

However PV have neither inertia nor synchronous torques at all.

How can we stabilize the system operation if large amount of PV occupies the system?

Large scale non-carbon new power technologies for long term future

1. Nuclear fusion
2. Space solar power sytems (SSPS)
3. Large scale concentrated power sytems (CSP)

Their main features

1) large outputs
2) huge resources
3) low environmental impacts

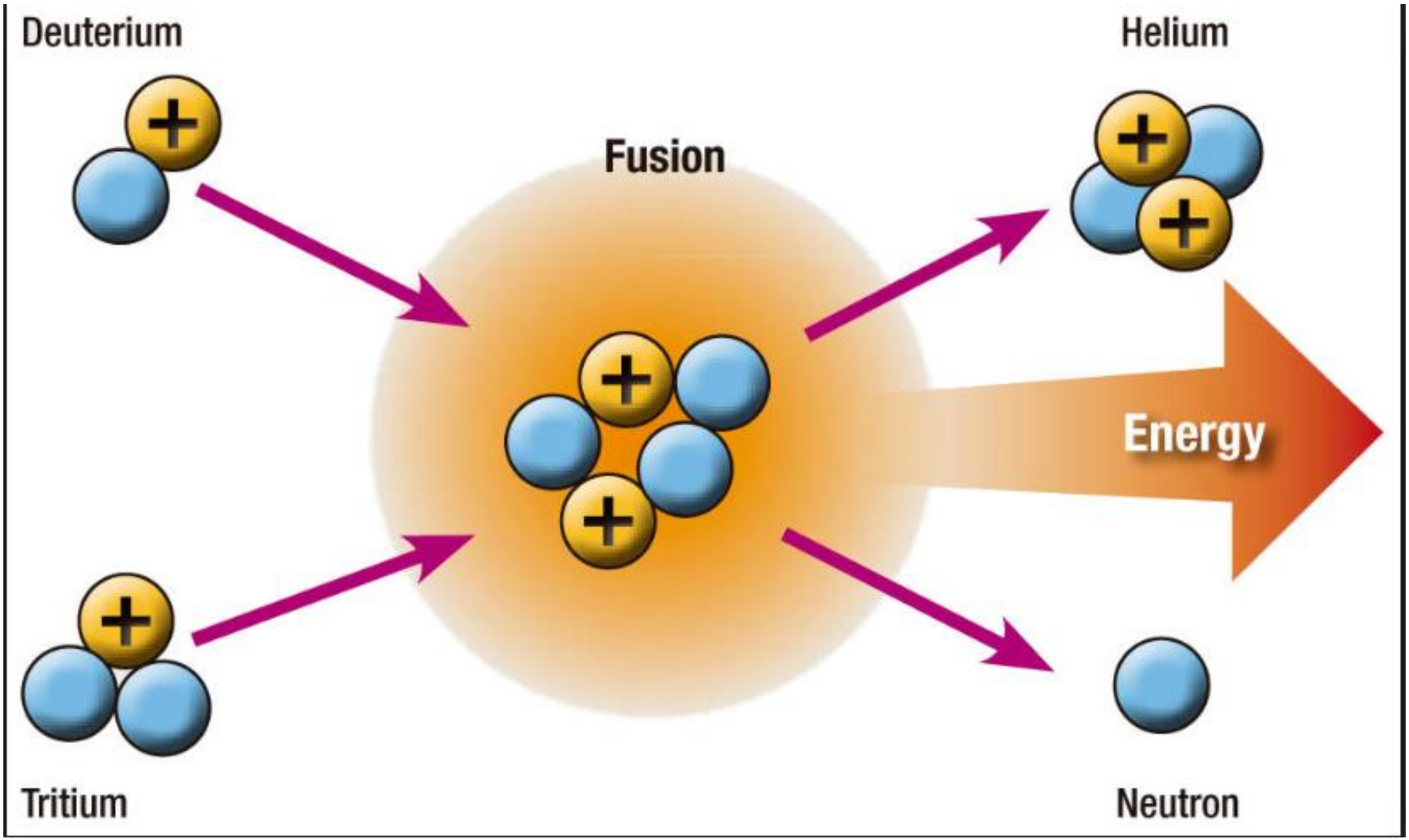
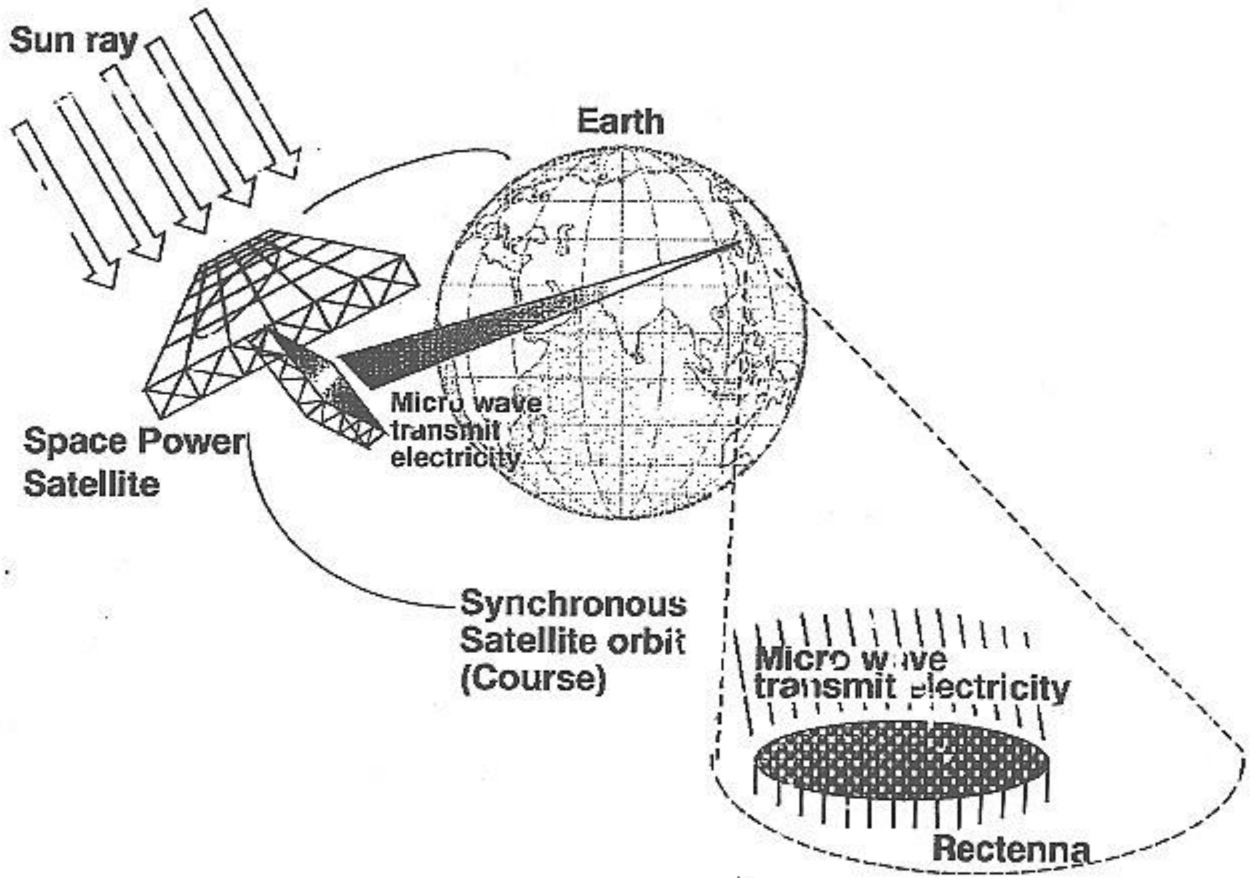


Fig. Principle of nuclear fusion

Fig. Space Power Generation System



Main feature of Space solar power system(SSPS)

１. Due to its location on stationary orbit of 36,000km far from the earth the location of SSPS

Relative to the rectenna on the earth is fixed.

２. Since the power from SSPS will be transported by microwave to the earth the power will be received with little turbulence by clouds. (lower than 20GHz)

３. The key is how to reduce high costs of facilities, transportation by rockets and of construction of the system in the space.

The PS10 solar power plant in Andalucía, Spain, concentrates sunlight from a field of heliostats onto a central solar power tower.

Features of concentrated solar power(CSP)

１. Power output can be stabilized due to heat storage.
２. Basic technologies are already developed. More than 3 GW plants are in operation around the world.
３. Power produced in deserts—dry area→
long distance transmission → demand area
Large scale power generation /transmission can be realized in the above scheme.

Example：Dessertec plan imagined in the early stage of 21 century
Sahara desert CSP → DC transmission → Europe
In the plan about 1/15 of the total European demand will be covered. It was however suspended due to political instability around Sahara area.

Problems: 1) how to supply large amounts of pure water to dry area?
2) how to reduce high device costs?

Concluding remarks

1. The final goal of future energy systems is achievement of net zero anthropogenic CO_2 emission.
2. Future expansion of the share of electric power demand is inevitable.
3. Innovative technologies for stabilization of DC/AC mixed power systems are required.
4. Long term innovative power technologies such as nuclear fusion and SSPS are to be developed on the basis of international cooperation.