Potential Fusion Market for Hydrogen Production Under Environmental Constraints

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Sep.14, 2004

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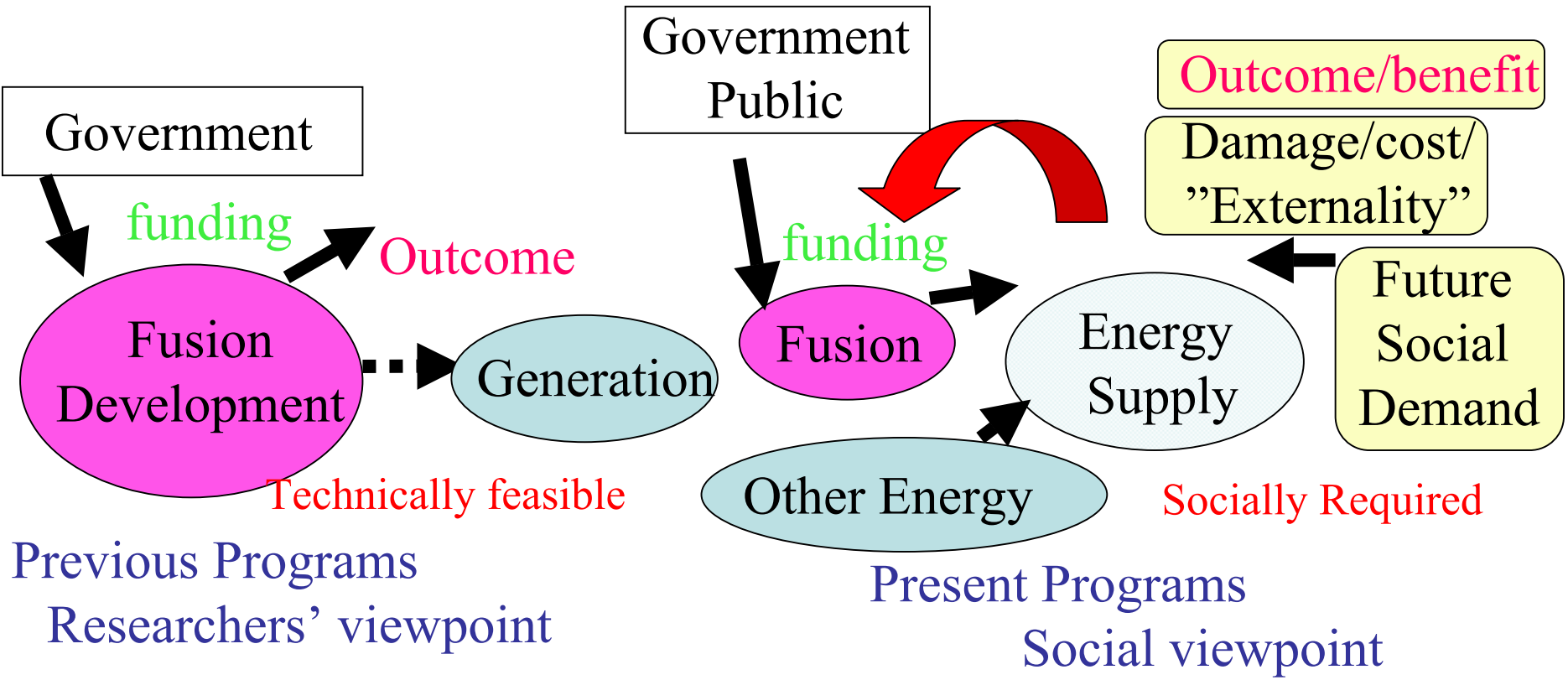
- Requirements and advantage of Fusion Energy
- Possible future energy scenario
- Comparison of hydrogen production process
- Advantage of fusion and its possible market

Socio-Economic Aspect of Fusion

- Future energy must respond to the demand of the society.
- Externality and social requirement could be more important than cost.
  - -without the consideration to fit future hydrogen system, fusion hydrogen cannot be accepted.

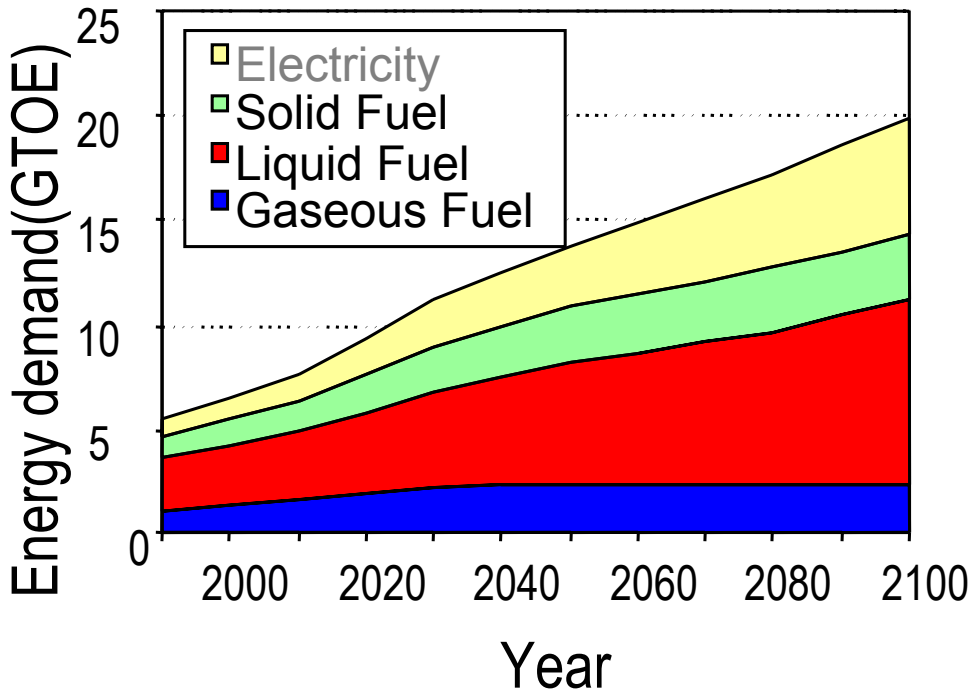


Why Hydrogen?

Automobile

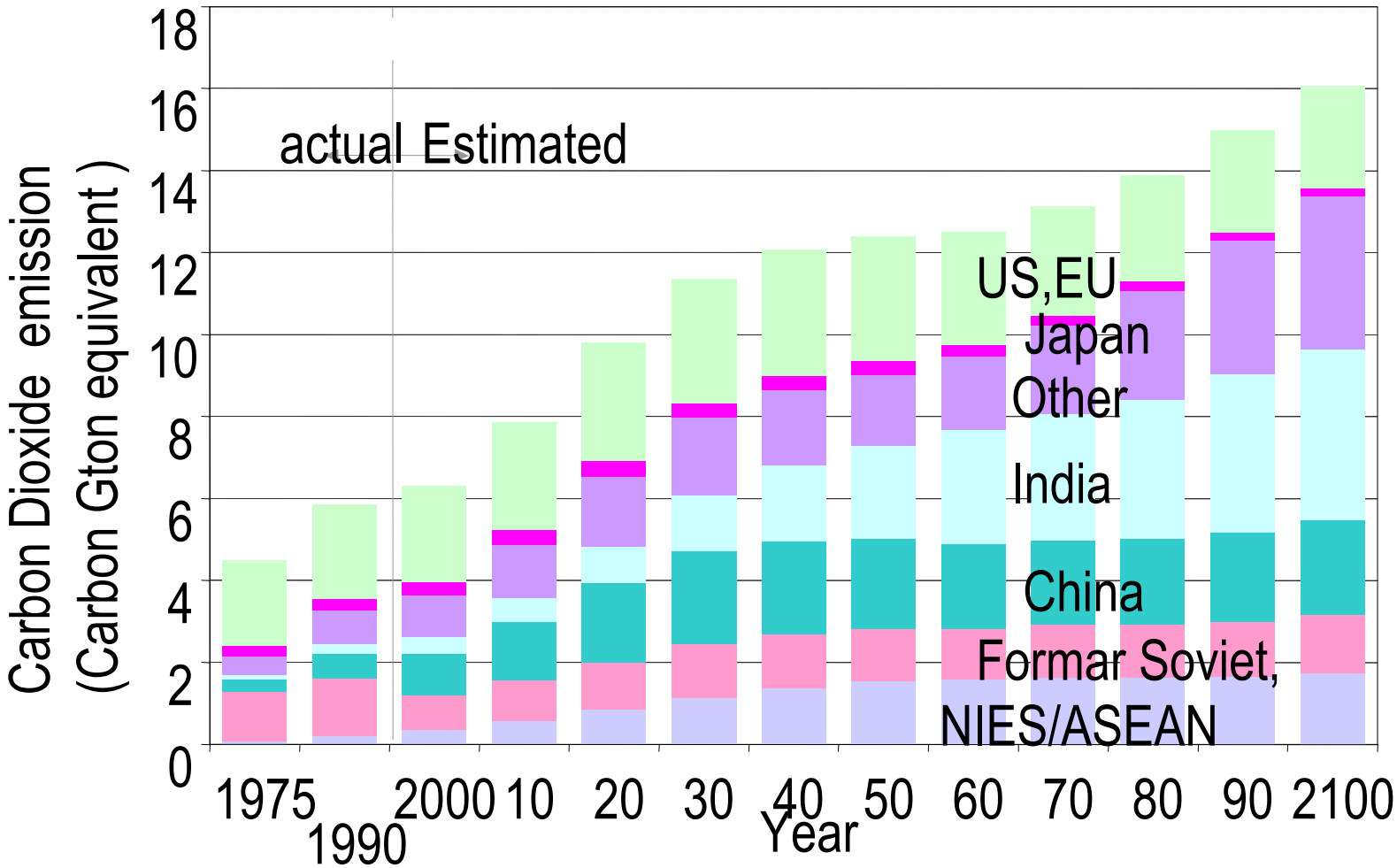
Aircraft

- Carbon-free fuels required
  - Exhausting fossil resources
  - Global warming and CO2 emission
- Future fuel use
  - Fuel cells for automobile
  - aircrafts
- Dispersed electricity system
  - Cogeneration
  - Fuel cell,
  - micro gas turbine
- Market larger than electricity (could be other synthetic fuels)



Future Global CO2 emission

- So the carbon dioxide emission.



Future Global Energy Consumption

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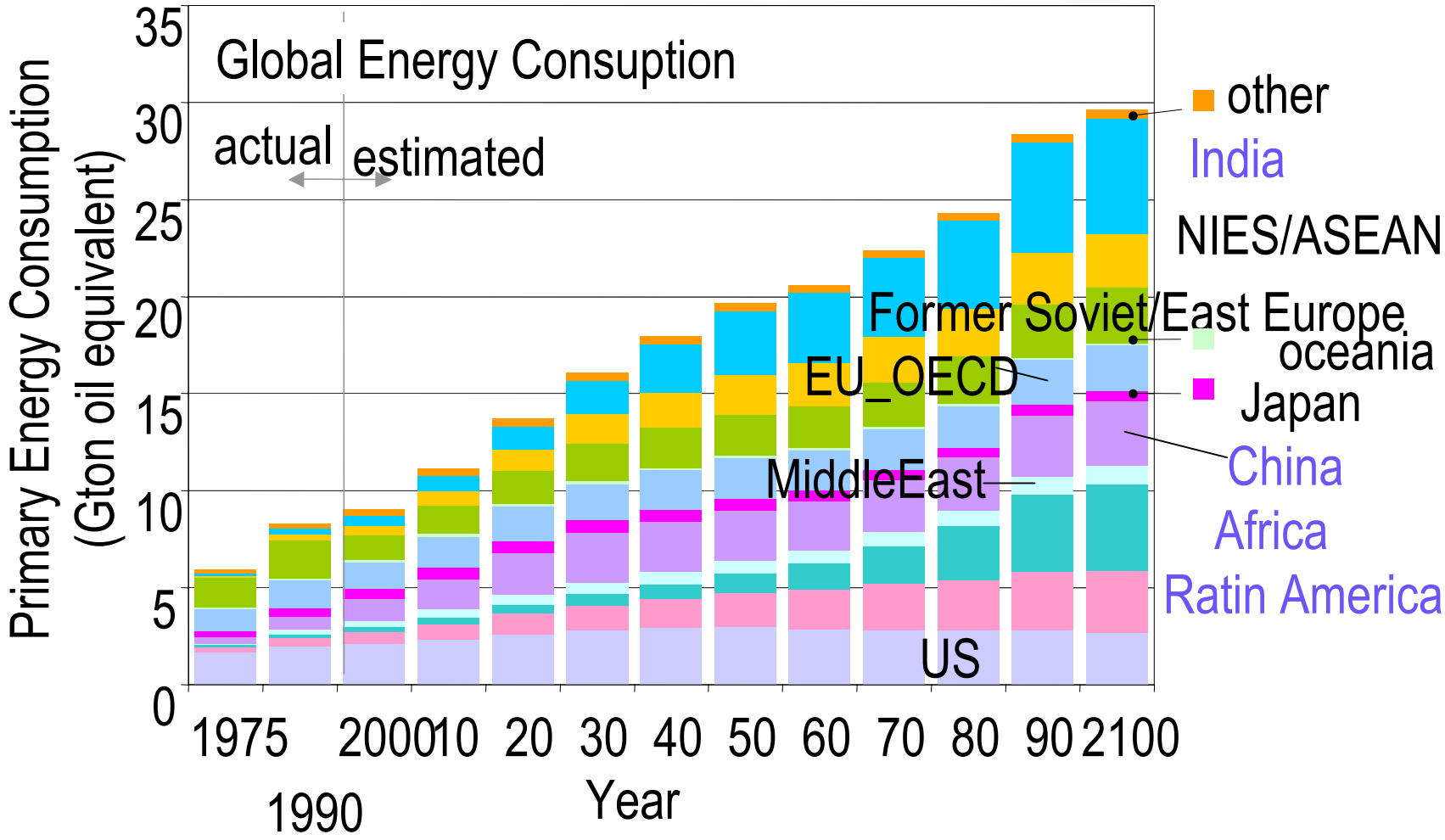
- Majority of energy will be consumed where fusion has NOT been studied.



Future Energy System

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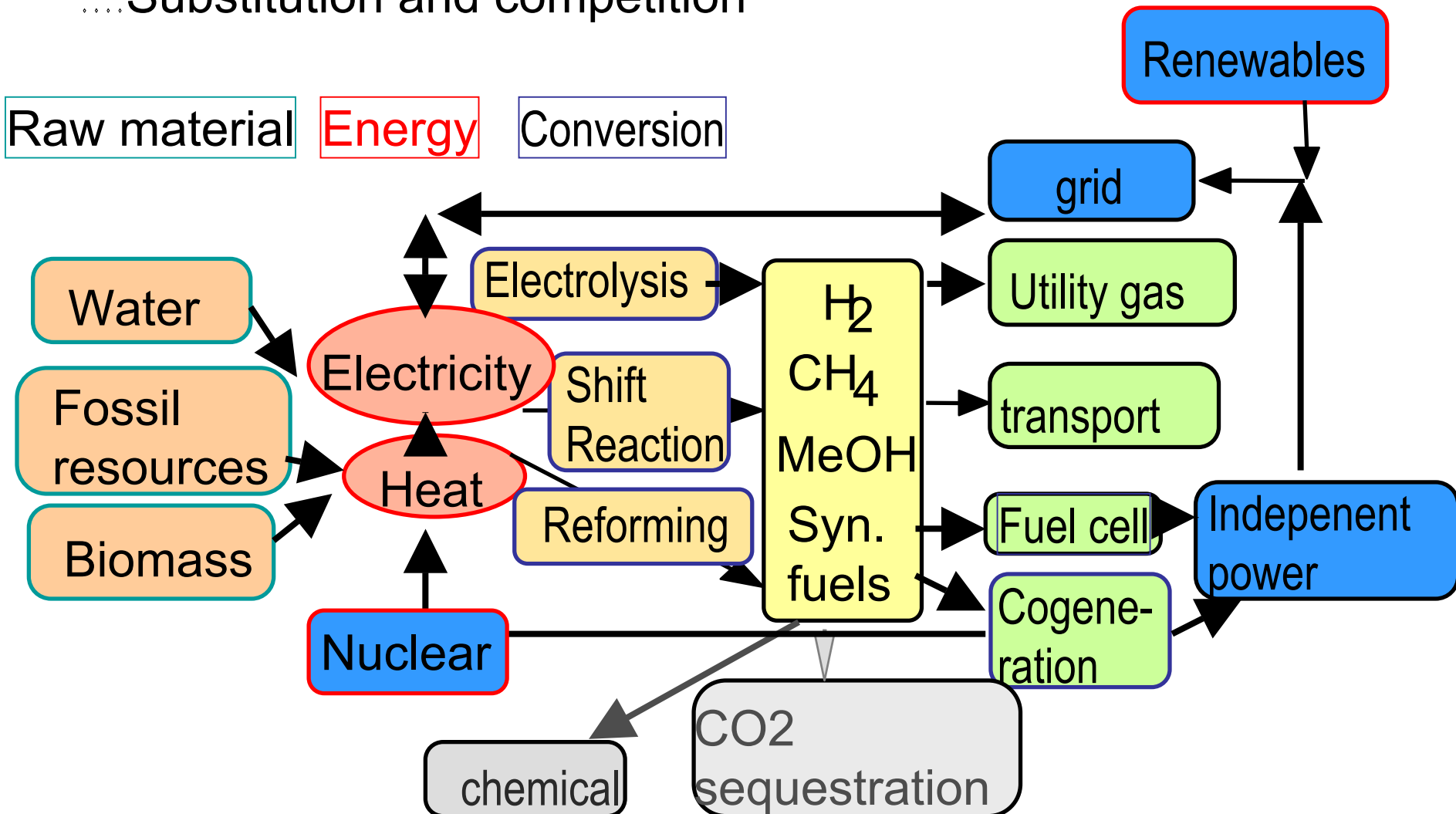
- Electricity and Synthetic fuels mutually converted
  - Resources required for raw material and energy
  - Substitution and competition



Hydrogen Production by Fusion

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Fusion can provide both high temperature heat and electricity

- Applicable for most of hydrogen production processes

As Electricity

-water electrolysis, SPE electrolysis : renewables, LWR

-Vapor electrolysis : HTGR

As heat

-Steam reforming:HTGR(800C),

-membrane reactor:FBR(600C)

-IS process :HTGR(950C)

-biomass decomposition: HTGR

Use of Heat for Hydrogen Production

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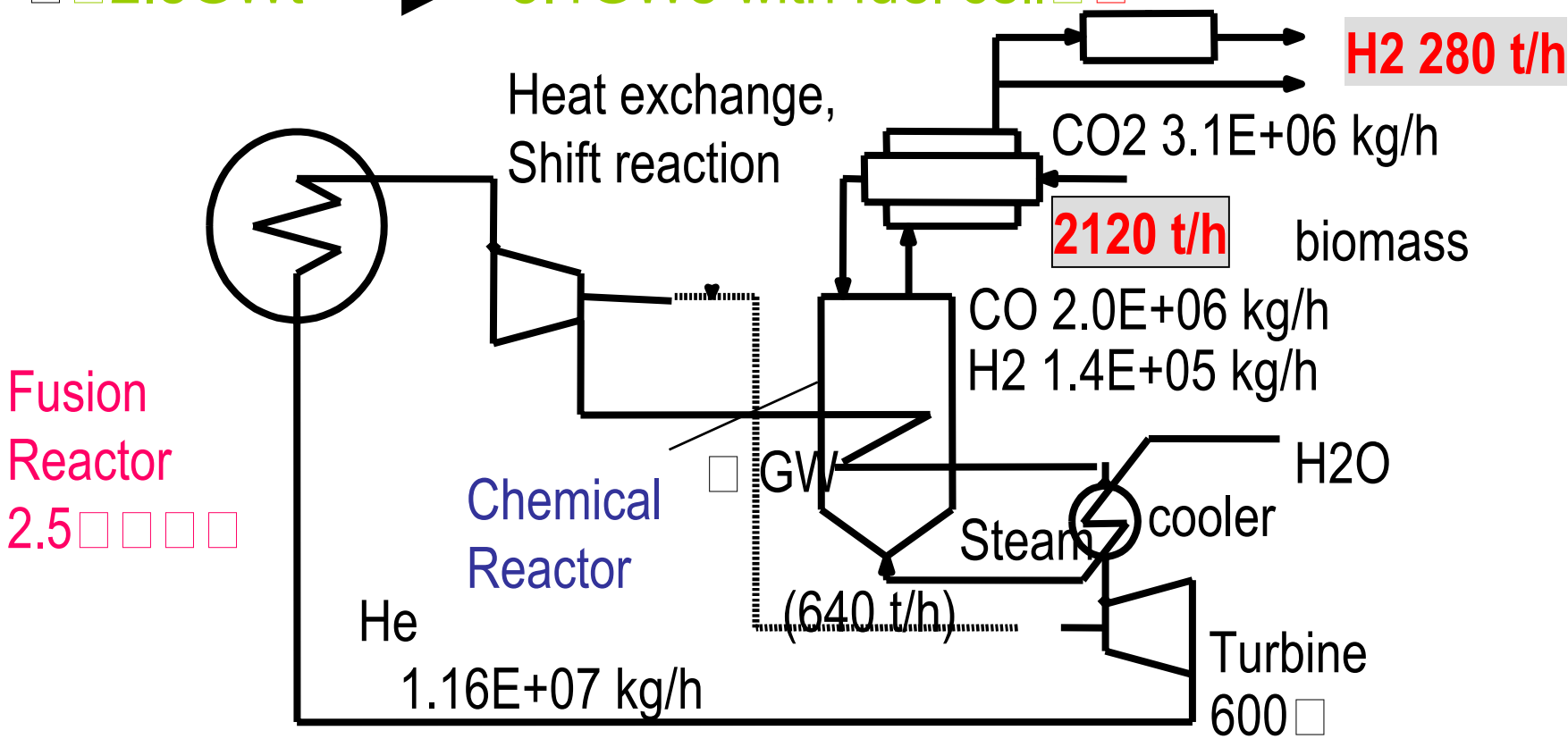
- Processing capacity
  - 4240t/h waste → 280t of H2
- Electricity Generation
  - 2.5GWt → 5.1GWe with fuel cell



Comparison of Hydrogen processes

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1) Raw material and CO2 emission

Coal	--	C + H2O → CO2 + H2
Oil	-	CH2 + H2O → CO2 + H2
Gas	+	CH4 + H2O → CO2 + H2
water	+	H2O → O2 + H2
Biomass	+	CH2O + H2O → CO2 + H2

carbon neutral

2) Resource

coal	+
Oil	-
Gas	+
water	+
biomass	

++

Coal, water and biomass(waste) are abundant and available in many countries.

Biomass consumption is beneficial to reduce wastes.

Comparison of Hydrogen processes

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3) Energy and carbon dioxide emission

coal	--
oil	-
gas	+-
nuclear	+
Renewable	+

By Life-cycle analysis, nuclear and renewable also generates carbon dioxide

efficient production process is better for environment

4) Energy efficiency

electrolysis is limited by the generation efficiency

-if hydrogen is used for generation with fuel cell, to convert electricity to hydrogen is inefficient.

thermochemical water decomposition (IS process) is a heat cycle, and limited by the cycle efficiency.

Energy Eficiency

□amount of produced hydrogen from unit heat

□ □low temperature□□□□□□generation□□□

→ conventional electrolysis

□ □high temperature□□□□□□generation

□□□→ vapor electrolysis

□ □ high temperature□□□□□□ → thermochemical production □

From 3GW heat	efficiency	electricity	Energy consumption	Hydrogen production
300C-electrolysis	33%	1GW	286kJ/ mol	25t/ h
900C-electrolysis	50%	1.5GW	231kJ/ mol	44t /h
900C-vapor electrolysis	50%	1.5GW	181kJ/ mol	56t /h
900C-biomass			60kJ/ mol	340t / h

Energy Source Options

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For hydrogen production, some energy sources provide limited options.

□□□□□□□□□□□□	renewables	LPR	fusion(HTGR)	FBR
Conv.electrolysis	□□□□○	□□□□○	□□□□□○	□□□□○
Vapor electrolysis	□□□□ ×	□□□□×	□□□□□○	□□□□×
IS process	□□□□□ ×	□□□□□×	□□□□□○	□□□□×
Steam reforming	□□□□□ ×	□□□□□×	□□□□□○	□□□□?
Biomass hydrogen	□□□□ ×	□□□□□×	□□□□□○	□□□□?

Renewables (PV, wind, hydro) cannot provide heat.
LPR temperature not suitable for chemical process.

Selecting use of fusion heat

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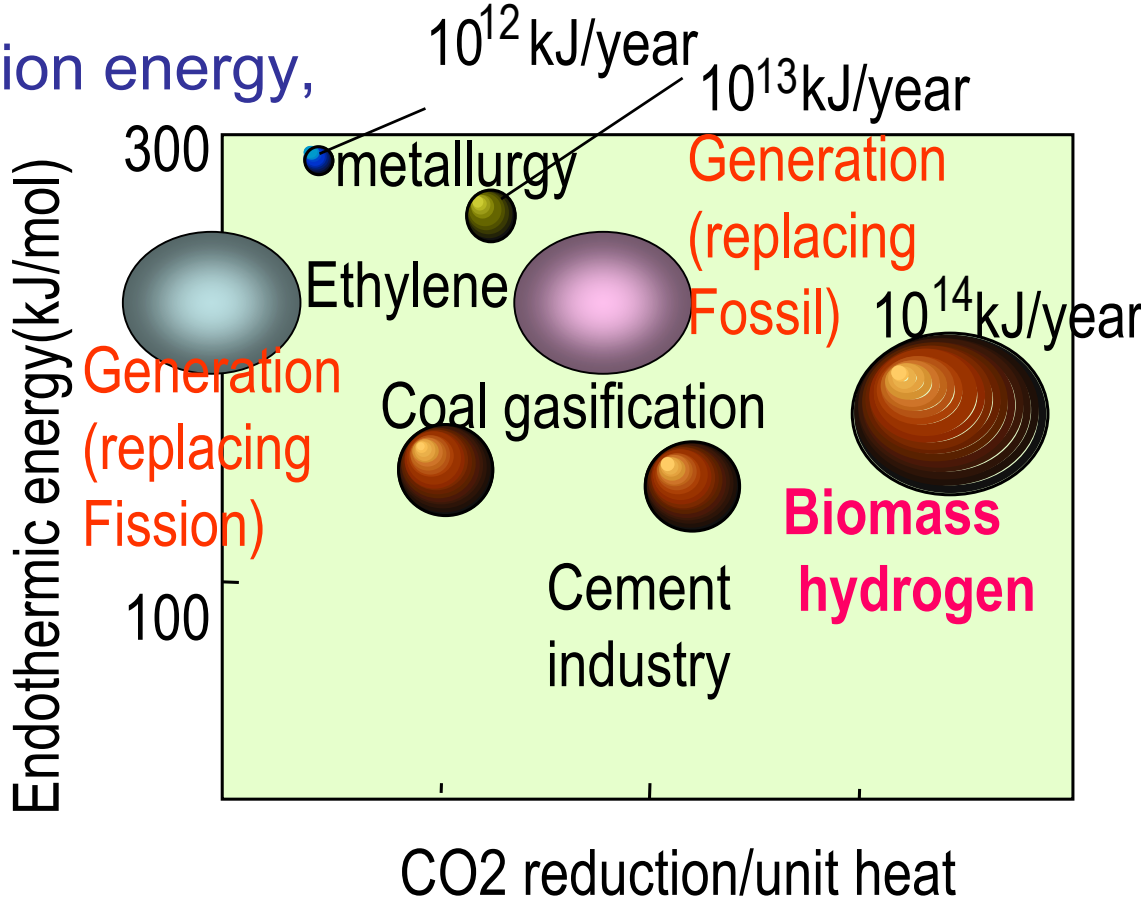
To utilize carbon-free fusion energy, criteria are;

- ○Endothermic
  - □□as transformation of fusion energy
- ○Reduce CO2 emission
  - □□Replacing fossil fuel with fusion
- ○Market scale
  - □□Large unit capacity



Electricity generation is a good option if fusion replaces fossil.
Biomass hydrogen saves fossil and generates larger energy.

Fusion and hydrogen market

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○Fusion has advantages for hydrogen systems.

..Serves various hydrogen production processes

..Fusion can improve in temperature by blanket development.

..High temperature application is suitable for hydrogen.

.. Fusion has less limitation in resource, site, environment, and nuclear proliferation.

..→suitable for deployment in developing countries.

○Hydrogen application provides fusion a better chance.

..Eventually larger market than electricity

..Global demands for fuel and its supply capability.

..Hydrogen requires both large scale source and remote supply. (Electricity and electrolysis)

..Blanket and energy plants can be developed independently.

.Possibly slower demand change than electricity.

Energy supply without fusion

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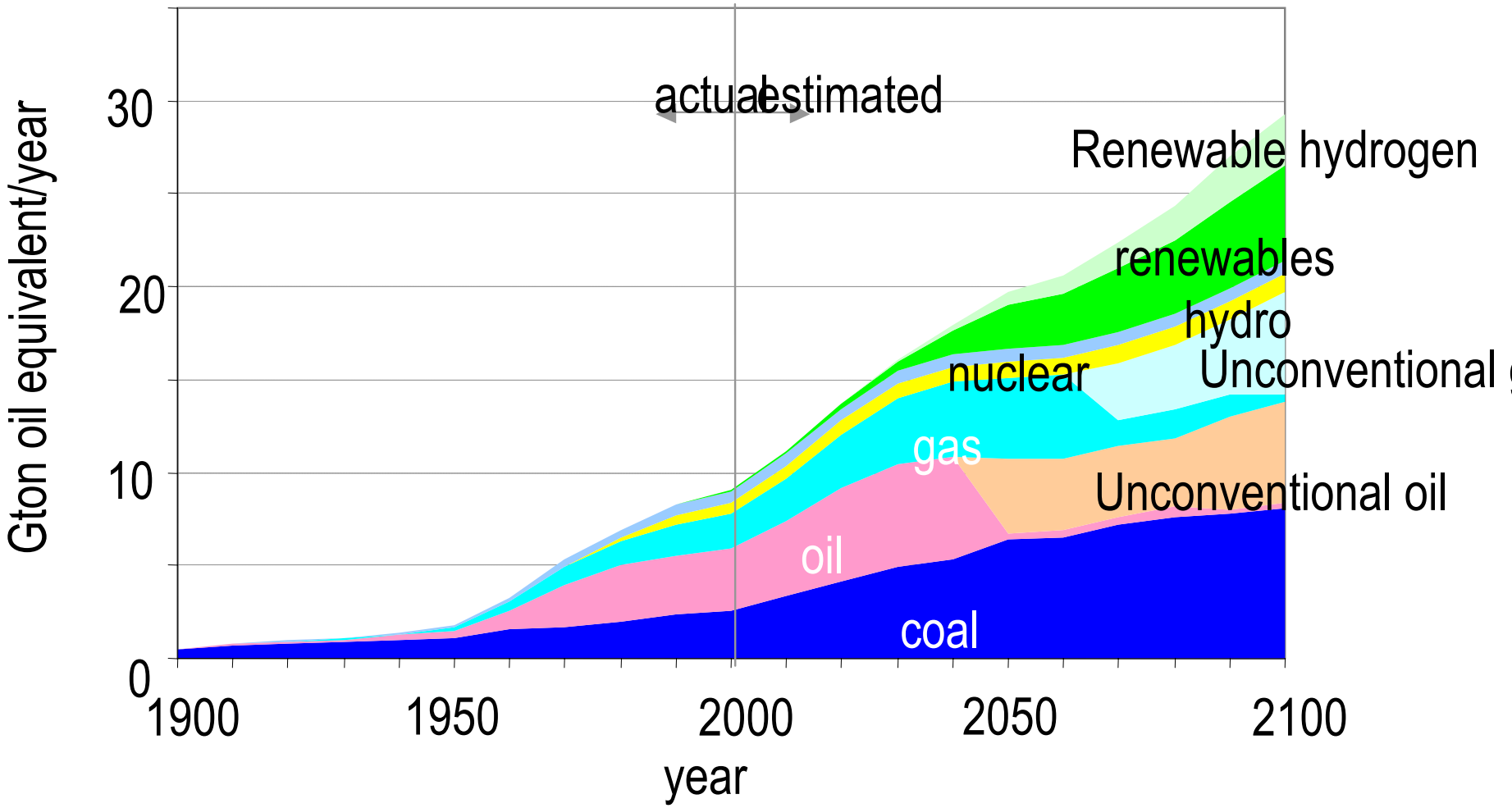

Fusion Electricity Share

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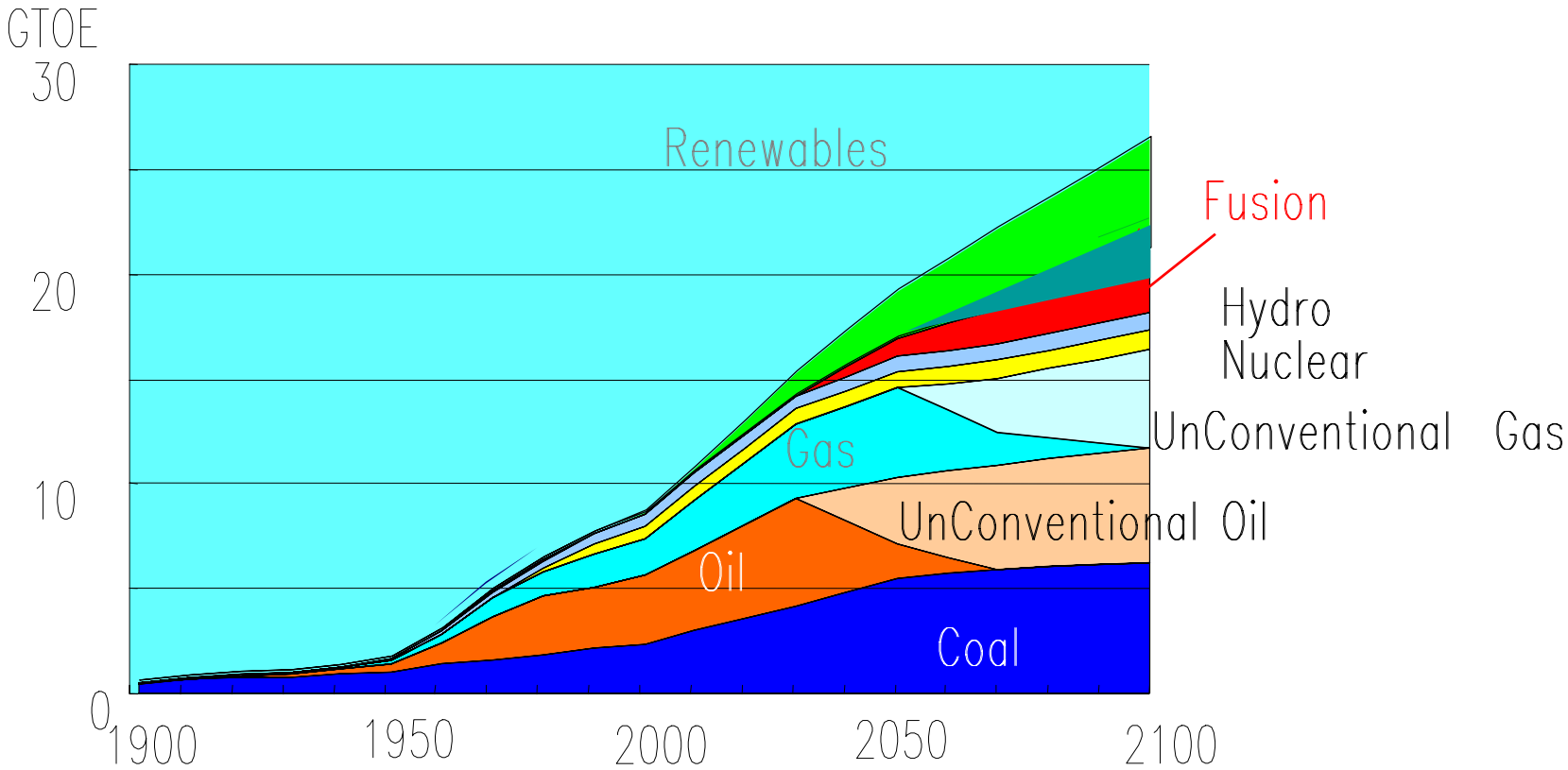

Fusion is estimated to have 10% share at 2100 under environmental constraint if successfully used for electricity.

Fusion Contribution with hydrogen

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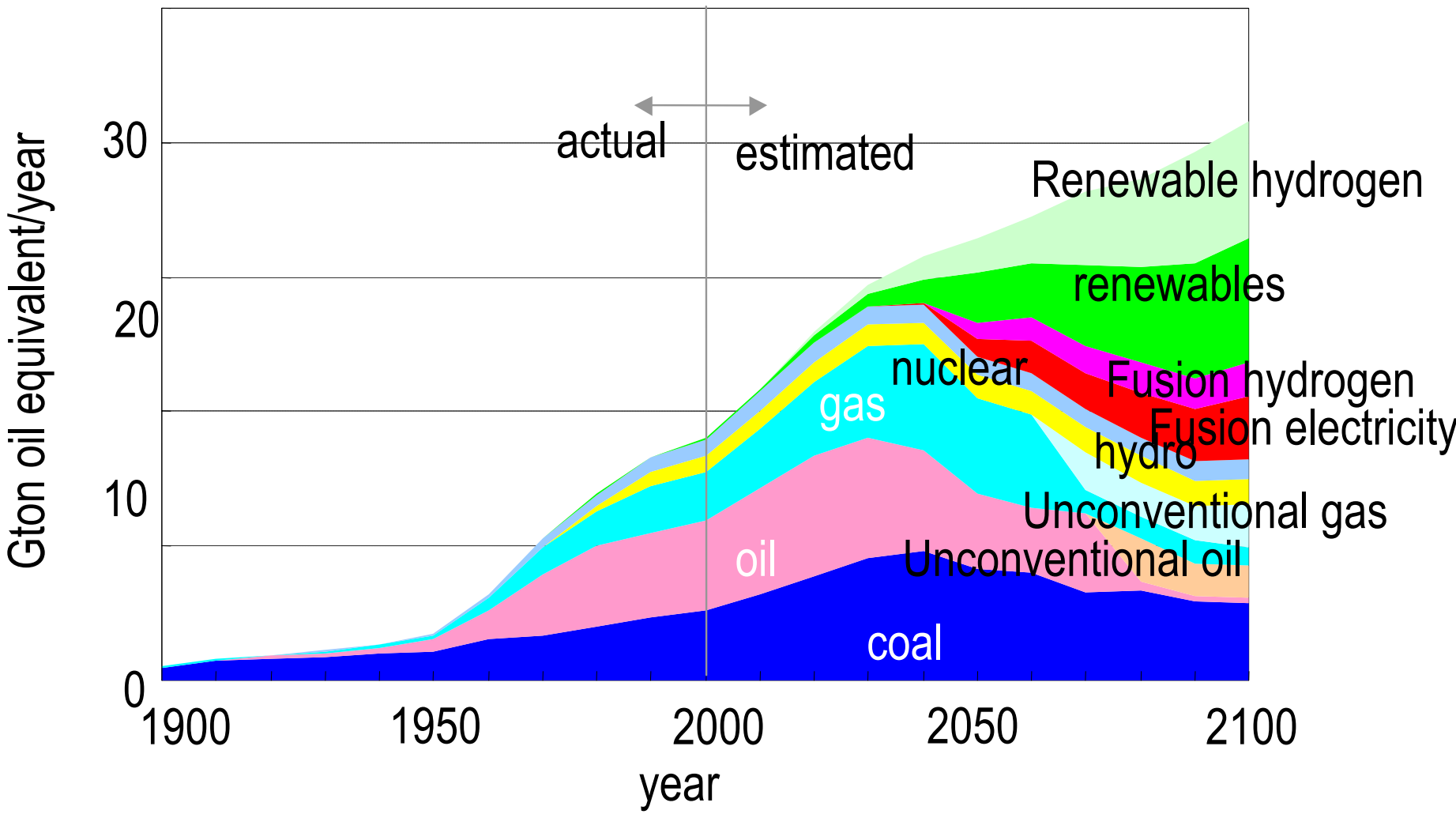

Scenario and Reduction of CO2

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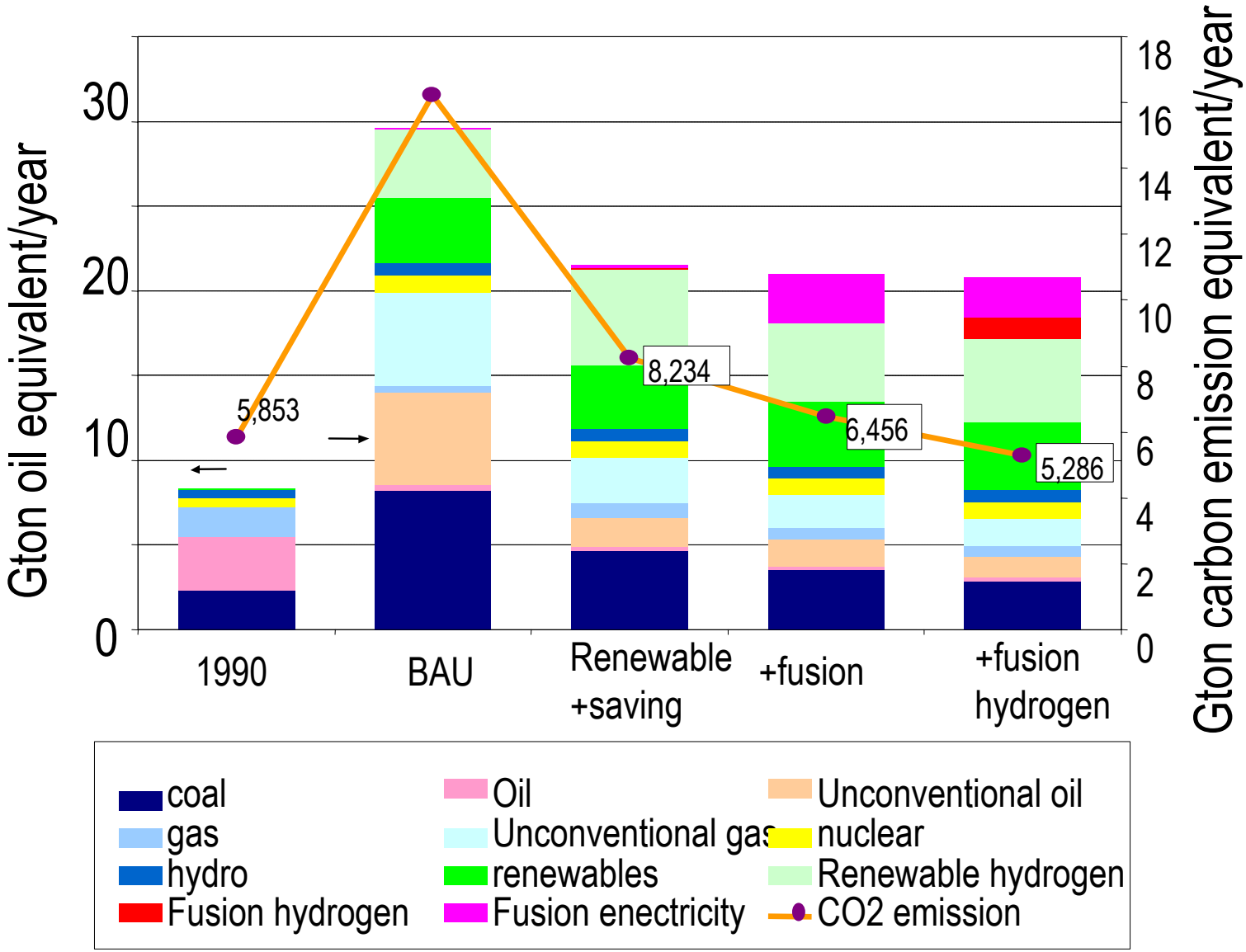


Advantage of fusion over other energy

○Possible high temperature

..impossible for PV, wind or LPRs.

..higher than FBR.

..Equivalent to HTGR.

○Site and location, deployment in developing country

..less limitation of nuclear fuel cycle, nuclear proliferation.

..while nuclear policies differ by the governments, fusion is internationally pursued.

..possible location near industrial area.

..independent from natural circumstance.

Conclusion

○Hydrogen replaces fossil fuel after 2050.

..while fossil is abundant, hydrogen is made from fossil.

..without expectation for large scale hydrogen production,hydrogen infrastructure will not be established.

..fusion and hydrogen fuel deployed at the same time.

○fusion provide various hydrogen production processes.

..conventional electrolysis will be the first generation.

..advanced blanket will serve vapor electrolysis, thermochemical processes.

..biomass hydrogen is expected to have advantages in environment, market and socio-economic issues.

..fusion have some advantages for deployment in developing countries.

Future world with fusion hydrogen

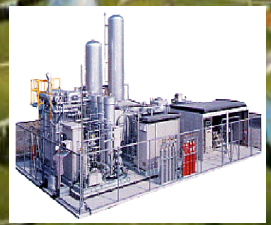
WASTE

RECYCLE

FUEL

Independen

Electricity



HEAT

Grid electrici

HYDROGEN

TRANSPORT

VEHICLE

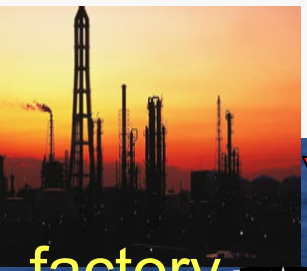
AIRCRAFT

Fusion Plant

Desalination

Of seawater

Future world with fusion hydrogen



factory

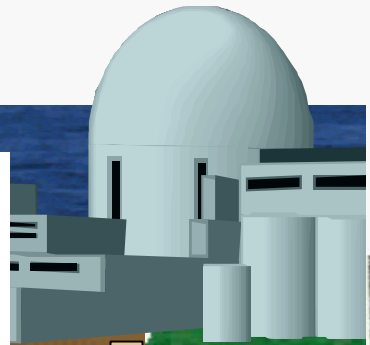
electricity

HYDROGEN

houses

Transport

Fusion Plant



Desalination Plant

Farming