MIZUHO

Energy Technology Vision 2100

Strategic Technology Roadmap in the Energy Field

29th Nov.'06

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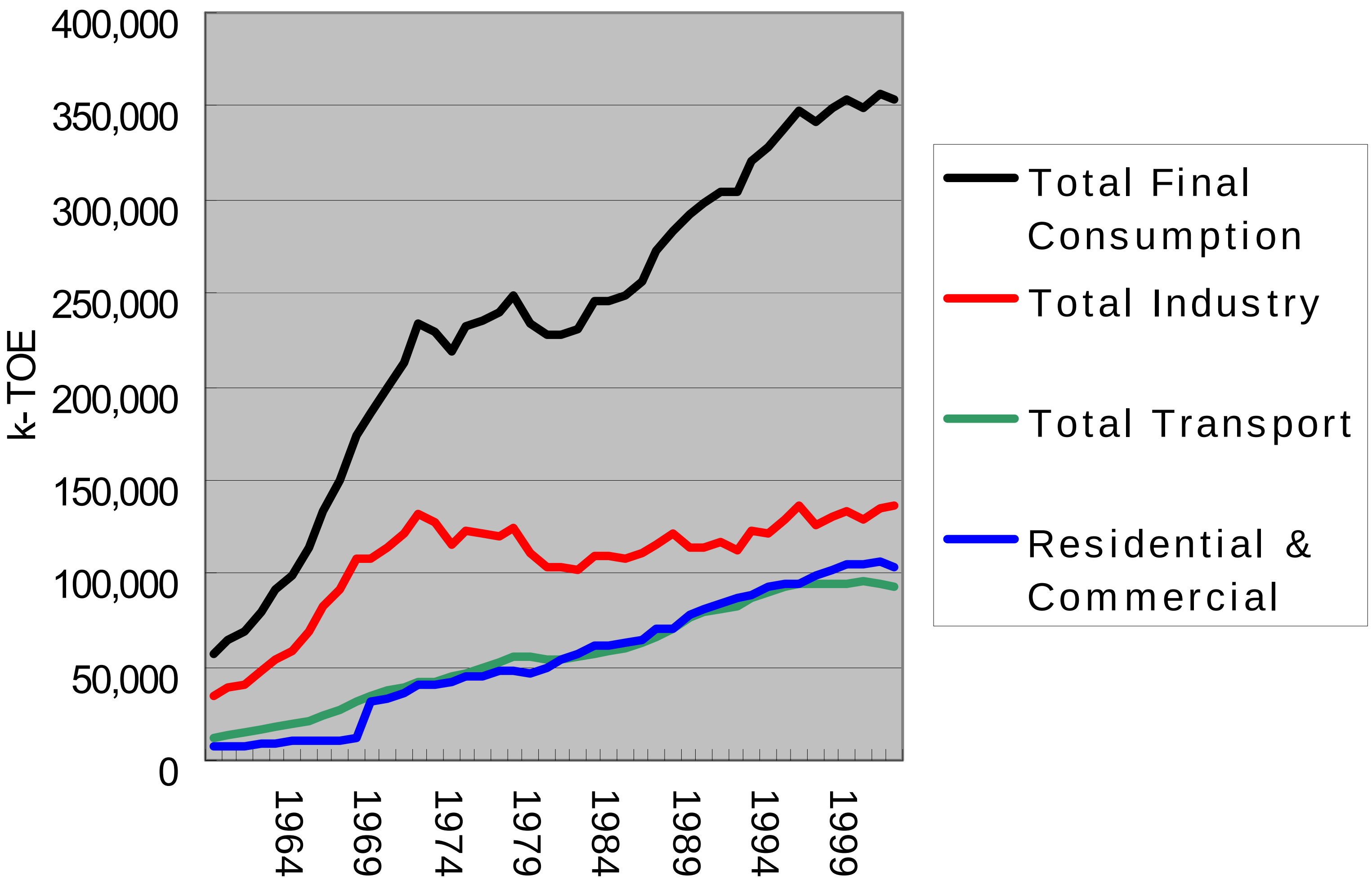
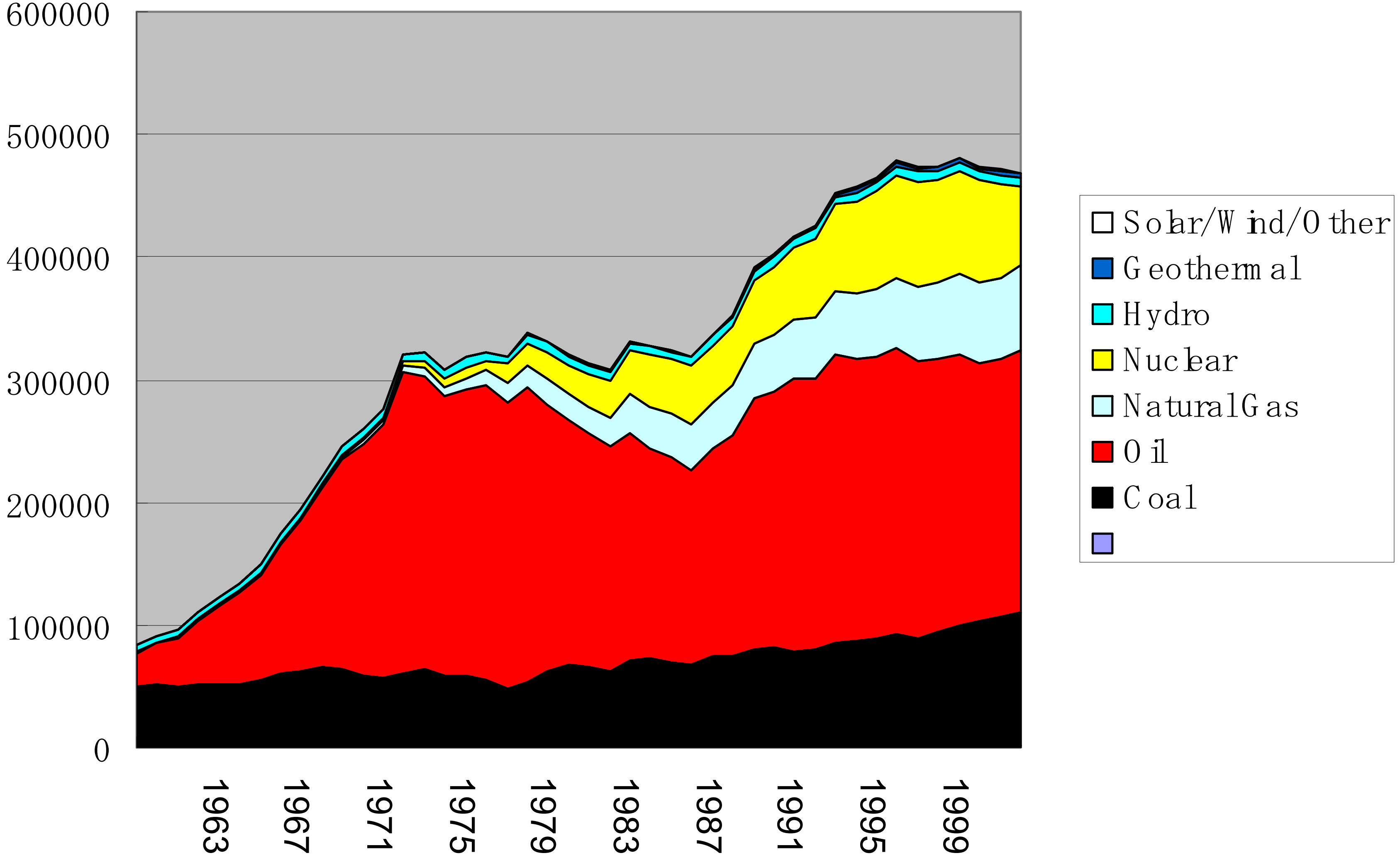
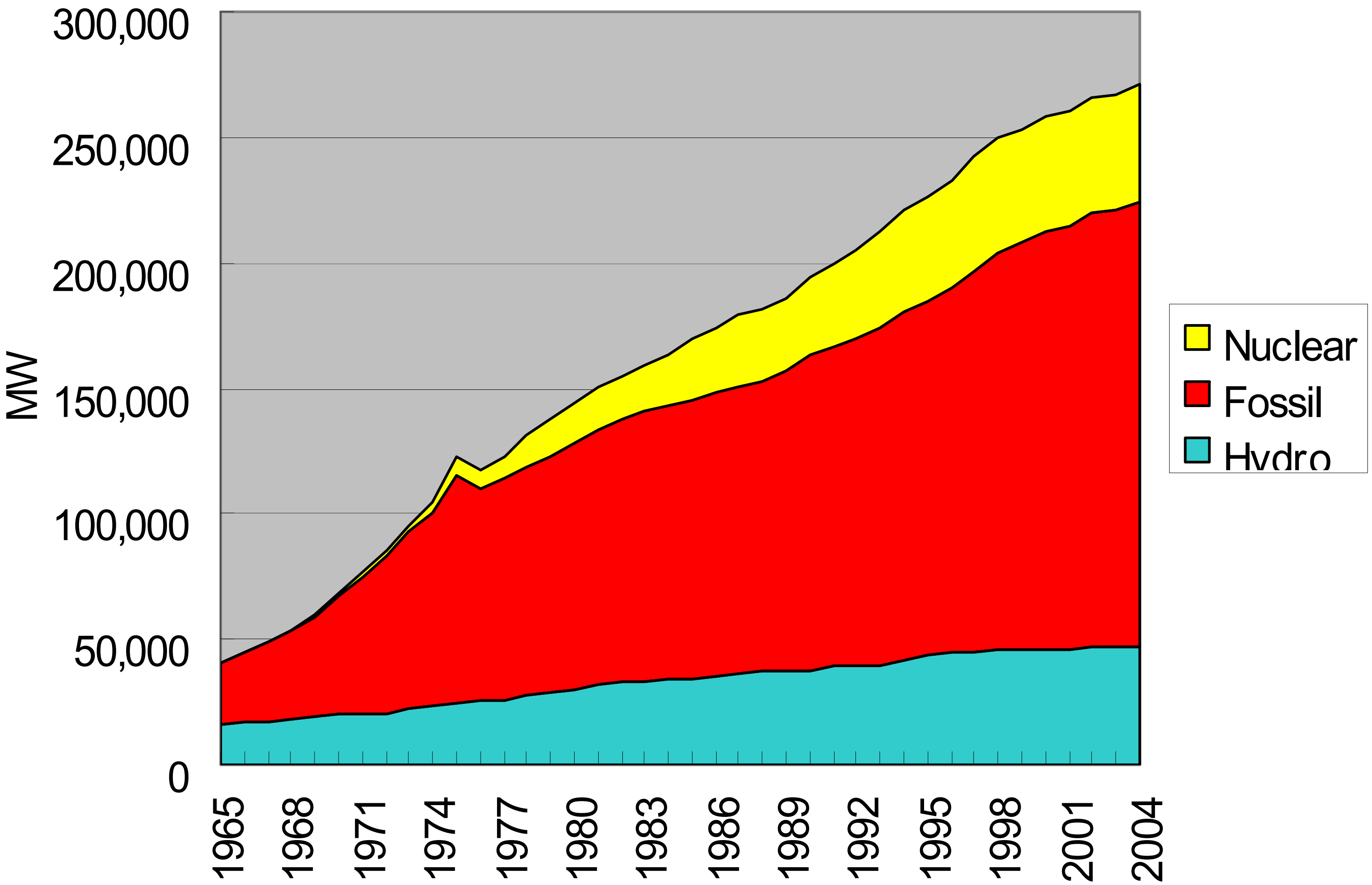
Final Energy Consumption in Japan



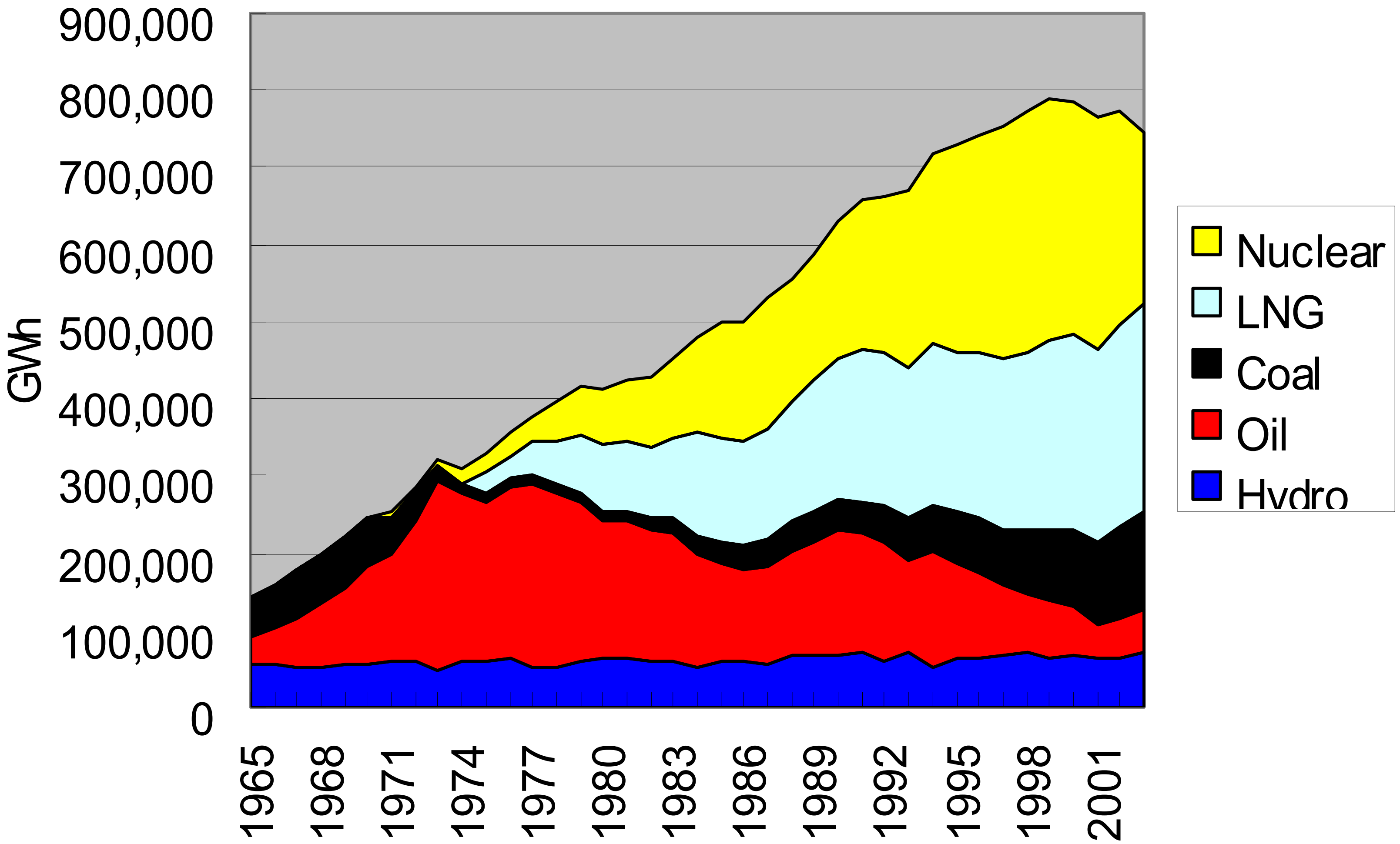
Primary Energy Supply in Japan



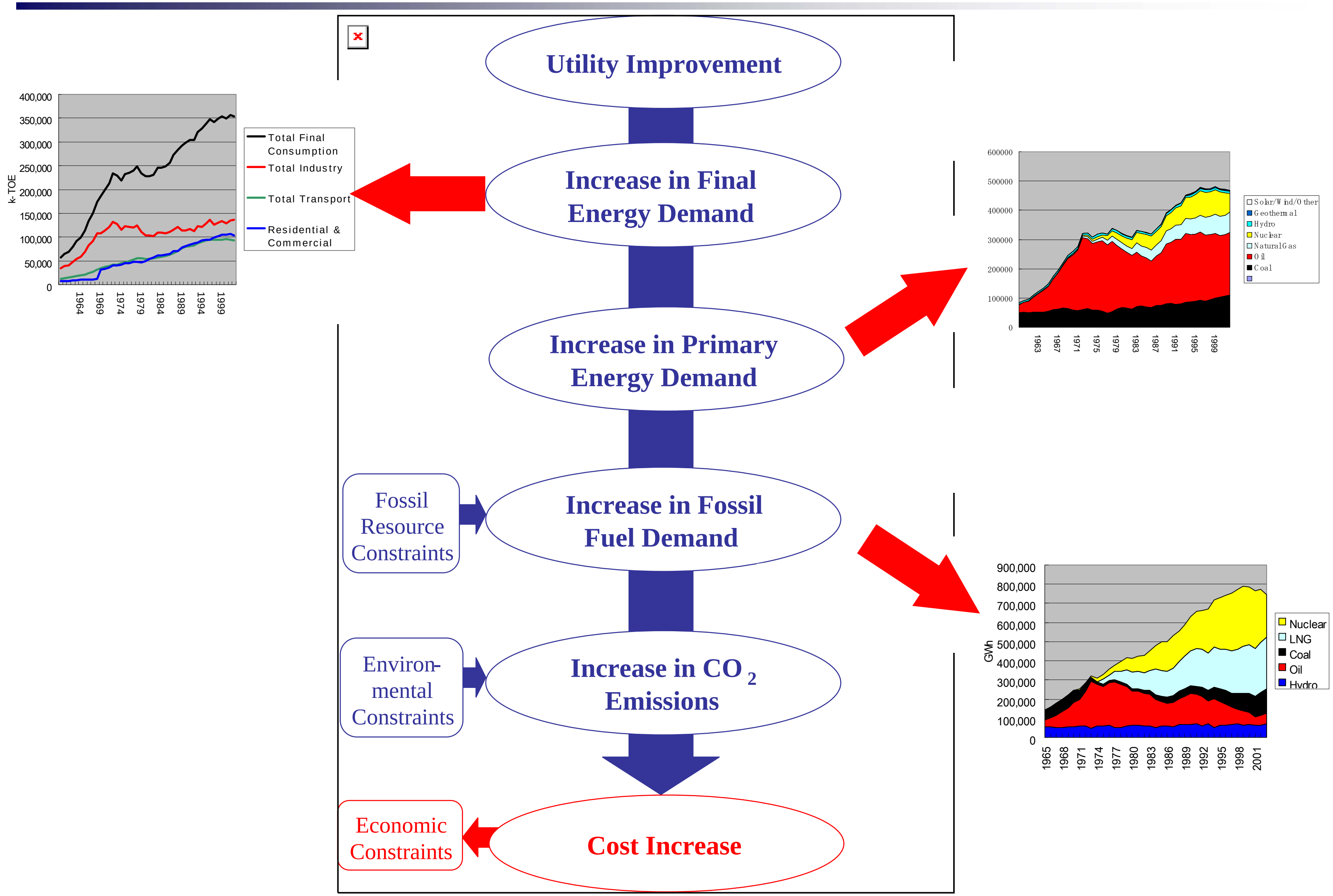
Power Plants Structure in Japan



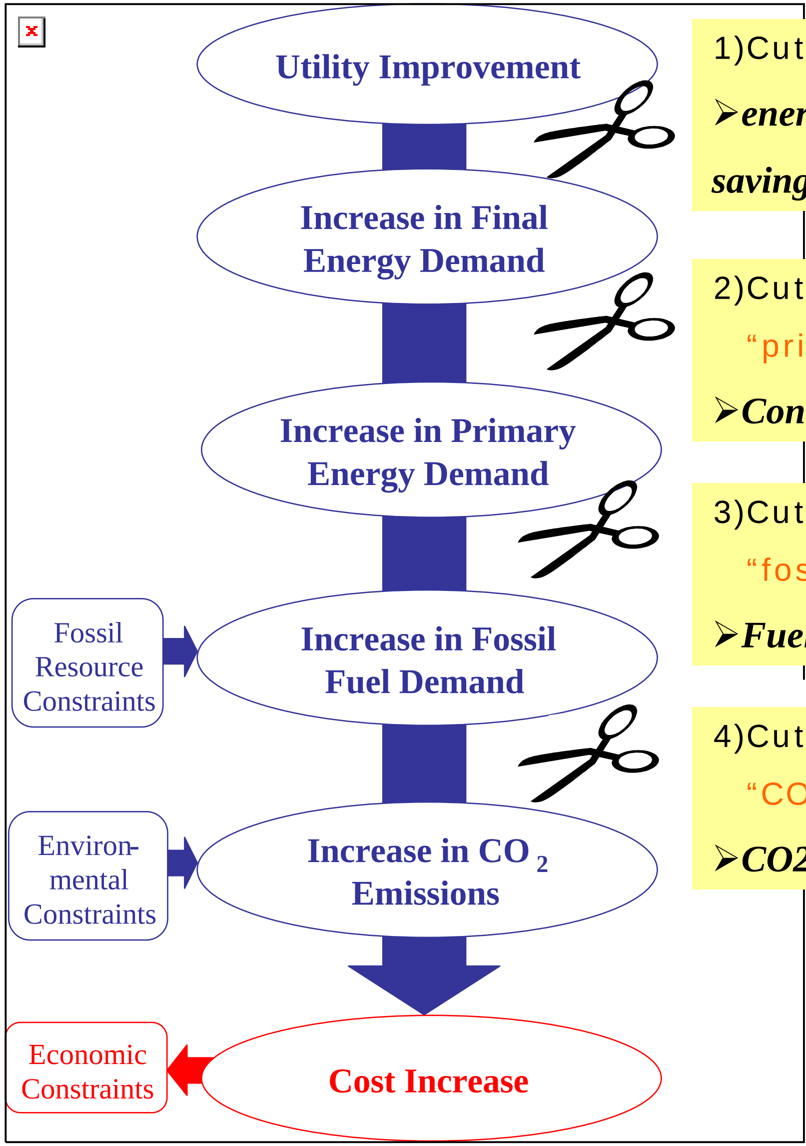
Source of Generated Power



A fundamental concept of measures



A fundamental concept of measures



1)Cut off the chain between "utility" and "energy demand"

➢***energy saving, efficiency improvement, self-sustaining, and material saving***

2)Cut off the chain between "final energy demand" and "primary energy demand"

➢***Conversion efficiency improvement***

3)Cut off the chain between "primary energy demand" and "fossil fuel demand"

➢***Fuel switching to non-fossil***

4)Cut off the chain between "fossil fuel demand" and "CO2 emissions"

➢***CO2 capture and sequestration***

Energy Technology Vision 2100

- Introduced by Ministry of Economy, Trade and Industry, METI
- To prioritize R&D based on the long-term vision
- Developed by "backcasting" method
- Excessive conditions on the 4 sectors

  residential/commercial

  transport

  industry

  energy transformation

Forecasting vs. Backcasting

	Forecasting	Backcasting
Question	what future is likely to happen?	how desirable futures can be attained?
Direction	exploratory (opportunity-oriented) from present to future	normative (goal-setting) from futures to present
Focus	prediction and likelihood	feasibility and choice
Execution	one-time snap-shot	on-going monitoring
Analysis	extrapolation from historical data	interpolation from goal setting (futures)
Quality	accuracy-dependent	implication-oriented
Result	converge on the most likely future	diverge to possible futures with respect to freedom of action
Future(s)	preceded by present assessment	interpreted and envisioned from present assessment

Goal Definition

- Based on the constraints of energy and environment
  - Population
  - Economy (GDP)
  - Resources (fossil fuels, nuclear fuels, etc.)
  - Environment (climate change)

$\Rightarrow$ ***Quantitative Target for 2100***

Population

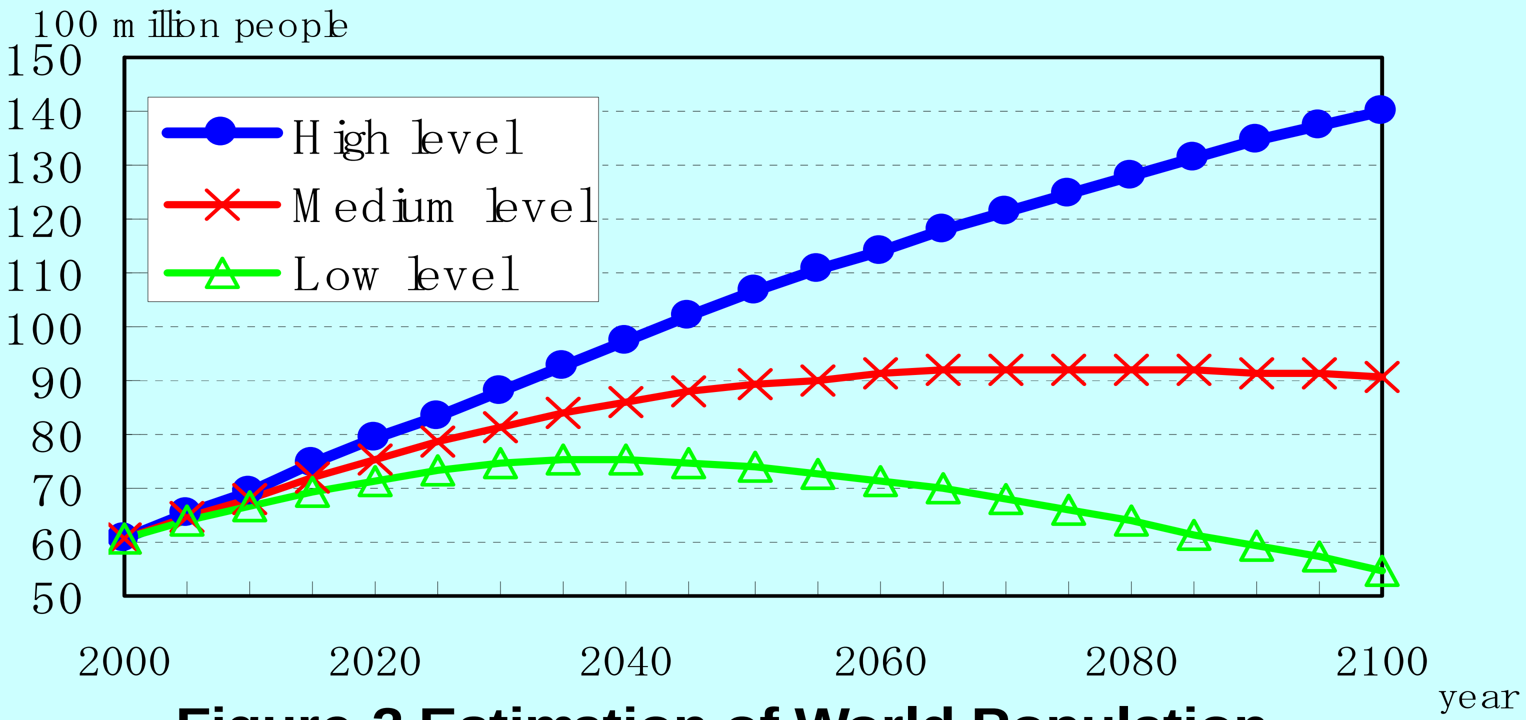
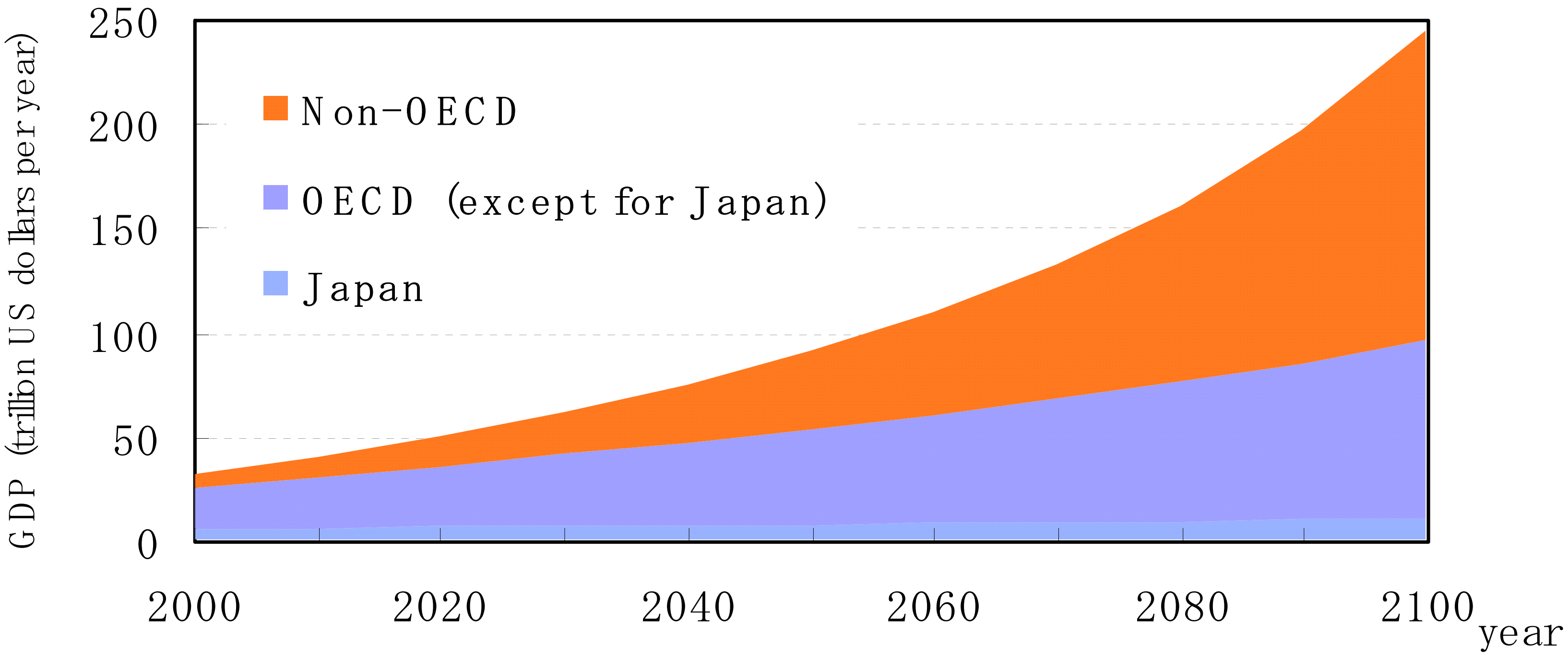


Figure 2.Estimation of World Population
(world population to the year 2300)

Economy

- Trial calculation of GDP (by an integrated assessment model - GRAPE)



- Also referring to IPCC scenarios

Resources - Fossil

	Oil	Natural gas	Coal
R/P ratio	40.6 years	60.7 years	204 years
Proved recoverable reserves	1,048 Bbbl	156 Gm^3	984.5 Bt
Annual production	27 Bbbl	2.5 Gm^3	4.83 Bt

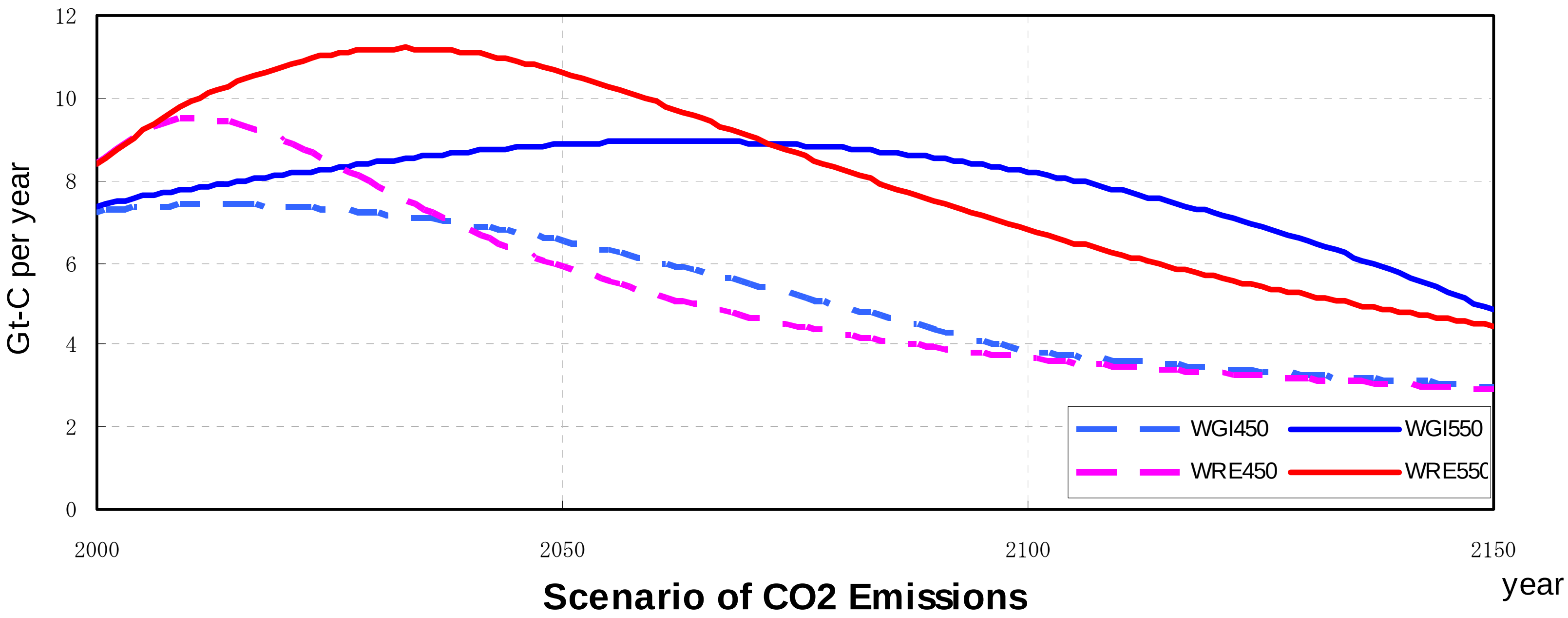
*** Source: oil, natural gas, coal: BP statistics 2003.**

Resources - Nuclear

Reactor/nuclear fuel cycle	Known resources of conventional types	Resources of conventional types (including known resources)
Present nuclear fuel cycle (Light-water reactor, once-through fuel cycle)	85 years	270 years
Nuclear fuel cycle (Pu, single cycle)	100 years	300 years
Light-water reactor And fast reactor (Combined recycle)	130 years	410 years
fuel cycle (Recycle)	2,550 years	8,500 years

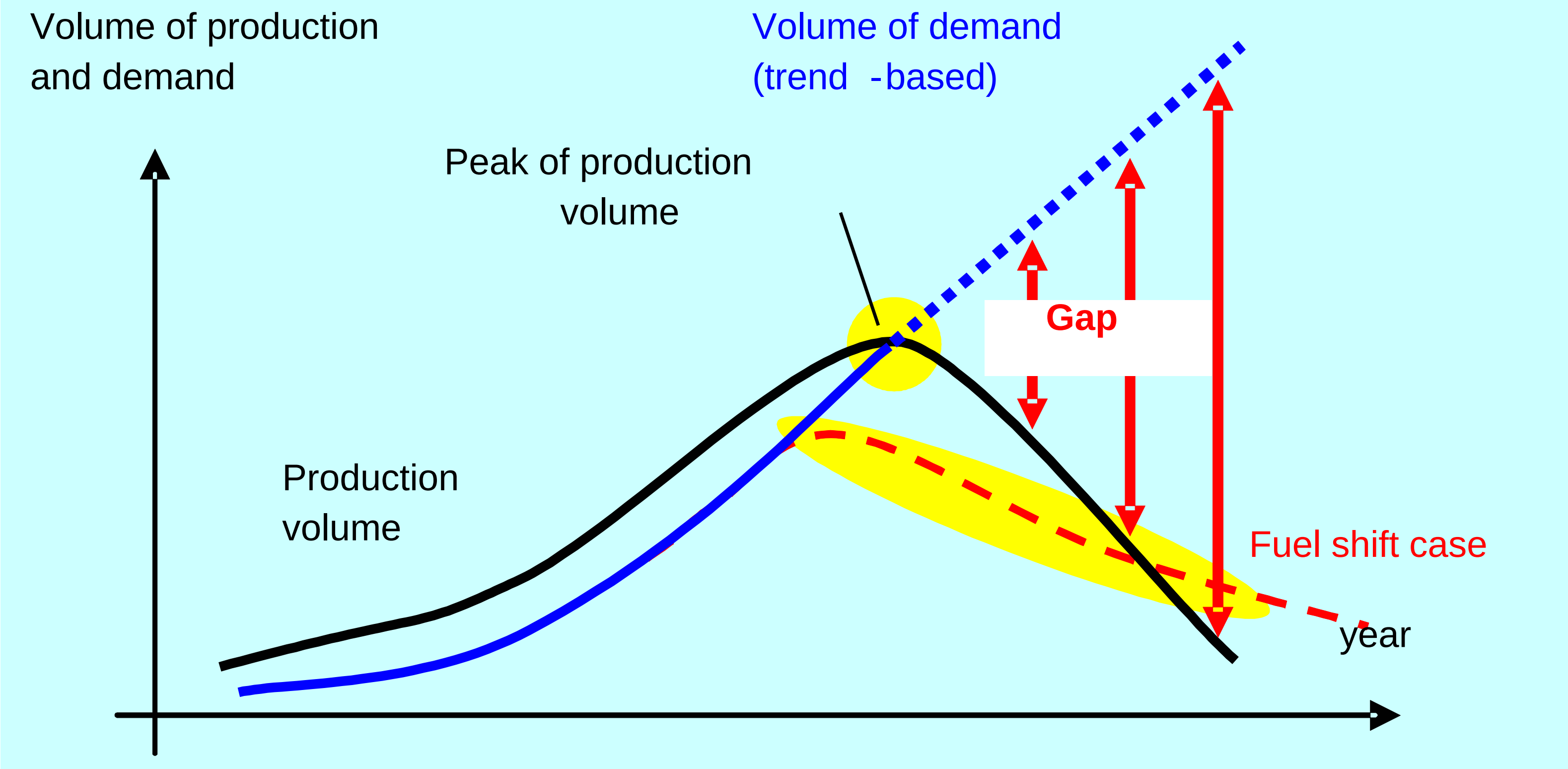
***Source: Uranium 2003, OECD/NEA.**

Environment – Climate Change



- Stabilization scenarios by WGI (IPCC WG1) and WRE (Wigley, Richels and Edmonds)

Surmounting Resource Constraint



Conceptual Diagram of Fuel Demand and Production

- If the demand continues to trend upward after the peak of production volume, the gap between the demand and production expands, and the balance of demand and supply is lost. Therefore, fuel shift is necessary before the peak.

(1)Assumption of constraints in the future

Global resource constraint:

>Oil production is assumed to peak in 2050

>Natural gas production is assumed to peak in 2100

Global environmental constraint:

>CO_2 emission intensity per GDP (CO_2/GDP) should be reduced to 1/3 in 2050 and less than 1/10 in 2100

Condition of the future image of technologies in Japan:

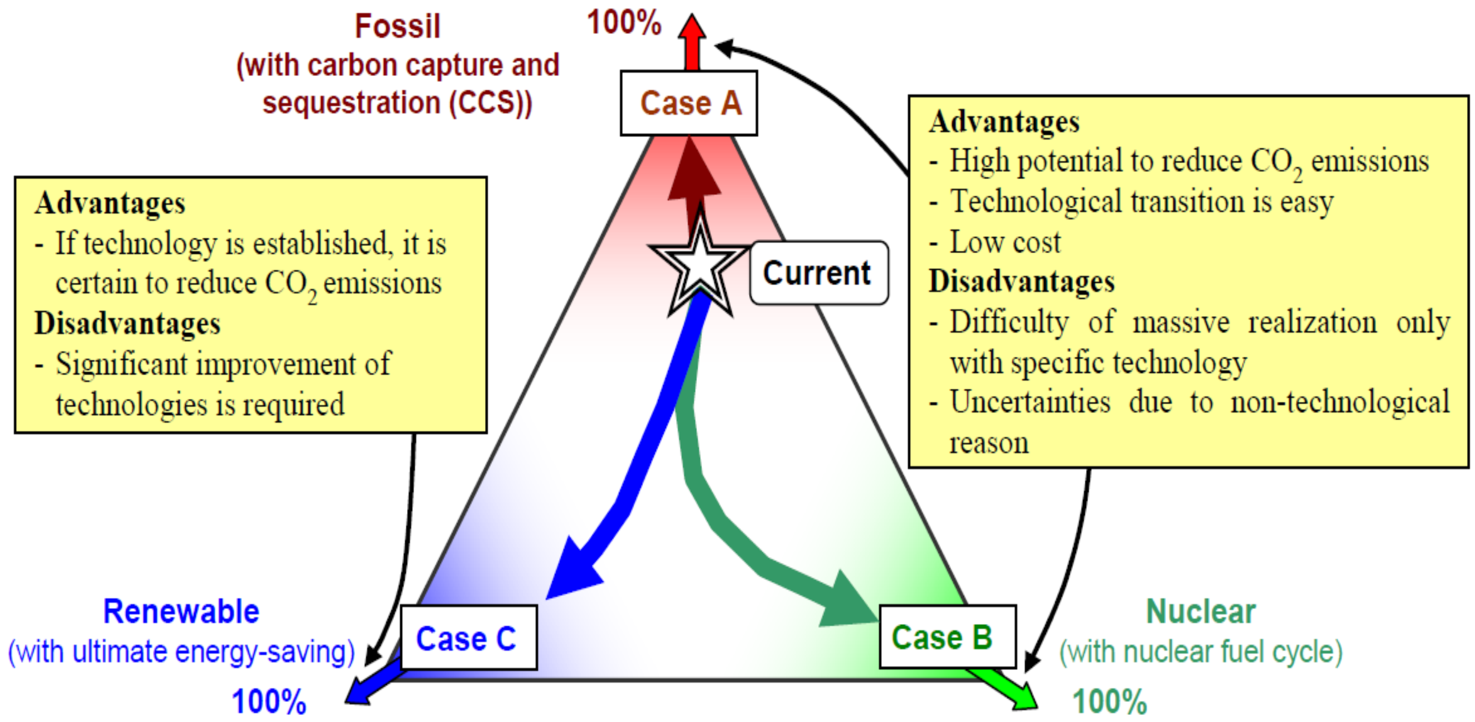
- Up to the production peaks, substitution of other energy resource should be realized

-CO_2 intensity should be reduced at the same ratio as above

➡ Japan leads the world into the foreseeable future

(2)Case studies under excessive conditions of energy structure

Case A: **Maximum use of fossil resources such as coal combined with CO_2 capture and sequestration**
Case B: **Maximum use of nuclear energy**
Case C: **Maximum use of renewable energy combined with ultimate energy-saving**

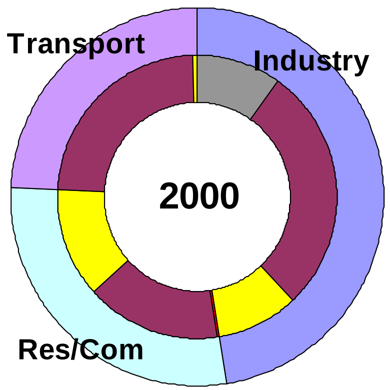


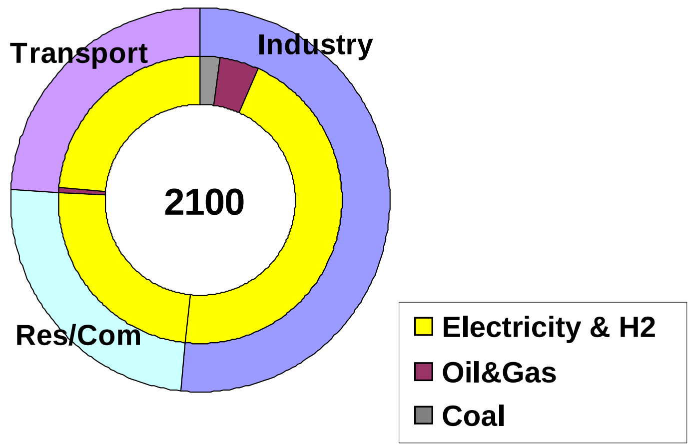
Images of the three cases of primary energy supply structures

Demand composition for each sector

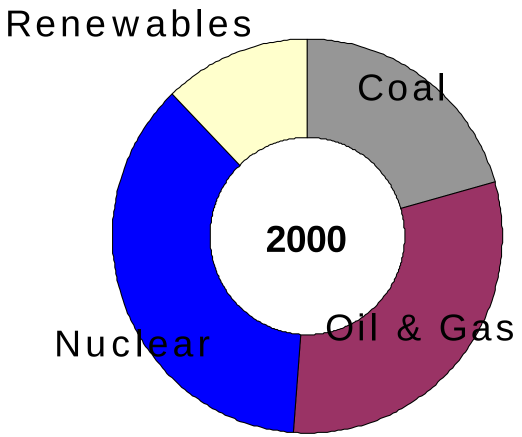
Composition of power generation and hydrogen production

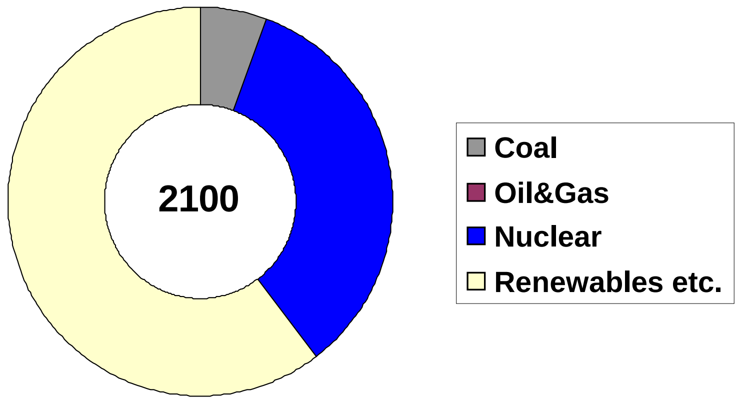
Demand composition for each sector



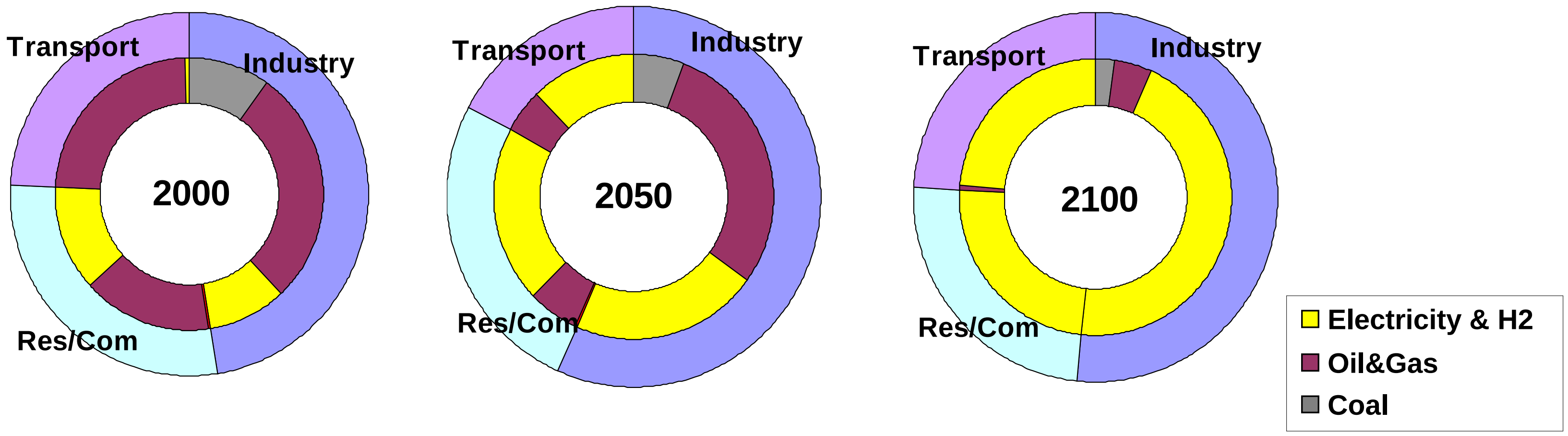


Composition of power generation and hydrogen production

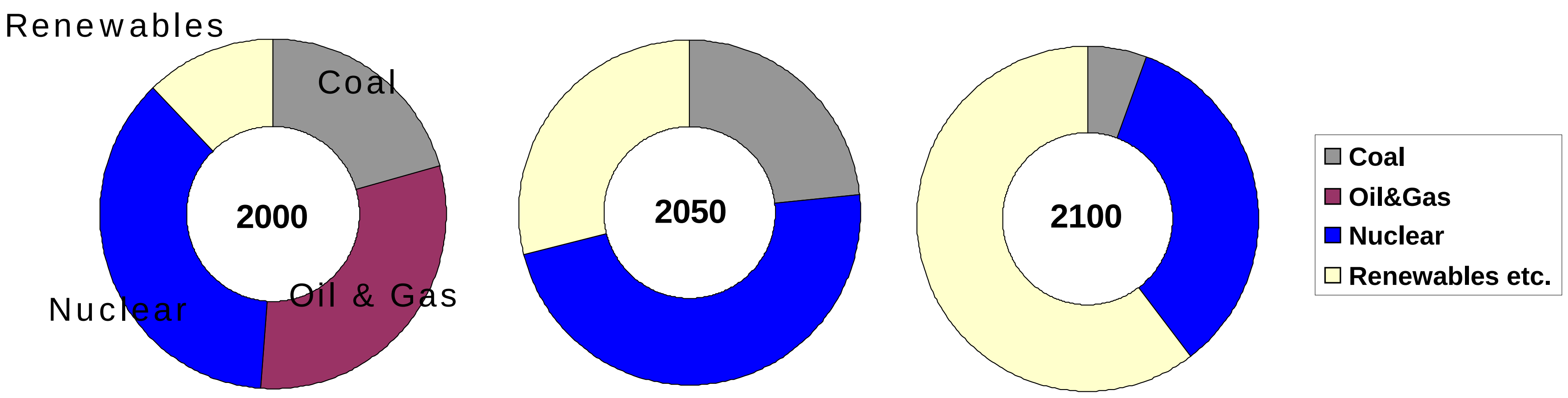




Demand composition for each sector



Composition of power generation and hydrogen production



(3) Extraction of technology specification which is required in each sector

(4) Expanding major technology menu which is needed to realize the technology specification along the time axis

Concept of technology specifications

(1) Common constraints of all cases and sectors

- Resource constraints:
  Up to the production peaks (oil: 2050, natural gas: 2100), substitution of other energy resources should be realized.

- Environmental constraints:
  CO_2 emissions intensity (CO_2/GDP) to be reduced to less than 1/3 in 2050 and 1/10 in 2100.

Concept of technology specifications in transport sector

>Utility will not decrease

-the utility (person·km and ton·km) increases in proportion to GDP

>The share will not change

- the share of each transport mode such as automobiles, aircraft, ships, and trains do not change.

>Contribution

-it aims at the energy saving for each utility of 70%
-the automobile sets the energy saving of 80%

>Both Hydrogen and electricity are welcome

-The share of electricity and/or hydrogen of 100% is necessary to achieve the technology specifications.

Concept of technology specifications in transport sector

All Transport Sector

	2000	2030	2050	2100
Utility Person-km, ton-km	**Unit**		**X 1.5**	**X 2.1**
Energy supplied from transformation sector	**Unit**	**- 20%**	**- 50%**	**- 70%**

Automobiles

Energy demand		**- 30%**	**- 60%**	**- 80%**
Share of Electricity and/or H2	**0%**	**1% ~**	**40%**	**100%**
CO2 intensity (CO2 / km)	**160g**	**100g**	**50g**	**ZERO**

Transport

	2000	2030	2050	2100
Utility (person-km, ton-km)	1 time		1.5 times	2.1 times
Energy supplied from transformation sector* (overall)		20% reduction	50% reduction	70% reduction
Automobiles — Energy demand		30% reduction	60% reduction	80% reduction
Automobiles — Share of electricity and/or hydrogen	0%	1% or more	40%	100%
Automobiles — CO_2 intensity	160 g-CO_2/km (1 time)	100 g-CO_2/km (2/3 times)	50 g-CO_2/km (1/3 times)	0 g-CO_2/km → Consequentially, 1/10 or less is achieved.
Aircraft, ships, and trains — Energy demand		10-20% reduction	20-35% reduction	30-50% reduction

*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with utility increases in proportion to GDP.

Energy Conservation

Automobiles

(Engine) → *Engine/Electric motor (hybrid system)* → *Electric motor Fuel cell/Battery*

Energy saving by vehicle weight reduction — *Super-light compact cars for regional use*

0 g-CO_2/km (Automobiles)

Liquid fuel (Oil) → *Synthetic fuel (mixture)*; *Biomass fuel (mixture)*

Hydrogen storage: *Compressed hydrogen → liquid hydrogen, hydrogen storage material*

Hydrogen supply: *Batch transportation → Effective on-site production → pipeline transportation (limited region)*

Electric energy storage: *Battery and capacitor, etc.*

Electricity supply: *Cable-connected charge → Cable-less non-contact charge*

Aircraft

Ships

Trains

Transport systems

Engine efficiency improvement

Energy saving by body weight reduction

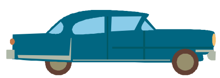
Hybrid drive

Hydrogen drive, Superconducting motor drive

Ship enlargement, Low-speed operation

Energy saving by transport system cooperation

Fuel switch



Transport

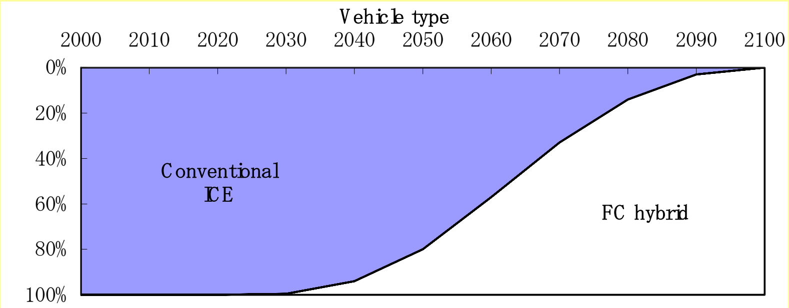
Transport-4

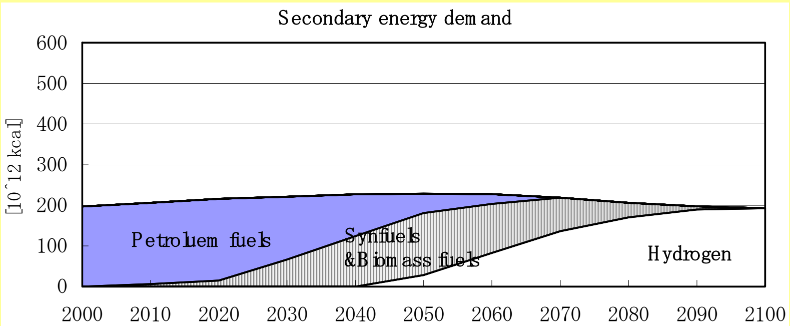
Image of share

according to vehicle type and secondary energy demand

Long distance vehicles

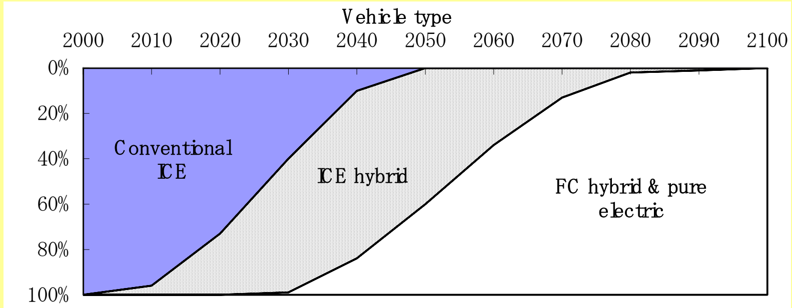
(heavy-duty truck etc.)

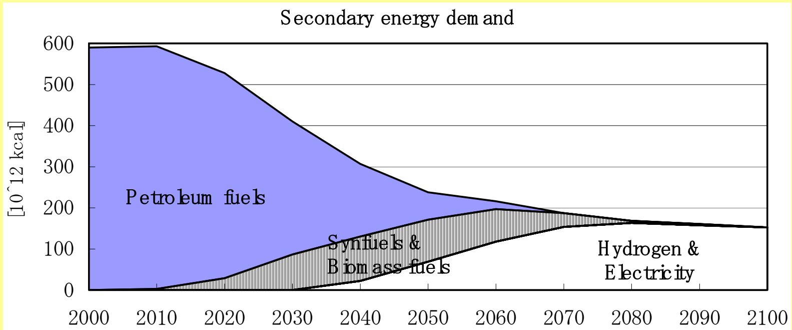




Intraregional running cars

(passenger cars and pickup trucks, etc.)





Industry

	2000	2030	2050	2100
(Production) X (Value of product)	1 time		1.5 times	2.1 times
Energy supplied from transformation sector*		25% reduction	40% reduction	70% reduction
1) Production energy intensity		20% reduction	30% reduction	50% reduction
2) Material/energy regeneration ratio		50%	60%	80%
3) Improvement of functionality such high-strength etc. (functionality / amount of material)	1 time	2 times	3 times	4 times

*The percentage of reduction of energy per utility (production x value of product) should be supplied from transformation sector, compared with the case where total energy demand increases in proportion to GDP.

High level of energy use at production process ***"create skillfully"***

(Energy saving in process)

Development of innovative production process
Use of bio/nano catalyst etc

Zero-emission process

Cogeneration & cascade use of heat

Integration and cooperation of material and energy

Co-production
(simultaneous production of material and energy)

(Fossil resource use) →

Biomass/hydrogen use

Regeneration of material/energy ***"use skillfully"***

Efficiency improvement of material regeneration process

Regeneration and utilization of material/energy in products

Regeneration & utilization of material/energy beyond sectors

Cross-boundary measures beyond sectors

Design technique for easy separation & sorting

Durability improvement

Improvement of functionality of material and parts

Material saving of products

Industry

Energy reduction for production with few resources ***"create good things"***

Transformation

	2000	2030	2050	2100
Total energy demand on the demand side (maximum case)	1 time		1.5 times	2.1 times
Share of electricity and/or hydrogen in final energy	1 time		2 times (Case A and C) 3 times (Case B)	4 times (Case A and B) 3 times (Case C)
CO_2 Intensity	370 g-CO_2/kWh (1 time)	270 g-CO_2/kWh (2/3 times)	120 g-CO_2/kWh (1/3 times)	0 g-CO_2/kWh *110 g-CO_2/kWh (1/3 times)* *In the case of fossil fuel use with CCS*

Reduction in fossil use

Efficiency improvement of fossil fuel use

Fuel switching and efficiency improvement

(oil) → *Natural gas*

(coal) → *Coal (clean coal technology + CO_2 capture and sequestration (CCS))*

0 t-CO_2/kWh

Nuclear energy use

Nuclear fuel cycle

Load following operation

Efficiency improvement

Renewable energy use

Solar — *Technology that can be set up in all places such as roads and dams*

Geothermal

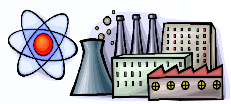
Wind power — *Onshore* → *Offshore*

Biomass — *Wood and biomass (waste and unused biomass)* → *Fuel crops production*

Efficiency improvement

Installation simplification

Energy storage



Transformation

Introduction of non-fossil energy

Res/Com

		2000	2030	2050	2100
Total energy demand		1 time		1.5 times	2.1 times
Energy supplied from transformation sector*	Residential		45% reduction	60% reduction	80% reduction
	Commercial		35% reduction	55% reduction	80% reduction
CO_2 intensity	Residential	3.5 t-CO_2/household (1 time)	1.9 t-CO_2/household (1/2 times)	1.1 t-CO_2/household (1/3 times)	0 t-CO_2/household
	Commercial	118 kg-CO_2/m^2 (1 time)	77 kg-CO_2/m^2 (2/3 times)	40 kg-CO_2/m^2 (1/3 times)	0 kg-CO_2/m^2

*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with total energy demand increases in proportion to GDP.

Energy saving

Efficiency improvement of equipment

Lighting with less heat loss *Equipment with less heat loss*

Improving thermal performance of housing and building → *Active control of sun shading and thermal insulation*

Efficient heating → *Efficient heat transfer, preheating by unused energy*

Improving electric power conversion efficiency → *Electric power conversion with least loss*

Food storage at room temperature

Self-sustaining

Use of ubiquitous energy
(minute pressure, temperature difference, vibration, radiowaves, etc.)

Energy saving enables equipment using little energy

Energy creation from ubiquitous energy

0 t-CO_2/household

0 kg-CO_2/m^2

Photovoltaic generation

Installation in all places such as PV paint

Installation in windows

Installation in curved surfaces

Installation facilitation

Energy creation *Efficiency improvement and increase of durability*

Residential Commercial

Energy management

BEMS•HEMS

Self-sustainable housing and building

Demand management → *Management of demand and energy creation* → *Energy accommodation in community*

(Energy supply in community) → *Supply and storage management in community* → *Supply and demand management in community*

TEMS **Self-sustainable community**

Thank you !

For detail :

http://www.iae.or.jp/2100.html

Energy Technology Vision 2100

Appendix

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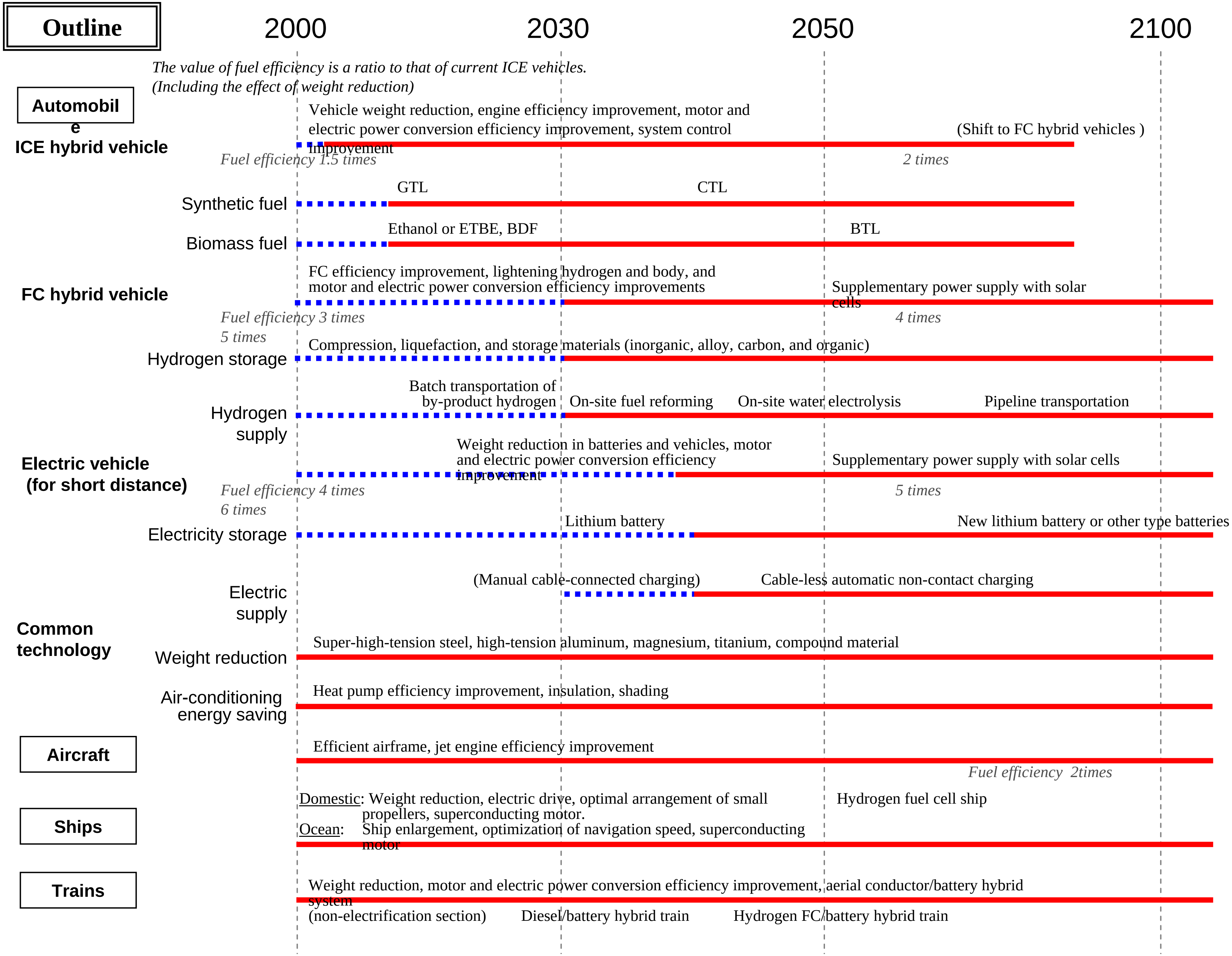
MIZUHO Information and Research Institute Inc.

Outline



2000
2030
2050
2100
The value of fuel efficiency is a ratio to that of current ICE vehicles.
(Including the effect of weight reduction)
Automobile
ICE hybrid vehicle
Vehicle weight reduction, engine efficiency improvement, motor and electric power conversion efficiency improvement, system control improvement
(Shift to FC hybrid vehicles)
Fuel efficiency 1.5 times
2 times
Synthetic fuel
GTL
CTL
Biomass fuel
Ethanol or ETBE, BDF
BTL
FC hybrid vehicle
FC efficiency improvement, lightening hydrogen and body, and motor and electric power conversion efficiency improvements
Supplementary power supply with solar cells
Fuel efficiency 3 times
4 times
5 times
Hydrogen storage
Compression, liquefaction, and storage materials (inorganic, alloy, carbon, and organic)
Hydrogen supply
Batch transportation of by-product hydrogen
On-site fuel reforming
On-site water electrolysis
Pipeline transportation
Electric vehicle (for short distance)
Weight reduction in batteries and vehicles, motor and electric power conversion efficiency improvement
Supplementary power supply with solar cells
Fuel efficiency 4 times
5 times
6 times
Electricity storage
Lithium battery
New lithium battery or other type batteries
Electric supply
(Manual cable-connected charging)
Cable-less automatic non-contact charging
Common technology
Weight reduction
Super-high-tension steel, high-tension aluminum, magnesium, titanium, compound material
Air-conditioning energy saving
Heat pump efficiency improvement, insulation, shading
Aircraft
Efficient airframe, jet engine efficiency improvement
Fuel efficiency 2times
Ships
Domestic: Weight reduction, electric drive, optimal arrangement of small propellers, superconducting motor.
Ocean: Ship enlargement, optimization of navigation speed, superconducting motor
Hydrogen fuel cell ship
Trains
Weight reduction, motor and electric power conversion efficiency improvement, aerial conductor/battery hybrid system
(non-electrification section)
Diesel/battery hybrid train
Hydrogen FC/battery hybrid train

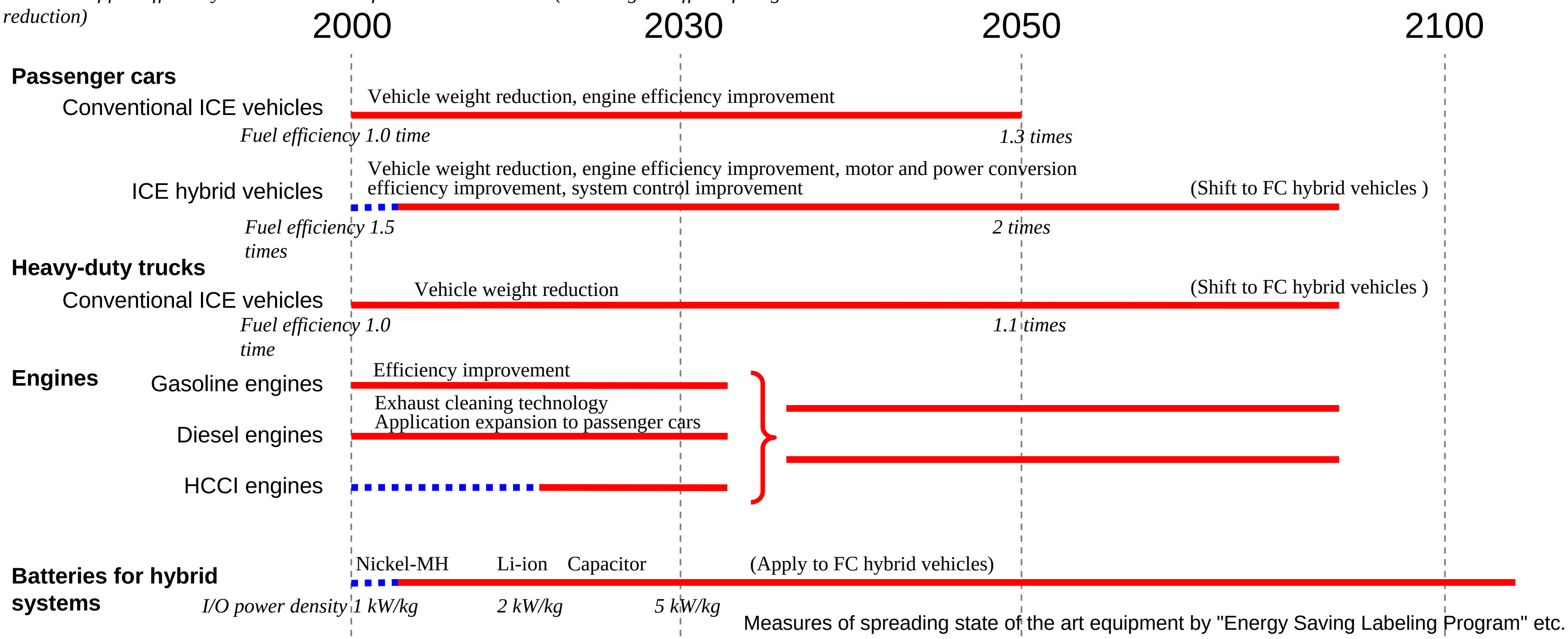
Efficiency improvement of automobiles

- The amount of utility (≈ vehicle number × running distance) supplied by automobiles increases in proportion to GDP.
- The efficiency improvement in power trains and energy saving by weight reduction is necessary to improve energy intensity.
- In order to decrease energy intensity and CO_2 intensity drastically in the future, hydrogen fuel cell vehicles or electric vehicles that have high efficiency and don't emit CO_2 should become mainstream.

Internal combustion engine (ICE) hybrid vehicles

- As for vehicles mainly used for intraregional driving such as pickup trucks and passenger cars, the shift to a hybrid system will progress, and non-hybrid vehicles will not be used by about 2050.
- The use of ICE hybrid vehicles for long-distance vehicles such as heavy-duty trucks will not advance because the advantage of hybridization is small (shift directly from conventional ICE vehicles to FC vehicle).
- Fuel efficiency improvement by weight reduction is expected for both conventional vehicles and hybrid vehicles.
- All ICE vehicles will disappear by 2100.
- When the HCCI engine is put to practical use, three kinds of engines will be integrated into two kinds (or even one).

The value of fuel efficiency is a ratio to that of current ICE vehicles (including the effect of weight reduction)

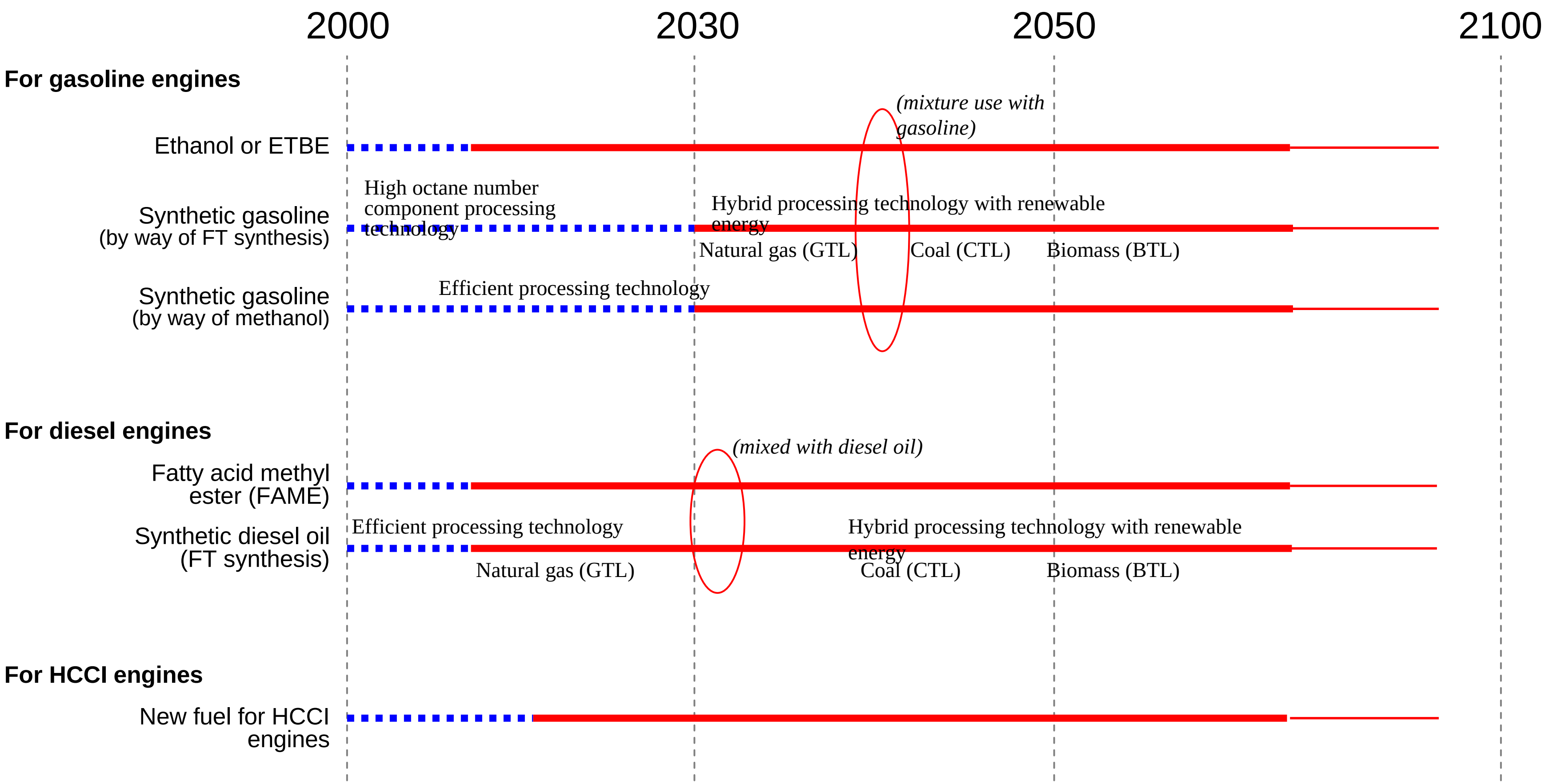


Non-technical factors

- Measures for the improvement of fuel efficiency by the "Top Runner Standards" of "Energy Saving Labeling Program" etc.
- Taxation discount and subsidies to gas-sipper (fuel efficient cars)

Fuels for internal combustion engine vehicles

- Fuels for ICE will shift from petroleum fuels to synthetic fuels by 2050. During the shift process, mixed petroleum fuels and synthetic fuels are assumed.
- Ethanol (or ETBE) and FAME have the possibility to be introduced in the early stage, but neither of them become a main component of the fuels due to their restricted supply.
- FT synthesis oil will be introduced as a blend component to diesel oil at first. In order to use FT synthesis oil for gasoline engines, processing technology development for high octane number fuel is necessary. The application will be later than that for the diesel engine. Also, synthetic gasoline by way of methanol produced from natural gas or coal may be used.
- The specifications of the fuel for HCCI engines are uncertain at the present time. There is the possibility that the fuels will be integrated into two kinds (or even one) in association with the integration of engines.
- Additionally, the use of DME, CNG, and LPG contributes to oil substitution and CO_2 emissions reduction.



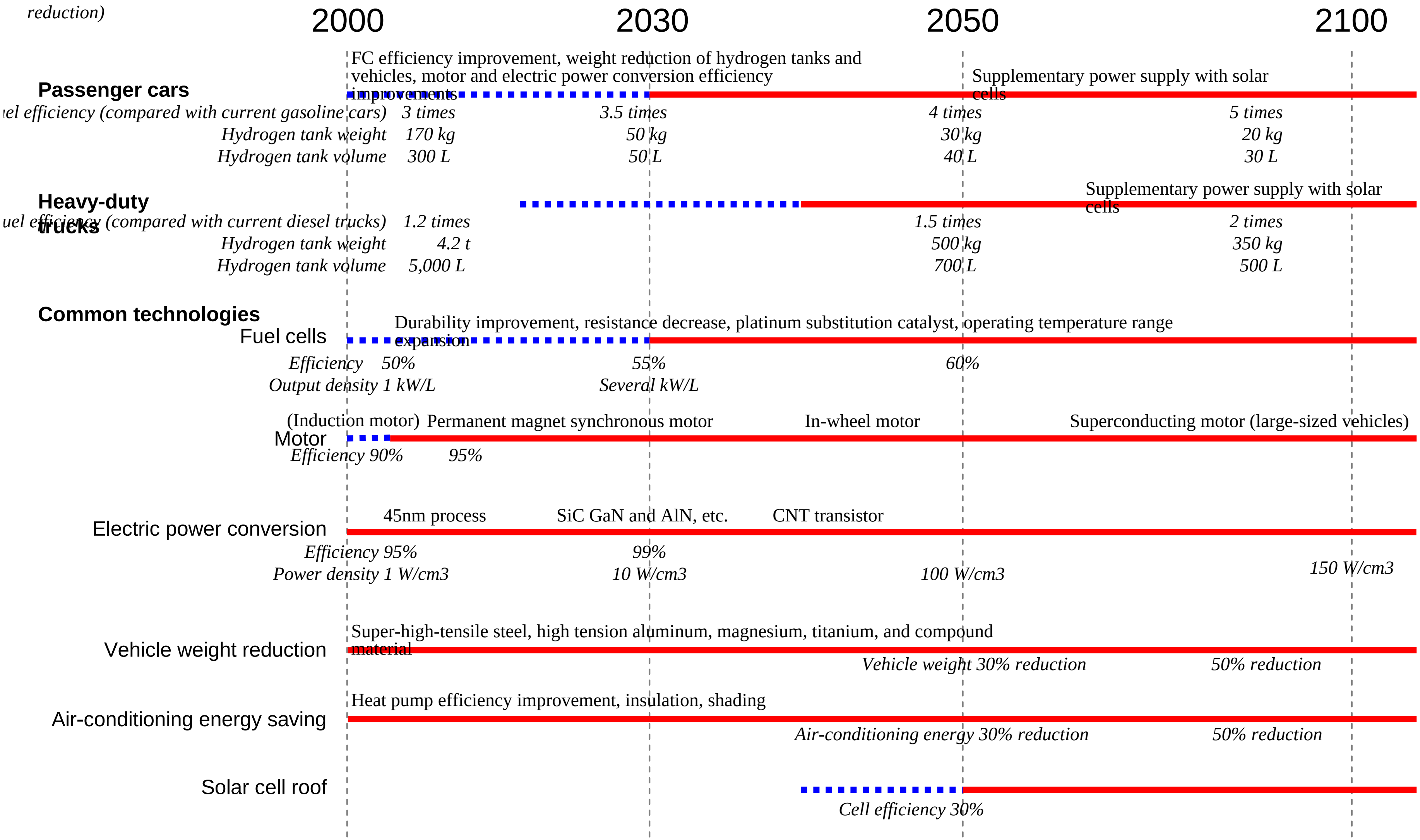
Non-technical factors

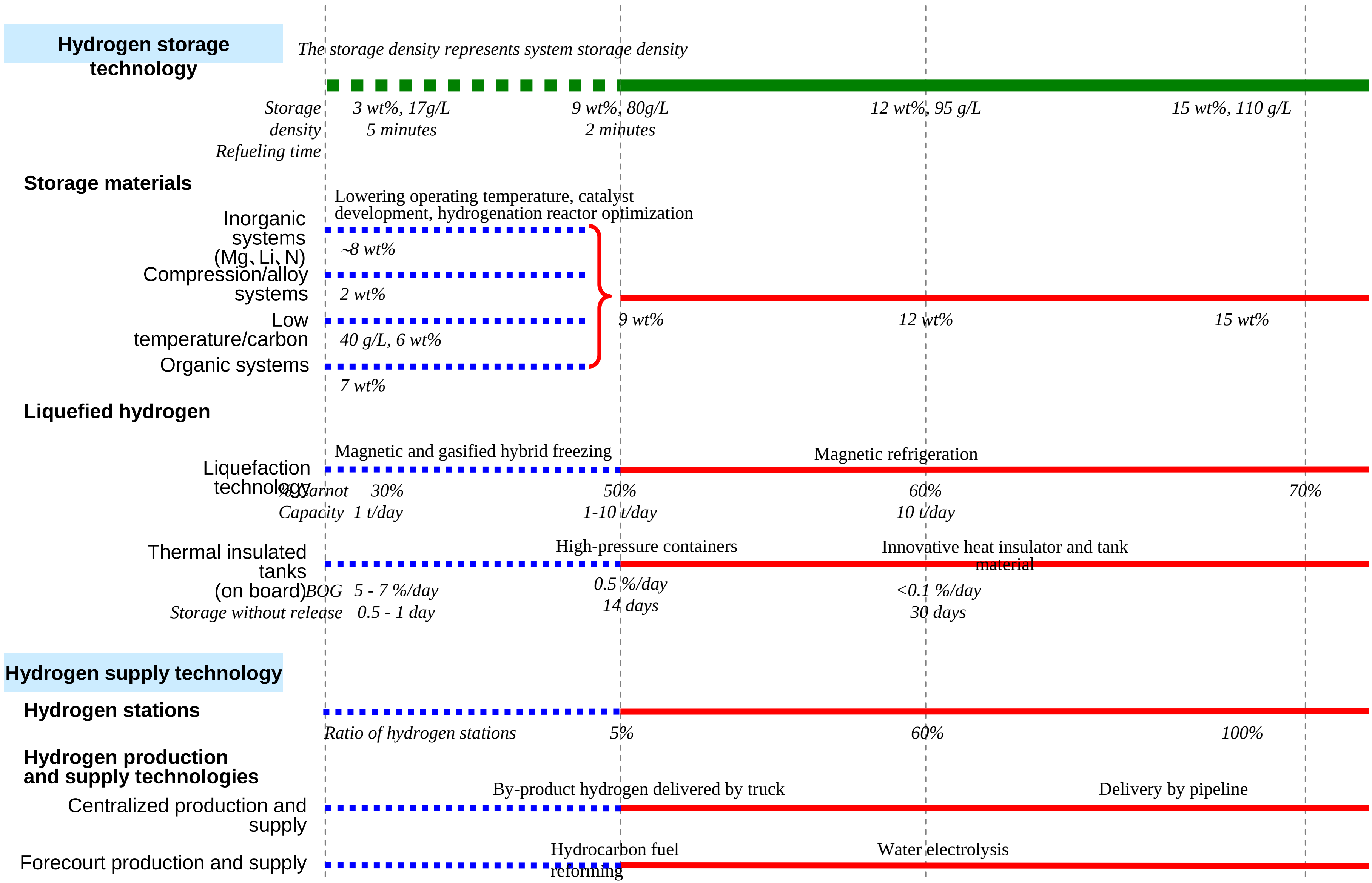
- Taxation discounts on new fuel
- Revision of fuel standards and adjustment with exhaust emissions regulations

Fuel cell hybrid vehicles

- Fuel efficiency is a ratio of the mileage for each consumption of the unit hydrogen which is converted to that of gasoline (or diesel oil). The weight and volume of the hydrogen tanks are critical to secure a driving range of 500 km.
- The most important challenge is performance improvement of on-board hydrogen storage technology. The efficient improvement of fuel cells and vehicle weight reduction also contribute to the decrease of the weight and volume of the hydrogen tanks. High performance is requested for hydrogen storage technology to be applied to heavy-duty trucks.
- The hydrogen supply will start with the use of by-product hydrogen and on-site reforming of hydrocarbons, and then on-site water electrolysis becomes mainstream with an increase in fossil fuels prices. It is assumed that concentrated production with pipeline transportation may be done in regions where enough demand density is realized through the increasing consumption of hydrogen.

The value of fuel efficiency is a ratio to that of current ICE vehicles (including effect of weight reduction)





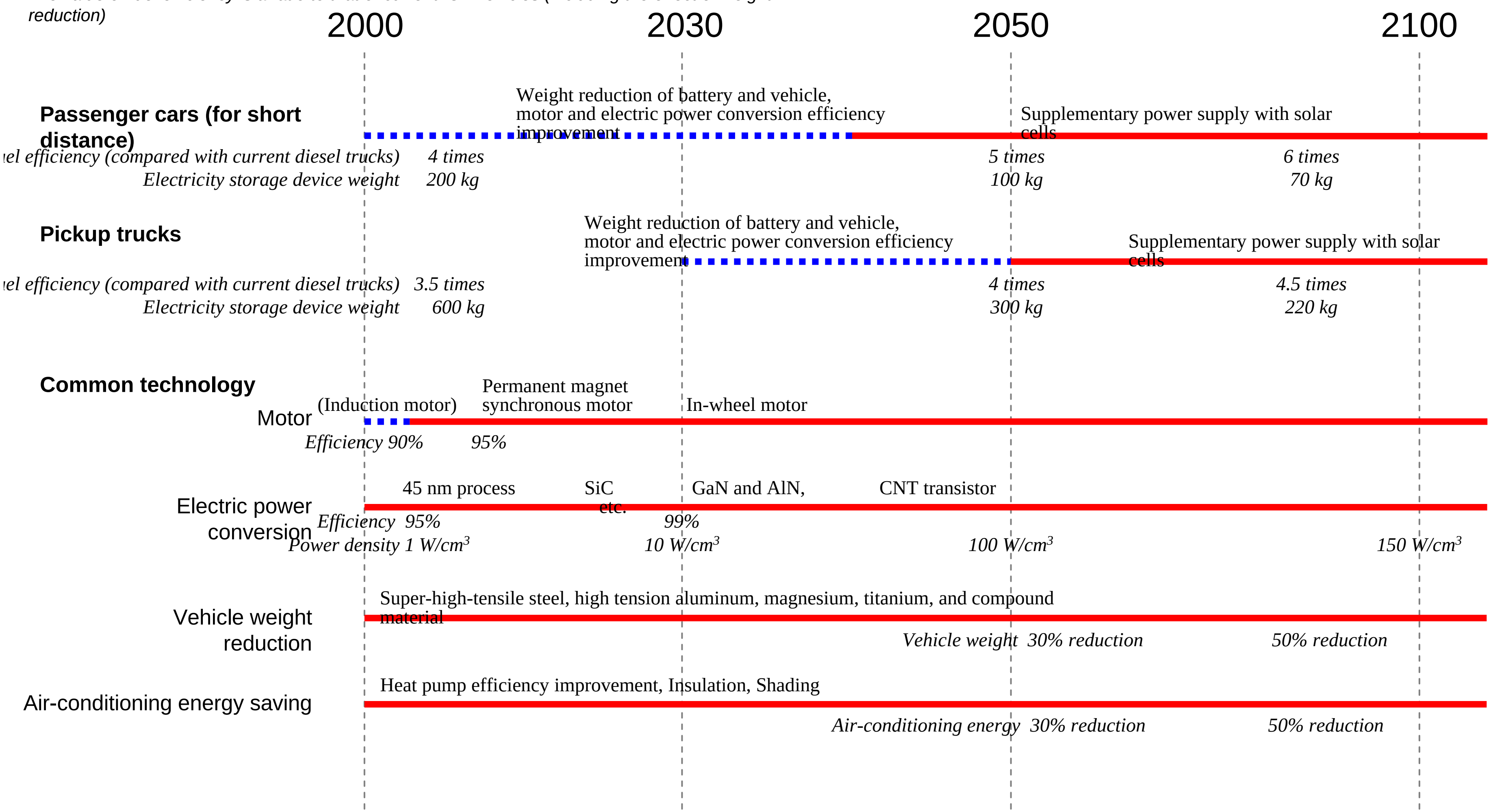
Non-technical factors

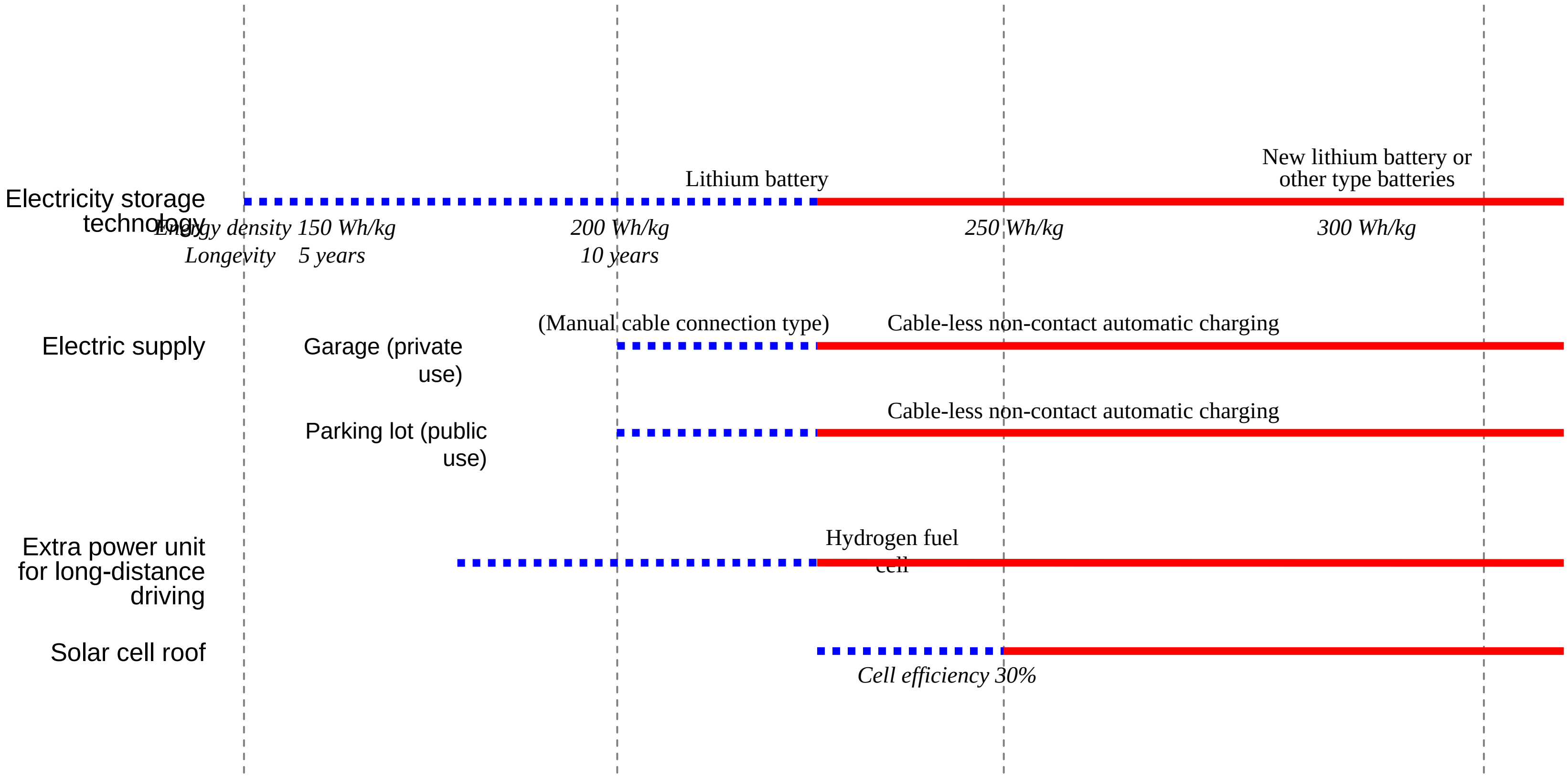
- Hydrogen supply networks developed by governmental investments, a strong initiative to introduce FCV into public vehicles, and FCV special zones
- Incentives to convert to FCV and a hydrogen society (favorable tax changes, higher priority on parking lots, and deregulation for driving into restricted places, etc.)
- Establishment of standards for FCV, fuel and hydrogen fueling equipments, and technological standards (both national and international)
- Promotion of maintenance industries and recycling systems for parts and materials of FCV.

Electric vehicle

- Fuel efficiency is a ratio of the mileage for each amount of the unit charged electric power which is converted gasoline (diesel oil) equivalent. The weight of electricity storage devices is critical to secure a driving range of 200 km.
- The energy density improvement and life extension of electricity storage devices are the most important challenges. Fuel efficiency improvement by body weight reduction also contributes to the weight decrease of the electricity storage devices. Small and light vehicles are easily converted to electric vehicles.
- The practical technologies with a moderate performance have been established for motors and electric power converters. After the prospect of electricity storage technology is established, the development of vehicles, new technologies for charging equipment, and extra power units, are started.
- For distance requirement of 200km or more, a satisfactory result may be achieved by the addition of a small extra power unit (several kW) only when necessary.
- There is a possibility that plug-in hybrid vehicles, which are both fueled and charged (refer to appendix 3), are put to practical use before pure 100% electric vehicles.

The value of fuel efficiency is a ratio to that of current ICE vehicles (Including the effect of weight reduction)

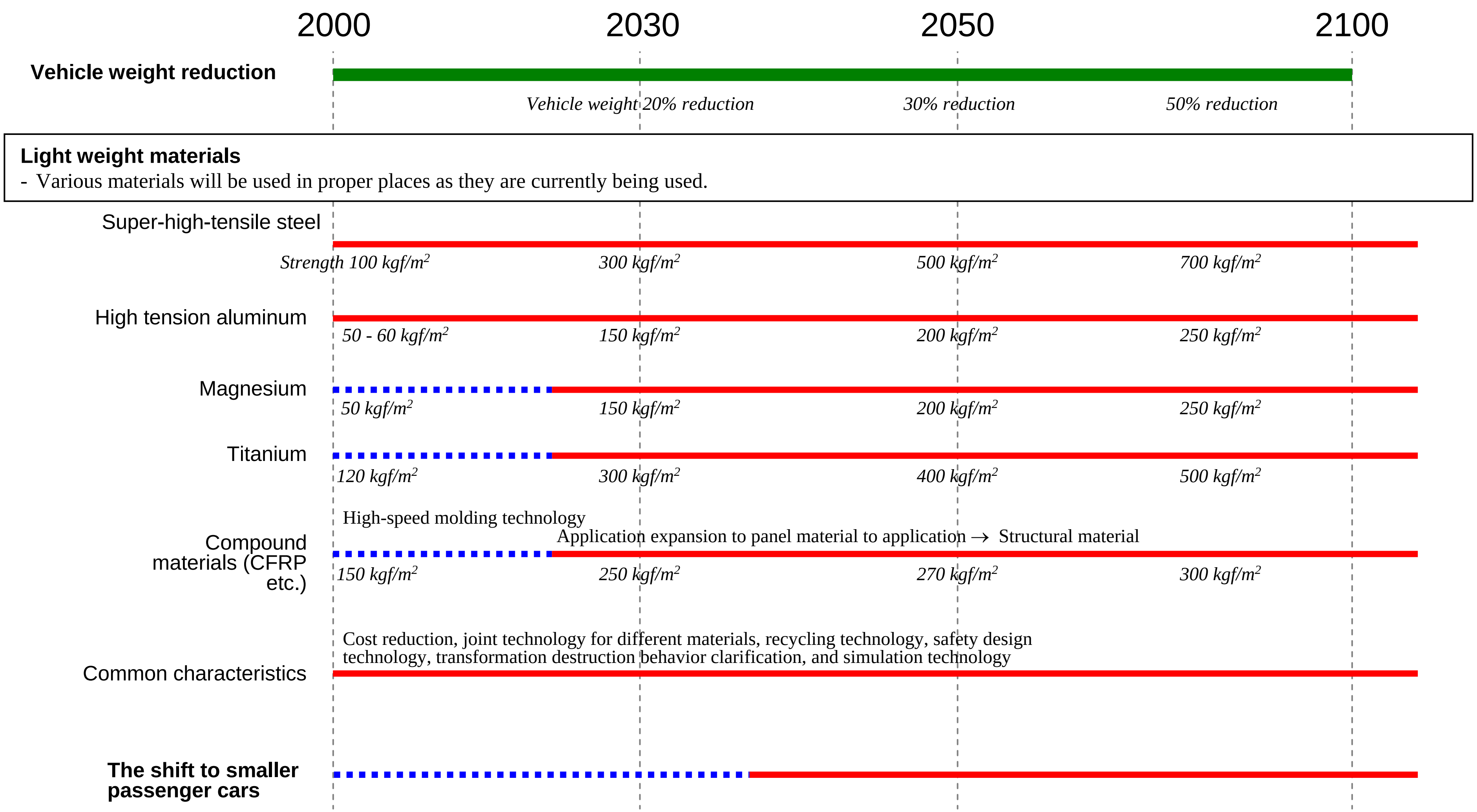




Non-technical factors
- Charging facility network development by government investment, a strong initiative to introduce electric vehicles in the public sector, electric vehicle special zones
- Incentives to convert to electric vehicle (favorable tax changes, higher priority in parking lots, and deregulation for driving into restricted places, etc.)
- Establishment of standards for electric vehicles and charging systems, and technological standards (both national and international)
- Promotion of maintenance industries and a recycling system for parts and materials of FCV.

Vehicle weight reduction

- Vehicle weight reduction will progress with the use of light-weight (high-strength) materials and the shift to smaller passenger cars.



Non-technical factors

- Incentives and user consideration in the shift to smaller passenger cars

Fast Charge ?

A conventional gasoline vehicle consume 295Mcal (10km/Litter)**.**

		Hydrogen		Electricity		Gasoline
Heating Value		2,580kcal/Nm3		860kcal/kWh		7,820kcal/L
Energy reauired for 500km driving	Mcal	-	-	-	-	391
Fule economy factor		3	5	4	6	1
Energy required for 500km drivingwith consideration of fuel economy factor	Mcal	130	78	98	65	391
	Nm3	51	30	-	-	-
	kWh	-	-	114	76	-
	Litter	-	-	-	-	50
Replenishment time	Min	5	2	5	2	2
Flow rate	L/sec	168	253	-	-	0.42
Charging power (Energy flow rate)	kW	1,819	2,718	1,705	2,842	13,640

Comparison of energy storage densities of hydrogen, electric power, and liquid fuel

(1) Weight base comparison

	Hydrogen			Electricity		Gasoline
Heating value[1]	28,900 kcal/kg			860 kcal/kWh		10,150 kcal/kg
Storage density[2),3)]	3wt%	15wt%	15wt%	150Wh/kg	300Wh/kg	90wt%
Stored energy per unit tank weight (kcal/kg-tank)	867	4,335	4,335	129	258	9,135
Ratio to gasoline tank	0.09	0.47	0.47	0.01	0.03	1
Vehicle fueleconomy factor[6)]	3	5	2	4	6	1
Ratio to gasoline tank (with consideration of fueleconomy factor)	0.28	2.37	0.95	0.06	0.17	1

(2) Volume base comparison

	Hydrogen			Electricity		Gasoline
Heating value[1]	28,900 kcal/kg			860 kcal/kWh		10,150 kcal/kg
Storage density[2),3)]	17g/L	110g/L	110g/L	240Wh/L	480Wh/L	700g/L
Stored energy per unit tank volume (kcal/L-tank)	491	3,179	3,179	206	413	7,105
Ratio to gasoline tank	0.05	0.35	0.35	0.02	0.05	1
Vehicle fueleconomy factor[6)]	3	5	2	4	6	1
Ratio to gasoline tank (with consideration of fueleconomy factor)	0.16	1.74	0.70	0.09	0.27	1

(Notes)

1) Lower heating value (LHV).
2) The values of storage density of hydrogen and electricity are referred to in the current performance and maximum values described in the road map.
3) The storage density of gasoline is a presumption value.
4) The volume based storage density of electricity is calculated with a specific gravity of batteries of 1.6.
5) Total weight of tank and fuel
6) The value of vehicle fuel efficiency factor is a ratio of the mileage for each LHV of stored energy compared to gasoline vehicles (Fuel cell vehicles are assumed for hydrogen and electric vehicles are assumed for electricity).

< Comments >

(1) Weight base comparison

The hydrogen storage density of 3 wt% is equivalent to energy storage density of 867 kcal/kg-tank, which is about 1/10 of that of gasoline, while it will be improved to about 1/2 with the hydrogen storage performance of 15 wt%. Taking good fuel economy of hydrogen fuel cell vehicles into consideration, 3 wt% for hydrogen storage corresponds to about 30% of energy storage performance of gasoline tanks. With the fuel efficiency factor of 2 times (assumed value for heavy-duty trucks), the hydrogen storage density of 15wt% is almost equivalent to gasoline tanks.

The technology specifications for the fuel economy factor of hydrogen aircraft, hydrogen fuel cell ships, and hydrogen fuel cell trains at 2100 in this road map are about 2 times, 1.7 times, and 2 times, respectively. (They are compared to the current fossil and engine technologies.) The energy storing density of batteries is smaller than that of hydrogen by one order of magnitude. Even if it is improved to 300Wh/kg, and the fuel efficiency of electric vehicles increased by a factor of 6, it would reach only 17% of gasoline.

(2) Volume base comparison

In the volume base comparison, the values for hydrogen are lower than those in the weight based comparison, while a little higher for electricity. The relative relation among gasoline, hydrogen, and electricity doesn't change.