

While energy demand is increasing in the world, we have reconsidered and showed what energy technologies ought to be in order to realize a society based on the truly sustainable structure of energy supply and demand. From a long-term view until 2100, we have described technologies by a "backcasting" method which can overcome resource and environment constraints we are globally anxious about in the future.

We hope that this vision will not only put emphasis on long-range research and development but also help people discuss an international framework for the post-Kyoto protocol. At the same time, we hope this roadmap will have a good effect on the research and development management after several revisions from a viewpoint of a short-and-medium-term vision.

(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: *CO₂ emission intensity per GDP (CO₂/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
 - CO₂ intensity should be reduced at the same ratio as above — Japan leads the world into the foreseeable future

(2) Case study under excessive conditions of energy structure

Case A: *Maximum use of fossil resources such as coal combined with CO₂ capture and sequestration*
 Case B: *Maximum use of nuclear energy*
 Case C: *Maximum use of renewable energy combined with ultimate energy-saving*

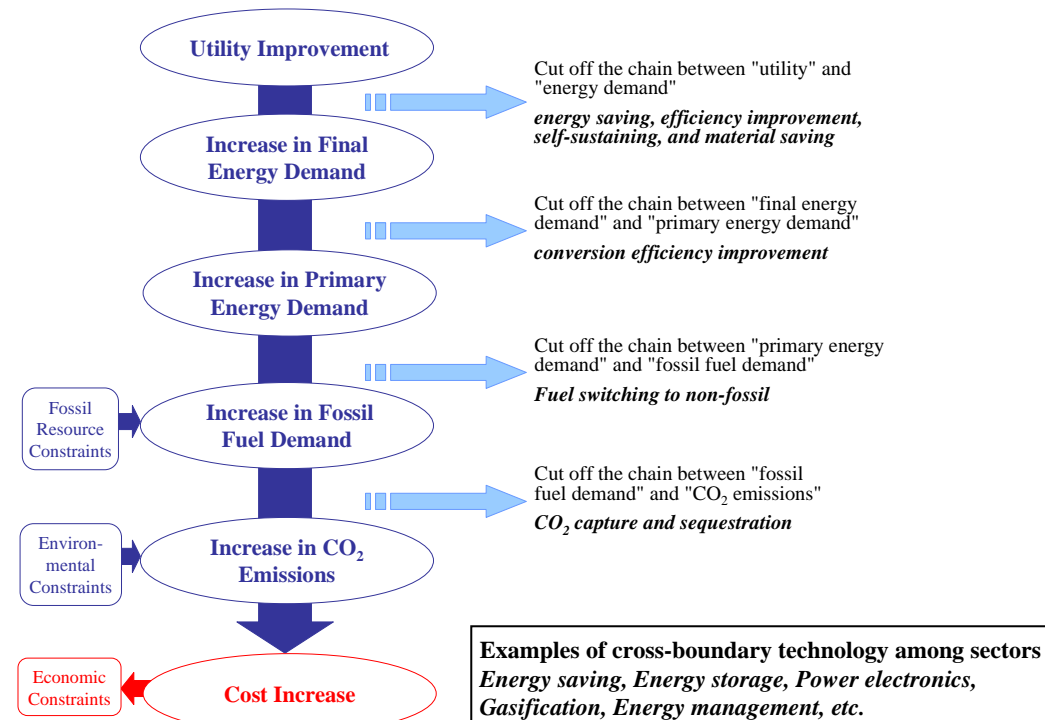
(3) Extraction of technology specification which is required in each sector

Example: *In each section, res/com, transport, and industry, while utility is growing, the necessary energy per unit which should be supplied from the transformation sector is reduced by 70 - 80%.*
 Note: *On the assumption that the necessary energy increases in proportion to a growth of GDP.*

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

A fundamental concept of measures

Technologies that realize the truly sustainable structure between supply and demand, which can break away from the "increasing chain" at present



Major technology specification required in each sector and a view of measures

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

Res/Com	2000	2030	2050	2100
Total energy demand	1 time		1.5 times	2.1 times
Energy supplied from transformation sector*		45% reduction	60% reduction	80% reduction
Residential		35%	55%	80%
Commercial				
CO ₂ intensity	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
Residential				
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

Energy saving *Equipment and building, etc.* **towards self-sustaining of each appliance, house or office, and community**
Energy creating *Photovoltaic etc.*
Energy management *Energy accommodation etc.*

(1) Energy saving containing new equipment in the future
 (2) Energy creation by ubiquitous energy such as solar power (ultimately self-sustainable system independent of transformation sector)
 Furthermore, maximum use of energy by accommodation, dispersed storage, etc.

"Energy saving" and "fuel switching" are the main energy saving equipment sector

- (1) Improvement of efficiency in engine and drive system
- (2) Weight reduction of the vehicle body, ship, and aircraft
- Fuel switching
- (i) use of synthetic fuel
- (ii) ultimate use of biomass-origin fuel
- (iii) switching to hydrogen and/or electricity

Transport	2000	2030	2050	2100
Utility (passenger-km, ton-km)	1 time		1.5 times	2.1 times
Energy supplied from transformation sector* (overall)		20% reduction	50% reduction	70% reduction
Automobile Energy demand*		30% reduction	60% reduction	80% reduction
Share of electricity and/or hydrogen	0%	over 1%	40%	100%
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
Aircraft, Ship, Railroad Energy demand*		10 - 20% reduction	20 - 35% reduction	30 - 50% reduction

Improvement of fuel efficiency *Hybridization Weight reduction* → **Fuel cell vehicle (FCV) Electric vehicle (EV) (Hydrogen/electricity storage) (Hydrogen/electricity supply)** **towards high fuel efficiency and zero-emission**
Fuel switching *Fuel mix* **Biomass fuel Synthetic fuel** → **Hydrogen/electricity**

Automobile
 Conventional internal combustion vehicle engine (ICE)
 → ICE-battery hybrid vehicle
 → FC-battery hybrid vehicle or EV
 I. Conserved in Materials
 II. Energy Loss
 III. Waste Heat

Industry	2000	2030	2050	2100
(Production) × (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

Improvement of production process *Energy saving Co-production (simultaneous production of material and energy) etc.* **towards maximum use of energy and material and supply high-performance products through the future**
Regeneration of material/energy *Regeneration and use of material and/or energy in products etc. Cross-boundary measures beyond sectors*
Improvement of functionality *Improvement of functionality of material and parts etc. Material saving of products*

Combination of
 - Improvement of production process (II and III)
 - Regeneration of material/energy from used products (I)
 - Improvement of functionality of products

Co-production
 Electricity or hydrogen are recovered from exergy loss by use of gasification process, for example, just like simultaneous production of material and energy.
Material/energy regeneration
 For example, it is possible to use as raw material or to generate energy by gasification of used chemicals.

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	1 time		2 times	4 times
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 kg-CO ₂ /kWh (1/3 times) in the case of fossil fuel use with CCS

Effective use of fossil resources *High-efficient use of fossil fuels CO₂ capture and sequestration etc.* **towards reliable supply of clean energy**
Use of nuclear power *Nuclear fuel cycle etc. (Large-scale energy storage)*
Use of renewable energy *Solar, geothermal, wind, biomass, etc.*

- (a) Technology for effective use of fossil resource
 - (b) Technology for use of nuclear power
 - (c) Technology for use of renewable energy
- Furthermore, as share of renewable energy increases, technologies for large-scale energy storage and energy network system are needed.

*Tentative Translation, Jan. 2006***Energy Technology Vision 2100****Summary**

1. This Strategic Technology Roadmap of the energy sector was developed by backward examination (backcasting) of the technology portfolio to overcome constraints in resources and the environment, which will become a big concern in the future globally, on the basis of the long-term vision until 2100. The object is to prioritize research and development based on the long-term vision, and to contribute to the discussion based on the long-term vision and the global point of view such as the post-Kyoto international framework.
2. In the development of the future technology portfolio, we have set excessive conditions for energy structure to identify the most severe technological specifications in sectors of residential/commercial, transport, industry, and transformation. As a result, if all of them are achieved, the constraints will be achieved in excess.

Assumptions of constraint

Global resource constraint: Oil production is assumed to peak in 2050

Natural gas production is assumed to peak in 2100

Global environmental constraint:

CO₂ emission intensity per GDP (CO₂/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 and the CO₂ intensity should be reduced at the same ratio as above so that Japan leads the world into the foreseeable future.

Case study under excessive conditions of energy structure

Case A: Maximum use of fossil resources such as coal combined with CO₂ capture and sequestration

Case B: Maximum use of nuclear energy

Case C: Maximum use of renewable energy combined with ultimate energy-saving

Technological specifications which are required in each sector (overview in 2100)***Residential/Commercial***

- While “utility” increases in proportion to GDP, 80% of required energy from transformation sector is reduced (per household, floor space).

- Share of electricity and/or hydrogen is 100%.

Transport

- While “utility (\approx person·km, ton·km)” increases in proportion to GDP, the fuel efficiency is improved equivalent to a 70% reduction of required energy (for automobiles, equivalent to an 80% reduction)
- Share of electricity and/or hydrogen is 100% (except aircraft)
- Fuel switching with appropriate timing to resolve resource constraints

Industry

- While “utility (\approx production volume \times production value)” increases in proportion to GDP, 70% of required energy from transformation sector is reduced (per utility)
- Primary fuel switch with appropriate timing to resolve resource constraints

Transformation

- Required energy for each demand sector is supplied sufficiently in each case

3. In order to realize the technological specifications in the future, we sorted out the menu for the key technologies according to the time series, as shown in the energy technology roadmaps.

Important points

Residential/Commercial

In order to realize the technological specifications for the res/com sector, we should (1) carry out energy saving as much as possible including the equipment that will appear in the future, and (2) execute energy creation by using ubiquitous energies such as solar power. Through the advancement of (1) and (2) ultimately, “self-sustenance” which does not depend on the energy supplied from the transformation sector becomes possible. It becomes possible that surplus energy is accommodated through the energy network and moreover, this energy is utilized to the fullest, as the amount of energy created from renewable energy increases.

Transport

The main paths for technological specifications achievement in the transport sector are “energy saving” and “fuel switching.” For energy saving in machine units (1) improve efficiency in engines and drive systems (2) weight reduction of bodies (vehicles, ships, aircraft) are important. For fuel switching, (1) synthetic fuel made of natural gas or

coal (for reducing oil consumption), (2) biomass fuel that is carbon-neutral, and (3) switching to hydrogen or electricity that generates no CO₂, are required.

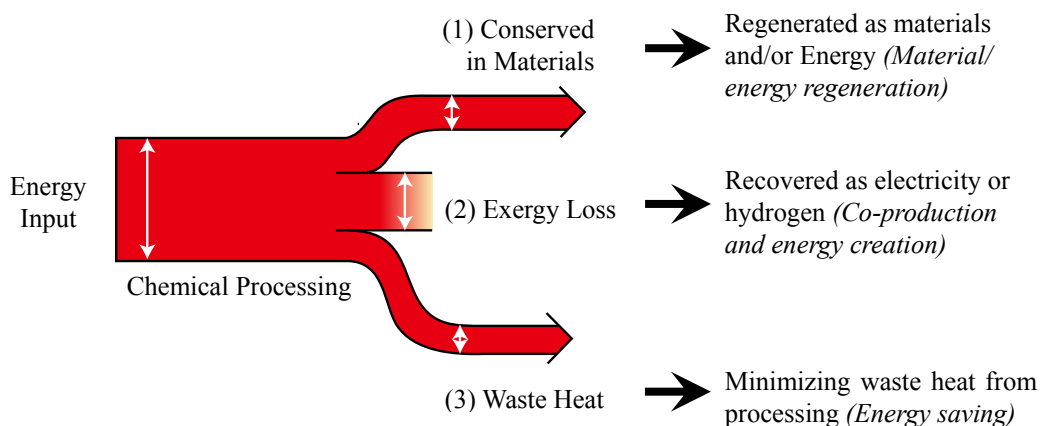
Automobile

The mainstream of automobiles will shift to “conventional ICE → ICE hybrid → FC hybrid”, and electric vehicles will be small with a short range. The fuels for ICE will shift from oil to synthetic fuels by 2050. In the process of the shift, petroleum fuels and synthetic fuels are used as a mixture.

Industry

Energy provided in the raw material manufacturing process (material conversion) is categorized in the following three ways:

- (1) Chemical energy stored in material
- (2) Exergy loss mainly in burning process
- (3) Waste heat in processes



High level of energy use at production process “create skillfully”

The required energy for production processes in (2) and (3) should be reduced.

**Co-production*: For example, we can collect heat, electricity, and hydrogen efficiently from gasification processes even while using fossil fuels. Since we can recover exergy that is lost in the conventional production processes as electricity or hydrogen, this method seems to generate material and energy together when the same raw material is processed.

Regeneration of material/energy “use skillfully”

As can be seen in (1), a product (material) has chemical energy inside. After the life of the product terminates, we can regenerate this (1) as material and/or energy.

**Regeneration of material/energy*: For example, since 60% of used energy is stored as material in the chemical production, it is possible to utilize it as a raw material and to regenerate energy by means of gasification of used products and so on.

Energy reduction for production with few resources “create good things”

Improvement of functionality of products is not only essential to maintain and expand our nation’s international competitiveness, but also important tasks to provide a seeds for technological innovation in each sector.

Common technology in the industrial sector

Biomass and wastes become important materials and fuel mainly in industries utilizing carbon (C) as a material. Therefore, management technology of materials including them becomes important in the future.

Transformation

It is necessary to provide the following three technological groups to fulfill energy demand efficiently with reducing CO₂ intensity.

Effective use of fossil resources

In preparation for the oil production peak, we execute a fuel switch to natural gas, and to coal that has comparably a rich volume of resources. Since coal is also a finite resource, it is important to improve the effectiveness of fossil resources use such as power generation (transformation) efficiency. Therefore, gasification power generation (fuel production) technologies and highly effective power generation technologies combined with fuel cells are required. Also, since fossil fuel generates CO₂ emission, CO₂ capture and sequestration (CCS) technologies are essential.

Nuclear power utilization technologies

Effective use of nuclear fuel resources is required. Therefore, it is fundamental to improve efficiency of the current light-water reactor, and to establish the nuclear fuel cycle.

Renewable energy utilization technologies

It is important to improve effectiveness of power generation (transformation) by renewable energy such as solar power, geothermal, wind power, and biomass. Since the capacity factor of solar or wind power generation is low, and these facilities need a large installed capacity, technologies for easy installation are also required. Since natural energy depends on weather conditions etc., it is essential to establish a large scale of storage technologies and network system technologies including system control (energy management).

Cross-boundary technologies

Once a cross-boundary technology is established, it can work effectively in a wide range of applications. Therefore, it can be an important technology.

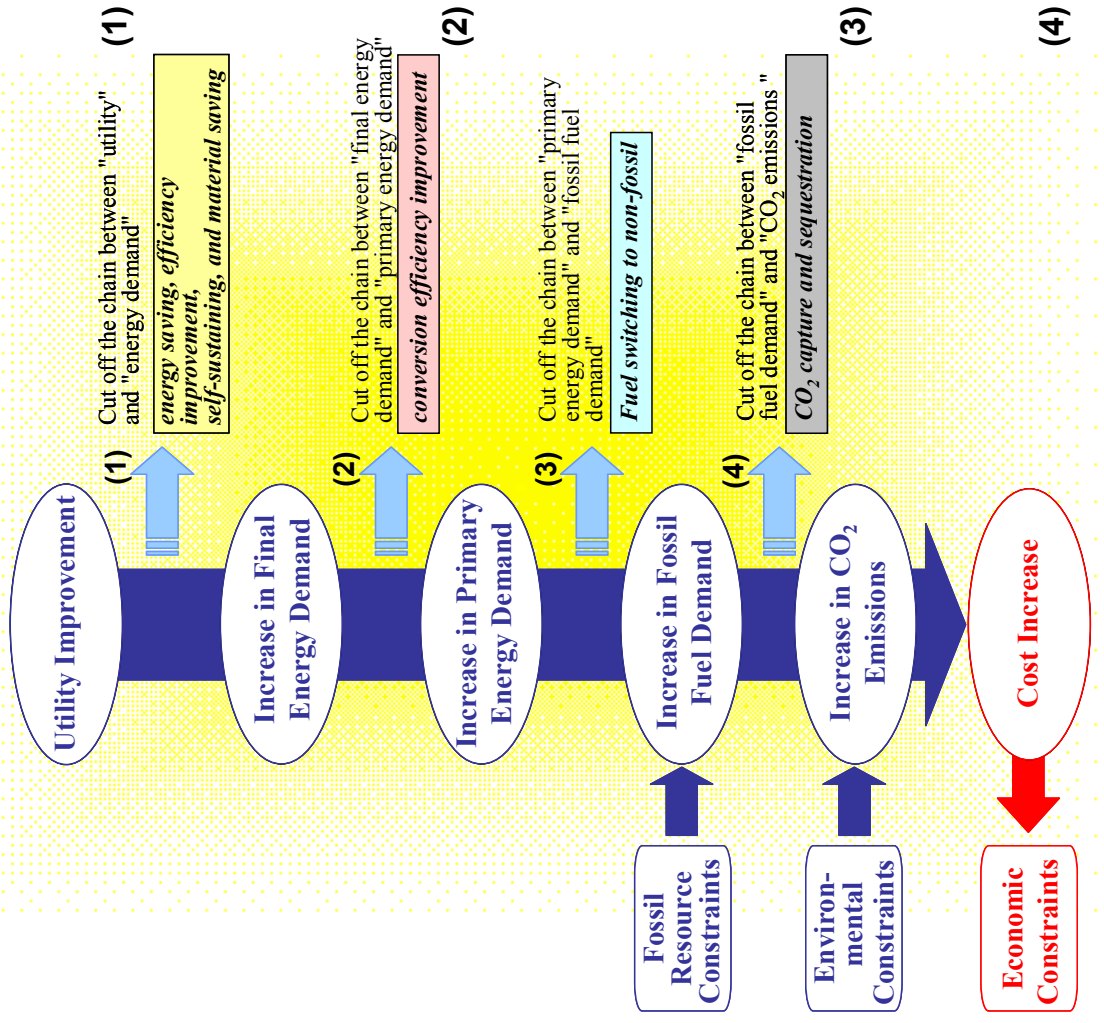
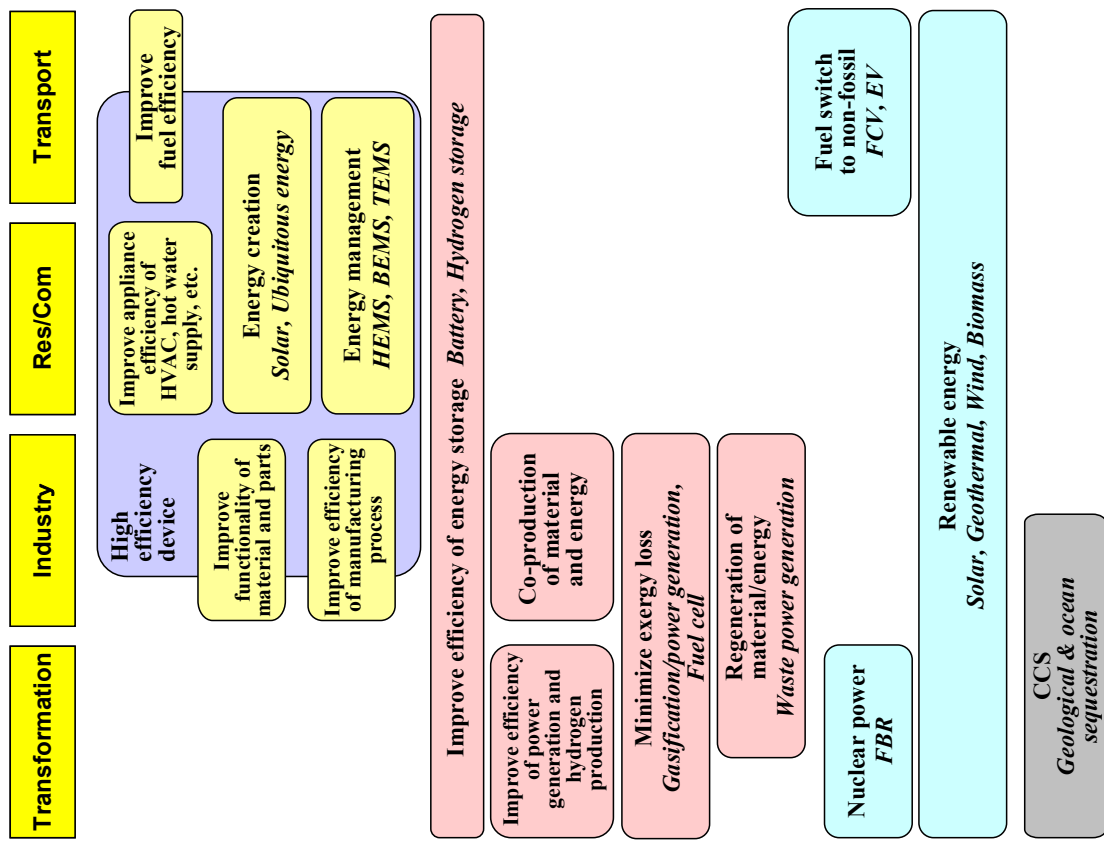
Example: Energy-saving technology, energy storage technology, power electronics technology, gasification technology, energy management technology, etc.

Image of society with a combination of three cases (highly possible image of society)

In Japan, current capacity for geological CO₂ sequestration is considered to have limitations. We have to consider ocean sequestration to satisfy required capacity, but there are necessary tasks for ocean sequestration that need to be undertaken, such as an environmental assessment and a social consensus. Case A cannot be a long-term solution when we consider finite fossil resources. Therefore, we think the combination of case C (utilizing renewable energy and ultimate energy-saving technologies) and case B (operating nuclear power reliably) is desirable for society on long-term basis, by avoiding climate change by CO₂ capture and sequestration as required on a mid-term basis. However, evaluation and combination of these cases can vary according to situations in the future. It is important to prepare technologies through R&D for change in the social and economic situations at various occasions in the future.

4. Issues in the future

- Examination on the basis of short and medium term
- Detailed studies on key technologies



Major technology specifications required in each sector and a view of measures

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

Res/Com	2000	2030	2050	2100
Total energy demand	1 time		1.5 times	2.1 times
Energy supplied from transformation sector*	Residential Commercial	45% 35% reduction	60% 55% reduction	80% 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)
	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)

Energy saving *Equipment and building, etc.* **towards**
Energy creating *Photovoltaic etc.* **self-sustaining of each**
Energy management *Energy accommodation etc.* **appliance, house or**
office, and community

Transport	2000	2030	2050	2100
Utility (passenger-km, ton-km)	1 time		1.5 times	2.1 times
Energy supplied from transformation sector* (overall)		20% reduction	50% reduction	70% reduction
Automobile Energy demand*		30% reduction	60% reduction	80% reduction
Share of Electricity/Hydrogen	0%	over 1%	40%	100 %
CO ₂ intensity	160 g-CO ₂ /km (1 time)	100 g-CO ₂ /km (2/3 times)	50 g-CO ₂ /km (1/3times)	0 g-CO ₂ /km
Aircraft, Ship, Railroad		10 - 20% reduction	20 - 35% reduction	30 - 50% reduction

Improvement of fuel efficiency *Hybridization
Weight reduction* → *Fuel cell vehicle (FCV)
Electric vehicle (EV)
(Hydrogen/electricity storage)
(Hydrogen/electricity supply)* **towards**
Fuel switching *Fuel mix (Biomass fuel
Synthetic fuel)* → *Hydrogen/electricity* **high fuel efficiency and zero-emission**

Industry	2000	2030	2050	2100
(Production) × (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

Improvement of production process *Energy saving
Co-production (simultaneous production of material and energy) etc.* **towards**
Regeneration of material/energy *Regeneration and utilization of material and/or energy in products etc.
Cross-boundary measures beyond sectors* **maximum utilization of energy and material and supply high-**
Improvement of functionality *Improvement of functionality of material and parts etc.
Material saving of products* **performance products through the future**

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	1 time		2 times	4 times
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 kg-CO ₂ /kWh <i>110 g-CO₂/kWh (1/3 times) in the case of fossil fuel use with CCS</i>

Effective use of fossil resources *High-efficient use of fossil fuels etc.
CO₂ capture and sequestration* **towards**
Use of nuclear power *Nuclear fuel cycle etc.
(Large-scale energy storage)* **reliable supply of clean energy**
Use of renewable energy *Solar, geothermal, wind, biomass, etc.*



Residential



Commercial



Transport



Industry



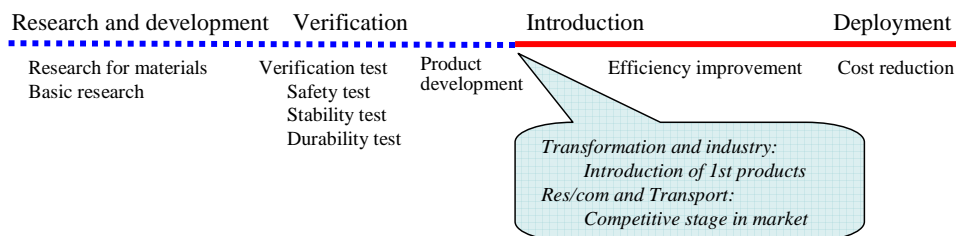
Transformation

Energy Technology Roadmap 2100 Summary

Tentative Translation, Jan. 2006

This summarized sectoral roadmaps includes Res/Com, Transport, Industry, and Transformation sectors, and each sectoral roadmap consists of 2 sheets as follows.

- 1: Main technological targets and a basic concept of technological specifications
- 2: Main technologies for achievement of technological specifications



Jan/04/2006

Summary-1

Basic concept in each sector

Common

The common assumption in demand sectors is that "utility (economic activity, quality of life, etc.)" increases in proportion to GDP. In order to breakaway from the "linkage" of risk enlargement between economic growth and the resource/environmental constraints, we should prepare the technologies for the future to minimize the intensity of required energy which is supplied from the transformation sector.

The growth of GDP in Japan assumes to be about 1.5 times in 2050 and 2 times in 2100.

Residential/Commercial sector

"Utility" per household in the residential sector and per floor space in the commercial sector increases in proportion to GDP. In order to improve the energy intensity, we should (i) carry out energy saving as much as possible including the equipment that will appear in the future, and (ii) execute energy creation by using ubiquitous energies such as solar power. Through the advancement of (i) and (ii) ultimately, "self-sustenance" which does not depend on the energy supplied from the transformation sector becomes possible. If the quantity of energy creation by renewable energy becomes large, we can distribute excessive energy through network, or store energy to utilize maximally.

Transport sector

"Utility (\approx person-km, ton-km)" of automobile use increases in proportion to GDP. In order to improve the energy intensity, we should (i) promote the energy saving by the improvement of engine efficiency and the reduction of vehicle weight, however, fuel cell hybrid cars or electric cars which are driven by carbon engines should be mainstream in the future in order to improve the energy intensity and CO₂ intensity drastically. (ii) As for fuels, the share of biomass fuels and mixed fuels of petroleum and synfuels will increase and then the share of hydrogen or electricity will increase after the oil production peak in the middle of this century

Industry sector

"Utility (\approx functionality)" of products increases in proportion to GDP. In order to improve the energy intensity, we should (i) improve quality and functionality of materials and products, (ii) improve production processes and develop an innovative production process (energy saving, effective energy use, co-production of materials and energy in the process), and (iii) regenerate materials and/or energy which is held in products. Moreover, the action of cross-boundary (collaboration between industries, industrial - residential/commercial, and industrial - transformation, and so on) by optimum integration of production processes improves efficiency in the entire society.

Transformation sector

In order to satisfy the energy demand efficiently and to reduce CO₂ emission intensity, we should (i) use fossil resources effectively, (ii) execute a fuel switching to non-fossil resources such as renewable and/or nuclear energies, and (iii) establish an energy network including a large-scale energy storage, because of the increased requirement of the energy management to control the fluctuation of energy supply.

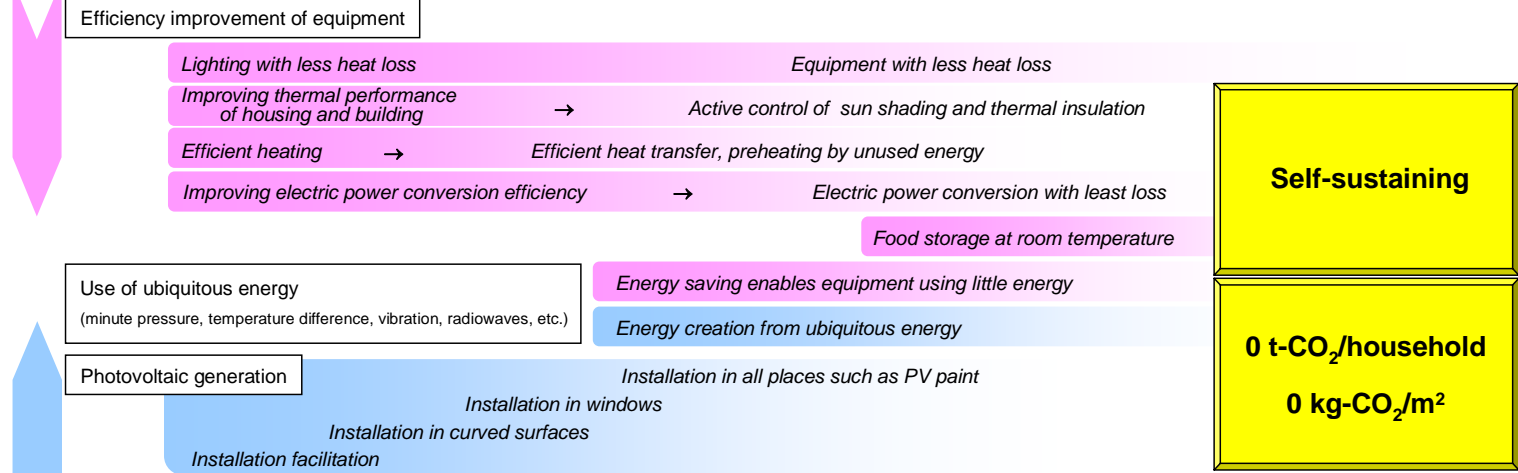
Jan/04/2006

Summary-2

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

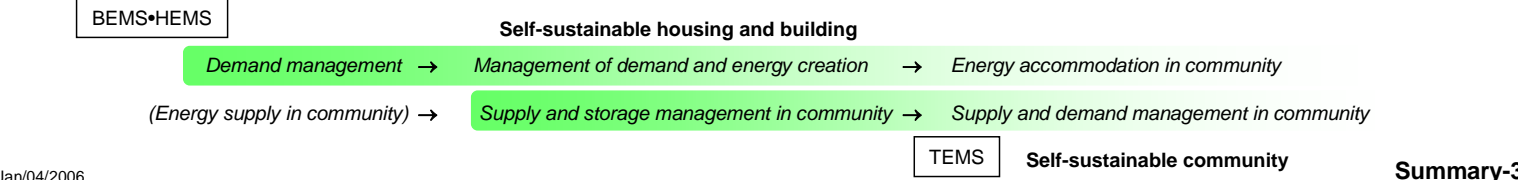
*The percentage of reduction of energy per unit should be supplied from the transformation sector, compared with total energy demand increases in proportion to GDP.

Energy saving



Energy creation Efficiency improvement and increase of durability

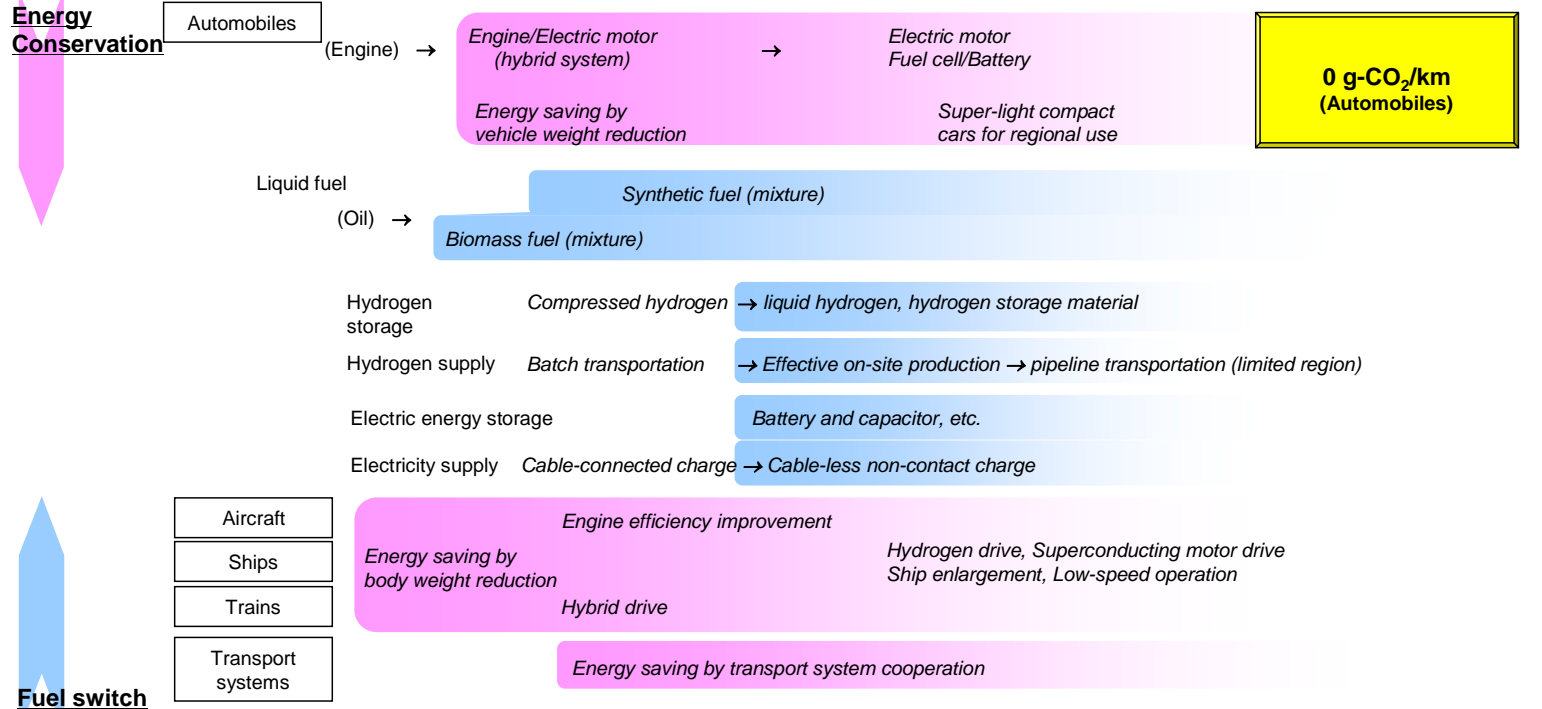
Energy management



Res/Com	2000	2030	2050	2100
Energy saving				
Lighting	High efficiency lighting	High efficiency LED	Organic EL lighting	Low heat loss & high efficiency lighting
	Use of natural light	Advanced use of solar light (high efficiency light focusing and transmission)		Light storage, bio-chemical light emission
HVAC & hot water supply	High performance construction material for housing and buildings	High thermal insulation, improvement of indoor air environment, improvement of wellness		Active controllable construction material
	High efficiency HVAC system	High efficiency heat pump, thermal storage air-conditioning, use of solar heat or unused exhausted heat		
	Distributed power generation using fossil fuels	Fuel cell cogeneration	FC/GT hybrid system (commercial use)	(Ultra-high efficiency FC using hydrogen)
	High efficiency hot water supply	High efficiency heat pump	Vacuum insulation storage	
Kitchens	High efficiency cooking	High efficiency cooking equipment	New technology for cooking	
Power and others	Information appliances (Big screen display etc.)	Low power consumption PDP/LCD, high-capacity optical networking/storage		LED/EL display (High definition large screen, low power consumption)
Common technology	High efficiency devices (electric power conversion etc.)	45nm process	SiC	GaN, AlN, etc. CNT transistor/diamond semiconductor
				Single electron transistor
Energy creation	Unused energy conversion to electricity etc.		Thermoelectric conversion	Piezoelectric/magnetostrictive/bio-photovoltaic conversion
	Photovoltaic generation	Thin film type	Dye-sensitized type, organic thin film type, etc.	Super-high efficiency new type
		Cost reduction, high efficiency, installation facilitation		
Energy management	HEMS/BEMS	Monitoring	Cooperation with the grid	Demand forecasting (Control including lifestyle and amenity)
	TEMS (Energy management system in community)		Energy accommodation	Cooperation with energy storage system Cooperation with power and energy grid
	Energy storage and network (Electricity, heat, and hydrogen)	Lithium battery	New rechargeable battery, thermal storage	Local energy network (LEN) Hydrogen fuel cell Distributed energy storing

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		30% reduction	60% reduction	80% reduction
Energy demand	0%	1% or more	40%	100%
Share of electricity and/or hydrogen				
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		10-20% reduction	20-35% reduction	30-50% reduction
Energy demand				

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

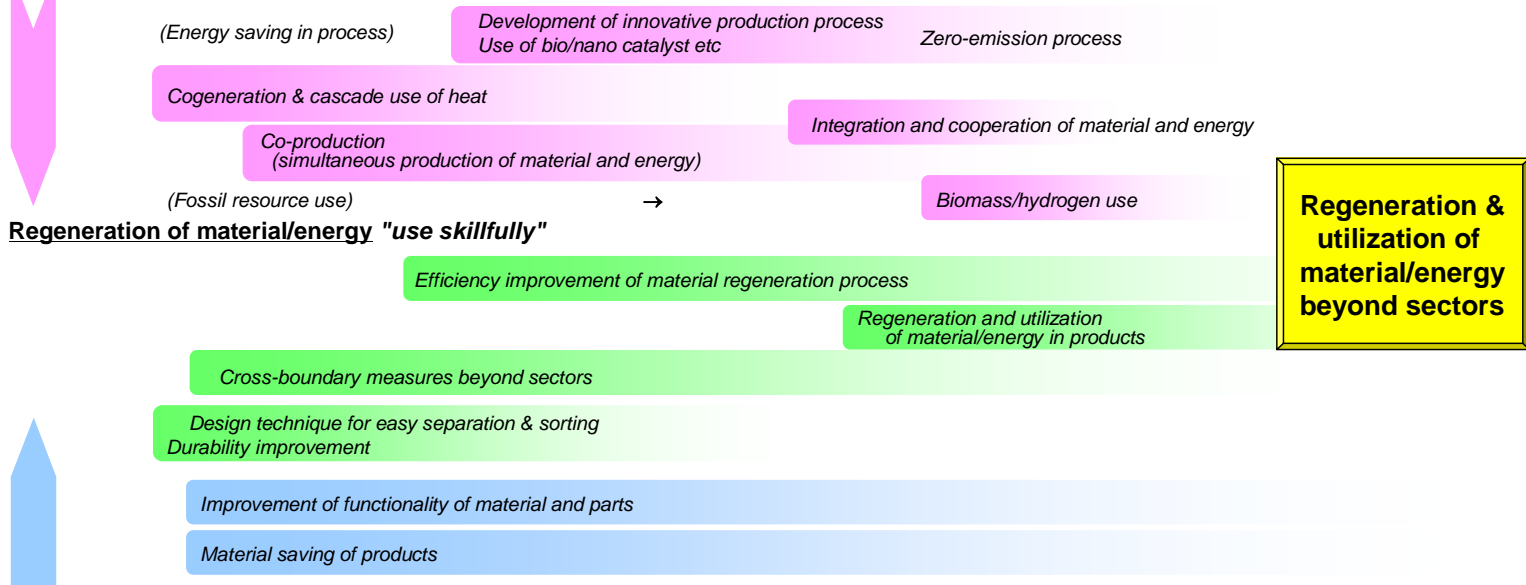


Transport	2000	2030	2050	2100
<i>The value of fuel efficiency is a ratio to that of current ICE vehicles. (Including the effect of weight reduction)</i>				
Automobile				
ICE hybrid vehicle		Vehicle weight reduction, engine efficiency improvement, motor and electric power conversion efficiency improvement, 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 2 times
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

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 reduction for production with few resources "create good things"

Jan/04/2006

Summary-7

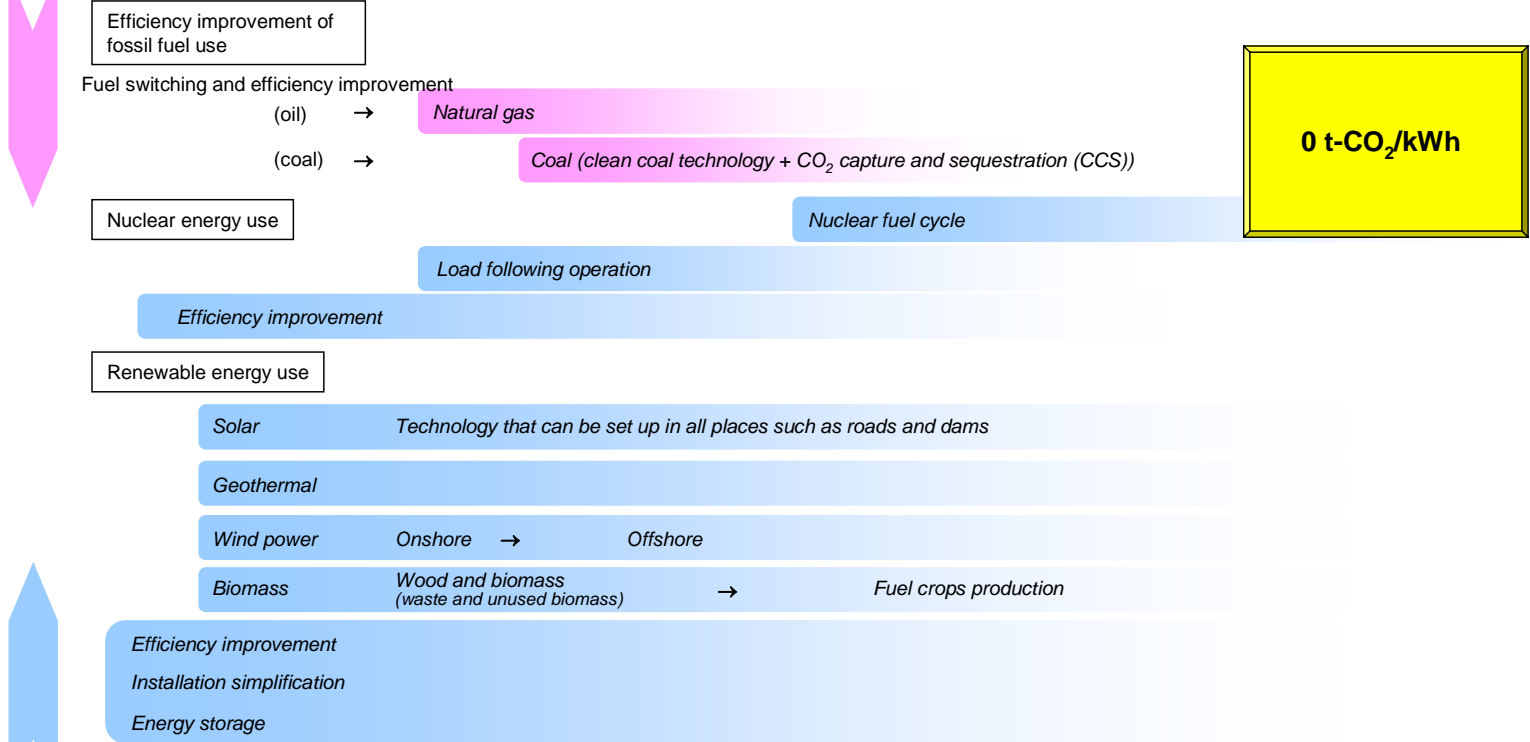
Industry	2000	2030	2050	2100
High level of energy use at production process "create skillfully"				
Energy saving		Energy saving of conventional process, development of next-generation rolling mill technology SCOPE-21, introduction of innovative sintering technology		Innovative steel production process
Iron & steel				
Coproduction (Material & Energy)		Energy saving production technology of petrochemical feedstock	System of sustainable carbon cycle chemistry (SC3)	
Chemical				
Regeneration of material/energy "use skillfully"		Energy conservation of conventional cement and eco-cement process	Zero emission cement process	
Cement				
Energy reduction for production with few resources "create good things"		Highly efficient technology for heat transfer, heat insulation and heat storage, high efficient industrial combined heat and power,		cascade use of heat, power recovery system
Common				
High performance materials/parts		Production and utilization technologies of biomass (use of biotechnology etc.)		
Iron & steel				
Material saving of products		Innovative production process (use of bio/nano-catalysts etc.)		
Others				
Regeneration of material/energy		Gasification technology, integration with GT	Industrial furnace combined with FC	
Common				
High performance materials/parts		Co-production of electricity, hydrogen, and chemicals		
Chemical				
Material saving of products		Innovative heat storage technology (industrial heat transformer, chemical heat storage, etc.)		
Chemical				
Regeneration of material/energy		Co-production of electricity and heat through gasification of wastes		
Cement				
High performance materials/parts		Use of biomass	IGCC using biomass as fuel	IGFC using biomass as fuel
Iron & steel				
Material saving of products		Coupling operation among industries for efficient energy use	Material cascade management	
Paper & pulp				
Regeneration of material/energy		Use of non-conventional fossil fuels and low quality materials, gasification of industrial wastes and biomass		
Common				
High performance materials/parts		Regenerative technologies of materials, byproducts, and energy		
Chemical				
Material saving of products		Removal, separation and recovery, and recycling technology of trace elements		
Common				
High performance materials/parts		Electrical steel	High-strength steel, innovative structural material, welding rod, etc.	Next-generation functional materials
Iron & steel				
Material saving of products		High functional and high tension plastics, ultra high strength and lightweight cement, highly functional and high quality paper		
Others				
Regeneration of material/energy		Integration, modularizing, and downsizing of products		
Common				

Jan/04/2006

Summary-8

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) <i>In the case of fossil fuel use with CCS</i>

Reduction in fossil use



Introduction of non-fossil energy

Summary-9

