CURRENT AND FUTURE CLEAN FOSSIL ENERGY TECHNOLOGICAL APPLICATIONS: "COMPLEXITIES IN MODERN ENERGY SYSTEMS"

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EXECUTIVE SUMMARY

Conversion of chemical energy into thermal energy by combustion of fossil fuels to generate electricity and power various transportation systems and various related applications has been the primary means of supporting human activities in the modern age. Evolution in modern energy systems has been dependent on various technical and non-technical factors: human cultures, social economics, natural resources, and scientific and technical advancements. The structure of modern energy systems depends on technology/utilization, and cuts across the complex boundaries between national and international economics and the environment. This last feature represents the *complexity*, which is a self-organized, multi-component system with various characteristic scales. The *complexity* of energy systems leads to the following features: (1) multiplicity of practical solutions, (2) multiplicity in technology and non-technology pathways and opportunities, (3) multiple criteria for system optimization, and (4) risks and issues associated with system implementation. The development of energy systems in the world since the 1970s has reflected these features of *complexity* and has frequently been burdened by significant financial and manpower commitments to achieve projected goals. Among many examples are the world energy crisis, which promoted the "New World" view on energy supply and demand in the 1970s, and more recently, global warming due to the effect of greenhouse gases, which promoted worldwide environmental concern. A recent study on "Technological Opportunities to Reduce Greenhouse Gas Emissions" by U.S. national laboratories elucidates how the *complexity* of modern energy systems can be coped with by comprehensive integrated knowledge of clean fossil energy technology, which focuses attention on energy efficiency, clean energy, and carbon sequestration. While this article does not intend to be a detailed elaboration of modern energy technology in the 21st century, it aims to elucidate how clean fossil technology can be developed in three major sectors— buildings, industry and transportation— to achieve fuel savings and preserve the quality of environments. Current global environmental concerns include: (1) the greenhouse gases (GHGs) that are predicted to cause climate change, (2) the emission of NO_X, generally known as Ozone Depleting Gases (ODGs), which have been known to deplete the ozone layer, (3) the formation of photochemical smog and acid rain precursors, and (4) the level of unhealthful tropospheric Oxidant Gases, (OXGs).

Two major efforts in global environmental protection that focus on combustion of fossil fuels are the first and second items listed above. The *1997 Kyoto protocol*, which serves

to set global guidelines for the control of CO_2 emissions, has stimulated new world interest in the control and minimization of CO_2 emissions. Additionally, approximately 19% of global NO_X and N_2O emissions, generated by combustion of fossil fuels and biomass, have contributed to global alteration by depleting the ozone layer and the level of tropospheric oxidants. Increasing global emission of NO_X prompted the *Montreal Protocol on Substances that Deplete the Ozone Layer, Final Act* (1987), which serves to guide control of ODGs. The NO_X emission control for stationary and mobile sources has been extensively researched among worldwide combustion communities since the 1970s, and significant reductions in NO_X emissions by post-combustion treatment have been successfully developed. In addition, the coming century poses regional and sub-global issues regarding the dynamics of supply and demand for fossil fuels, which continue to decline while economic growth spurs continued increases in energy demands under stringent environmental restrictions.

As world energy reserves continue to decline in the face of increasing demand, efforts to develop viable clean energies are vitally important. Recovery of wastes and harnessing of renewable energy, including solar and wind energy, is a vital strategy to provide a balanced energy mix system. Clean fossil energy (CFE) technology and its implementation have been deemed a viable means of achieving global and regional environmental protection, and careful planning and effective international collaboration will lead to successful resolution of the dynamics of energy economics and the security of the fuel supply in the coming century.

The science and technology at the heart of clean energy and environmental protection includes:

- energy conversion, exploration and development of energy resources;
- conservation;
- combustion and chemical processing;
- hydrogen technology;
- key energy-systems technology;
- material and information engineering; and,
- management and economics.

Looking toward the future, broad interdisciplinary technologies, including Micro-Electronic Mechanical Systems (MEMS), nanotechnology, biotechnology, and optical and molecular computers, are expected to bring new tools and provide in-depth understanding of the mechanisms, diagnostics, analysis, simulation, control and optimization of modern energy systems. There is an emerging concept of a *new global order* in energy and environmental protection, coupled with a *global energy economic restructuring*. This concept forms the basis of the modern concept of *earth village*. The infrastructure of world and regional energy systems is benefiting from linkages between government, industry, research establishments and academia throughout the world. Asia-Pacific Economic Cooperation (APEC) was chartered to improve regional energy supply structures, and promote utilization of energy-efficient technologies and R&D, as well as energy technology transfer. New energy and environmental technologies have been exchanged through international/regional collaborative efforts or information exchanges including conferences, workshops and archive publications, and more recently by global electronic communications. Education and training in energy and related subjects are being implemented through global and regional manpower development programs.

The objectives of this article, represented with conference view-graphs, are to present (1) the state-of-the-art in clean energy technology, (2) major technical and non-technical issues, and (3) the future prospects for application of clean-fuel technologies. Development of advanced gas turbines, fuel-cell technology, integrated gasification combined cycle technology, and distributed power generation technology, are examples of clean fuel technologies of the present and future.
This article concludes with a review of the research and development required to preserve energy efficiency, produce cleaner environments, and ensure energy security for continuing economic growth.

APEC —EWG Experts Group on Clean Fossil Energy

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Clean Fossil Energy Technical Application

Current and Future

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Outline of Presentation

- ***Introduction***
  - ***--Complexities of Modern Energy systems***
- ***Clean Fossil Energy Technology***
  - ***--Factors affecting clean Fossil Energy Technological Applications***
  - ***--Technical Application - current and Future***
- ***Technical Pathways in Energy Utilization Technology***
  - ***--Industry***
  - ***--Transportation***
  - ***--Building***
- ***Advanced Energy Technologies***
- ***Energy Research and Developments***
- ***Conclusions***

Complexities in Modern Energy Systems(1)

"Modern energy system is an organized system that cut across the boundaries between science and technology, economics, environment, and resources. The system has many characteristics that depend on GDP, reserves, supply, conversion, utilization, efficiency, quality, price and it has and many subsystems, structures in various scales; market size manufacturing capacity, energy consumption and population)"

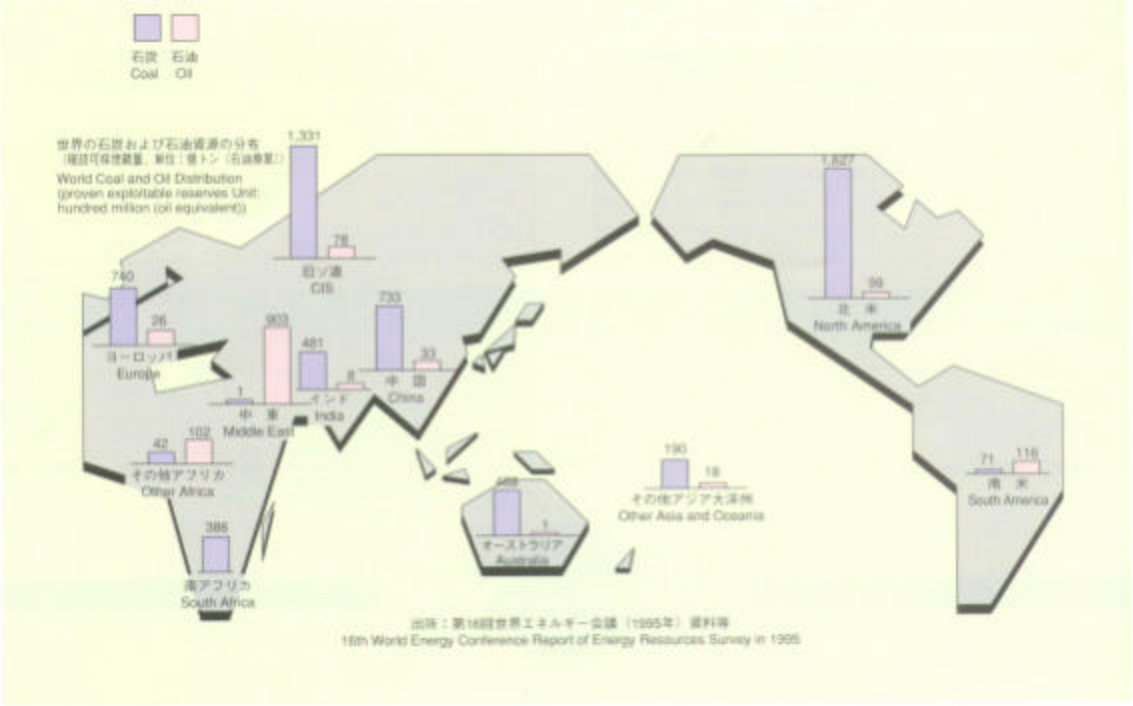
Complexities in Modern Energy Systems (2)

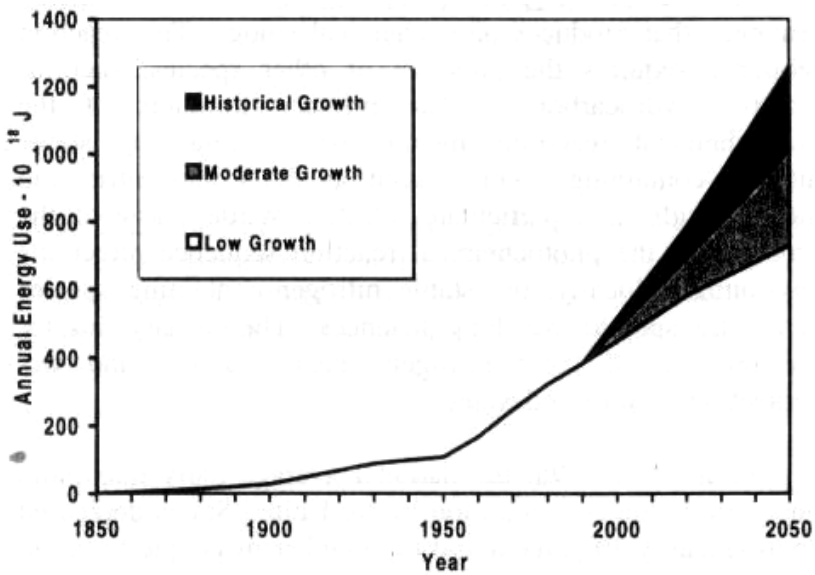
Complexities of the systems exhibit

(1) multiple solutions

(2) multiple technology and non-technology path ways and opportunities

(3) complex criteria of optimization, risk and issues associated with implementation and commercialization.





Global Energy Consumption Scenario

Impacts of Combustion Generated Emission

Combustion Generated pollutants

- ***Greenhouse Gases (GHGs)***

  Impact : climate change

  GHG : water vapor, CO_2 , N_2O, methane, O_3 CFC

  1997 kyoto protocol : global guidelines for the control of emissions of GHG

- ***Ozone Depleting Gases (ODGs)***

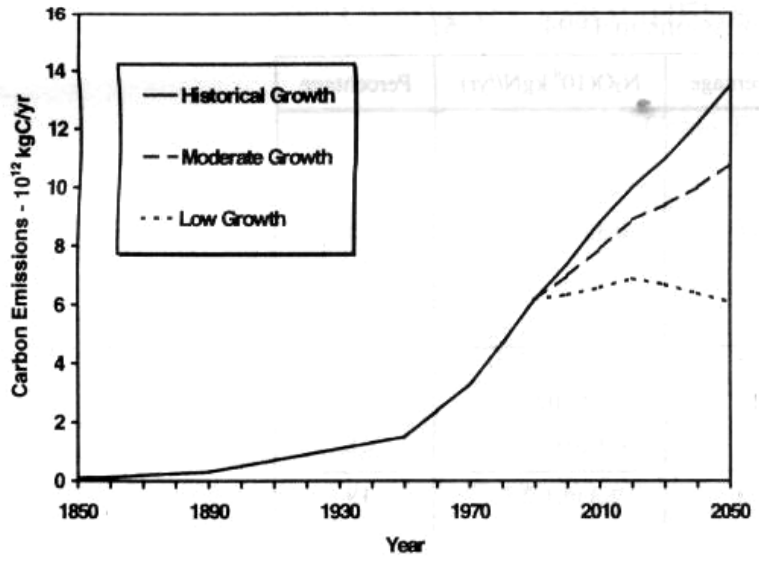
  Impact : Ozone layer depletion

  OPGs: Nox N_2O

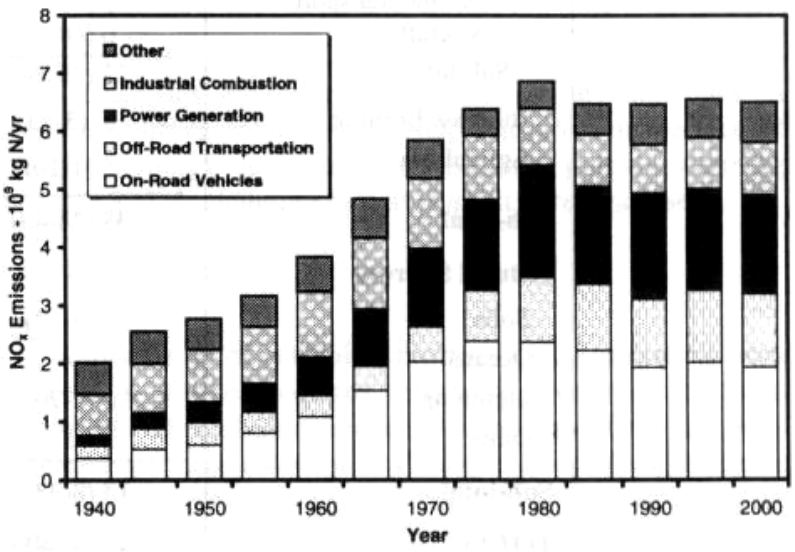
  1987 Montreal Protocol : guideline for the control of ODG

- ***Oxidants gases (OXGs)***

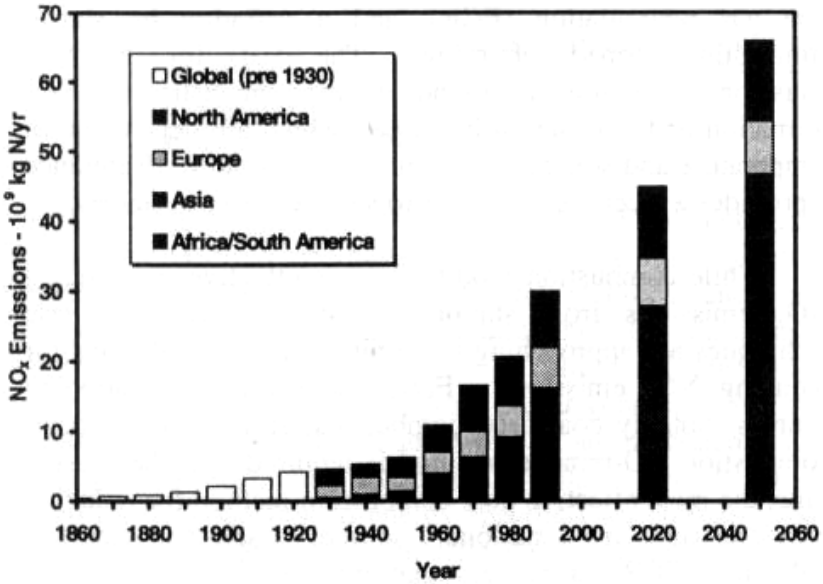
  Impact : unhealthful troposphere oxidants



World's Carbon Emissions Scenario



US NOx Emissions Scenario



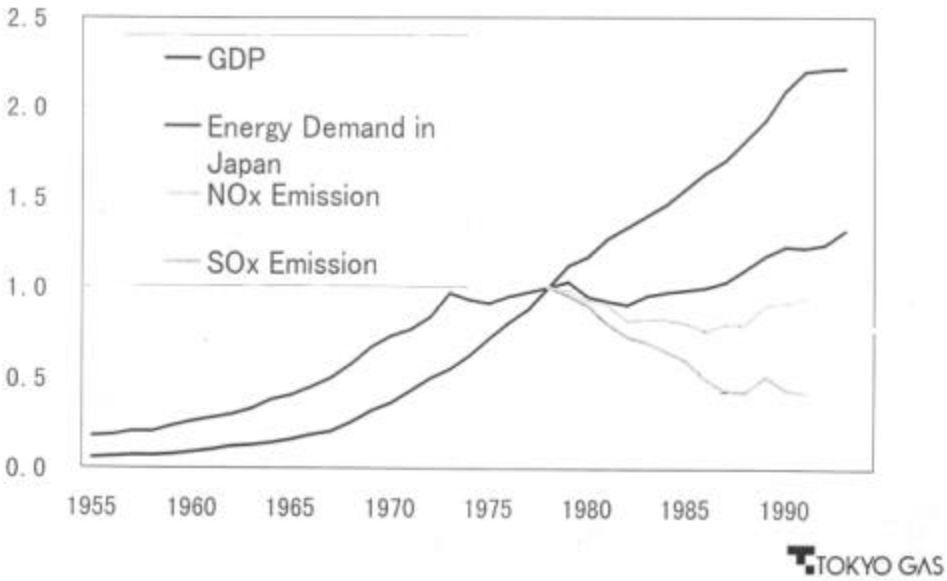
Global NOx Emissions Scenario

Estimated Global NO_x and N_2O Emissions in 1994 [2, 4, 5].

Source	NO_x (10^9 kgN/yr)	Percentage	N_2O(10^9 kgN//yr)	Percentage
Human Sources				
Fossil Fuel Combustion				
Stationary Sources	13	27	0.35 (0.1-0.5)	3
Mobile Sources				
Ground transport	8	17	-	-
Aircraft	0.6 (0.4-0.9)	2	-	-
Sub-total	22 (20-24)	46	0.35 (0.1-0.5)	3
Biomass Burning	8 (3-13)	17	< 1 (0.02-1)	< 8
Agriculture	5 (1-10)	10	< 1 (0.02-1)	< 8
Sub-total	**35 (24-48)**	**73**	**2.3 (0.1-2.5)**	**19**
Natural Sources				
Soils	7 (5-12)	15	5.0 (2.9-5.2)	41
Oceans	-		2.0 (1.4-2.6)	16
Lightning	5 (2-20)	10	-	-
Other	1 - 2	2	3.0 (0.2-6.3)*	24
Sub-total	**13 (8-33)**	**27**	**10.0 (4.5-14)**	**81**
TOTAL	**48 (32-81)**	**100**	**12.3 (5-17)**	**100**

* estimated N_2O emissions from soils due to N-deposition from the atmosphere

Changes in Energy Demand, GDP, and SOx and NOx Emissions in Japan



October 1997

U.S. carbon dioxide emissions by end-use sector
(in MtC per year)

	Emissions				Change from 1990		
	1995	2010	2020	2030	2010	2020	2030
Buildings							
Fossil	159	170	178	185	22	30	37
Electricity	335	406	463	515	94	151	203
Subtotal	494	576	641	700	116	181	240
Industry							
Fossil	293	335	357	380	49	71	94
Electricity	171	213	241	269	47	75	103
Subtotal	464	548	598	649	96	146	197
Transportation							
Fossil	464	591	655	727	160	224	296
Electricity	1	7	10	14	6	9	13
Subtotal	465	598	665	741	166	233	309
Total							
Fossil	918	1096	1189	1291	231	324	426
Electricity[a]	506	626	714	798	147	235	319
Total	1424	1722	1904	2089	378	560	745

Clean Fossil Energy Technology

Goals For CFE Technology

Energy Efficiency

- ***Efficient use of electricity through the development of advanced technologies, intelligent building control systems cost effective refrigerators and fuel cells***
- ***Reduced use of gas and oil for space and water heating through building efficiency measures(space insulation gas-fired heat pumps)***
- ***Improve industrial resource recovery and use integrated gasification combined cycle (IGCC) for industrial processes to save energy, advanced catalysis.***
- ***Increased transportation efficiency through new technologies (hybrid electric vehicle)***
- ***Us technology opportunities to reduceGreehouse Gas Emissions***

Clean Fossil Energy Technology (1)

Clean Energy

- ***Adopt energy mix to increase use of sources with higher generating efficiencies , increased use of natural gas ,renewable energy , (solar and wind power , biomass and hydrogen).***
- ***Develop "energyplexs that would use carbon efficiently with out emitting greenhouse gases for the integrated production of power , heat , fuels and chemicals from coal , biomass or municipal wastes***

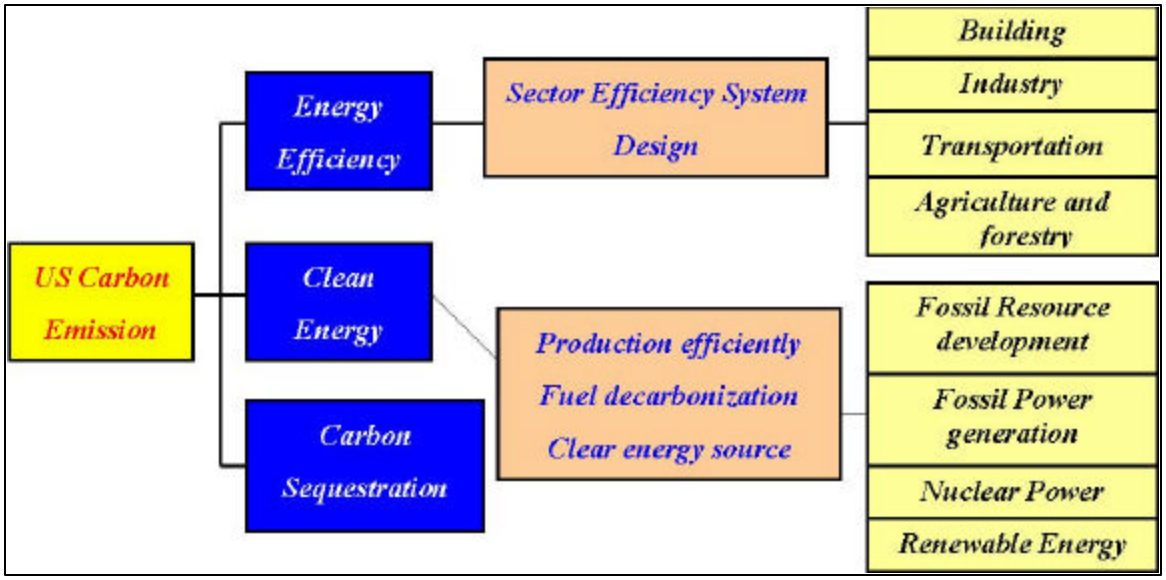
Clean Fossil Energy Technology (2)

- ***Use fuel with lower emissions in transportation (truck powered by bio diesel fuel ; ethanol from cellulosic feed stocks)***
- ***Distributed electric generation to reduce emissions , super conducting transformers , cable and wires .***

Clean Fossil Energy Technology

Carbon Sequestration

- ***Remove carbon dioxide from combustion emissions***
- ***Increase the rate at which oceans , forests and soil naturally absorb atmospheric carbon dioxide.***
- ***Develop technologies for long-term carbon storage in geological deposits , acquirers or other reservoirs .***



Clean Fossil Energy Technical Application

Gas Firing Technology

- ***Natural Gas:***
  - ***-general heating furnaces;direct/indirect firing***
  - ***-Drying, curing and cleaning; direct/indirect firing***
  - ***-Space Heating***
    - ***- Working flame burners***
    - ***- Power generation, cogeneration***
    - ***- Transportations***
- ***Liquid Petroleum Gases:***

Future Outlook

- ***Enhanced Utilization in early to mid 2000***
- ***New technological problems:storage, safety.***
- ***Distribution:Space limitation (Taiwan).***
- ***CO_2, NOx and other pollutant emissions.***
- ***High temperature preheating technology***

Clean Fossil Energy Technical Application

Liquid Fuel combustion :

- ***Industrial Burners***
- ***power generation, cogeneration***
- ***Transportation***

Spray Combustion Technology

- ***Atomization, Injection***
- ***NOx, Soot, SOx and Other pollutants emission control***
- ***High combustion efficiency***
- ***Cost Reduction***

Future Outlook

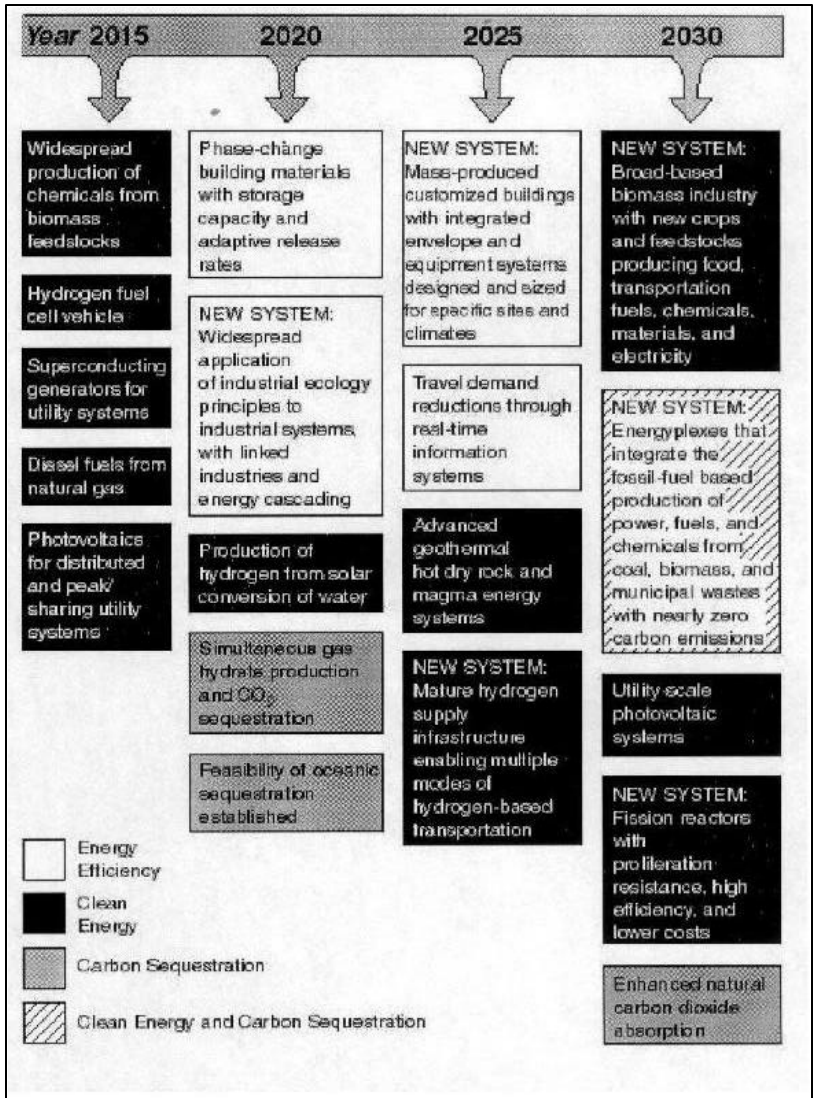
- ***automatic control for High combustion efficiency.***
- ***Low NOx, Soots and SOx.***
- ***Direct injection engines.***
- ***Alternative fuel engines. Low BTU***

Clean Fossil Energy Technical Application

Clean Fossil Energy Technical Application

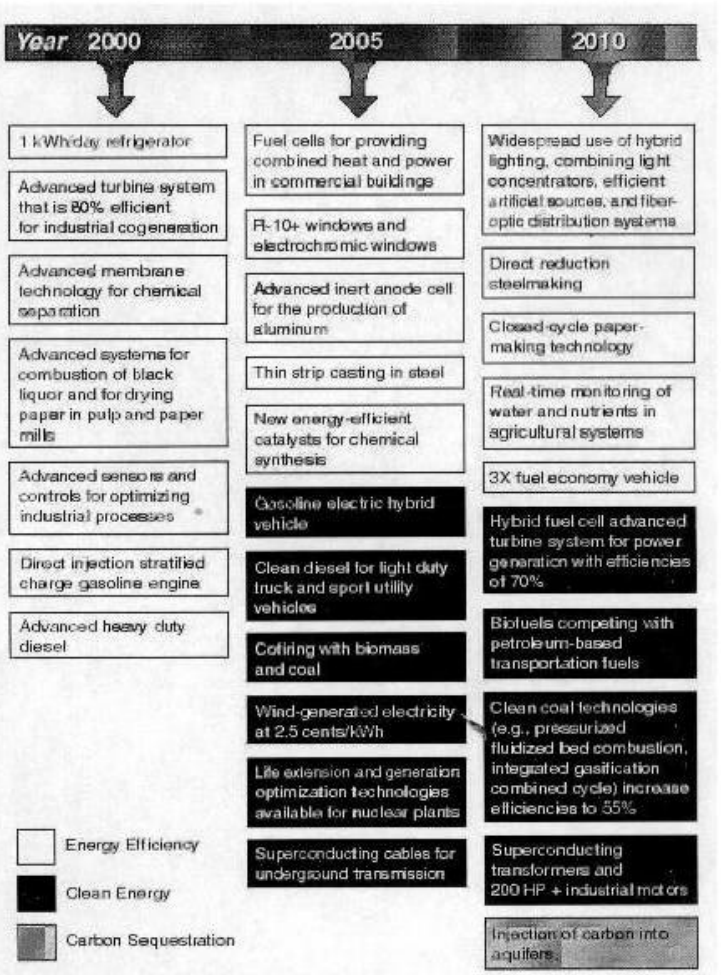
Feasibility of Technical Application Opportunities

- ***Incremental improvements to existing equipment and processes by scientific breakthrough and subsequent technological developments***
- ***Technologies that can be translated into market-ready products during next decades***
- ***Advanced technologies that may be available as one-of-a-kind prototype by 2025***
- ***Technologies that can be adopted in the current energy economy***
- ***Technologies that require major transformation***



Same as Before

Anticipated Technology Product



From "Technology Opportunities to Reauce U.S. Greenhouse Gas Emissions"

Oct. 1997 USDOE

Industry Energy Conversion and Utilization (1)

- ***System concepts***
  - ***Law GHG fuels, gasification of waste materials advanced combustion turbines and fuel cells.***
  - ***Modern design and system approach to minimize the generation of low-level heat.***
- ***Technologies***
  - ***ATS*** – ***Waste heat utilization***
  - ***Fuel cells*** – ***System design approach***
  - ***Gasification*** – ***advanced combustion technologies***

Industry Energy Conversion and Utilization (2)

Carbon Reduction

Industrial sector

	1997 (base)	*2010*	*2020*	*2030*
BAU case quads	*34.4*	*39.7*	*43.8*	*48.5*
Eff. Case(mod) quads		*36.6*	*38.3*	*40.5*
MtC reductions		*25-50*	*69-95*	*100-140*
(35% allocation to this pathway)				
Mt reductions			*9-18*	*23-33*	*35-50*

The estimated MtC reduction for the sector have wide ranges to account for uncertainties in market adoption and economics.

Industry : Industrial Process Efficiency

System concepts

- ***Increase system efficiency by single process optimization or process substitution in the manufacturing steps of raw material conversion, processing, product separation.***

Technologies

- ***Advanced separations, new material-and energy efficient reactor concepts, biotechnology/bio-derived materials.***

Industry : Resource Recovery and Utilization

System concepts

- ***Cradle-to-grave stewardship over industrial products***
- ***Advanced separations, improved chemistry and catalysts advanced materials, optimal process and design, sensors and controls, biotechnology.***

Technologies

- ***Recovery – filters, separation***
- ***Reuse – recycling, new market, industrial ecology***
- ***Improve understanding of chemistry and biotechnology to use CO_2 and other recovered by products as feed stocks algae to form carbonates, bioenzymes for biodegradable polymers.***
- ***Industrial ecology to minimize wastes.***

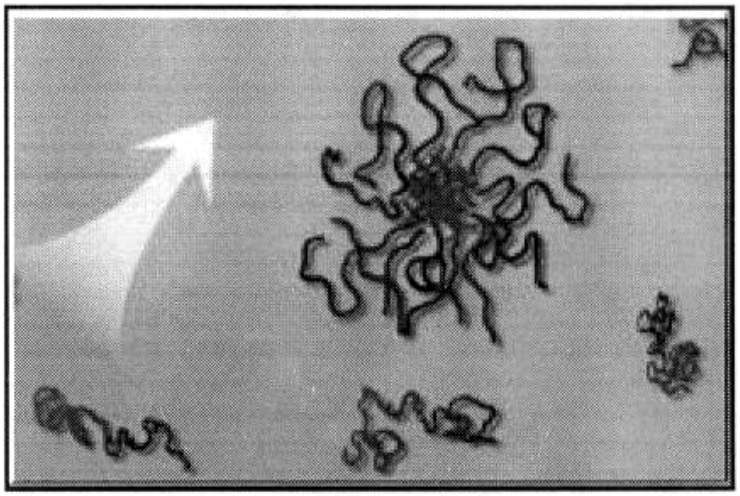
Industry : Enabling Technology

System Concepts

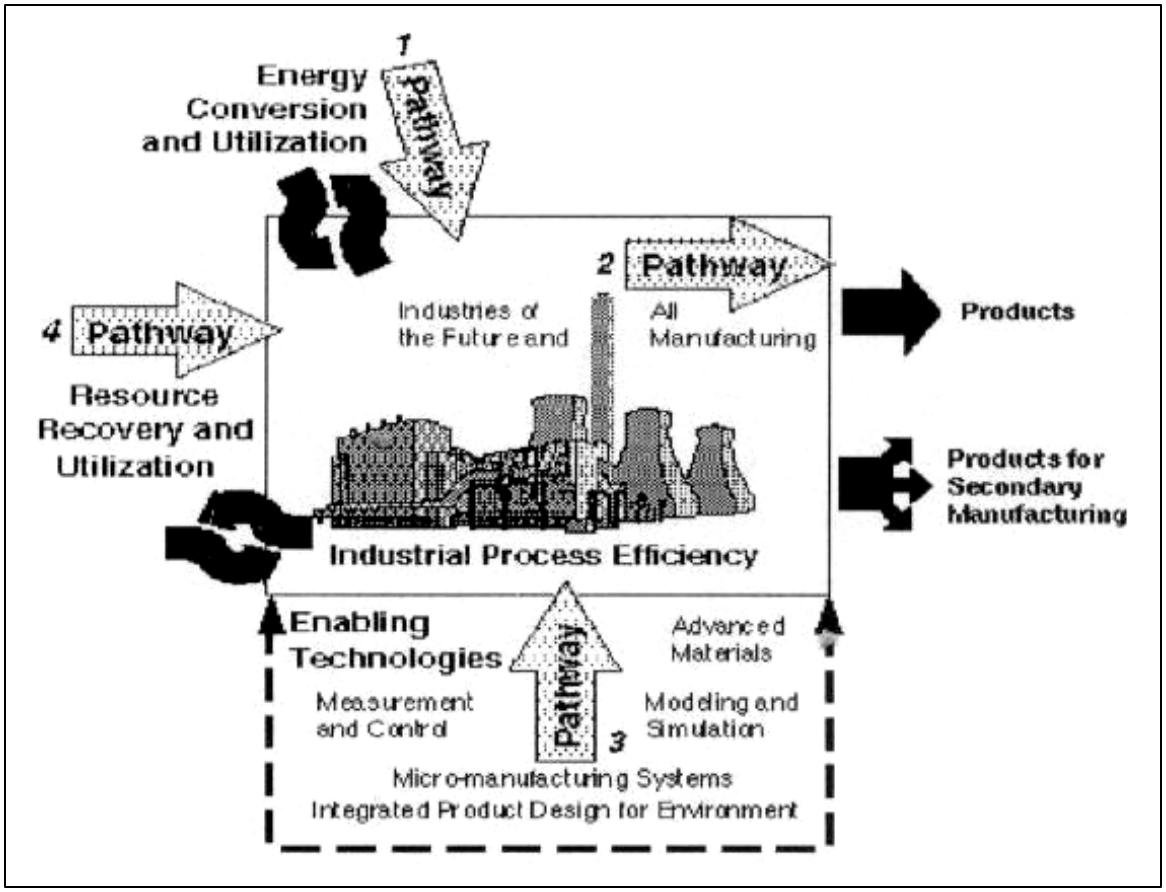
- ***Complement and enhance conversion and utilization and industrial process efficiency.***
- ***Increase understanding of process and application of new methods in fabricating products.***

Technologies

- ***Advanced materials***
- ***measurement and controls***
- ***new chemical reactions***
- ***modeling and simulation***



Neutron scattering aids the design of environmentally friendly ways to make polymers.



Industrial Vision on Fossil Fuel Energy Systems (1)

Key factors shaping the Future Energy/Power Industry

- ***Market economics***
  - ***Deregulation of the electric utility industry stimulates cogeneration and scales of power.***
  - ***Asia-pacific region is expected to have potential power market of small to intermediate size cogeneration system***
- ***Environmental Quality, Greenhouse Gases and NOx control***
  - ***CO_2 Reduction***
    - ***increased system efficiency***
    - ***innovative new combustion processes***
    - ***sequestration***

Industrial Vision on Fossil Fuel Energy Systems (1)

- ***Fuel/Oxidant selection***

  --The choice of the fuel oxidant depends on the cost and fuel availability.

  --The potential of hydrogen-based economy is a future consideration.

  1.quality of fuel is expected to decline

  2.clean fuels priority,natural gas, hydrocarbon liquid fuels

- ***Energy efficiency***

  --Energy costs are competitive issue and the energy efficiency has strong environmental and economic impacts.

  1.reduction of specific energy consumption

  2.reduction of greenhouse

Industrial strategies on Fossil Fuel Energy Systems

Burners

- ***Robust, process friendly***
- ***Energy efficient***
- ***Compliant with emission regulations, NO_x , CO_2***
- ***Multi-fuel capability***
- ***Advanced flame-management to achieve reliable and safe operation***

Boilers

- ***Energy-efficient***
- ***Low emission***
- ***Fuel-flexibility, reliable and safety***
- ***Advanced technology:***
  - ***automated control***
  - ***total system integration***
  - ***improved material***
  - ***Smart technology with automated controls for system integration, minimum operator requirement***

Industrial Strategies on Fossil Fuel Energy Systems (2)

Furnace and Process Heating Systems

- ***Produce uniform, high quality end product at high production rate with low specific fuel consumptions***
- ***Minimum environmental impacts***
- ***Advanced burner have flame management features with user friendly, high reliability and safe***
- ***Fuel flexibility***
- ***waste fuels, biomass, renewable fuels***
- ***up front processes for the fuel tailoring***
- ***Energy Efficiency***
- ***Fuel characteristics***
- ***Design considerations***

Industrial Vision on Fossil Fuel Energy Systems (2)

- ***Process Improvement***

In order to increase process efficiency advanced controls and sensors, system integration and analysis to assess environmental quality, energy efficiency, and health safety and reliability.

(1) Controls and sensors for the regulation of Combustion

(2) System integration and analysis to determine design and operation of future combustion systems.

Industrial Strategies on Fossil Fuel Energy Systems (1)

- ***Environmental Quality***
  - ***NO_x emission is less than 2ppm and CO_2 emission is less than 5 ppm.***
  - ***Volatile organic compounds and unburned Hydrocarbons are less than 1ppm.***
  - ***Particulate emission is less than 0.003 pounds per million BTUs of fuel burned.***

Industrial Vision on Fossil Fuel Energy Systems (1)

NOx control:mobiles sources

- ***improved injection technique:sequential-port-fuel- injection***
- ***catalytic reactors for emission control***
- ***reformulated gasoline with lower aromatic content***
- ***improved injection, fuel/air mixing***
- ***homogeneous charge for advanced diesel engine***
- ***catalytic removal***
- ***Hybrid power generation/engine***
- ***Hydrogen powered engine***
- ***Aircraft engine design and operational factors***

Industrial Vision on Fossil Fuel Energy Systems (2)

NOx control

- ***Staged combustion, low NOx burner (LNB)***
- ***flue gas recirculation(FGR)***
- ***Reburning***
- ***Selective catalytic Reduction(SCR)***
- ***Selective non-catalytic reduction(SNCR)***
- ***Lean fuel combustion***
- ***Preheated high temperature air combustion***

Industrial Vision on Fossil Fuel Energy Systems (2)

- ***Health, safety and reliability***

  The combustion, heating systems must be designed to operate under various operating conditions with optimal performance and the minimum toxicity.

  - ***safety standard***
  - ***maximum flexibility and robustness***
  - ***reliability***

Industrial Vision on Fossil Fuel Energy Systems

- ***Research and Education***

  Identification of the area of potential improvement of all the systems and establish new research and education programs. Strong link and collaboration between industry, research institutions and academia. Current education programs in US, Japan, Taiwan and other European Nations have been relatively weak, largely due to the lack of instructor and experimental facilities.

  1. research in the area of high priority

  2. long term research for the future competitiveness.

  3. Strengthen combustion education in universities and colleges.

Transportation Advanced Conventional Vehicle **(1)**

System concepts

- ***Weight reduction: light weight materials, redesign for structural integrity with less material.***
- ***Reduce friction and pumping processes, higher thermodynamic efficiency.***
- ***Reduce aerodynamic drag and rolling resistance***

Technologies

- ***Supercomputer design, direct injection diesel and stratified-charge gasoline engine, variable value control, continuously variable transmission, aluminum and graphite composite material.***

Transportation Advanced Conventional Vehicle (2)

Carbon Reductions

- *Potential carbon reductions include effects of non-drive train improvements on vehicles with unconventional drive trains(e.g., hybrids and electric vehicles)*

–	2020	2030
15-25MtC	40-60MtC	80-100MtC

Transportation Freight vehicles (1)

System concepts

- *Four stroke, direct injection diesel engines (high peak cylinder pressure,thermal barrier coating, high pressure fuel injection system and turbo charging)*
- *Light weight materials, truck aerodynamics, advanced tires*
- *Hybrid electric vehicles or regenerative braking*
- *Trains use laser glazing of rails, flywheels, diesel and oxygen rich air systems*

Transportation
Freight vehicles (2)

Technologies

- ***High pressure common-rail fuel injection, bottoming cycles, friction and wear reduction***
- ***Oxygen enriched combustion air technology***
- ***Software technology for improved aerodynamic***

Carbon Reductions

In MtC/year

2010	2020	2030
7-10	15-30	25-30

Transportation
Hybrid, Electric and Fuel Cell Vehicles (1)

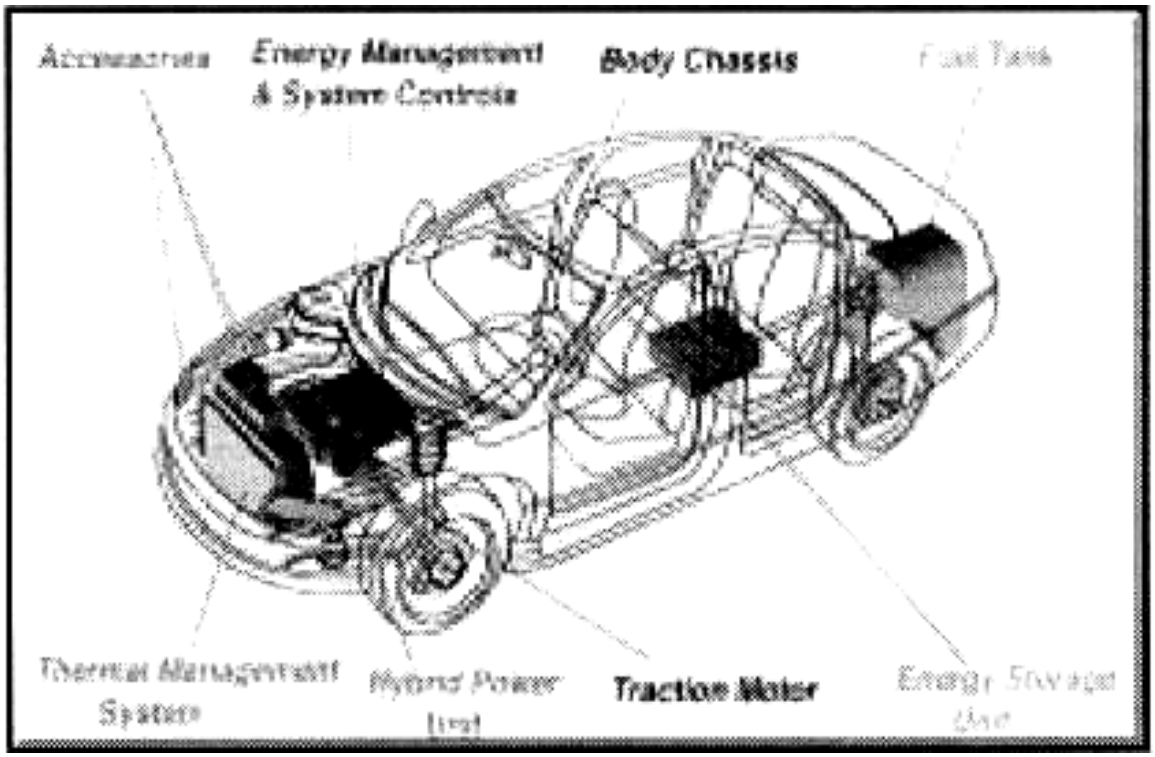
System Concepts

- ***A series HEV drives the wheels using an electric motor while drawing energy from battery pack, which is charged by a on-board engine or other types of power unit***
- ***A parallel HEV uses both an electric motor and power unit***

Transportation
Hybrid, Electric and Fuel Cell Vehicles (2)

System Concepts

- ***An EV uses a rechargeable battery pack, a motor controller, an electric drive motor, and gear reducer to drive vehicles***
- ***For fuel cells, hydrogen can be stored on the vehicle or can be made on board using gasoline or alternative fuels***



Transportation
Hybrid, Electric and Fuel Cell Vehicles (4)

Carbon Reduction

- ***Combination of advanced vehicles reduce GHG emission of 10-15 MtC by 2010, 25-45 MtC by 2020 and 50-75 MtC by 2030***

Transportation
Alternative Fuel Vehicles (1)

System Concepts

- ***Alternative fuel vehicles are similar to current vehicles except for certain fuel-and emission-related systems***
- ***Alcohol vehicles requires corrosion resistant fuels and tanks modified fuel injectors***
- ***Gaseous-fuel vehicle fuel system components includes fuel regulators, air and fuel mixing apparatus and modified fuel injectiors***

Transportation
Alternative Fuel Vehicles (2)

Technologies

- ***Flexible-fueled vehicles are available from three major US domestic automobile manufactures***
- ***Compressed natural gas and LPG vehicles are available***
- ***Heavy-duty alternative fuel engines are offered as option***

Carbon Reductions

2010	*2020*	*2030*
2-10MtC	*4-12MtC*	*15-30MtC*

Transportation
Air and High-Speed Ground Transportation (1)

System Concepts

- ***High speed rail (HSR) speed up to 200 mph, use locomotive-drawn coaches***
- ***Maglev (300mph) use magnetic forces for non-contact support, guidance, propulsion and braking***
- ***Propulsion efficiency in air craft is increased by high by-pass ratio, high pressure ratios, high turbine inlet temperatures, improved turbine aerodynamics and lighter weight reduction of drag by laminar flow control***

Transportation

Air and High-Speed Ground Transportation (2)

Technologies

- ***HSR: French TGV, German ICE, JapaneseNozomi, Energy storage systems, high temperature super conducting components, Taiwan HSR is currently being planed***
- ***Maglev: German Trans rapid, Japanese Linear Motor Express***
- ***High by pass turbofan engines, prop fan technology***

Transportation

Air and High-Speed Ground Transportation (3)

Technologies

- ***Advanced materials, structures***
- ***CFD for airframe and engine design***
- ***Hybrid laminar flow control***

Transportation

Hybrid, Electric and Fuel Cell Vehicles (3)

Technology

- ***High-power energy storage devices: (ultra capacitors, flywheels)***
- ***Small high-efficiency integrated power unit: (gas turbines, direct injection diesel engines, spark ignition engines, fuel cells)***
- ***Compact electric power systems: (electric drive motors, electronic controllers)***

Advanced Gas Turbine (1)

Advanced Combined Cycle Program

- ***800-megawatt natural gas- fuel power turbine combined cycle***
- ***NO_x emission is reduced to less than half the current emission level***
- ***CO_2 emission is reduced by 20%***
- ***60% net efficiency***
- ***Turbine temperature 2600F***
- ***High temperature alloy turbine blade with ceramic coating***
- ***Closed loop cooling of the first and second rotor and stator blades***

Advanced Gas Turbine (2)

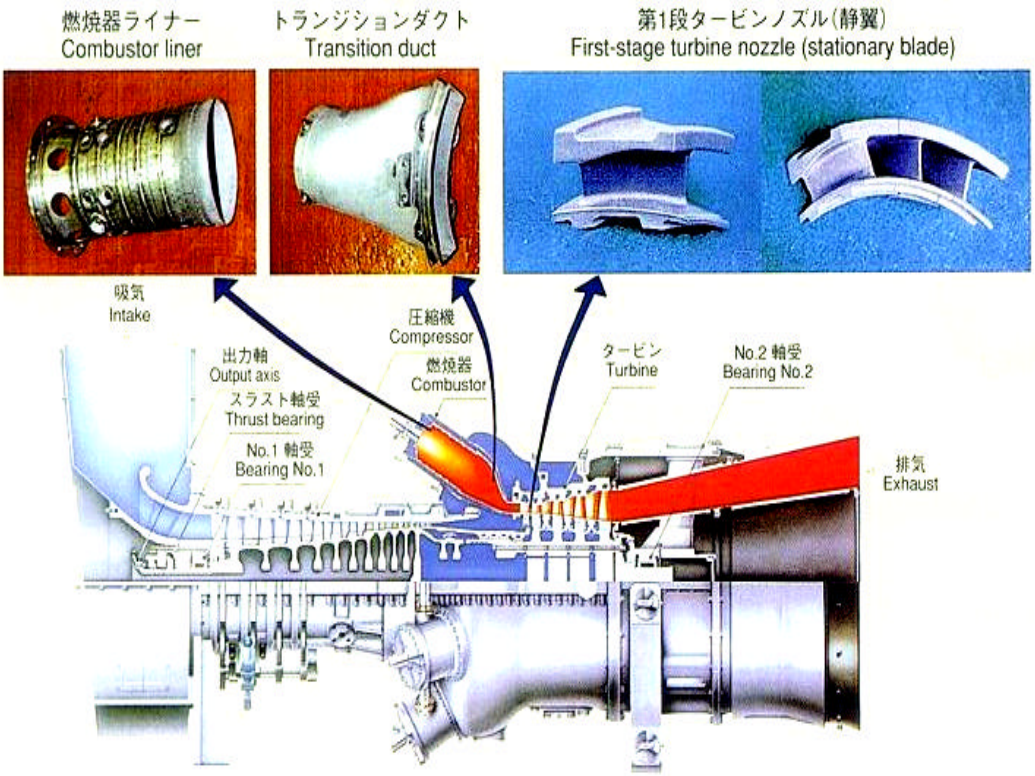
- ***NO_x emission and Air Management***
  - ***lean fuel combustion***
  - ***combustor and turbine cooling by air from compressor***
- ***Air Management by Staging and Cooling***
  - ***fuel and air staging for flame stability at near lean limit***
    - ***fuel stage: single or group of injector turn off***
    - ***air stage: redirection of air***
  - ***Advanced sensor programmablescontrol systems***
  - ***combined cycle power generation use closed loop steam coding***
  - ***Advanced materials Ni-Co super alloys requires less cooling air***
  - ***Ceramics for gas turbine components gives 2% increase in efficiency***

Advanced Gas Turbine (3)

- ***Lean Premixed Combustion***
  - ***NO_x reduction from 200 PPM to 25 PPM in natural gas fired heavy-duty gas turbine power generation system***
  - ***Premixing and autoignition: use premixer to avoid flush back***
  - ***Combustion dynamics and control***
    - ***Oscillation control***
      - ***Fuel staging***
      - ***Active control modulate flow to disturb Rayleigh oscillation***
  - ***Catalytic combustion offer stable combustion at lean blow out limit***

Advanced Gas Turbine (4)

- ***Non-Premixed Combustion***
  - ***Natural gas or gaseous fuel derived from coal or biomass***
  - ***Liquid fuels: NO_2 oil (Diesel) or Jet fuel***
  - ***Advanced spray injection management for improved efficiency by 5% above conventional injector (non-optimized). This is achieved by controlling the optimum spray pattern described by Chiu number. Furthermore pollutants emission can be controlled by fuel flow rate***



Fuel Cell Technology (1)

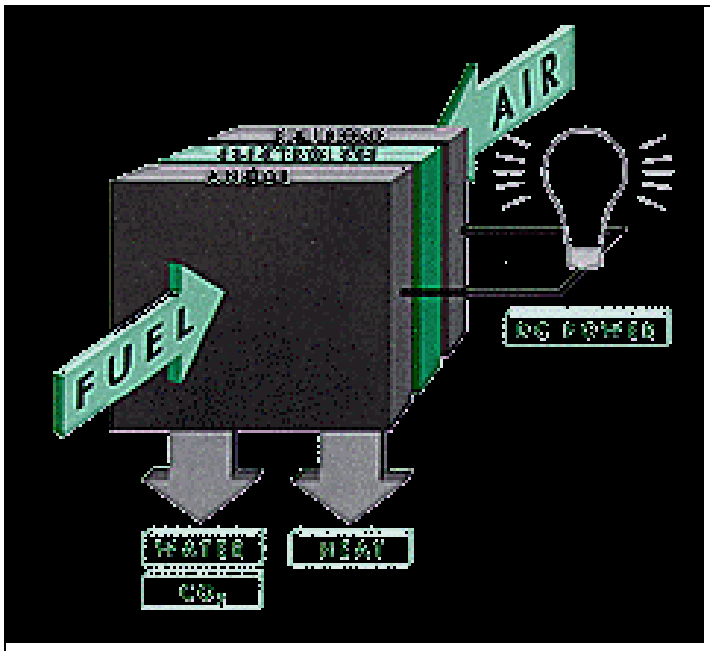
Advantages

- ***Environmentally clean, No_x emission for below current and future control levels***
- ***Higher fossil fuel energy conversion efficiencies to electricity than the best of the competing combustion technology***
  - ***Reduce cost of electricity***
  - ***Reduce CO2 emission per unit of useful out put***
- ***High-tech power conversion units, support jobs***
- ***Large anticipated market, rapid commercialization***
- ***Modular construction to allow size adjustment***
- ***Fuel flexibility: natural gas, coal gas, methanol landfill gas***

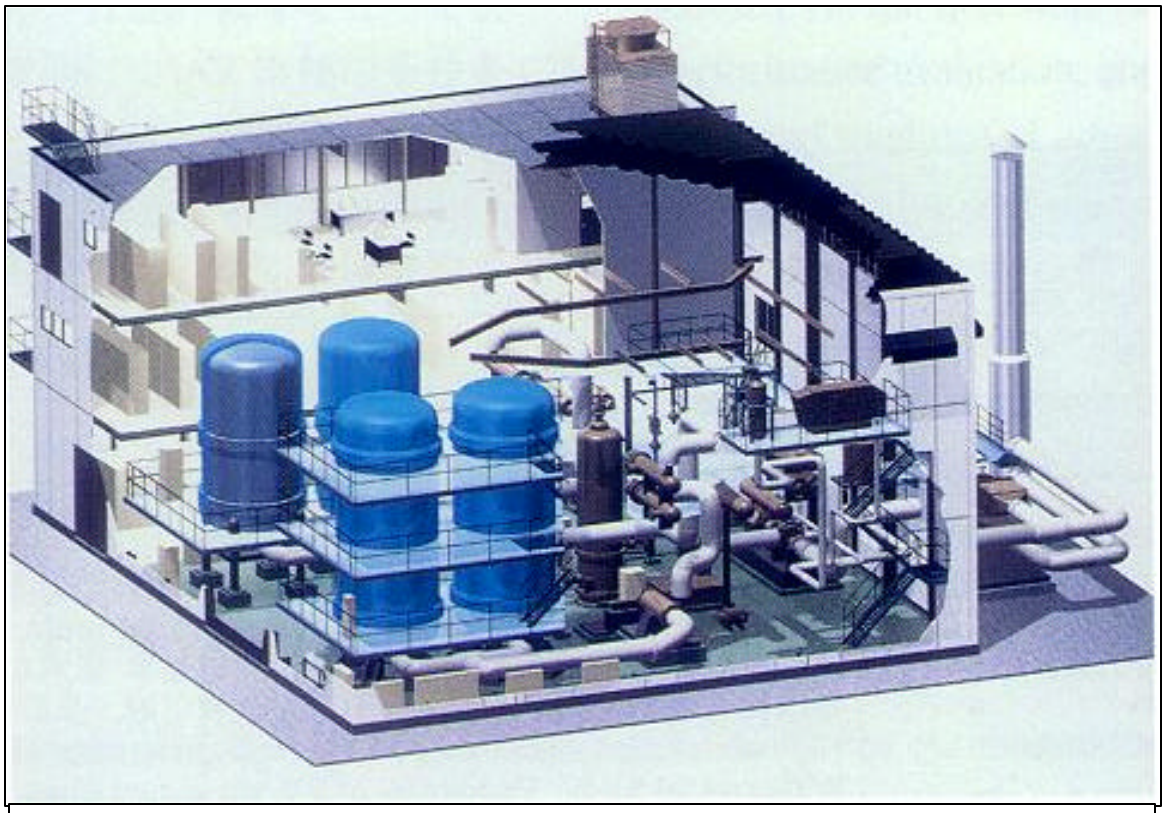
Fuel Cell Technology (2)

- ***Phosphoric Acid Fuel Cell***
  - ***Mature fuel cell technology and in commercialization***
  - ***200 KW plants installed in 70 sites in U.S., Japan and Europe***
  - ***Produce neat for domestic use***
  - ***Electric efficiency exceeds 40%***
- ***Molten Carbonate Fuel Cell***
  - ***Demonstration stage***
  - ***Electric efficiency exceed 60% at operating temperature of 650 ^{o}C***
  - ***Combined cycle application with thermal efficiency of 85%***
- ***Solid Oxide Fuel Cell***
  - ***100KW plant: solid state ceramic construction operates at 1000 ^{o}C***
  - ***Fuel flexibility***
  - ***Combine cycle application with 60% electric efficiency 85% thermal efficiency***

	Fuel Cell Type			
	Polymer Electrolyte Membrane	Phosphoric Acid	Carbonate	Solid Oxide
Electrolyte	Ion Exchange Membrane	Phosphoric Acid	Alkali Carbonates Mixture	Yttria Stabilized Zirconia
Operating Temp., °C	80	200	650	1,000
Charge Carrier	H^+	H^+	$CO_3^=$	$O^=$
Electrolyte State	Solid	Immobilized Liquid	Immobilized Liquid	Solid
Cell Hardware	Carbon- or Metal-Based	Graphite-Based	Stainless Steel	Ceramic
Catalyst	Platinum	Platinum	Nickel	Perovskites
Cogeneration Heat	None	Low Quality	High	High
Fuel Cell Efficiency, %LHV	<40	40-45	50-60	50-60



Schematic of Fuel Cell



Prototype Fuel Cell Power Plant

Hybrid Power Plant

- ***Combined Technology - Feasibility Study***
  - ***Gas turbine and fuel cell hybrid plant with 70% efficiency and 30% less CO_2 emission***

    (1) MC Power Co. -Bechtel, IGT, Allison Engine Co.

    Feasibility of 20MW combined cycle process natural gas fueled molten carbon fuel cell combined with gas turbine

    (2) Fuel Cell Engineering - ERC, Allison Engine Co.

    Carbonate fuel cell combined with gas turbine and steam turbine generator and double fuel cell

    (3) Westinghouse Electric Co. - Allison Engine Co.

    Pressurized solid oxide fuel cell combined with conventional gas turbine without steam plant

PRESENT TECHNOLOGY

MICRO gas turbines

FUTURE TECHNOLOGY

MICRO cogeneration

Homes, shops and stores

Hybrid heating

Industry

Fuel cell

Vehicle and industry

New Energy Resources and Clean Energy Technology (NERCET) Development Program

NERCET development

Waste utilization Technology	Advanced Energy utilization Technology	Renewable Energy Technology
•Agriculture waste •Municipal waste • Industrial waste •Waste Energy	•Gasification combined cycle power generation •Fuel cells and Hydrogen Technology •Electric vehicles	•Solar Energy •Biomass Energy •Geothermal Energy •Ocean thermal Energy •Small Hydro power

Clean Fossil Energy Utilization Technology Development Progrom

CFEUT

- I.T.R.I.
- Univ.of Calif at Berkeley
  Argonne National Lab.

Clean solid Fossil Energy

- Gasification of Solid fossil fuel
- H_2S removal tech
- Simulation of IGCC.

Advanced Energy Technology

- Advanced Diesel Engine Combustion Simulation
- Hydrogen Production
- Low-Pollution, Low BTU catalytic combustion
- Low Nox boiler
- High efficiency Electrostatic precip[itator

Alternative Fuel for Ttansportation

- Alternative fuels for transportation

Technologies	2011-2020 Prod.cap.inc. MKLOE/y	2011-2020 co_2 Reduction Mt/y	2011-2020 Invest. NT.Billions	Contribution/Billion	
				Prod.cap.inc. MKLOE/y	co_2 Reduction Mt co_2/y
Renewable:					
▪Solar	0.36	1.013	217	0.166	0.467
▪Hydro	0.87	2.42	791	0.11	0.306
▪Wind	0.93	2.64	531	0.175	0.497
▪Geothermal	0.157	0.441	93.5	0.168	0.472
▪Solar photovoltaic	1.624	4.58	1488	0.109	0.308
▪Biomass	1.07	3.032	181.64	0.589	1.669
▪Ocean thermal	0.391	1.105	250.2	0.156	0.442
Advanced Energy utilization					
▪Coal Gasification combined cycle	3.173	11.804	210	1.511	5.621
▪Electric vehicles	0.0492	0.1387	100	0.049	0.139
▪Fuel cells	0.424	1.145	518	0.082	0.221
Waste utilization					
▪Agriculture	0.031	1.73	17.6	0.176	9.83
▪Industrial	0.781	2.906	151.8	0.514	1.914
▪Municipal	0.221	0.623	79.2	0.279	0.787
▪Waste Energy Recovery	0.704	1.984	458.68	0.153	0.433

New Energy Resources Development Profile in Chinese Taipei

Conclusion

- Develop and promote clean fossil energy technology in industry transportation, and buildingsecfersto achieve high efficiency, and low greenhouse gas and zone depleting gases.
- Clean fossil energy technology aims to develop technologies energy efficiency, clean energy, and carbon sequestration for the current and future applications.
- Advanced technologies including advanced turbine system, Fuel cell, integrated gasification combined cycles and related technologies are the potential technology for electric power and transportation systems
- Advanced combustion technologies including low NO_x combustion, lean combustion, staged combustion,catalyst combustion, preheated combustion, Spray combustion play important roles in clean fossil energy system.

Conclusions

- Produce clean fuels from various natural resources, wastes, petroleum cone, coal, biomass and hydrogen enhance future energy supply.
- Develop energy collaboration in technology transfer, joint research projects exchange of scientists and engineer energy conference in the current APEC infrastructure.