GHG emission mitigation by renewable and alternative energy technologies backed by innovations in advanced materials

Zuhair S. Khan, Ph.D.
Centre for Energy Systems
National Univ. of Sciences & Technology
Islamabad, Pakistan.

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Outlines

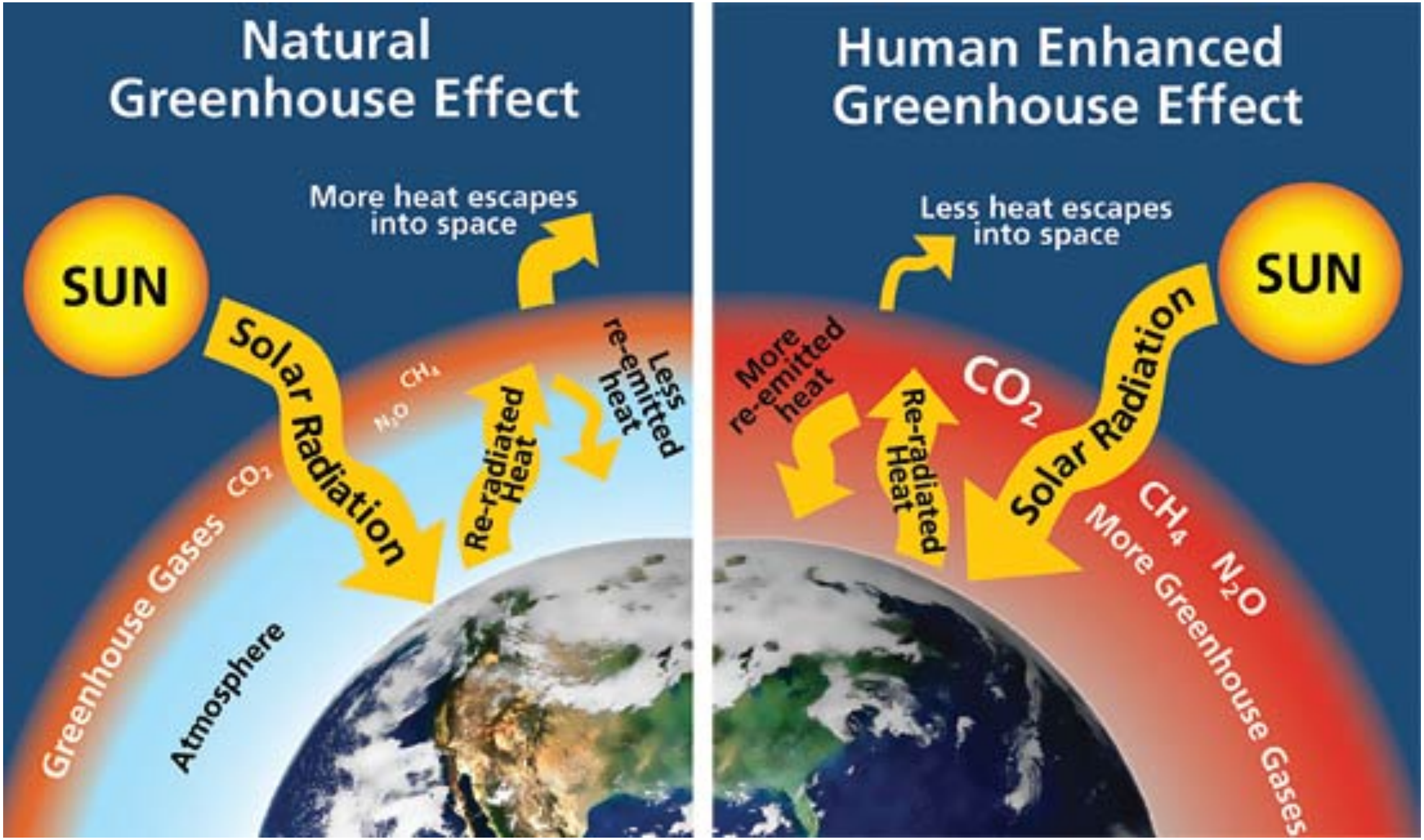
- **Abstract**
- **GHG emission and mitigation**
- **Overview of various carbon mitigation technologies and advanced materials**
  - **Solar energy technologies for GHG Mitigation**
  - **Hydrogen and Fuel Cells**
  - **Wind power**
  - **Geothermal electricity**
  - **Biomass and Biofules**
  - **Fossil fuel energy**
  - **Nuclear**
  - **Transport**
  - **Hydropower**
- **Findings/Conclusion**

GHG emission mitigation by renewable and alternative energy technologies backed by innovations in advanced materials

Abstract:

World energy demand has been increasing continuously and is projected for a strong growth by 50 percent from 2005 to 2030. The most critical issues and major challenges for global economy and climate change are energy supply security, high oil prices and growing greenhouse gases emission. In order to overcome these challenges, some clean sources of energy, such as fuel cells, photovoltaic devices, solar heating, wind energy, geothermal energy and biofuels which produce least greenhouse gases or pollutants, need to be developed. High temperature fuel cells such as molten carbonate fuel cells and solid-oxide fuel cells harness the chemical energy of fuel to generate electricity and promise high efficiency in generating electricity from hydrogen and even hydrocarbons. Similarly, energy from sunlight is used for heating and electricity generation without polluting the environment. Meanwhile, within solar energy stream, photovoltaic technologies are broadening its spectrum in generating the electricity. Other renewable options include the use of wind energy which has the great potential among various clean energy power systems for GHG emission mitigation, in particular at those locations with high wind energy density and/or high GHG emissions from local grid power supply. Biomass is equally promising source of energy for the production of biofuels as well as electricity with potential of lowering the GHG emission. In addition, geothermal and hydropower are also important areas of renewable energy. In this session, we are going to discuss the modalities and role of these renewable and alternative energy resources with their pros and cons and their potential for GHG mitigation and sustainability, etc. Some relevant advanced materials used for the manufacture of various components in selected renewable and alternative technologies will be mentioned. Finally, some recent achievements would be reported from the CES platform within the selected areas.

How the Greenhouse Effect Works



Green House Gases (GHGs)

Greenhouse gases are those that can absorb and emit infrared radiation.
The most abundant greenhouse gases in Earth's atmosphere are:

i. Water vapor (H_2O)
ii. Carbon dioxide (CO_2)
iii. Methane (CH_4)
iv. Nitrous oxide (N_2O)

About 80-90% of the Earth's natural greenhouse effect is due to water vapor, a strong greenhouse gas. The remainder is due to carbon dioxide, methane, and a few other minor gases.

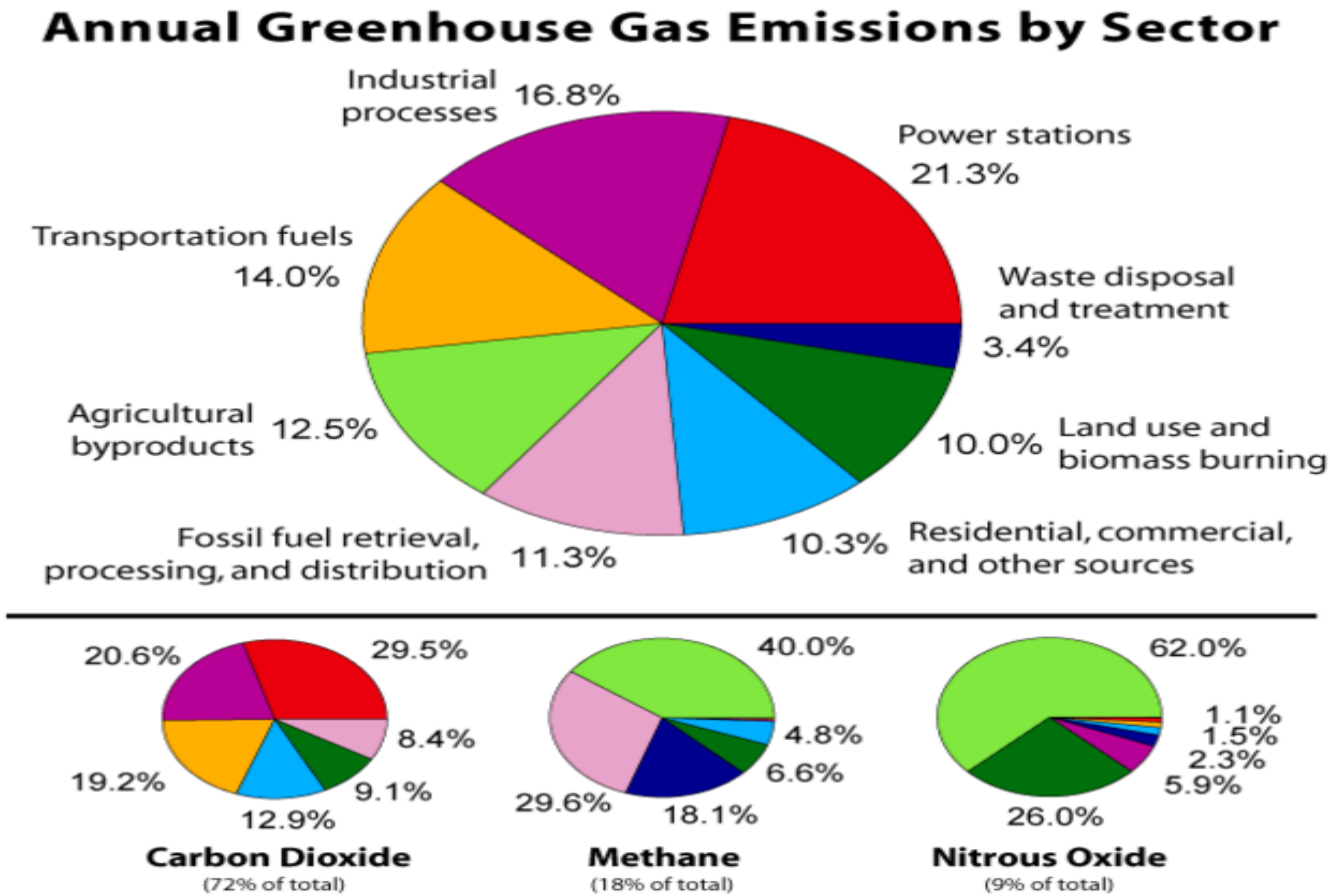
Among these GHGs Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities like the burning of fossil fuels and through deforestation.

➔ **Advanced renewable and alternative energy technologies can be helpful in the mitigation of CO_2 emissions by reducing the usage of fossil fuels used for electricity generation or for water heating purposes.**

Sources of Green House Gas Emission

- The primary sources of emission of green house gas
  - Electricity generation
  - Transportation
  - Industry
  - Commercial and residential
  - Agriculture
  - Land use and forestry

GHG Emission by Sector: power stations dominate CO2 emission followed by industrial processes and transportation sectors

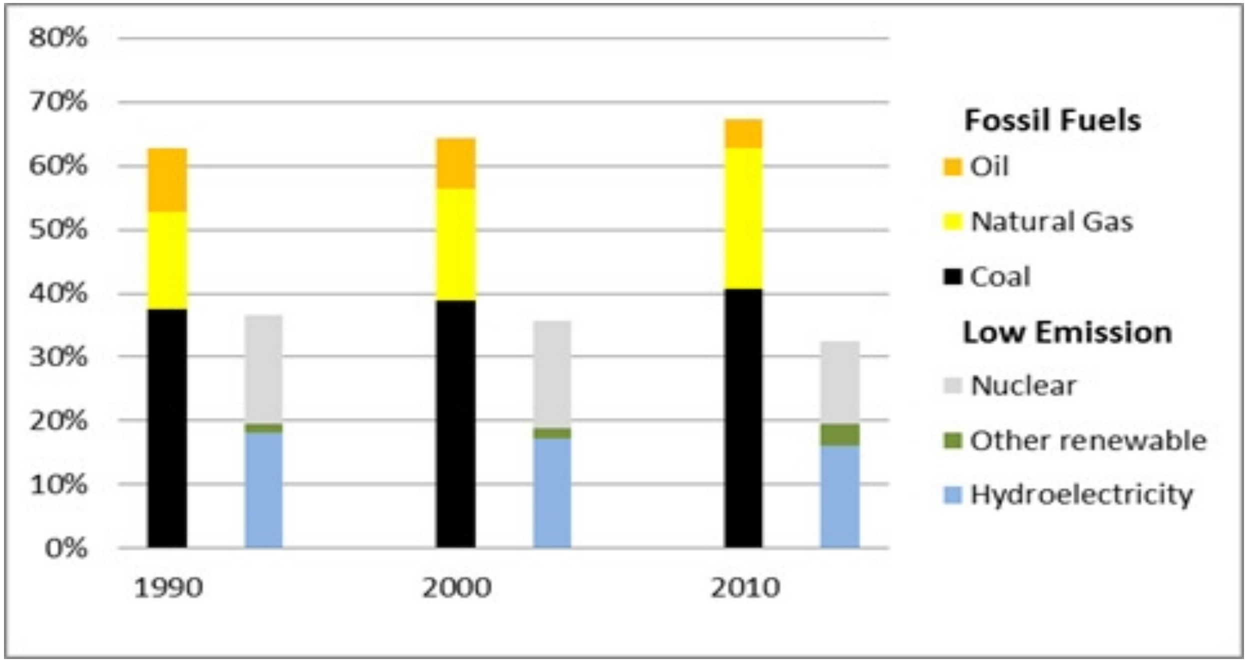


- Source: World Resources Institute

Categorization of Resources with High & Low GHG Mission

Electricity Generation

- **High GHG Emission Electricity**
  - Fossil fuels (Oil, Natural gas, Coal)
- **Low GHG Emission Electricity**
  - Nuclear , Hydro Electricity, Renewable Energy

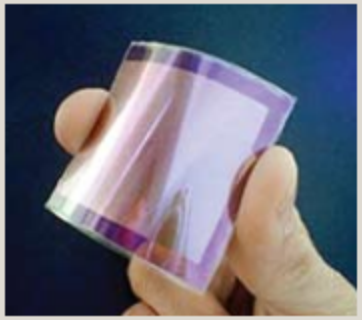


•Sources: World Energy Outlook 2002 and World Energy Outlook 2012, IEA

Carbon mitigation by renewable and alternative energy sources: Overview & issues/options / developments in advanced materials

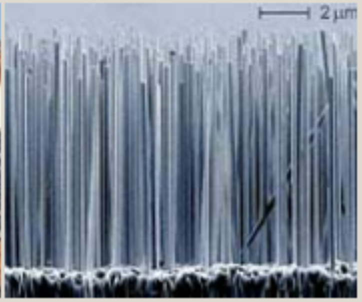
Solar energy technologies for GHG mitigation

Solar energy technologies for GHG mitigation



Flexible solar cell

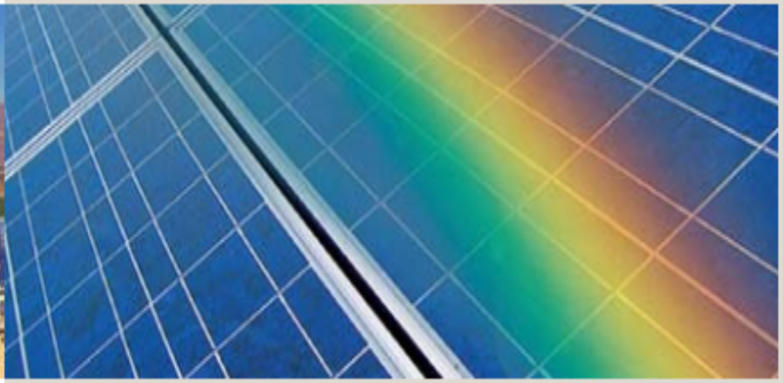
Home solar power



Nanowire array

Silicon PV system – courtesy SunPower Corporation

Concentrating solar power tower – courtesy Sandia National Laboratories



Silicon PV module

Solar Energy

- **More energy from sunlight strikes the Earth in one hour (13 terawatts) than all the energy consumed by humans in one year.** Sunlight is an important carbon-neutral energy source and continues to grow at a rapid pace.

- **Advantage**s of producing electrical power from sunlight include
  - **Unlimited free and renewable energy source**
  - **Produces maximum energy during the day** during periods of greatest demand
  - Energy payback is less than 3 years
  - Power output can be tailored to match requirements
  - OffGrid installation possible for energy self-sufficient communities
  - **Low carbon foot-prints (less than 35 grams CO_2/kilowatt-hour)**
  - Materials used can be recycled

- **Advanced materials offer the potential to significantly increase the amount of electricity generated from solar energy.**

- **Solar energy technologies**:
  A variety of solar technologies can be used to effectively capture energy from the sun: **Photovoltaics (PV),** Concentrating Photovoltaics (CPV), Concentrating Solar Power (CSP) and **SolarThermal**

Photovoltaics (PV)

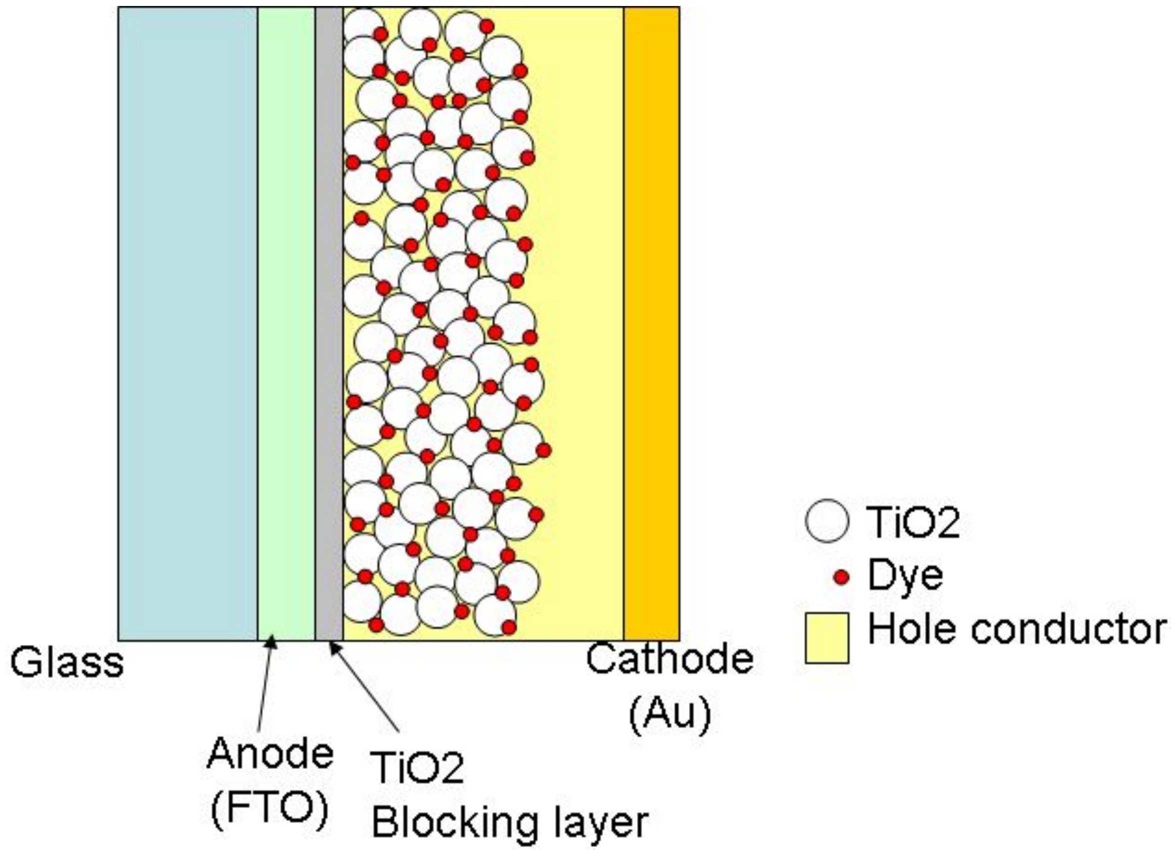
- There has been significant **growth in PV** over the past decade, and the **cost of electricity from PV continues to decrease**.
  The recent growth of PV has been driven by lower costs due to increased efficiency, primarily from advances in advanced materials.
- **PV technologies are classified in three main generations:**
  - **Silicon based: Crystalline silicon and poly-silicon**
  - **Inorganic Thin Films such as cadmium telluride (CdTe), copper-indium-gallium-diselenide (CIGS) or amorphous silicon (a-Si)**
  - **Dye-sensitized solar cells and Organic PV**
- **Materials R&D challenges for PV technologies** include the need to continue to increase solar cell efficiency by improving material properties and cell designs. This can be achieved by :
  - **Identifying or developing alternate materials that are abundant, non-toxic, low-cost**
  - **Developing novel nano-scale surfaces to reduce reflection and increase capture of the full spectrum of sunlight**
  - **Extending the lifetime of photovoltaic systems by addressing materials aging issues**
  - **Reducing manufacturing costs and** creating efficient, high volume methods to recycle solar system materials at end-of-life

CO_2 EMISSIONS FOR DIFFERENT POWER PLANTS

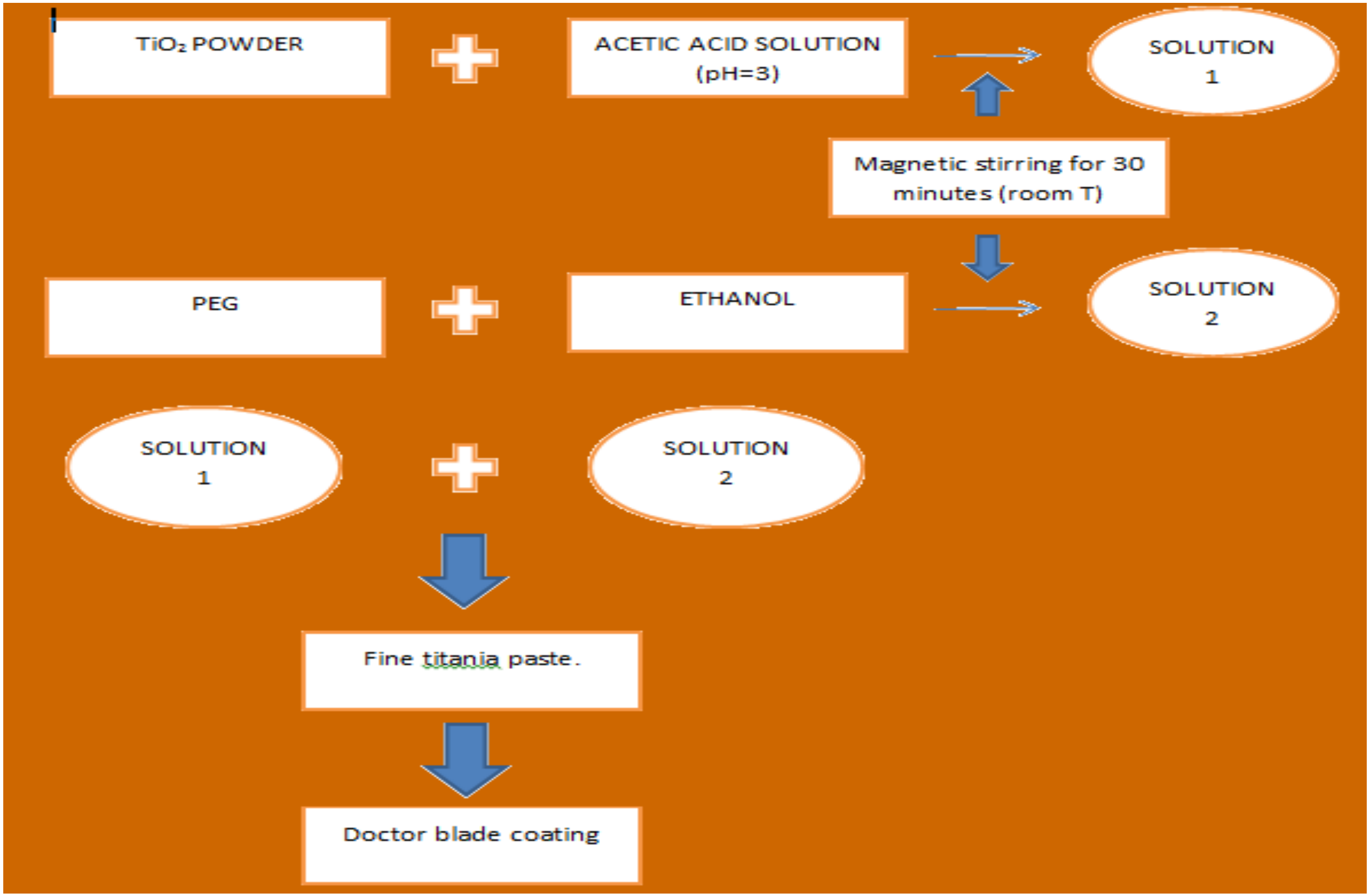
Table
Comparison of specific CO_2 emissions (in g/kWh_{el}) for different kinds of electrical power plants

Fuel of electrical power plant	Emission of CO_2 (g/kWh_{el})	References
Lignite	1140.1	German Government
Coal	915.8	Tahara et al.
Oil	755.6	Tahara et al.
Gas (natural)	420.1	Kaltschmitt and Wiese
Wind (5.5 m/s)	17.3	Voß
Hydro	16.9	Tahara et al.
PV (m-Si)	259.2	Voss
	190.1	Kaltschmitt and Wiese
	74.9	Sørensen
PV (p-Si)	317.2	Kaltschmitt and Wiese
	265.0	Brauch
	51.1	Frisson et al.
	10.1	Frisson et al.
	60.0	Alsema
PV (a-Si)	37.5	Hagedorn
	42.2	Kaltschmitt and Wiese
	11.9	Sørensen
	50.0	Alsema

Departmental initiatives: Synthesis of 3rd generation Dye-Sensitized Solar Cells DSSC

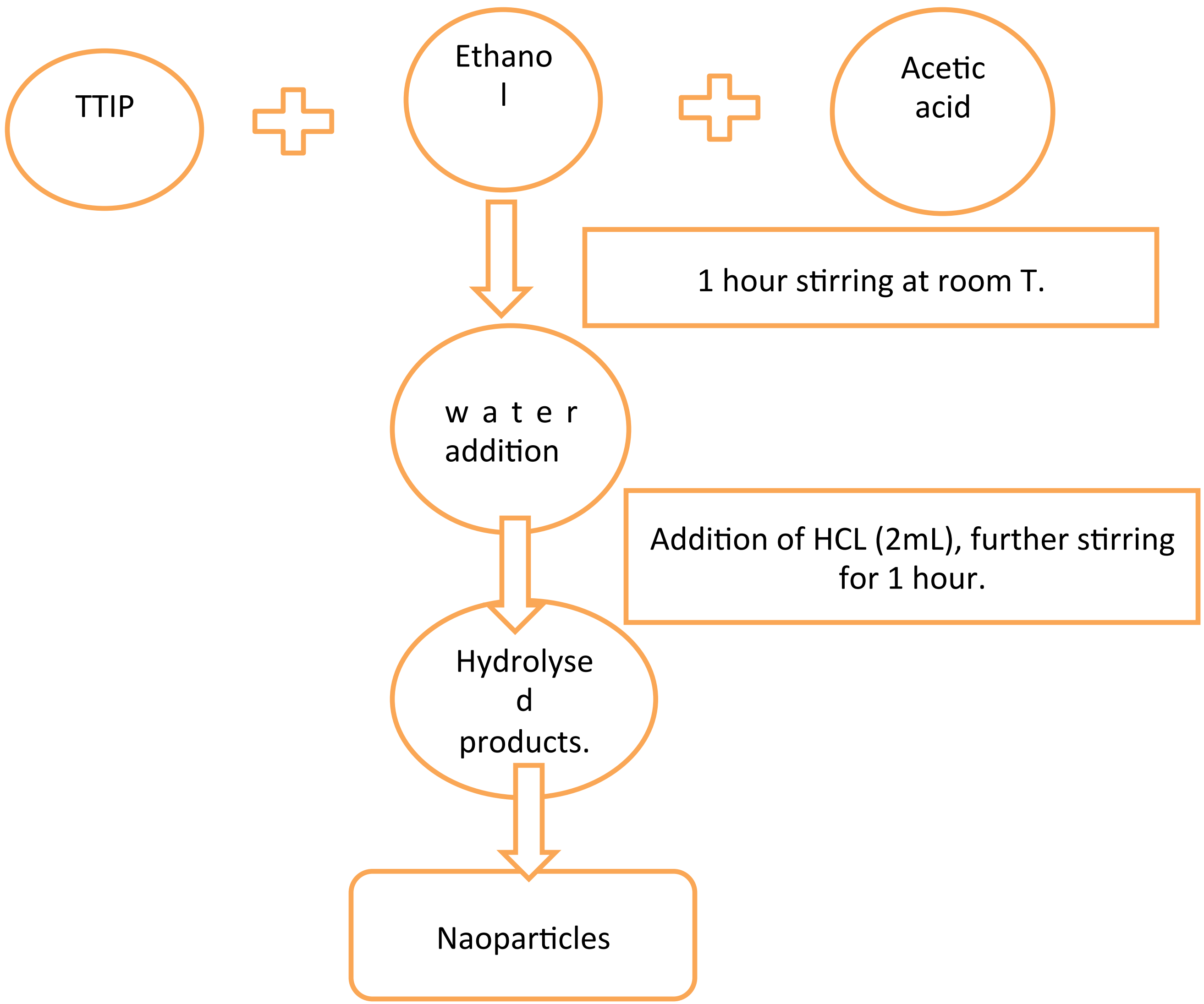


EXPERIMENTAL – Electrode Layer based on TiO2 by doctor blade method

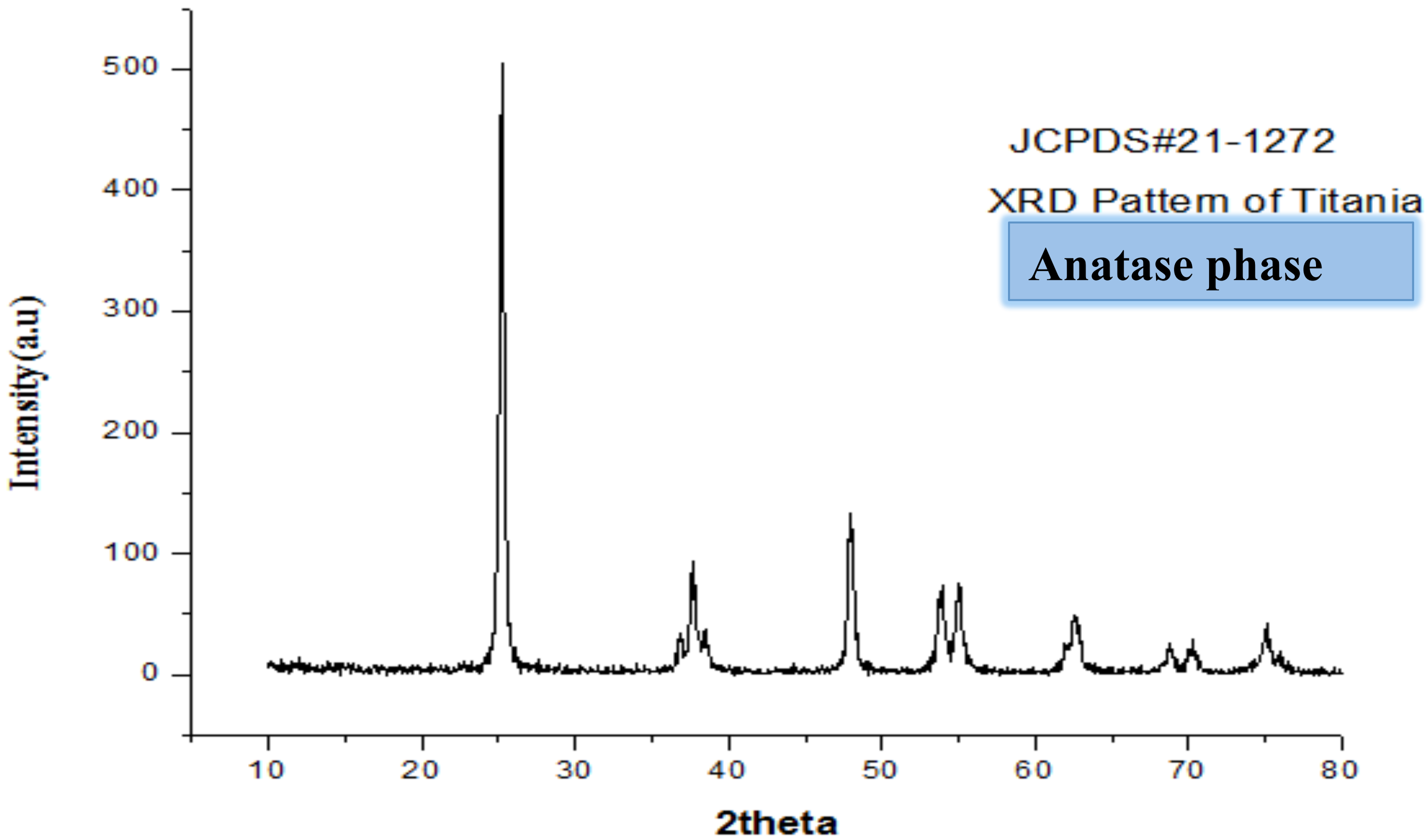


Doc blade thin films of Titania anode on FTO Coated Glass for 3rd Gen solar cells (DSSCs)

Departmental initiatives: preparation of TiO_2 nano-particles for DS Solar Cells: Sol-gel method



Titania nano-particle growth based on wet chemistry routes



Concentrating Solar Power (CSP): Another arm of solar energy

- **CSP uses reflectors to concentrate sunlight to generate high temperatures to heat fluids that drive steam turbines to produce utility-scale electric power.**

- **Main CSP types are as following:**

  Parabolic trough, Dish and power tower systems.

  Each makes use of reflective mirrors to focus sunlight on fluid such as oil, water, gas or m-salts

- **Materials research is needed to;**
  - **Improve optical materials for reflectors** with greater durability and low cost
  - **Enhance absorber materials and coatings** with higher solar absorbance and low thermal emittance
  - **Develop thermal energy storage materials with improved heat capacity**
  - **Improve corrosion resistance of materials in contact with molten-salts**

Solar Thermal Technologies

Solar Thermal Systems

Low Temperature thermal

Low temperature solar thermal systems are used to heat air and water for domestic and industrial applications

- *space heating for homes, offices and greenhouses*
- *domestic and industrial hot water , pool heating, desalination*
- *solar cooking, and crop drying.*

High Temperature Thermal systems

These systems use mirrors and other reflective surfaces to concentrate solar radiation. Parabolic dish can produce **temperatures up to 1000ºC**

The resulting high temperatures can be used to create steam to either drive electric turbine generators, or power chemical processes such as the production of hydrogen

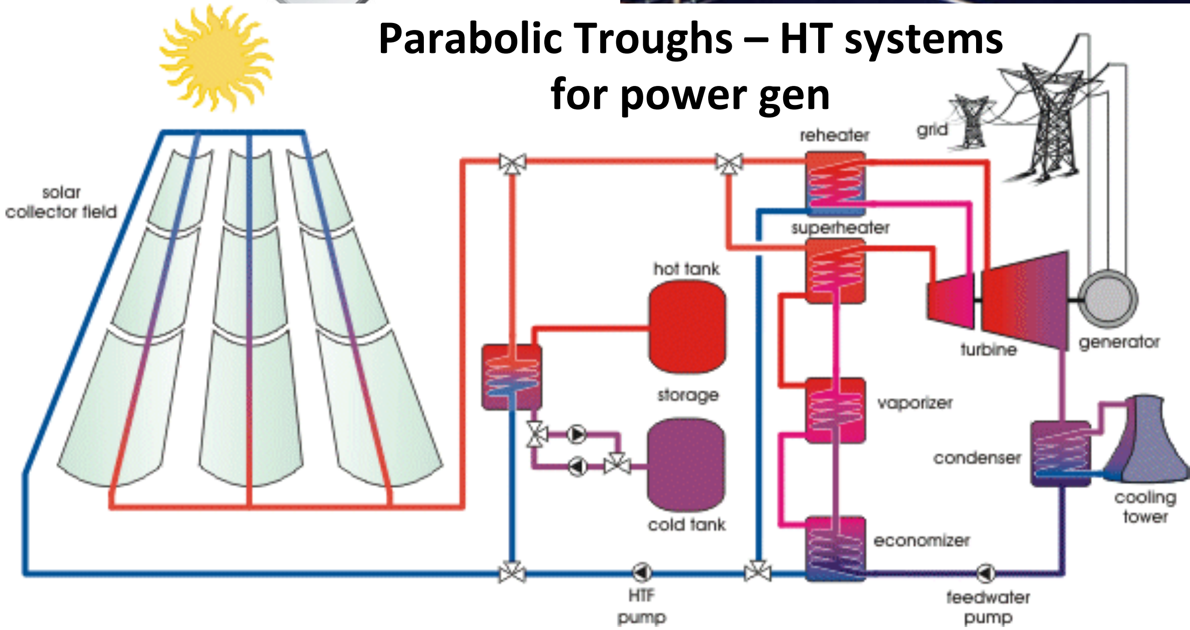
Examples of Low & High Solar Thermal application Systems

There are two types of solar collectors:

1. **Flat plate solar collector.**
   - Unglazed flat plate solar collect
   - Glazed flat plate solar collector

2. **Evacuated tube solar collector.**

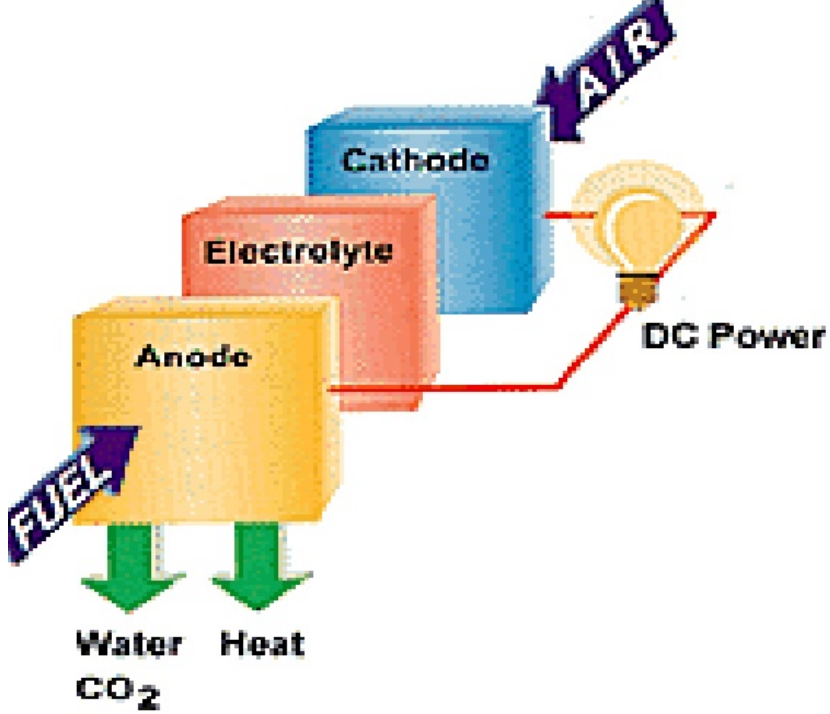
Parabolic Troughs – HT systems for power gen



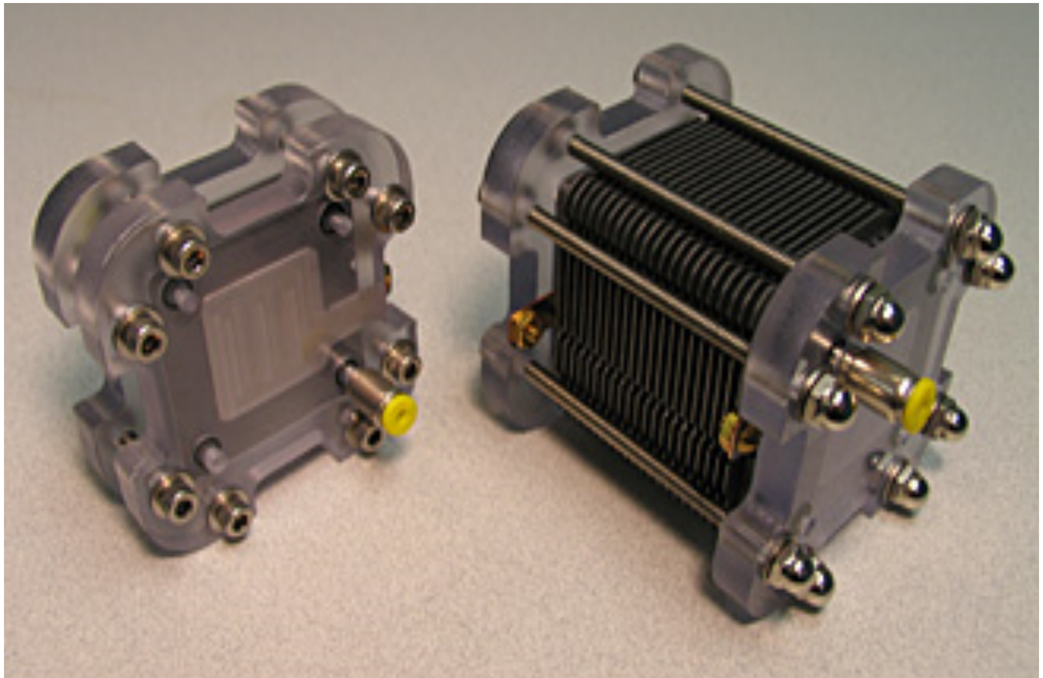
These plants, which continue to operate daily, range in size from 14 to 80 megawatts (MW) and represent a total of 354 MW of installed electric generating capacity.

Hydrogen and Fuel Cell technologies for GHG Mitigation

Hydrogen and Fuel Cell technologies for GHG Mitigation



Planar SOFC - Courtesy of Siemens Westinghouse Power Corp.



Common Types of Fuel Cells

Fuel Cell	AFC	PEMFC	PAFC	MCFC	SOFC
Charge carrier	OH^{-1}	H^{+}	H^{+}	CO_3^{-2}	O^{-2}
Electrolyte	KOH	Polymer	H_3PO_4	Li_2CO_3+K_2CO_3	Zr_2+Y_2O_3
T_{oper} (^oC)	100	80	200	650	650-1000
Fuels	Pure H_2	Pure H_2	CO free H_2	H_2, CO, CH_4	H_2, CO, CH_4, NH_3
Electrical efficiency	40%	40%	40%	60%	60%

SOFC is the most inherently fuel flexible of the fuel cell types and offers ultimate efficiencies

comparison data

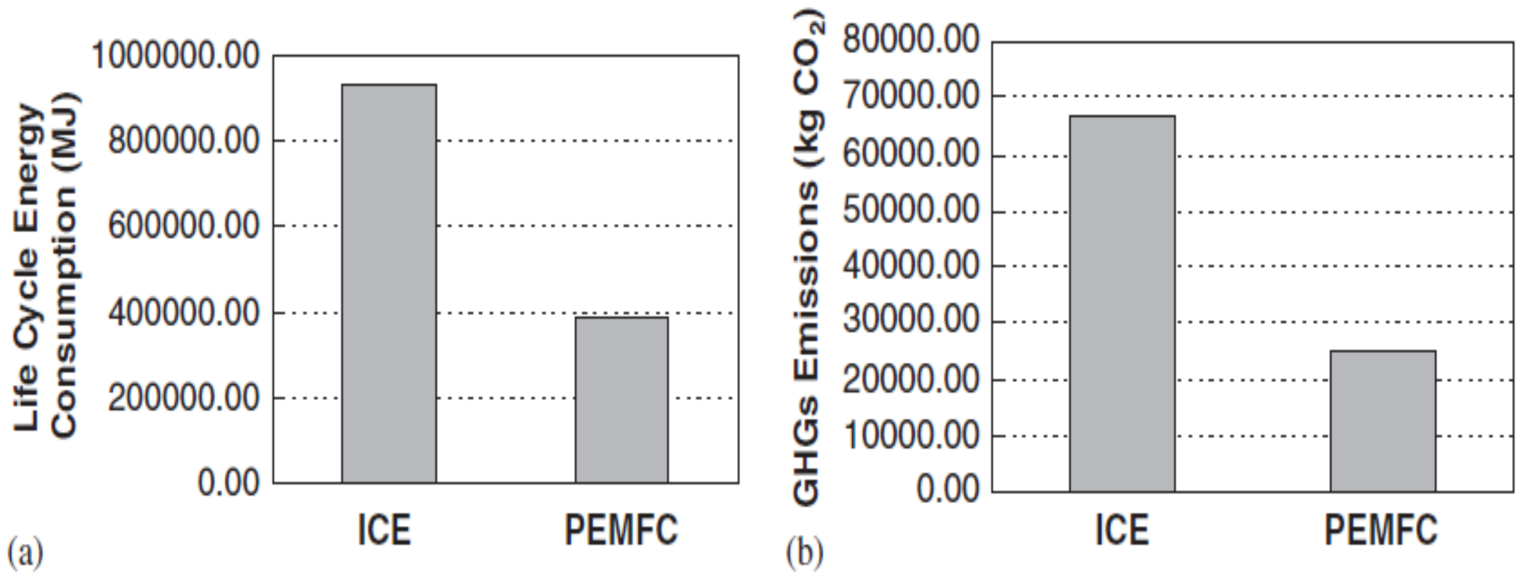


Fig. **(a) Life cycle energy consumption; and (b) GHGs emissions of vehicle technologies**

Technology comparison

	Reciprocating Engine: diesel	Turbine Generator	PV	Wind Turbine	Fuel Cells
Capacity Range	500kW-5MW	500kW-25 MW	1kW-1M W	10kW-1 MW	200kW-2 MW
Efficiency	**35%**	**29-42%**	**6-19%**	**25%**	**40-60%**
Capital Cost ($/ kW)	200-350	450-870	6600	1000	1500-300 0
O&M Cost ($/kW)	0.005-0.015	0.005-0.00 65	0.001-0.0 04	0.01	0.0019-0. 0153

Emissions

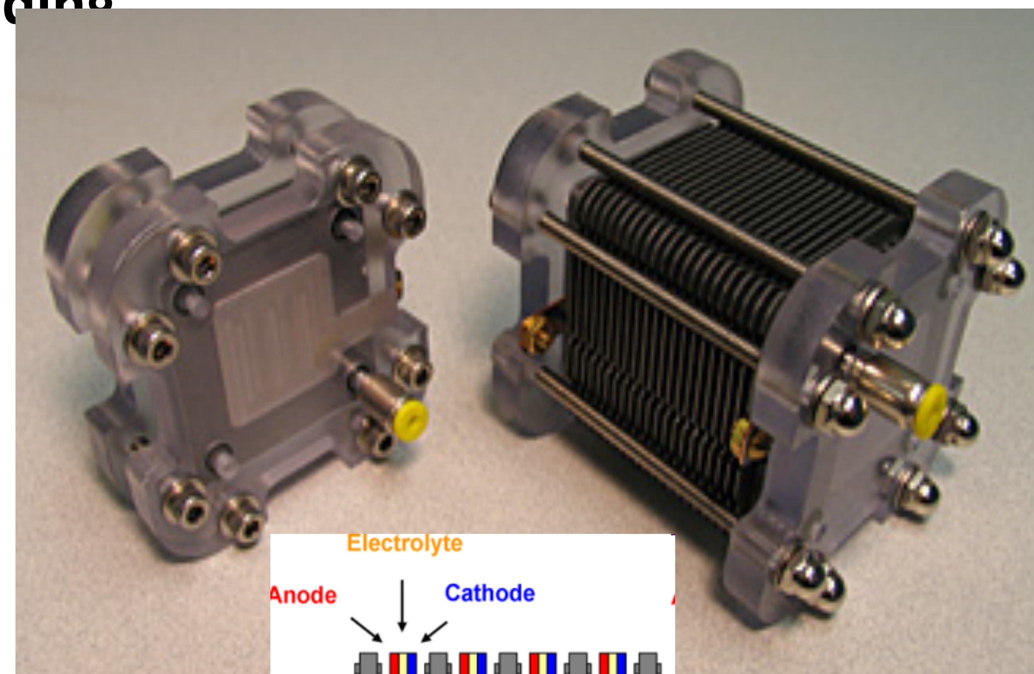
Air emissions[a]	SO_x	NO_x	CO	Particles	Organic compounds	CO_2
Fossil fuelled plant	12,740	18,850	12,797	228	213	1,840,020
SOFC system	0	0	32	0	0	846,300

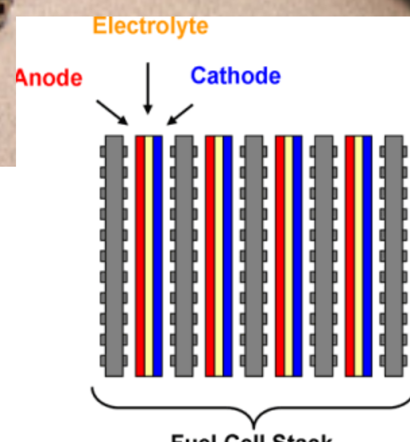
a kgs of emissions per 1650 MWh from one year full operation

How it looks like?

- Individual fuel cells can be placed in a series to form a **fuel cell stack**.
- The stack can be used in a system **to power a vehicle or to provide stationary power to a building**.

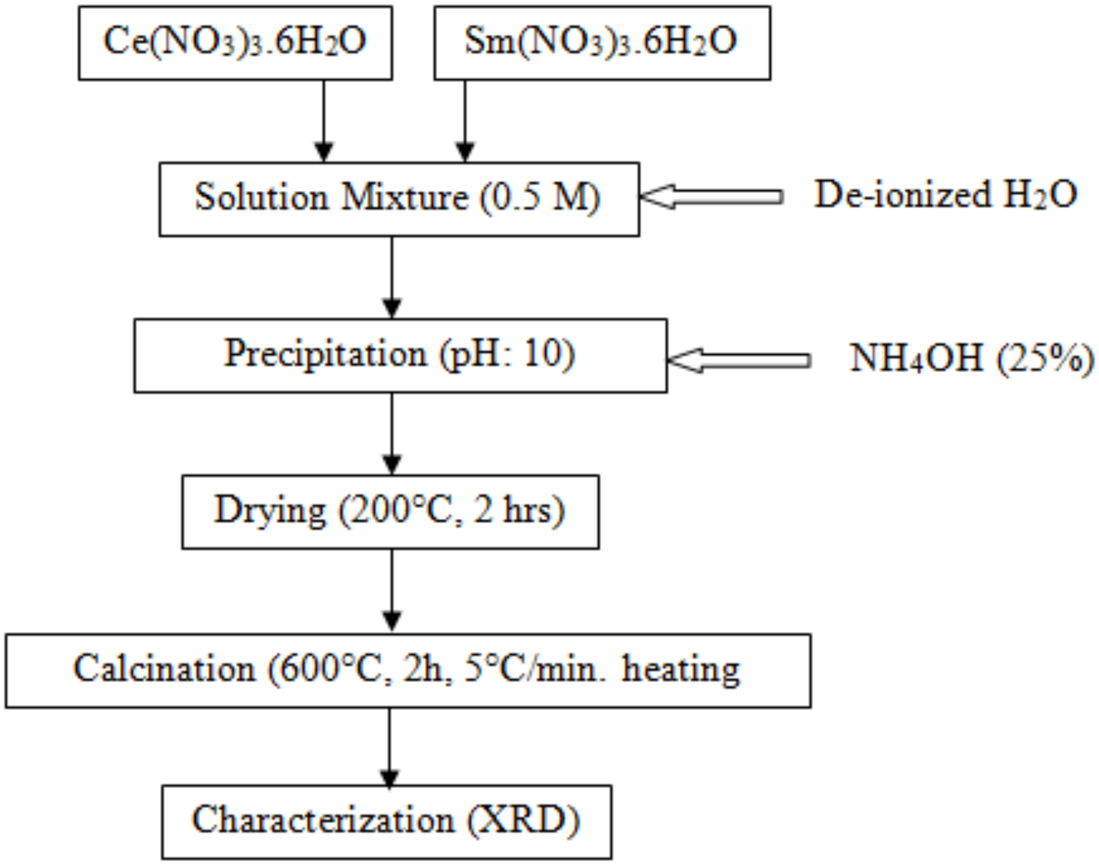
Planar SOFC - Courtesy of Siemens Westinghouse Power Corp.





Departmental initiatives:
Synthesis of advanced SDC Electrolytes for SOFCs

Co-precipitation routes



SDC, LiCO3-SDC and Na2CO3-SDC electrolytes fabricated – XRD patterns

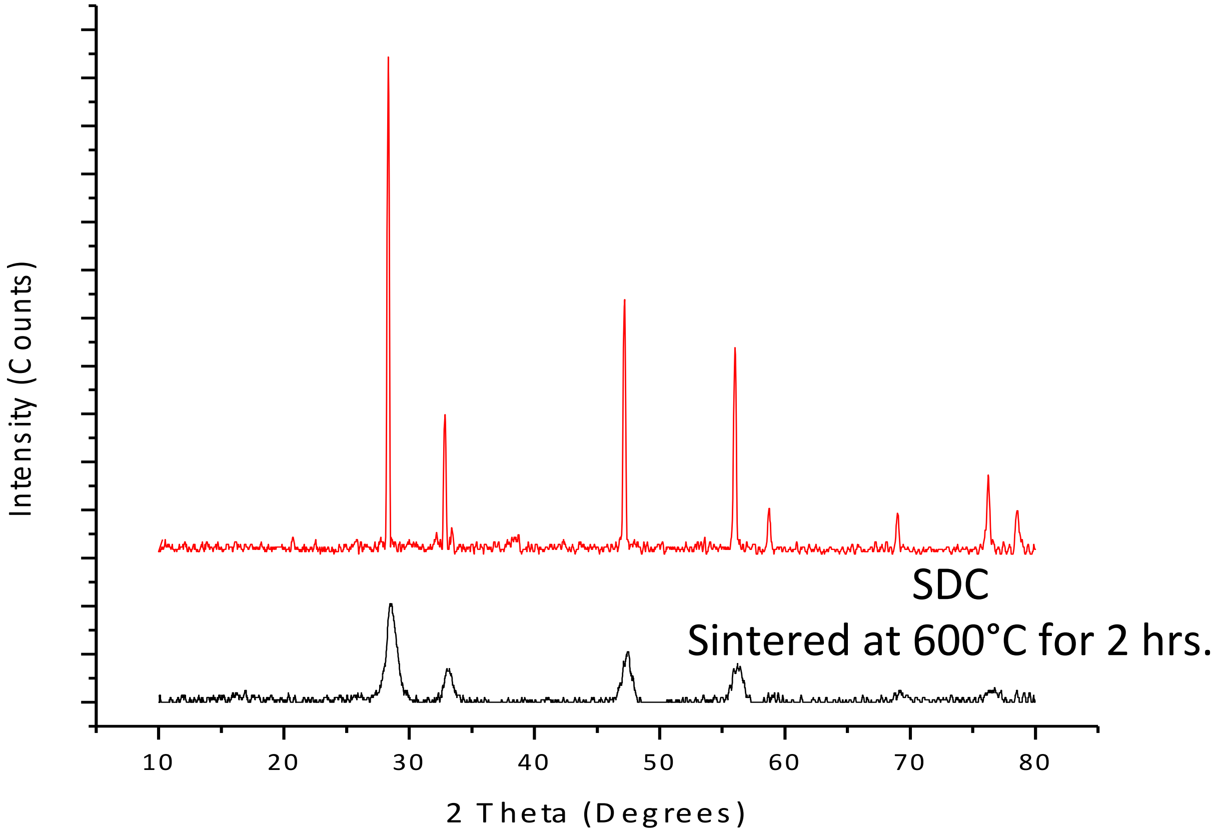


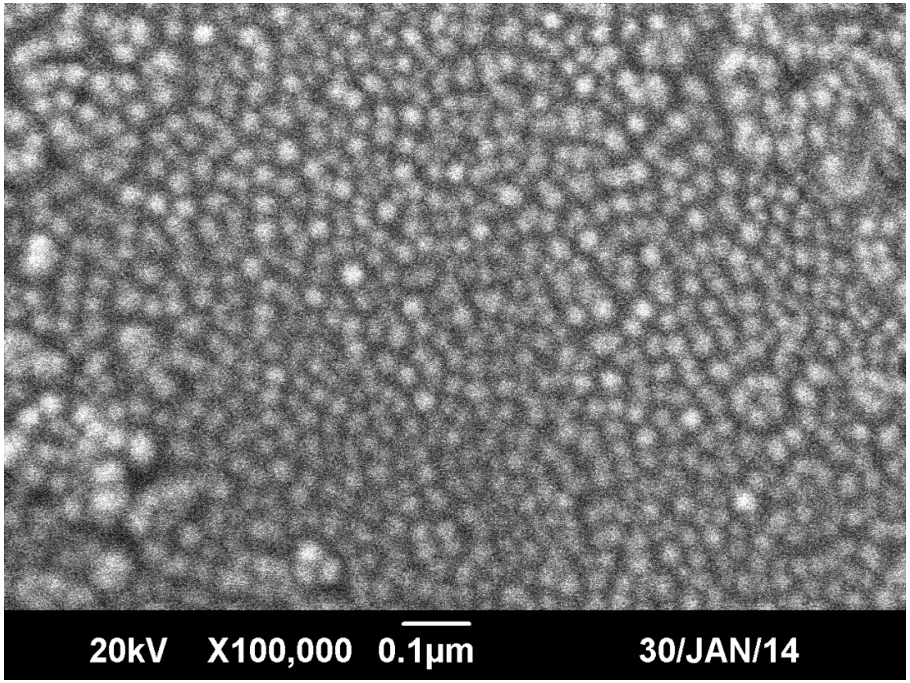
Figure 3 XRD Patterns of SDC & LN-SDC

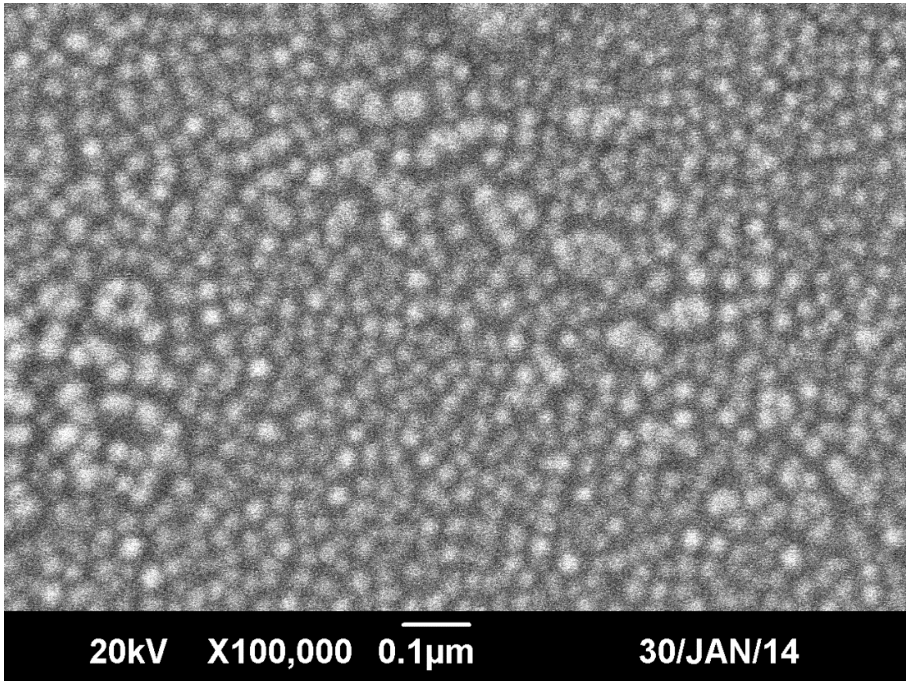
SDC and LN-SDC fabricated: Lattice parameters

Table 1 Results based on XRD Patterns

Sample	d (nm)	a (nm)	V (nm^3)	D_{XRD} (nm)	ρ_{XRD} (g / cm^3)
SDC	0.3135	0.5430	0.1601	14.1	7.16
LN-SDC	0.3145	0.5447	0.1616	55.0	7.09

SEM Images of SDC electrolyte for SOFC applications

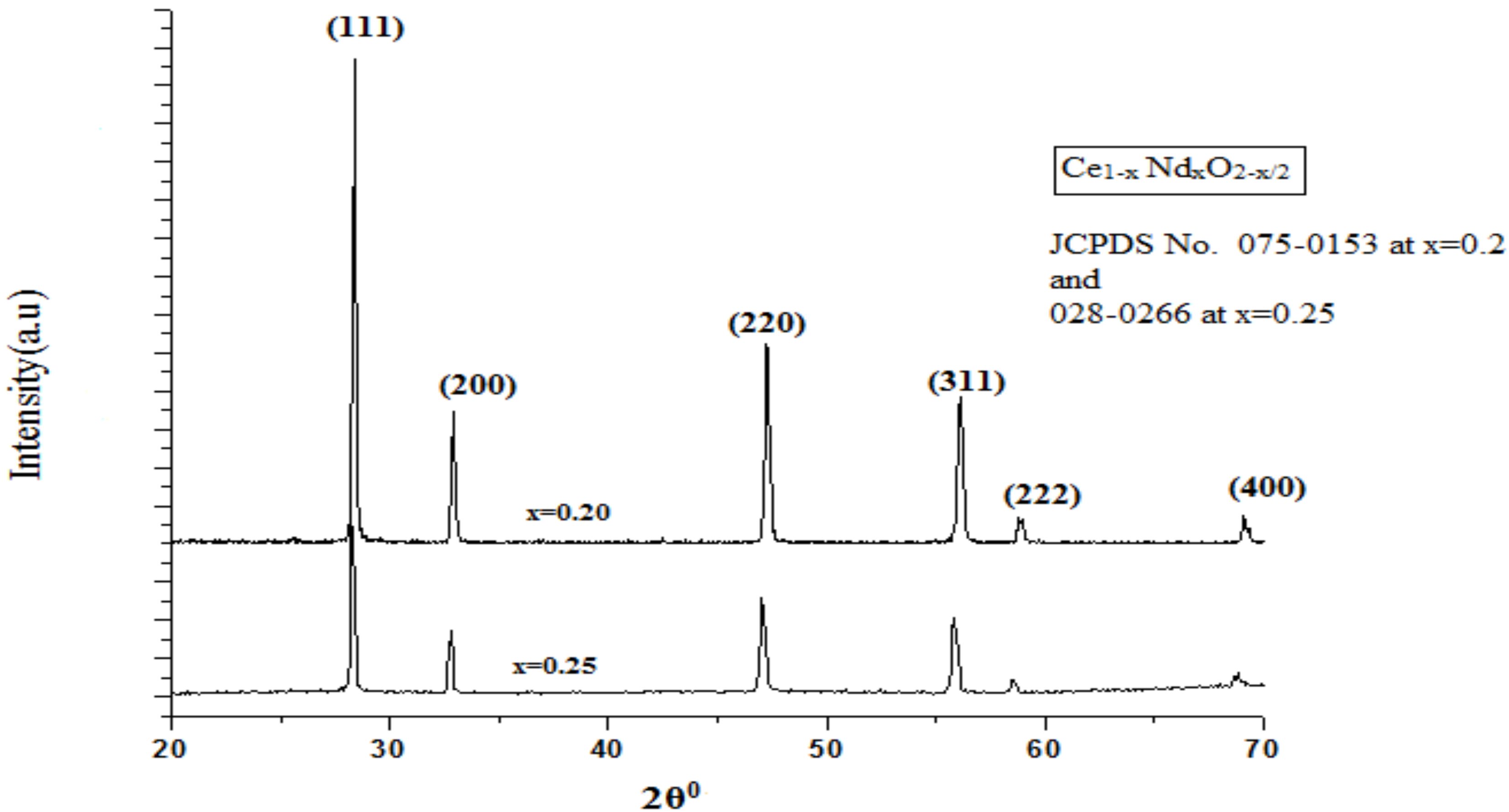


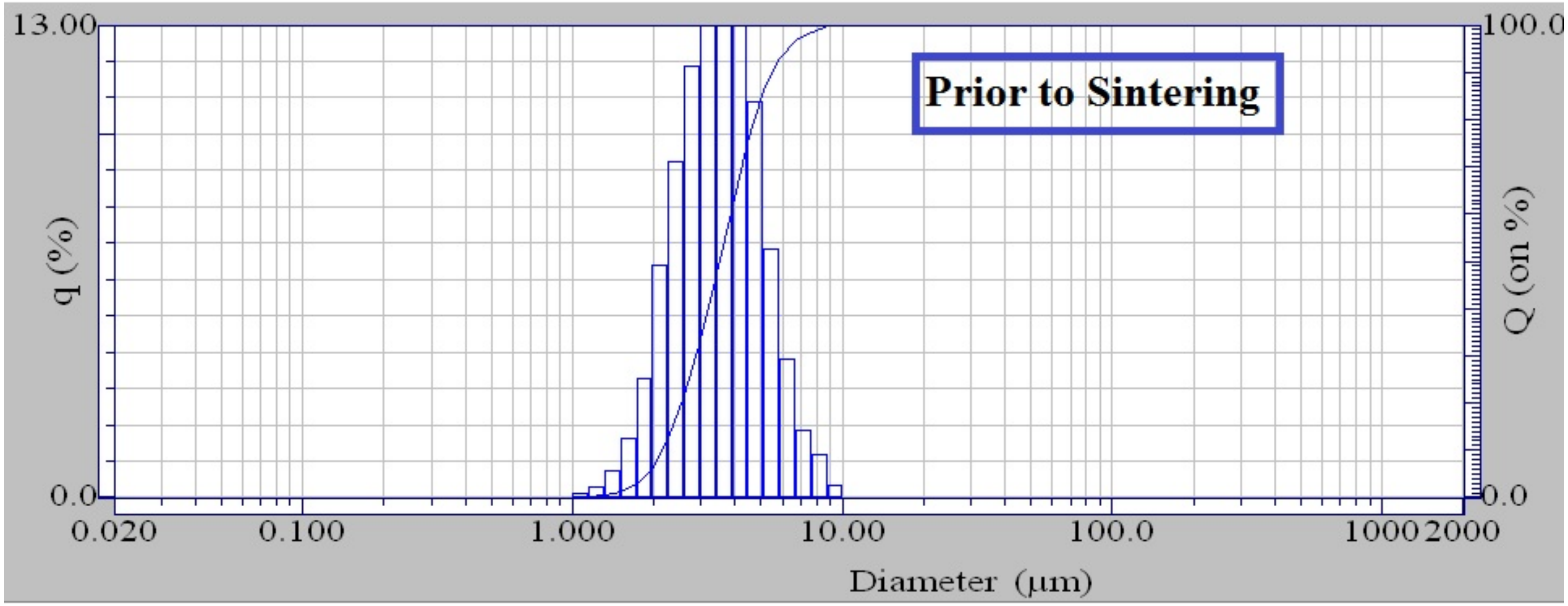


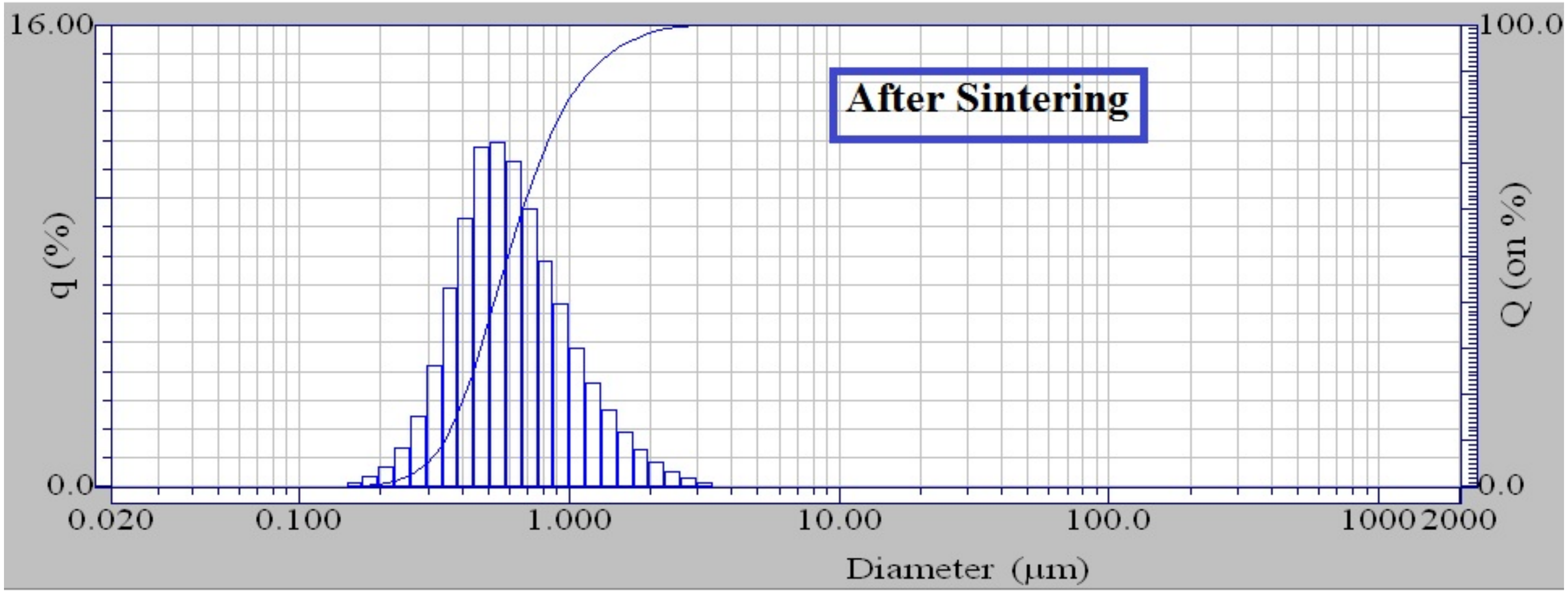
>> Spherically uniform morphology

>> Nanometric particle sizes

Neodymium based ceramic membrane for SOFC fabricated with x=0.2, 0.25 – XRD patterns

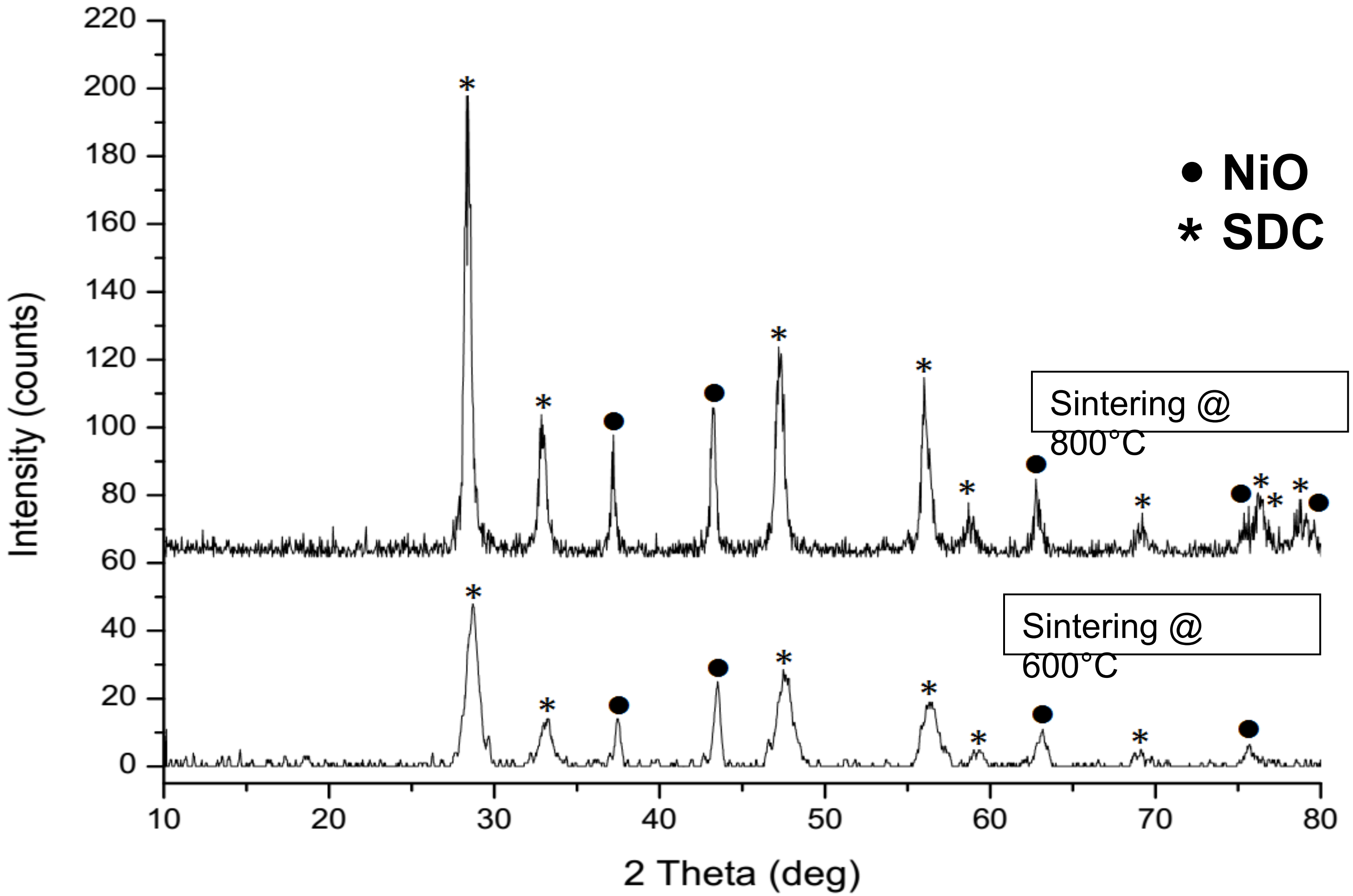






Particle size graph of NDC25 at pH10

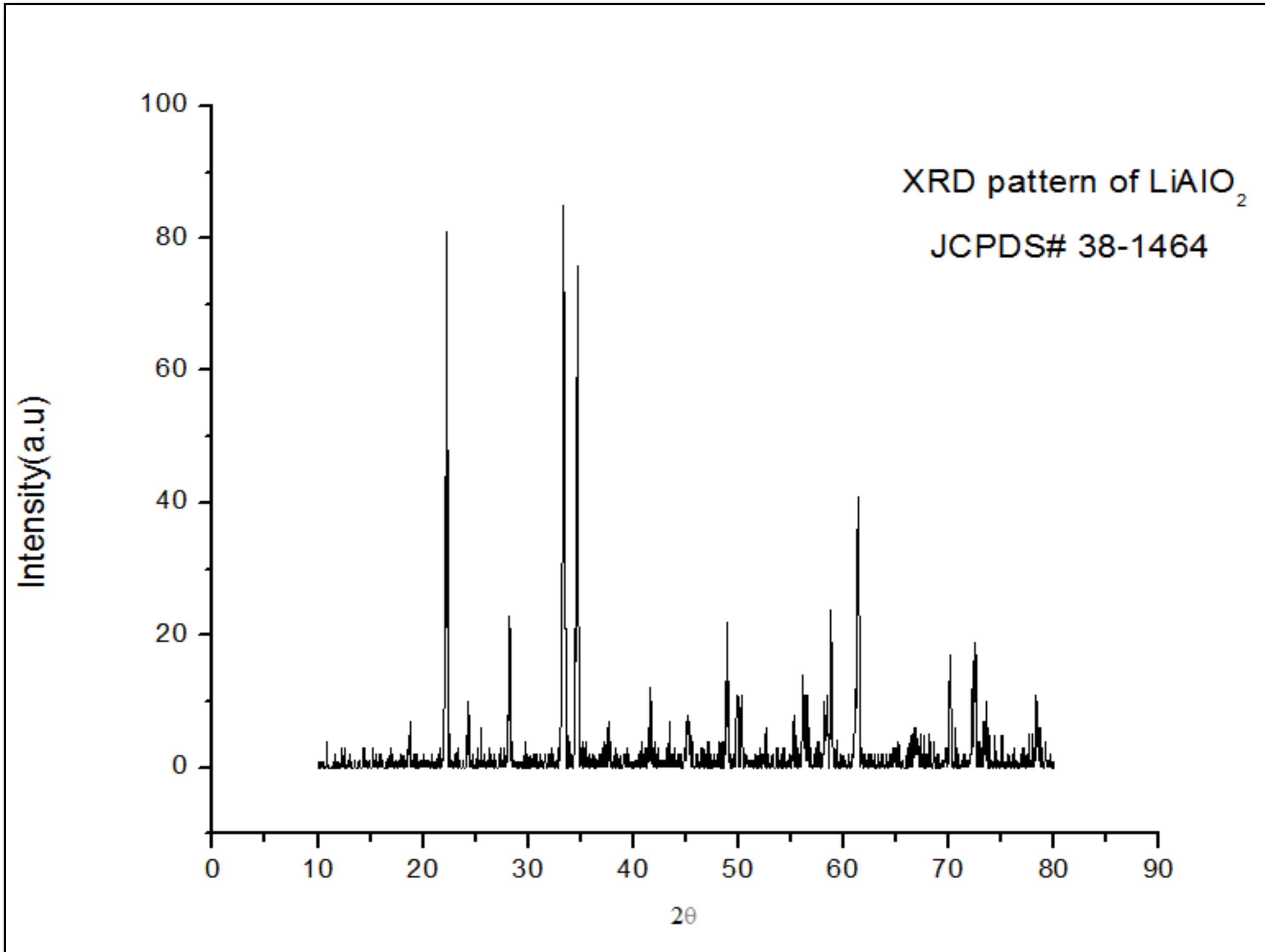
Anode/Catalyst for SOFC (NiO-SDC)



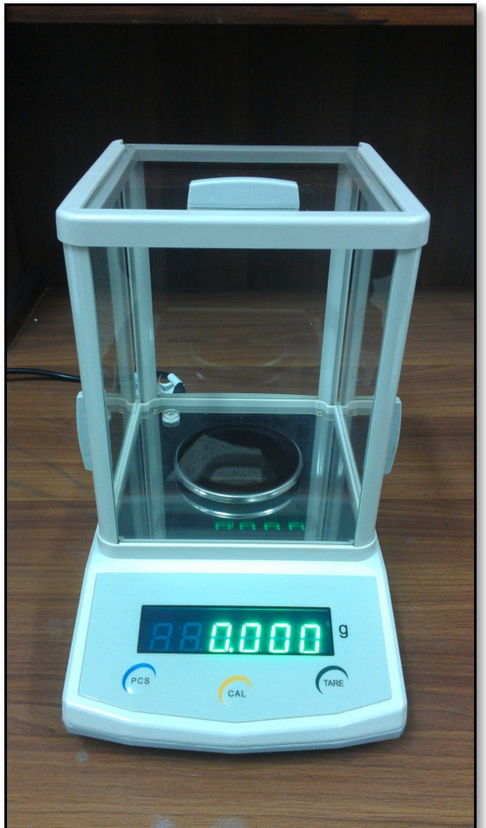
Another category focused in fuel cells is MCFC: Cathode & Matrix Development

	Compound	$Li_{0.68}Ni_{1.32}O_2$*	$LiNi_{0.8}Co_{0.2}O_2$**	$LiAlO_2$***
	Method	Sol-Gel	Sol-Gel	Sol-Gel
	Solvent	De-ionized Water	De-ionized Water	Ethanol
Steps	**1.**	Mixing	Mixing	Mixing
	2.	Stirring	Stirring	Stirring
	3.	Heating	Heating	Heating
	4.	Oven Drying	Oven Drying	Oven Drying
	5.	Sintering	Sintering (2 parts)	Sintering

XRD showed the fabrication of pure matrix material for MCFC



Some research devices for processing



(a)

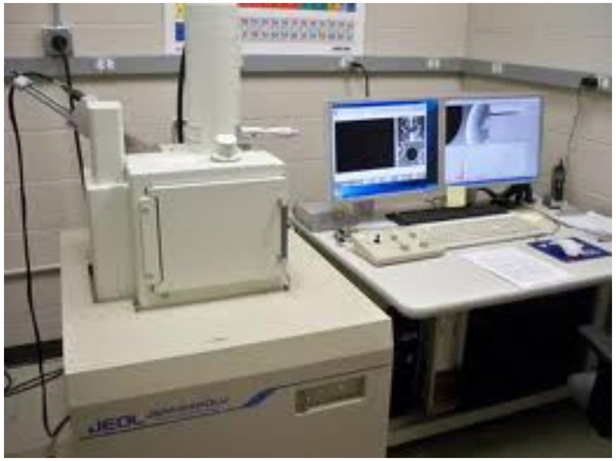
(b)

(c)

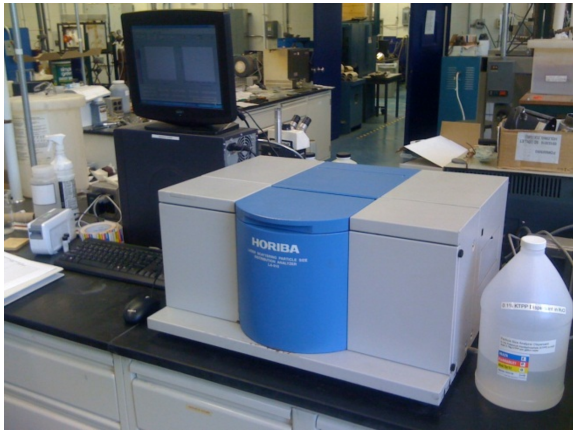
A view of available equipments (a) Analytical Balance
(b) Muffle Furnace (c) Desktop Oven

Characterization Tools

STOE X-ray Diffractometer



Scanning Electron Microscope



Particle size analyzer

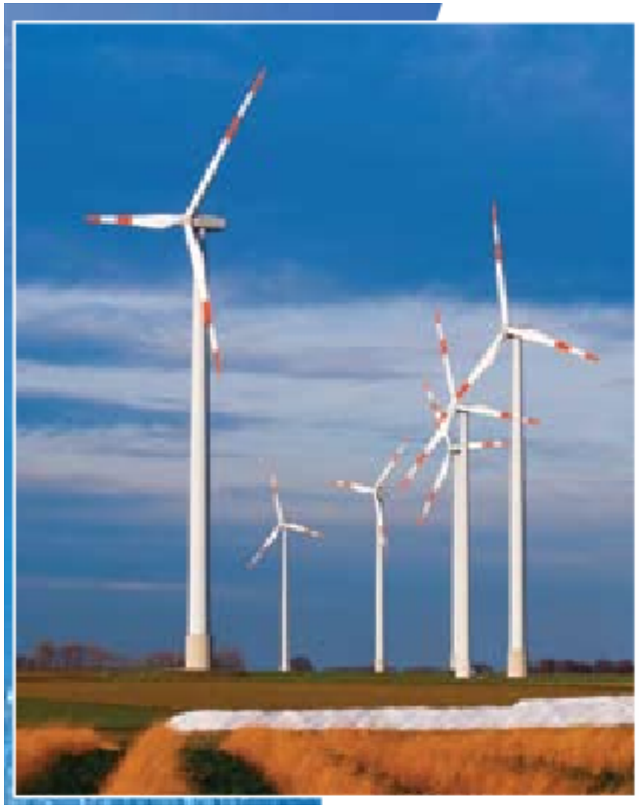
LCR meter

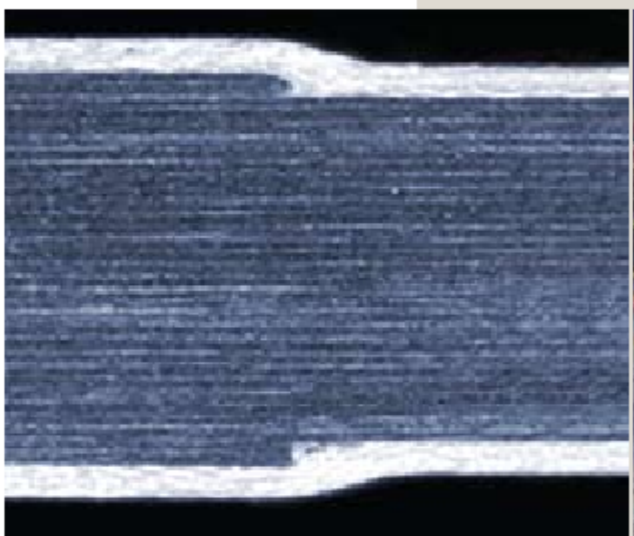
Netzsch DIL 402C Dilatometer

Netzsch STA449 F3 Jupiter – Simultaneous TGA-DSC

Carbon mitigation through wind energy technologies

Carbon mitigation through wind energy technologies





Layered composite blade material

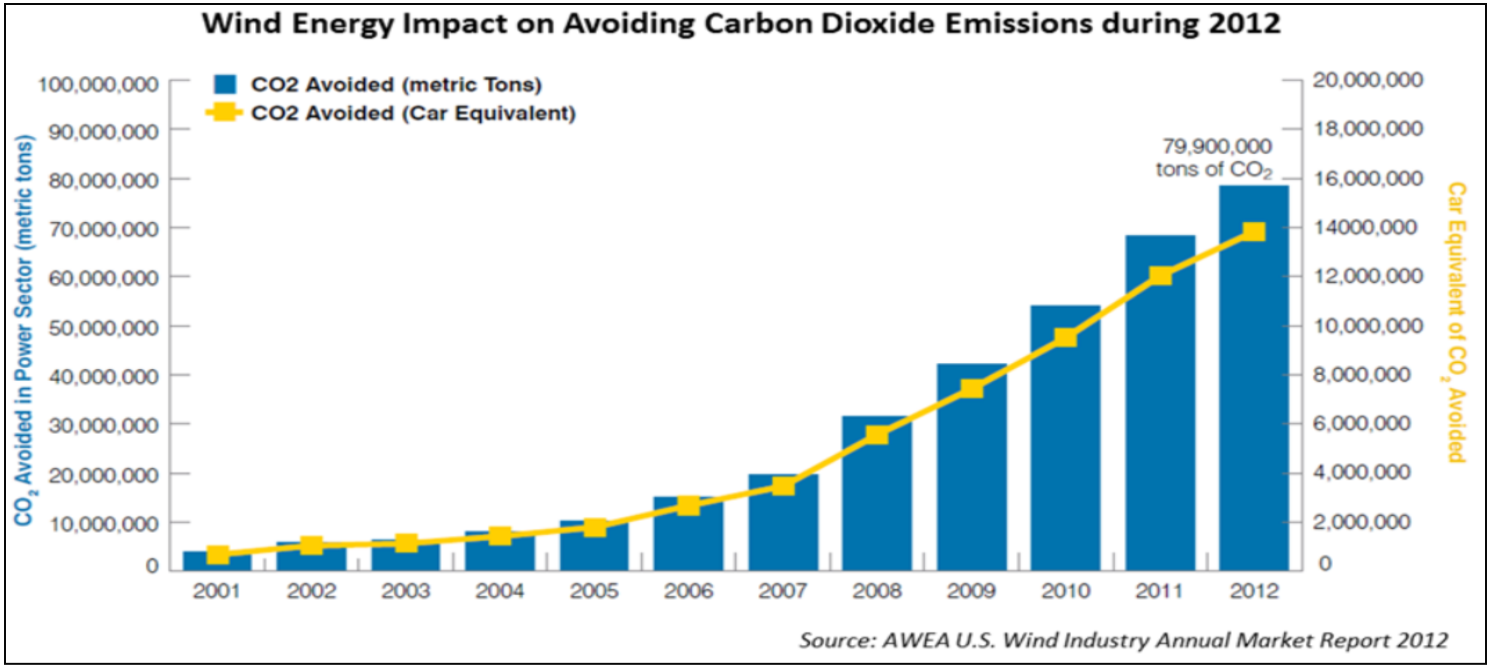
Wind turbine blade manufacture – courtesy TPI composites

Renewable Energy and GHG Mitigation

- **Wind has the greatest application potential among the three types of clean energy power systems for GHG emission mitigation, in particular at those locations with high wind energy density and/or high GHG emissions from local grid power supply**

Wind Energy and GHG Mitigation

- **Wind power has great potential, e.g., In USA in 2012, the roughly 140 million megawatt-hours (MWh) generated by wind energy avoided 79.9 million metric tons of carbon dioxide (CO2) -- the equivalent of reducing power-sector CO2 emissions by 3.6%, or taking over 14 million cars off the road.**



- **A study by the Electric Reliability Council of Texas (ERCOT) found that 9,400 MW of added wind capacity on their system would avoid 17.6 million tons of CO2.**

Wind energy technologies

- **Materials play a critical role in wind power**.
  - Today, **wind turbine blades** made up of **polymer-matrix composite reinforced with fiber glass or graphite fibers.**
  - Compact **electrical generators** in the turbines contain powerful **magnets** made from **rare earth materials**.
  - The rotation of the turbine blades is used to drive an electrical generator through a **gearbox, which uses special alloys** in order to accommodate a wide range of wind speeds.

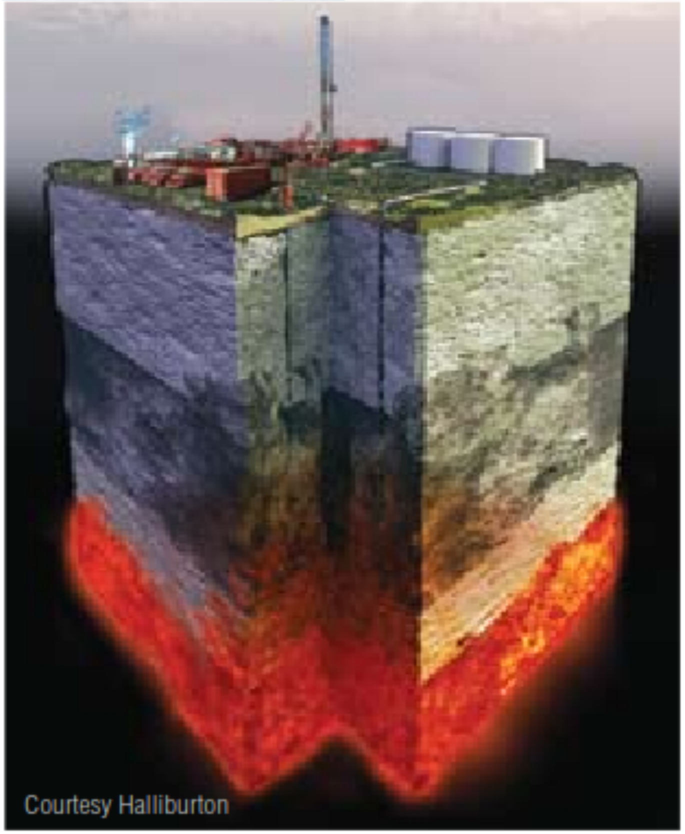
- Turbine sizes continue to increase. The growth of **off-shore installations** means long-time exposure to **higher stresses and hostile environments** that can challenge the durability of turbine materials.
  The turbine blades must have **adequate stiffness** to prevent failure due to deflection and buckling. They also need adequate long term **fatigue life** in harsh conditions, including variable winds, ice-loading and lightning strikes.

- Current materials research continues to address these critical issues.

- **"Smart" blade materials are to be developed which automatically adjust pitch to accommodate wind speed variations**

Geothermal energy technologies for GHG mitigation

Geothermal energy technologies for GHG mitigation



Synthetic diamond drill bit –
courtesy Sandia National Laboratories

Geothermal power

- **Geothermal power is green energy generated by converting heat stored in the earth to electricity via heated water pumped in and out of deep wells, using a steam turbine** or in a binary system using heat exchange fluids.

- **Deep wells with depths of 3-10 kilometers are dug by hard rock tools and fitted with high alloy tubing.**

- There are several conversion methods for geothermal power and there is massive potential for use of geothermal energy by countries the world over. Geothermal power can provide fully reliable power that is always available.

- **Currently *Enhanced Geothermal Systems (EGS)* are being worked out that do not require naturally occurring hot water resources**. Rather, high pressure cold water is pumped down an injection well into rock. Water travels through fractures in the rock, capturing the heat of the rock until it is forced out of a second borehole as very hot water, which is converted into electricity.

- **New materials technologies are crucial for the success of EGS**.

Geothermal power

Challenges include

- **Development of new hard materials for drilling hard rock for deep geothermal wells (Tungsten and Hafnium based carbides for drilling applications)**
- **Development of new piping materials that resist the extreme hot corrosion conditions of fluids used to transfer heat in geothermal systems**

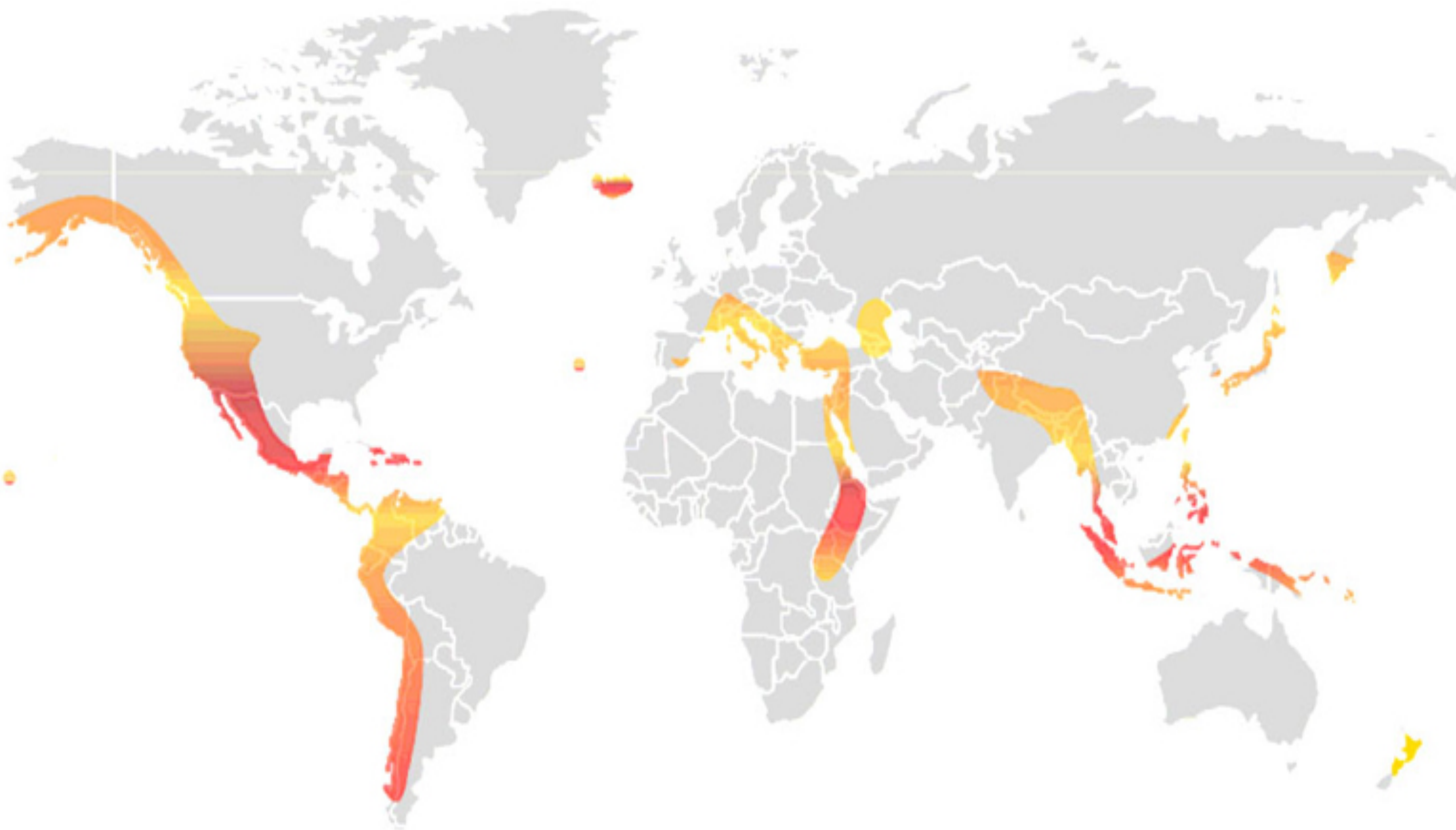
Geothermal Energy Worldwide

- **The International Geothermal Association (IGA) has reported that 10,715 MW of geothermal power in 24 countries is online**.

- In 2013, the **United States** led the world in geothermal electricity production with **3,086 MW of installed capacity** from 77 power plants. The largest group of geothermal power plants in the world is located at The Geysers, a geothermal field in California.

- **IEA** projects that geothermal electricity generation could provide about **1.4 percent of global electricity generation by 2035**

Worldwide distribution of Geothermal Resources



Distribution of resources: Red zones indicate hottest known geothermal regions with high energy density
(practical geothermal utilization temperatures range from 100-300 °C)
Source: Glitnir Bank, Emerging Energy Research May 2009

Environmental Benefit and Emission Reduction Potential

- **Environmental benefits from geothermal energy include near-zero greenhouse gas emissions** from plant operations and low freshwater use and contamination. Traces of carbon dioxide (CO_2) and other greenhouse gases are found dissolved in some hydrothermal reservoirs

- **A geothermal plant will emit only zero to four percent as much CO_2 as a traditional coal-fueled power** plant per unit of electricity generated.

Geothermal Resources in Pakistan

- **In the North of Pakistan, there are many hot water springs**, some generating surface water temperature up to 83°C
- Geothermal sites have also been identified in **Baluchistan and Sindh.**
- Pakistan suffers from an energy crisis, importing up to $15 billion in oil in order to feed power plants to generate electricity is very costly for the public finances
- **estimated potential from Geothermal in Pakistan is about 1000 MW**

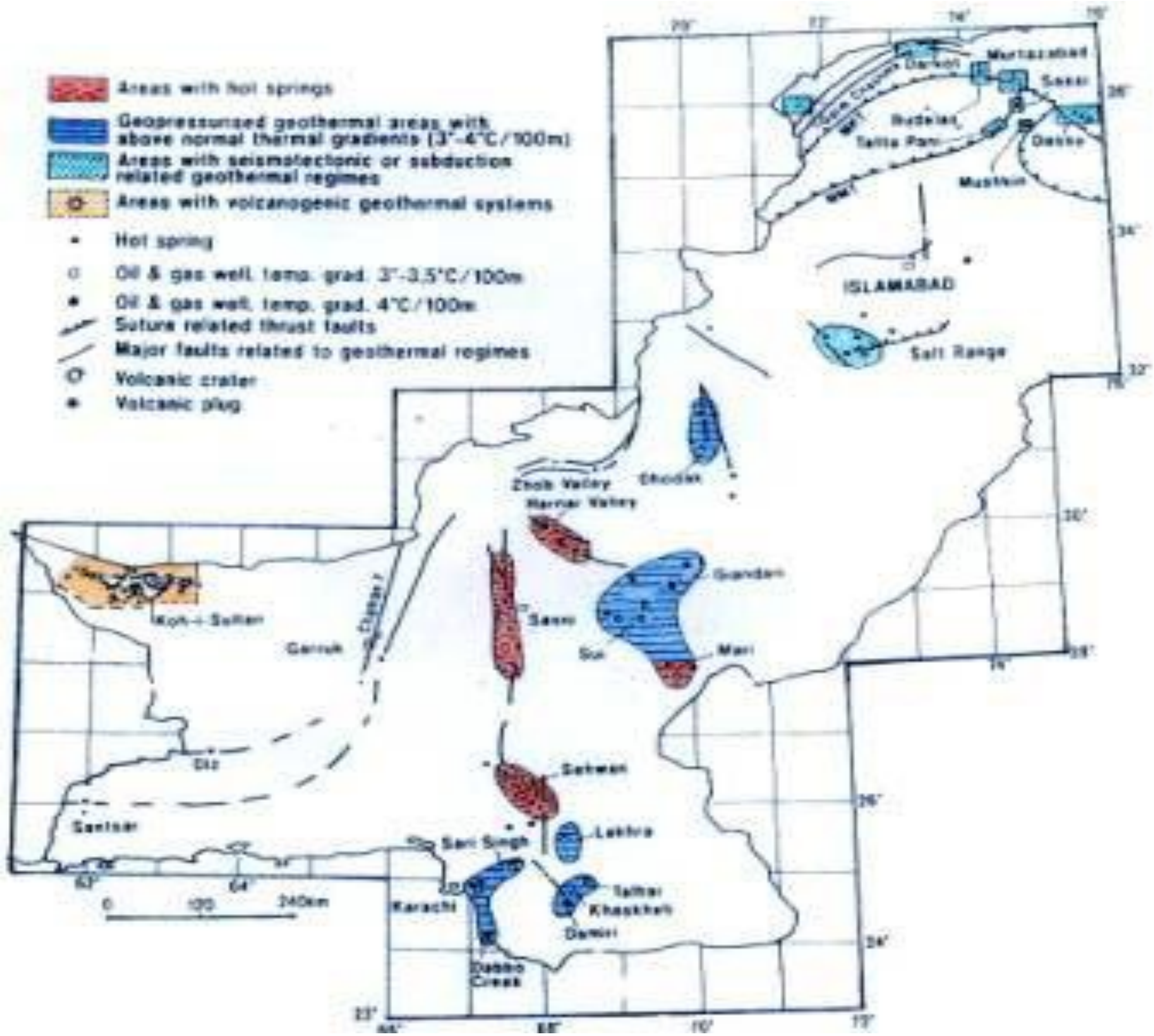
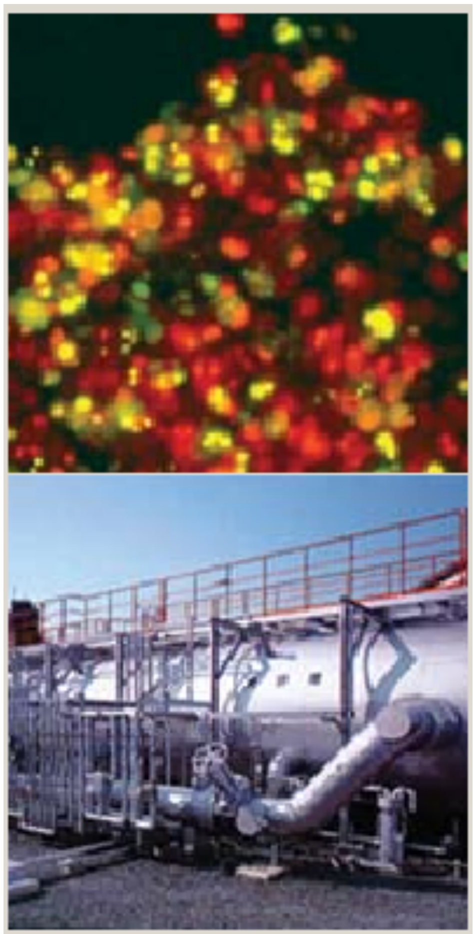
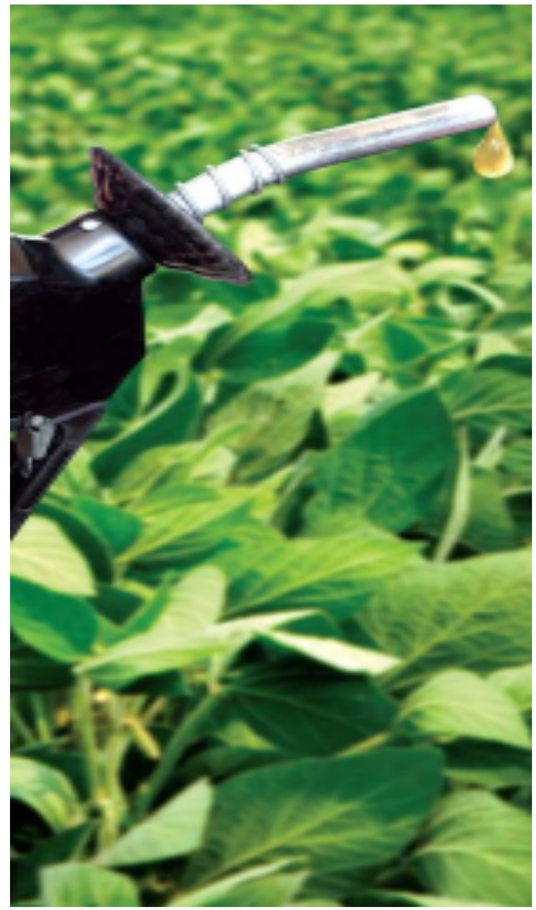


Figure 3 Map of Pakistan showing areas of Geothermal Activity

Biomass & Biofuel technologies for carbon mitigation

Biomass & Biofuel technologies for carbon mitigation





Microalgae for biodiesel
Biomass gasification plant

Biomass/Bioenergy for Climate Change Mitigation

- **Unlike fossil fuels**, **the emissions of greenhouse gases** produced during the use of biofuels are **re-absorbed** from the atmosphere during the growth of feedstocks.
- Thus, any burning of biomass does not add to the Earth's carbon dioxide inventory. For this reason **biomass is considered a "*carbon neutral*" fuel.**
- **It reduces NO_x and SO_2 emissions**
- It causes **Low/no net increase in CO_2**
- Plays effective role for the **soil Conservation through soil erosion control, nutrient retention, carbon sequestration, and stabilization of riverbanks.**
- Serves for water conservation through better retention of water in watersheds

Biomass Resource Potential of Pakistan

Wheat straw, rice husk, rice straw, cane trash, bagasse, cotton sticks are some of the major crop residues in Pakistan

- Potential of 50 million cubic meters of biogas per day through available animal resources.
- Only Punjab can produce 5,000 MW from available biomass
- Sugar mills produce around 30-32 million tons of bagasse each year >>> 5kg Sugarcane bagasse produces ~1KWh

Source : (http://www.pres.org.pk/2012 ,Report by German NGO GIZ)

Biomass Resource Potential of Pakistan

In Pakistan, about 6.30 million hectares of land are salt-affected.

Photo by Pavel Kosenko © http://pavel-kosenko.livejournal.com

Catalysts for Bio-mass Upgradation

- For Hemicellulose Derived compounds
- Oxides of Ti, Zr and Ce (with Pd, Pt, Rh, Co)
- **Silica supported Cu, Ru, Ni, Pt or Pt-Fe**
- Cu-SiO2 for aldehydes and Pt-SiO2 for Ketones
- For Sugar Derived Compounds
- MgO-ZrO2 - highest Aldol Condensation activity
- Pd/Mgo-ZrO2 – Bifunctional Catalyst
- Pt/Pd-Bi as Promotor
- **TiO2 & CeO2 supported Au**
- For Lignin Derived Compounds
- Beta Zeolites
- Pd/Ni in the presence of H3P04 or Nafion/Sio2

Biofuels

- ***Biomass such as cellulose and the Algae*** **have the potential to be used as biofuels after necessary processing .** This is turn can replace e.g., 30 % of US transportation fuel (reducing economic drain of up to $ 300 biillion)
- **New processes neede to be developed along with catalysts/materials with long lifetimes to contain and manipulate the corrosive chemistries in biomass processing.**

- **The cellular membranes of algae are rich in the raw materials for production of hydrocarbon chains of gasoline and diesel fuel, but need their own special chemical routes and catalytic materials for conversion.**
  Many of these chemical processes and catalysts exist in nature, such as in the digestive systems of termites, where cellulose is converted to sugars that can be further fermented to alcohol.
- **Advanced materials and analytical tools are needed to understand the subtleties of these natural fuel production processes, and then to design artificial analogs that directly and efficiently produce the desired end fuels.**

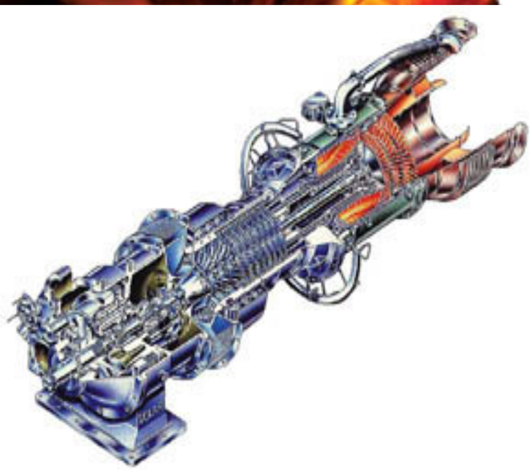
Biofuels - Materials Challenges

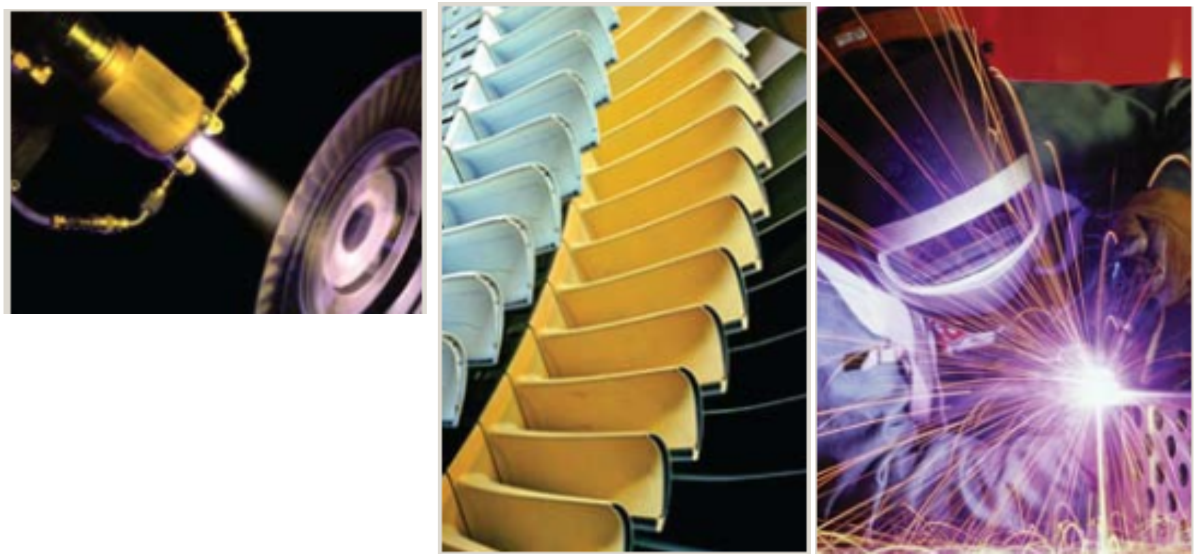
Materials challenges are inescapable in implementing biofuel technologies and in developing new biofuel types:

- **Corrosion resistant materials for biofuel processing** due to the corrosive nature of **alcohols**
- **New catalysts for thermochemical conversion** of lignocelluloses to fuels
- Materials for combustion processes
- **Materials for capturing CO2 for using as a nutrient to cultivate algae**
- Improved materials and chemical processes for water filtration and desalination
- New analytical tools to characterize important biological processes like lipid formation as **a function of gene modification**
- **Nanoscale modification** of genes and protein assemblies to enable **plants and algae to directly produce hydrocarbon fuels** is a new frontier of materials research.

GHG mitigation through improved processing technologies in fossil energy sector

GHG mitigation through improved processing technologies in fossil energy sector





Plasma spray coating process, Coated turbine blades, Welding process

Fossil Energy

- **More than two thirds of the current and projected energy generation is from fossil fuels. Advanced materials in past have enabled significant improvements in energy conversion efficiency.**

- **Either using gas turbine or steam turbine/boiler, for higher conversion efficiency of fuel into electricity, high temperature is critical which in turn requires durable materials.**

- **Advanced ceramic coatings applied to hot-components in gas turbines have allowed higher operating temperatures , e.g., the newest combined cycle gas turbine plants have net plant efficiencies of 60% or greater.**

- **New materials and the new power cycles have allowed efficiencies of coal fired power plants to be increased to 42%.**

Fossil Energy

- **Through the development of advanced coatings and new methods of applying the coatings as well as new materials >>>>**
significant reductions in fuel consumption with an associated reduction in green house gas and other criteria pollutant emissions have been realized.

Spray controller Unicoat

Plasma power supply

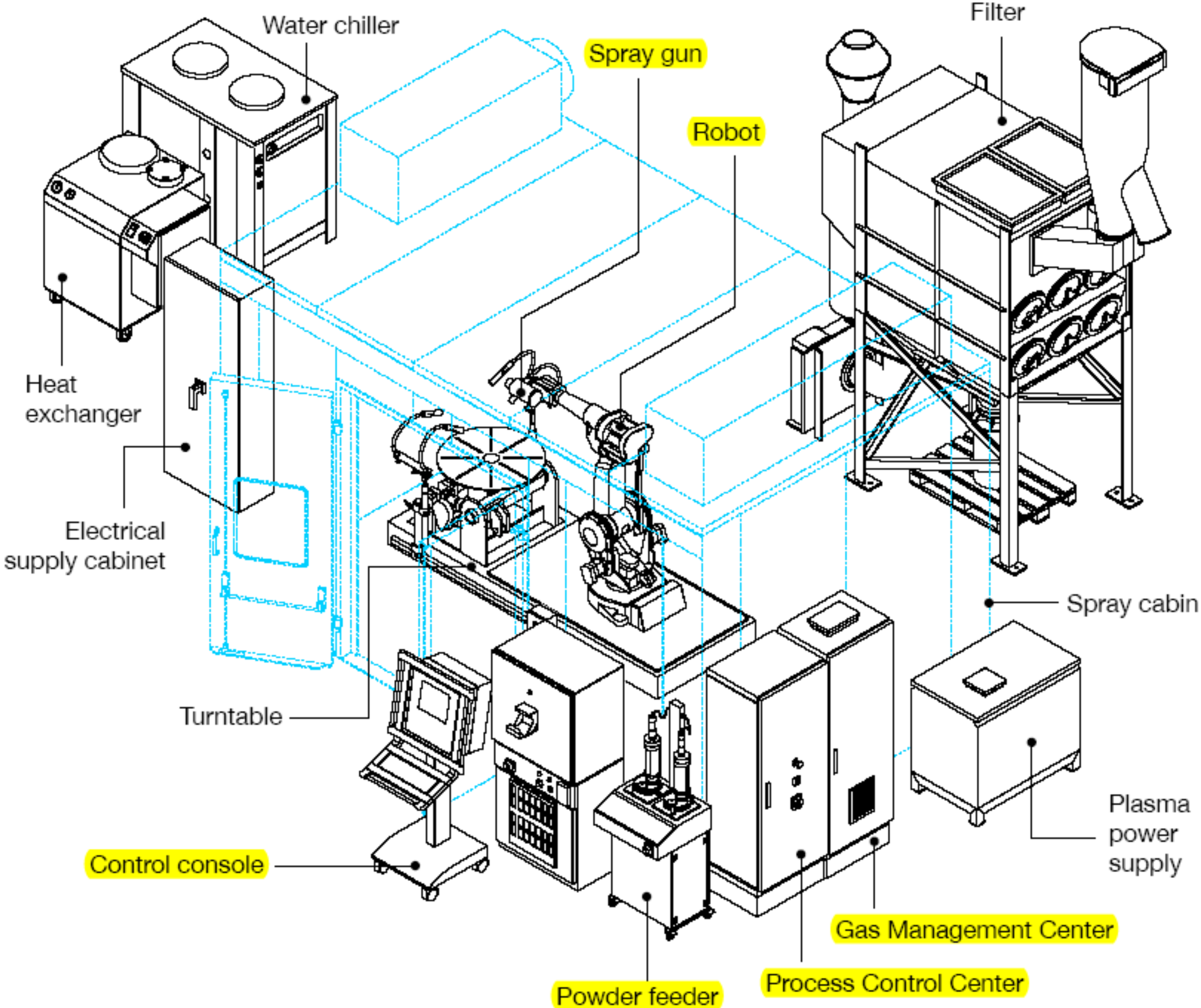
Gas management controller

Inside view of spray cabin _ robotic arm for gun manipulation

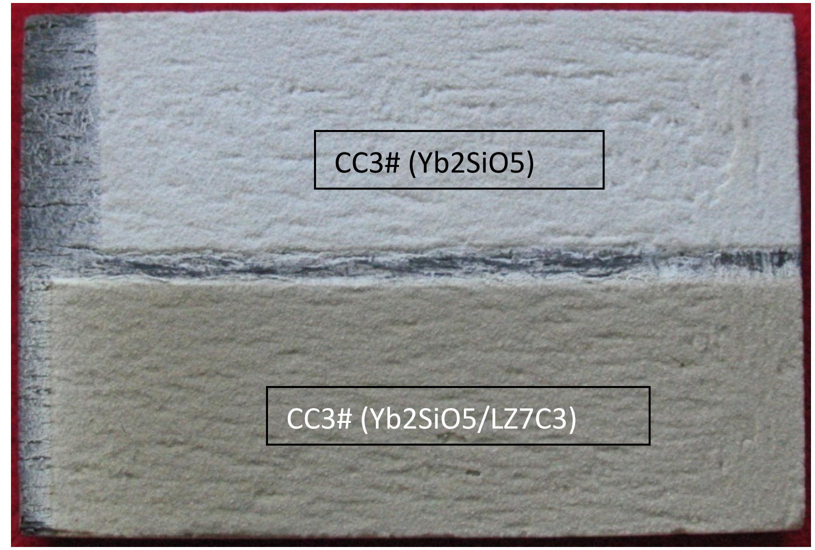
Powder feeder TWIN 120A

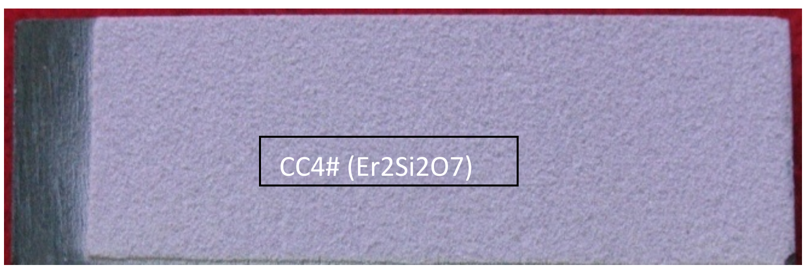
Plasma gun F4-MB

The overall infrastructure



As-sprayed single and multilayered coatings on C/C-SiC

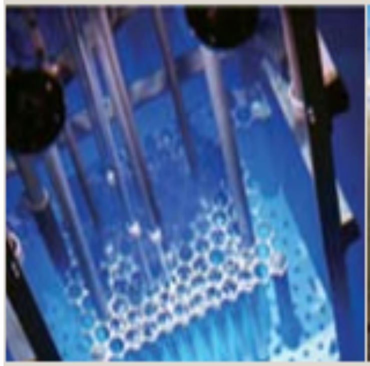




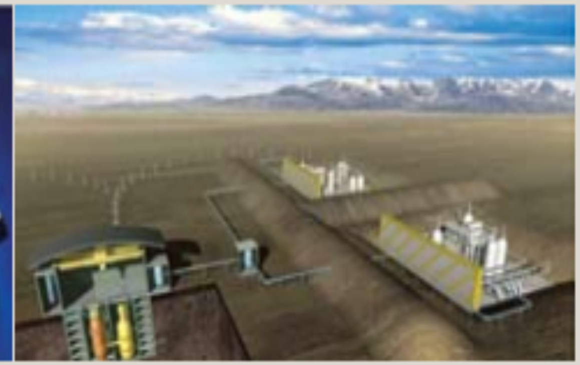
GHG mitigation through improved nuclear energy technologies

GHG mitigation through improved nuclear energy technologies

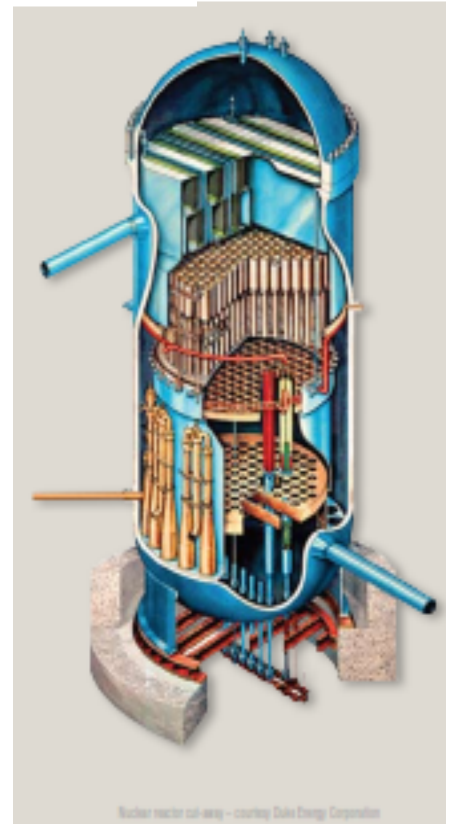
Nuclear Energy generates 17% of world's electricity and globally avoids ~610 million tons of Carbon emissions annually



Nuclear fuel rods



Artist rendition of next generation nuclear plant



Nuclear power plant on Hutchinson Island, FL

Nuclear fuel pellet

Nuclear fuel assembly

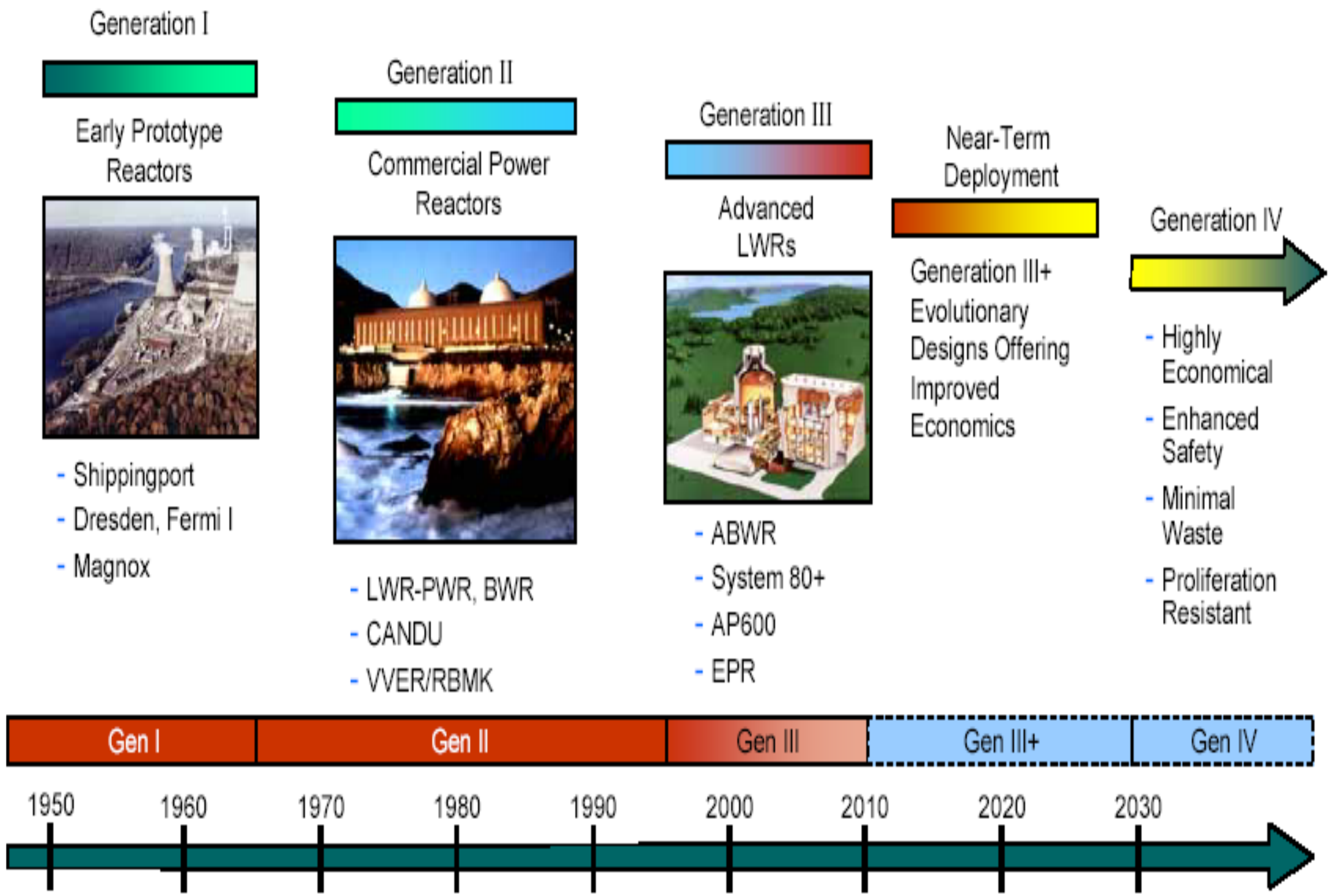
Nuclear energy technologies for reduction in carbon imprints

- **Nuclear energy is one of the most mature emission-free electrical power generation technologies with low carbon footprint.**
  For example; it is responsible for about 2/3 of the power generated in the U.S. from pollution-free sources although it provided only 20% of the national electricity.

- **Industry wide, it provides safety record superior to any major industrial technology in many advanced countries where it additionally helps to avoid reliance on foreign petroleum.**

- **New generations of nuclear power plants (Gen3/Gen4) hold a key to meeting the energy independence and clean energy goals and will be a catalyst for job growth in the energy sector.**
  >>> These new plants will be expected to have passive safety systems, provide more efficient use of nuclear fuel resources and produce lower volumes of nuclear waste, and include operation at higher temperatures or radiation fields.

Innovative Nuclear Energy Systems



Materials requirements for nuclear energy technologies for reduction in carbon imprints

- **Advanced materials offer the promise to meet the challenges of more demanding operating environments and solutions to effective nuclear waste disposal.**

- **Development of durable materials and manufacturing technologies for reactor components and nuclear fuels.**
  These materials need to offer tolerance against e.g.,
  - **High temperature**
  - **High corrosion**
  - **High radiation fields**

Materials requirements for nuclear energy technologies for reduction in carbon imprints

Nuclear power plants make substantial contributions to local economies:

- Each nuclear power plant generates several thousand jobs during construction and over 400 high paying jobs during operation.

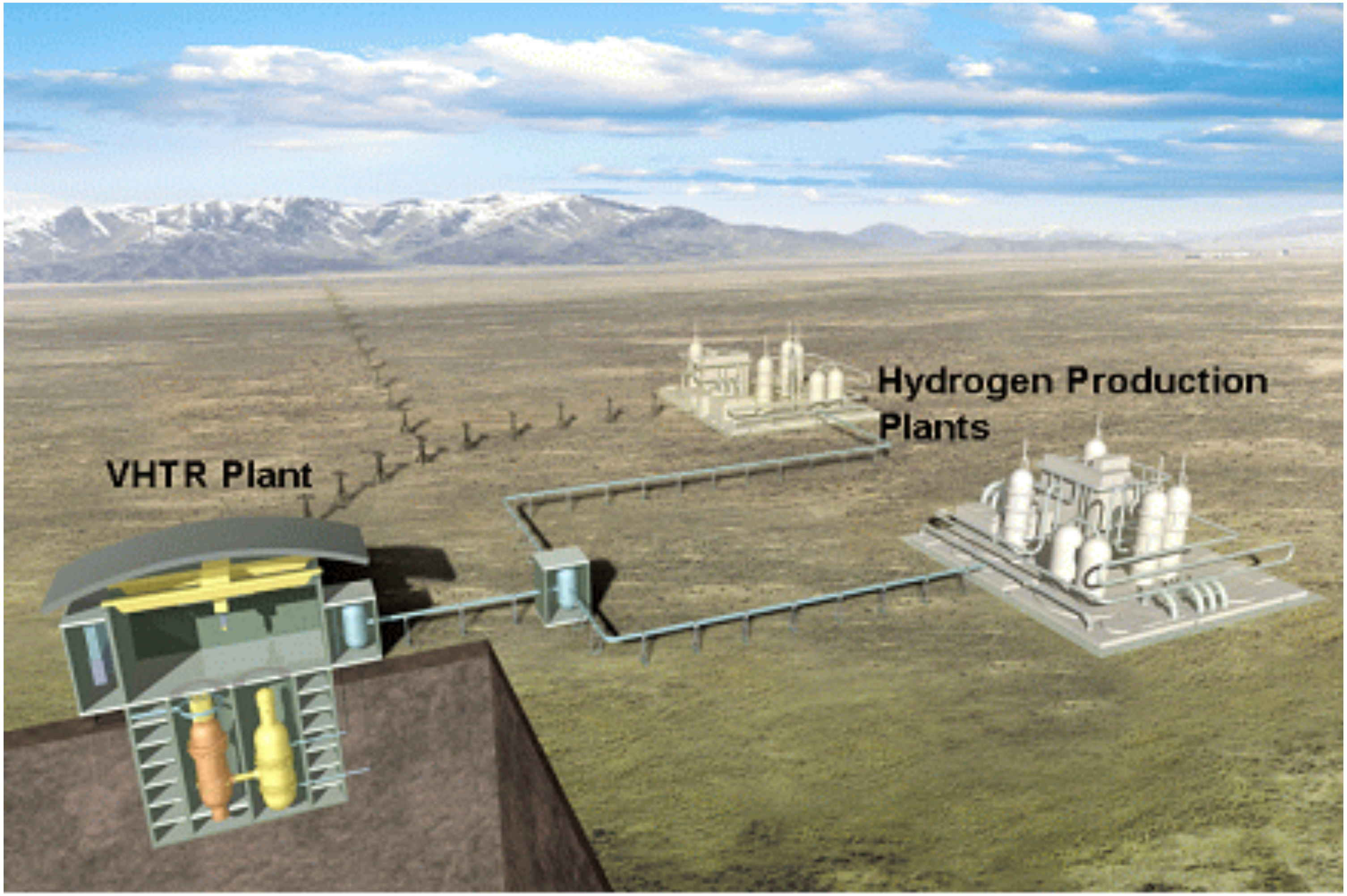
Much of the success and reliability of nuclear power plants is the result of advances in materials:

- **Understanding of long term pressure vessel steel behavior**
- **Corrosion resistant nickel base alloys**
- **Dimensionally stable zirconium fuel cladding**
- **Uranium oxide fuel pellets**

Materials R&D is needed to meet advanced reactor system and waste disposal requirements:

- Develop new classes of structural materials capable of operating at temperatures higher than that of today's light water reactors
- Develop advanced computational materials performance modeling tools
- Develop proliferation resistant nuclear fuel through advances in ceramics and coatings technology
- Develop new materials to contain nuclear waste for geologic lifetimes

Utilizing nuclear heat for production of Hydrogen by e.g., S-I Cycle



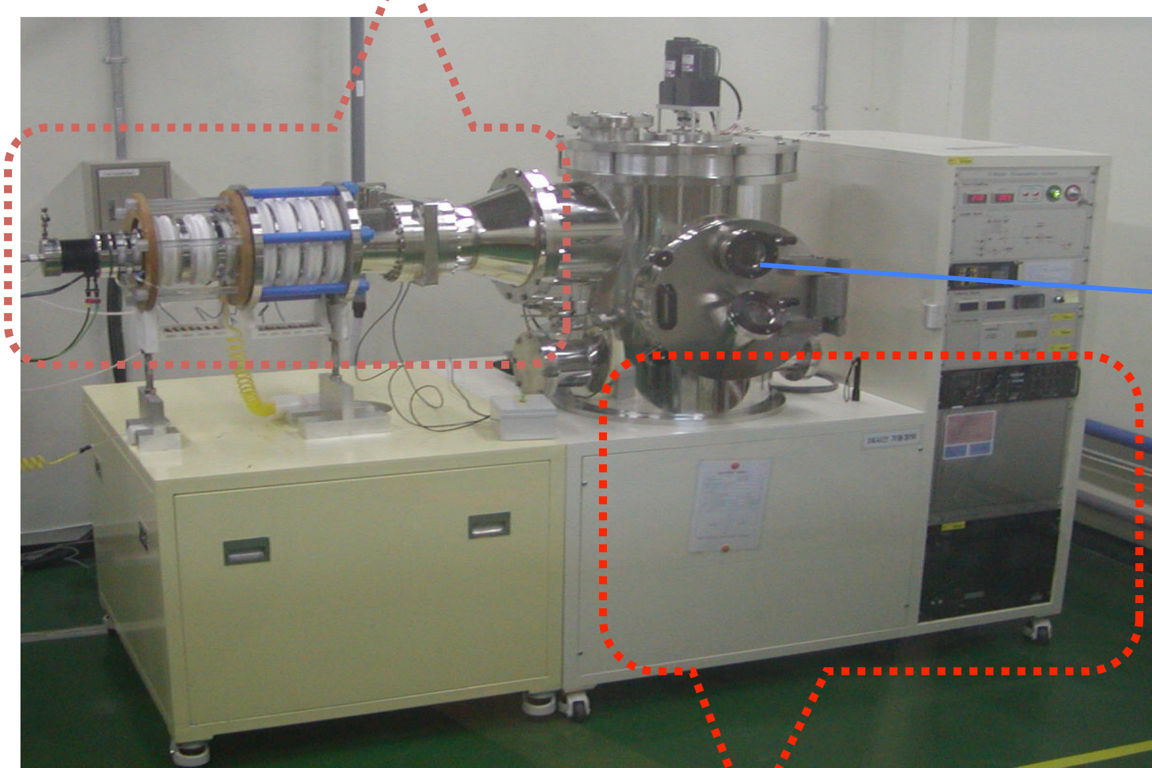
Recent activities in nuclear energy initiatives for low carbon imprints

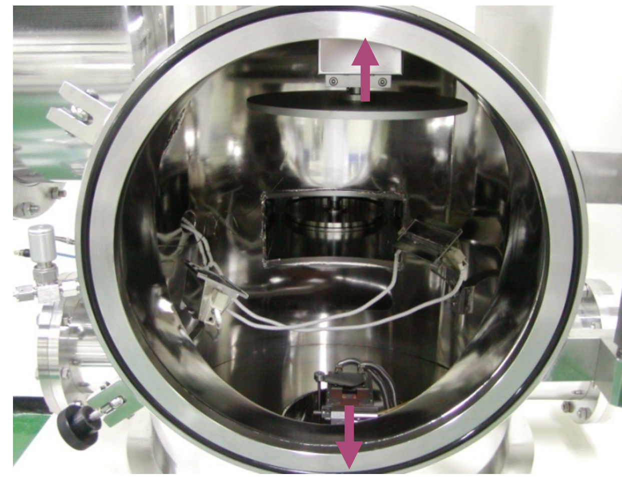
- **Development of process heat exchangers (PHE) for S-I cycle of hydrogen production by surface engineering approach using ceramic coatings.**

- Utilizing **electron beam evaporation (PVB**) and **ion beam technologies** (in collaboration with the partners)

Coating/Ion Beam Mixing System

Ion-implanter
100kV 15mA





Evaporation chamber with Jig ♪
and Evaporator♪

e-beam evaporator
10kV 500mA

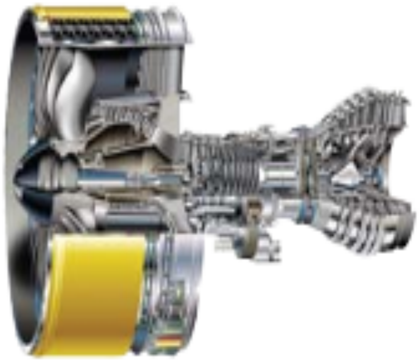
GHG mitigation through energy efficient transportation technologies

GHG mitigation through energy efficient transportation technologies

Tire cut-away – courtesy Goodyear Tire & Rubber Company

Crash test – courtesy Insurance Institute for Highway Safety

Fuel cell powered vehicle – courtesy General Motors Company



Advanced jet engine – courtesy General Electric Company

First flight of Boeing 787

Increase efficiency in Transport is required

- (1) Aviation
- (2) Rail
- (3) Road transport
- (4) Shipping

Areas to be focused in Aviation sector

- Fuel efficiency improvement by

  (1) Aerodynamic improvements

  (2) weight reductions

  (3) engine fuel efficient development
- Air traffic control
- Open more air corridor, shortest path saves energy

- Alternative fuel - HYDROGEN

Areas to be focused in Rail Sector

- Aims of technology

  (1) Reducing aerodynamic resistance

  (2) Reducing train weight

  (3) Regenerative braking

  (4) Higher efficiency propulsion system

Road Transport

- Incremental improvements in current vehicle technologies
- Advanced technologies: greater use of electric-drive technologies (hybrid electric power, fuel cells and battery electric vehicles)
- Alternative fuels: natural gas, biofuels, electricity, hydrogen
- Electronic road price system.
- Electronic real-time traffic volume information dissemination.

Energy Efficient Transportation

- **Advances in materials science have been key enablers of our modern lifestyle, including personal transportation (e.g. automobiles), and mass transportation of people and products (by air, truck, rail, ship).**
- **For example,**
  advanced rubber composites have dramatically extended the life of tires,
  Application of new steels has led to improved exhaust systems that commonly endure for the life of the vehicle.

- **Similarly, the development of corrosion resistant coatings has now enabled long lifetimes of the body structure and improved cosmetic appearance.**

- ***Lightweighting* is also being achieved for enhanced fuel efficiency by development of special alloys and composites**

GHG Mitigation in hydro power plants

GHG mitigation- a case for hydro power

- The IHA (International Hydro power association) claims that **hydropower contributes very little to climate change when compared to fossil fuel** generating options (UN Climate convention, Milan 2003)
- In generating electricity, hydroelectric power plants do not release carbon dioxide (CO_2). **The carbon footprint associated with hydropower comes mostly from the construction and decommissioning** processes.
- Research has found that a large hydroelectric power station emits the equivalent of between 10 and 30 grams of CO_2 for each kilowatt-hour (kWh) of electricity it generates.

Continued…

- The **carbon footprint involved in making and transporting the concrete** used to construct a large-scale hydroelectric power station is significant. Making cement, an ingredient of concrete, releases large quantities of CO_2 into the atmosphere.
- **But the working life of a large-scale hydroelectric power station can exceed 100 years,** so when the average lifetime emissions of a hydroelectric power station are calculated, these **initial CO_2 emissions are offset by the subsequent decades of zero-carbon** electricity generation.

Materials technology needs in hydropower sector

- High strength civil engineering materials and structures
- Development of materials for manufacturing high tolerant turbine components such as blades
- Development of highly efficient power transmission systems

References / Bibliography

- Various journals from Elsevier Co. and Springer Co.
- Various internet resources
- Research collaborators

Findings and Conclusions

- Renewable and alternative energy technologies have very strong potential in terms of carbon mitigation

- Applied research in Advanced Materials is required to be carried out on priority basis as they are to play very positive role in realizing GHG emission mitigation targets

- 3E Nexus initiative is need of time for enhancing and developing multinational research collaboration in the nexus of energy, environment and ecosystems in Asia-Pacific partners

- The efforts to develop advanced renewable and alternative energy technologies should be supported by the world.

Acknowledgement

- Research collaborators:
  - Inst of Advanced Energy, Kyoto University, Japan
  - NUST Islamabad, Pakistan
  - CIIT Islamabad, Pakistan
  - Changchun Institute of Applied Chemistry, Chinese Academy of Sciences
  - KAERI- South Korea.
- IR3S, Univ of Tokyo, and Ministry of Climate, Govt of Japan

THANKS

Notes from meeting 24/2/14

- APN : Dr Akia Takemoto
  - Funding agency through e.g. regional collaboration,
  - Funding of regional research projects for low- carbon, climate adaptation and relevant capacity building
- Dr Alexnadros (Agenda setting)
  - How we may contribute to 3E?
  - Capacity buildinng such as copurses/lectures, etc.
  - Co-benefit indicators?
  - Collaboration , linkages, bases line date on energu uses-case studies,