Prof Y Nayudamma Memorial Lecture,
27th January, CLRI, Chennai.

ENERGY ETHICS AND EQUITY

An Interactive, Intricate & Inevitable Triad of Sustainability Matrix

Baldev Raj
President - Research, PSG Institutions, Coimbatore
President, Indian National Academy of Engineering
President, International Institute of Welding

Tel: 91 422 4344201
Email: baldev.dr@gmail.com
secdmg@igcar.gov.in

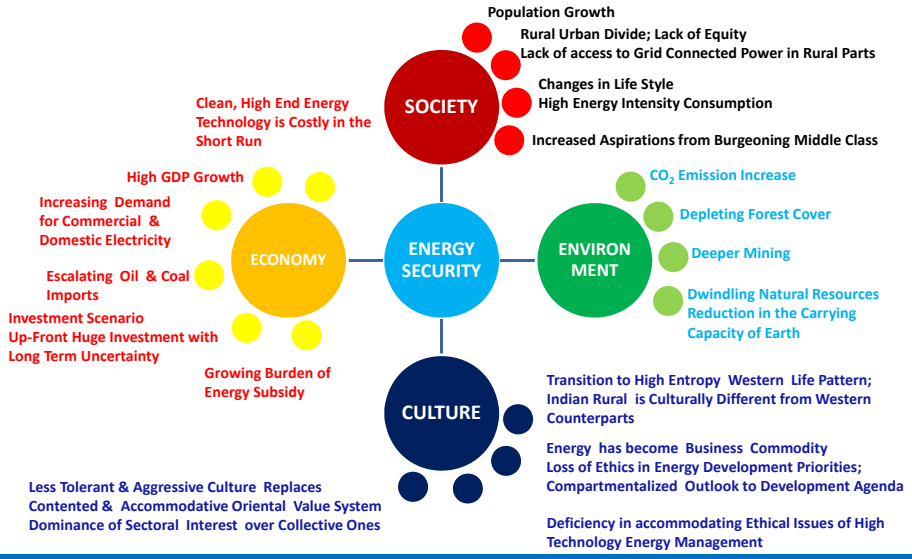
Ancient times to prior Industrial Revolution : Abundance of Natural Resources and fairly unlimited and unrestricted access. Relatively low energy consumption. Earth's carrying capacity is not impaired.

Industrial Revolution : Rampant expansion in the use of global resources; Yet, remained manageable, until oil crisis of seventies struck. Shrinking nature of Earth's capacity is gradually felt; Decreasing returns upon further expansion through fossil option.

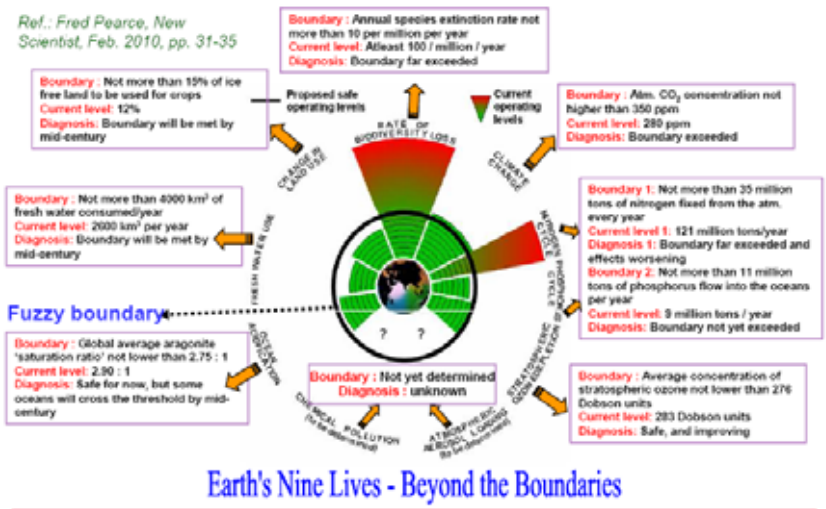
Present time : Energy Crunch: Manageable, if Sustainable Energy Culture is put in place . Excessive strain on Nature; GHG emission, Carbon foot print; **Loss of Equity & Ethics in Energy management**

Time line of Growth in Energy Consumption & Onset of Energy Crisis

Energy Security is a Multi-Dimensional Phenomenon

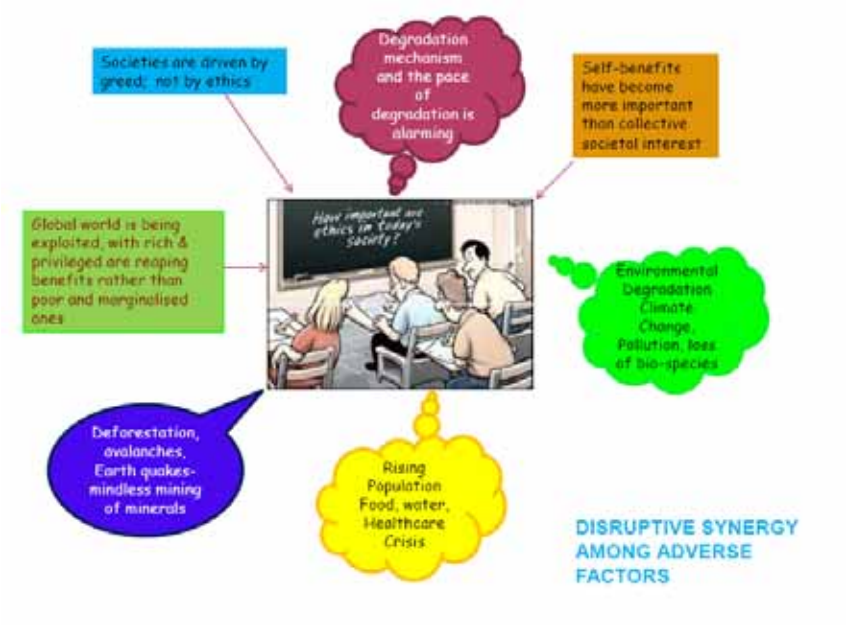


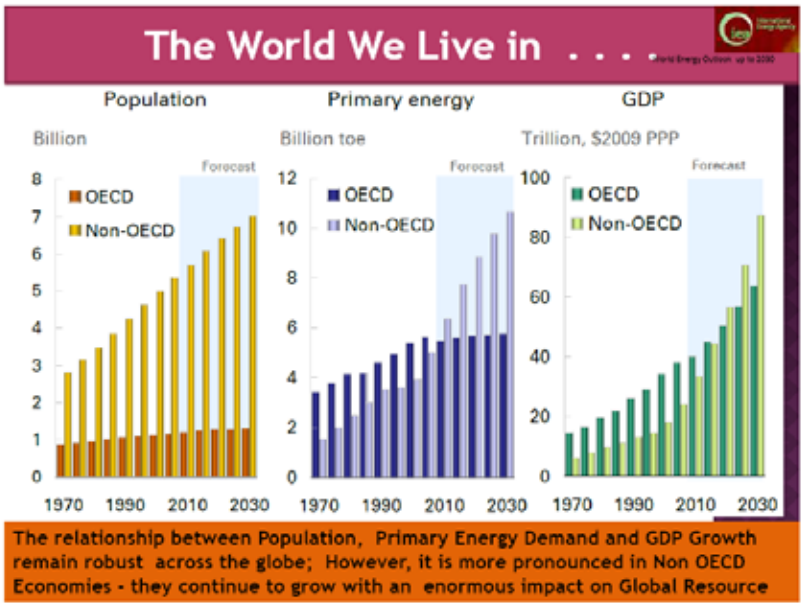
Economical & Environment friendly Energy Options which contribute to Sustained Development with the preservation of Ethics and Cultural Specificities of India, are the Challenges facing Energy Sector



Earth's Nine Lives - Beyond the Boundaries

Balmy springtime of earth is known as the Holocene, but we are in a new era Anthropocene which is defined by human domination of the key systems that maintain the conditions of the planet. We have today controlled the 'Earth', but in our reckless desire to advance, we forget to maintain its life-supporting systems.


Societies are driven by greed; not by ethics
Degradation mechanism and the pace of degradation is alarming
Self-benefits have become more important than collective societal interest
Global world is being exploited, with rich & privileged are reaping benefits rather than poor and marginalised ones
How important are ethics in today's society?
Environmental Degradation Climate Change, Pollution, loss of bio-species
Deforestation, avalanches, Earth quakes- mindless mining of minerals
Rising Population Food, water, Healthcare Crisis
DISRUPTIVE SYNERGY AMONG ADVERSE FACTORS

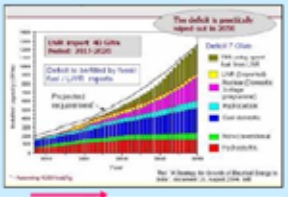

The World We Live in . . . .
Population
Billion
Forecast
OECD
Non-OECD
0 1 2 3 4 5 6 7 8
1970 1990 2010 2030
Primary energy
Billion toe
Forecast
OECD
Non-OECD
0 2 4 6 8 10 12
1970 1990 2010 2030
GDP
Trillion, $2009 PPP
Forecast
OECD
Non-OECD
0 20 40 60 80 100
1970 1990 2010 2030
The relationship between Population, Primary Energy Demand and GDP Growth remain robust across the globe; However, it is more pronounced in Non OECD Economies - they continue to grow with an enormous impact on Global Resource

World Energy Scenario Analysis: Quirin Schiermeierr et al., Nature 454, 14 (2008) 816-823.

- World Energy Requirement would increase twofold by 2050 and by three fold by 2100
- Enough Clean Electricity in World but needs short term (realistic) and long term (ambitious but with adequate resources) strategy. Needs allocations and sustained commitment
- Hydro Electric Power: Cheap and mature technology with substantial environmental costs
- Nuclear Fission: Major constraint will be politico-social acceptability, but has potential for large scale deployment. Fast Breeders with closed fuel cycle can supply complete electricity demand for a few centuries
- Nuclear Energy is not a good option to be deployed in all countries
- Fusion is a break through technology
- Biomass: The only possible carbon-negative system. But increasing Opposition likely with increase in cultivation of energy crops in preference to agricultural crops
- Wind: A wind power capacity of terrawatt is likely, but at select locations in the globe
- Geothermal: Unlikely to be a major energy resource based on present day technology
- Cost is a consideration of distributed energy resources for societal (desalination), education and healthcare use and employment is a good option
- Solar: One of the most promising carbon free technology for future. But energy storage options should develop for effective utilisation of solar power
- Ocean Energy: Not a major energy resource presently

Energy Scenario for India

Energy Resource	Amount	Electricity Potential* GWe-yr
Coal	53.3 -BT	10,660
Hydrocarbon	12 –BT*	6,853
Uranium-Metal	84,000 -T	
- in PHWR		320
- in Fast Breeders		42,000
Thorium-Metal (in Breeders)	2,25,000 –T	155,000
Hydro	150 -GWe	60 GWe-yr / yr
Renewables	100 GW(e)	



Nuclear Power Scenario

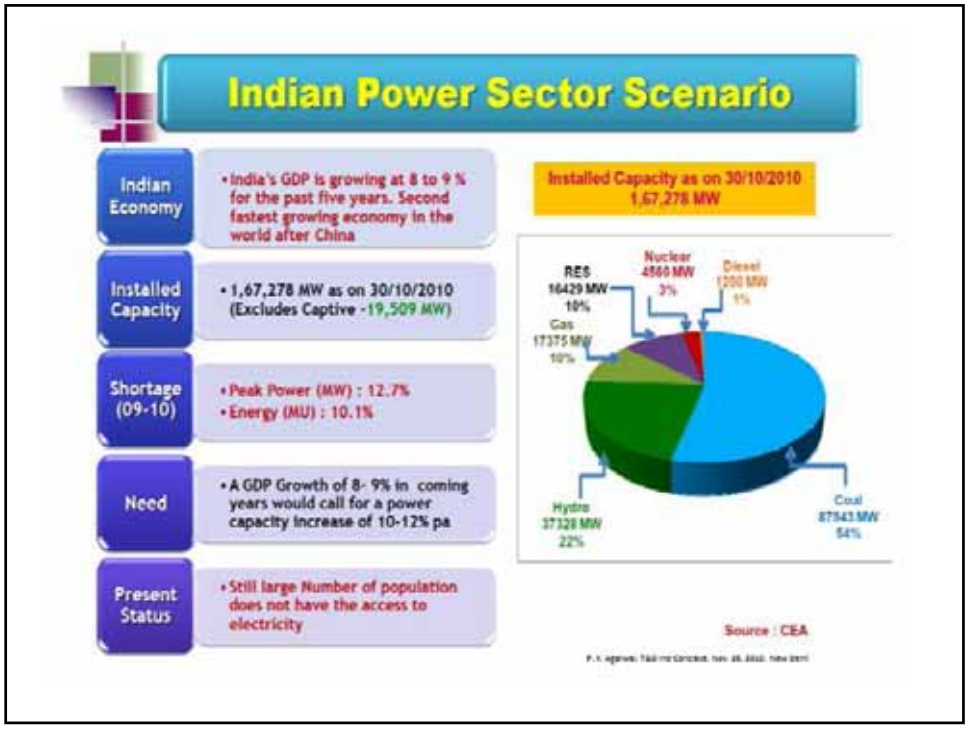
Stage-I PHWR's
- 18 Operating
- 3 under construction
- Planned Construction of 700 MWe
- Gestation period being reduced
- Power Potential : 10, 080 MWe

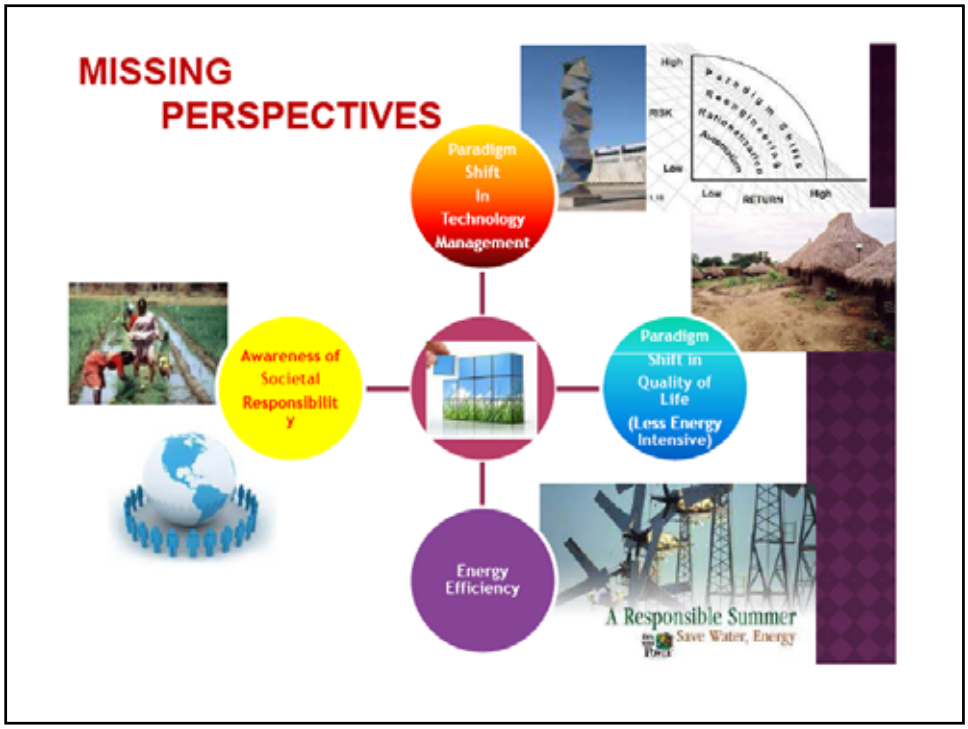
LWRs
- 2 BWRs operating
- 2 VVERs under construction

Stage – II
Fast Breeder Reactors
- 40 MWth FBTR – 25 years of successful operation
- (U,Pu)C fuel burn up 155 GWd/t achieved in FBTR
- Sodium Technology mastered - Na pumps operate more than 1,82,000 h
- 500 MWe Commercial FBR – Advanced stage of construction
- Power potential – Minimum 630 GWe

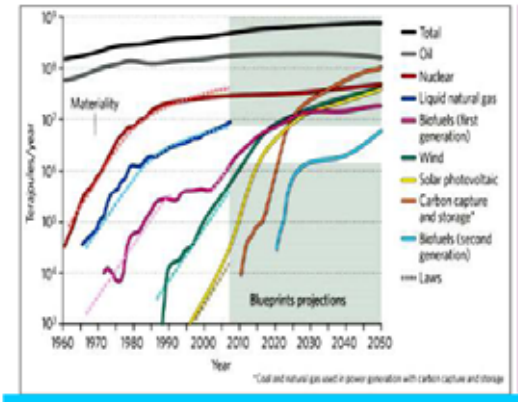
Stage – III and Beyond
Thorium Based Reactors
- 30 MWth KAMINI – Operating
- 300 Mwe AHWR – Regulatory Evaluation
- Power Potential = 155,000 GWe-y
- Availability of ADS can enable early and enhanced introduction of Thorium Fuel Cycle
- Participation in ITER towards development of fusion technology

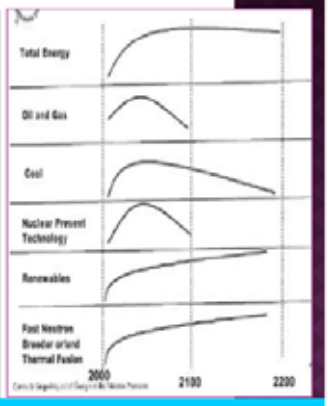
Energy sustainability with closing the fuel cycle is the policy; Growth limited by our ability to expand in a robust manner


Indian Power Sector Scenario
Indian Economy
• India's GDP is growing at 8 to 9 % for the past five years. Second fastest growing economy in the world after China
Installed Capacity
• 1,67,278 MW as on 30/10/2010 (Excludes Captive -19,509 MW)
Shortage (09-10)
• Peak Power (MW) : 12.7%
• Energy (MU) : 10.1%
Need
• A GDP Growth of 8- 9% in coming years would call for a power capacity increase of 10-12% pa
Present Status
• Still large Number of population does not have the access to electricity
Installed Capacity as on 30/10/2010
1,67,278 MW
RES
16429 MW
10%
Nuclear
4560 MW
3%
Diesel
1200 MW
1%
Gas
17375 MW
10%
Hydro
37328 MW
22%
Coal
87543 MW
54%
Source : CEA

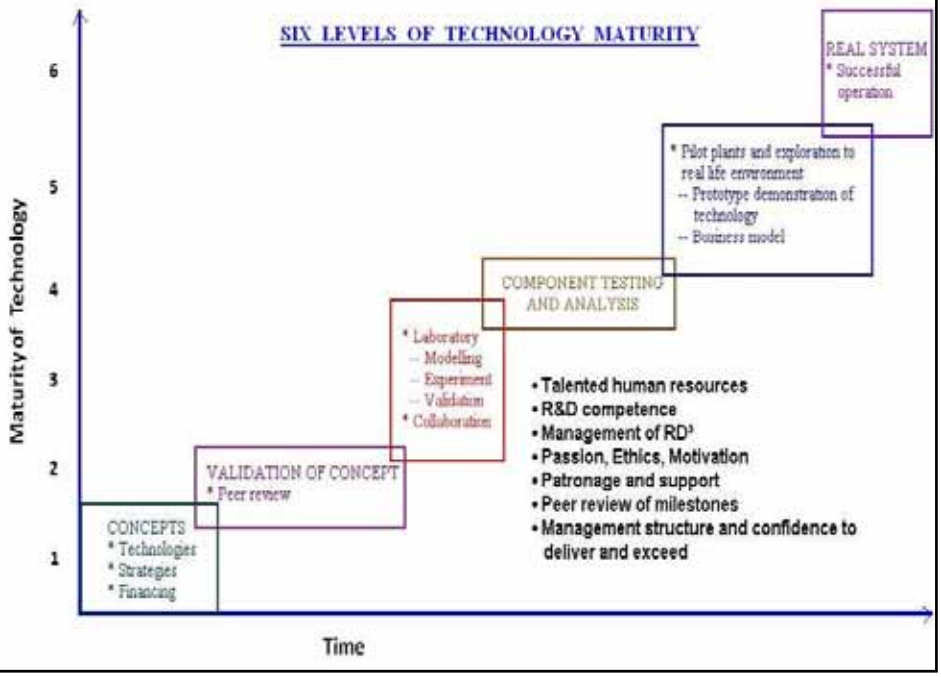

MISSING
PERSPECTIVES
Paradigm Shift In Technology Management
Awareness of Societal Responsibility
Paradigm Shift in Quality of Life (Less Energy Intensive)
Energy Efficiency
High
RISK
Low
Low
RETURN
High
A Responsible Summer
Save Water, Energy

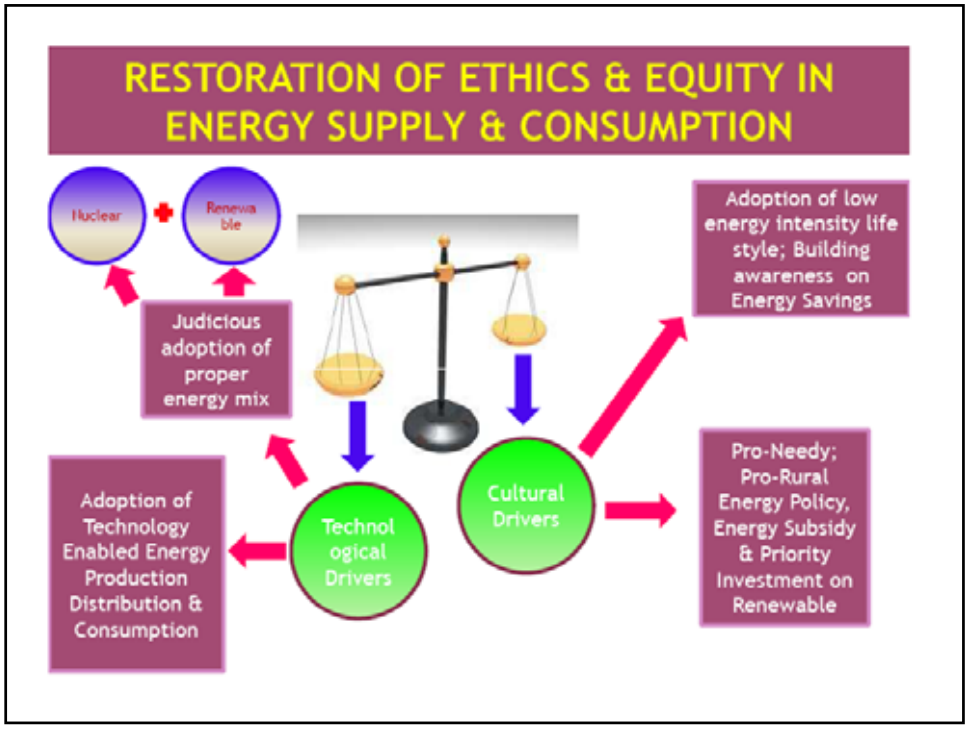
ENERGY-TECHNOLOGY DEPLOYMENT





No Single Energy Option - A Portfolio of Energy Solutions & Energy Technologies are required for Sustainable Energy Development in future.




RESTORATION OF ETHICS & EQUITY IN ENERGY SUPPLY & CONSUMPTION
Nuclear
Renewable
Judicious adoption of proper energy mix
Adoption of low energy intensity life style; Building awareness on Energy Savings
Adoption of Technology Enabled Energy Production Distribution & Consumption
Technological Drivers
Cultural Drivers
Pro-Needy; Pro-Rural Energy Policy, Energy Subsidy & Priority Investment on Renewable


Low income group tend to live in areas more likely to be adversely affected by climate change – developing country scenario
Lower income households are currently less able to introduce measures to improve energy efficiency – lack of rural funding (World Bank Report, 2009)
On average, low income group spend a greater proportion of income on meeting basic demands of lively hood
With good financial and other incentives from the government, the majority of households may be able to afford investment in energy efficiency, despite up-front costs
Without SOCIAL EQUITY, energy policy measures & designed responses to mitigate climate change could adversely affect low income households
Energy Equity is very important for People of lower strata in India

TECHNOLOGY AS DRIVER FOR ENERGY EQUITY

SOLAR & BIOGAS: TYPICAL EXAMPLES

Solar PV – water pump

Solar PV – microwave repeater

Bio-Gas for Cooking in Rural Tamil Nadu

Solar lantern use in Rural Tamil Nadu

23

Materials For Energy Security . . *Better, Faster, Cheaper & Cleaner Development of Energy Portfolio*

Meeting the objectives involves

- **Substitution of materials**
- **Increased understanding of the existing materials :-** to enhance design , predict and improve the properties in service

Key Approaches to meet challenges

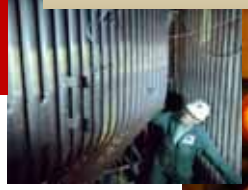
(i) Understand the materials – Basics
(ii) How they interact with surroundings- Applied
(iii) Materials Design in the context of power plant requirements, component fabrication & Cost: Total Technology Development
(iv) Energy Materials Management

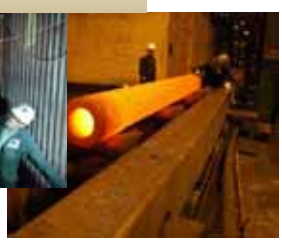
Materials For Advanced Fossil Options

- Boilers
- Steam Turbines
- Gas Turbines
- Gasifiers
- CO2 capture, transportation and storage

High Temperature Materials; Large Component Fabrication; Total Quality Audit & NDE life Cycle Monitoring – Prediction are the key material Issues

ADVANCED WELDING & FABRICATION TECHNOLOGIES ARE CRUCIAL





higher temperatures and pressures.

Fuel flexibility will lead to more aggressive environments (co-firing, biomass firing, oxy-firing, energy from waste)

Need incremental changes to current materials

Need quantum change in the development of integrated materials system solutions for the future of energy materials

Materials development should be able to scale the process cost effectively, and help develop new low cost alternatives

Capability to process and fabricate large size components for mega plants

Ultra super / super critical boilers — Steam turbines — Gas turbines — Gasification — CCS

Global market for new and replacement thermal power plants is currently about 140 GW per annum (IEA 2010). In 2012 –2017 plan period, 2,00,000 Mwe capacity addition is planned, of which bulk is from Coal

---

A Visionary's Dream on Nuclear Sodium Cooled Reactors . . .

" The country that learns to build breeder reactor would have solved its energy problems for ever "

" The country which first develops a breeder reactor will have a great competitive advantage in Atomic Energy " - *India made an early entry to Nuclear Energy*

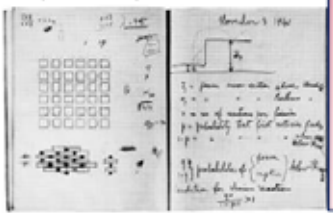
Equity through Technology

1901 - 1954

Enrico Fermi Nuclear Generating Station

Enrico Fermi, Meeting in April 26, 1944 With Wigner, Szilard and Others on :

" How the Chain Reaction would be used for the production of power "



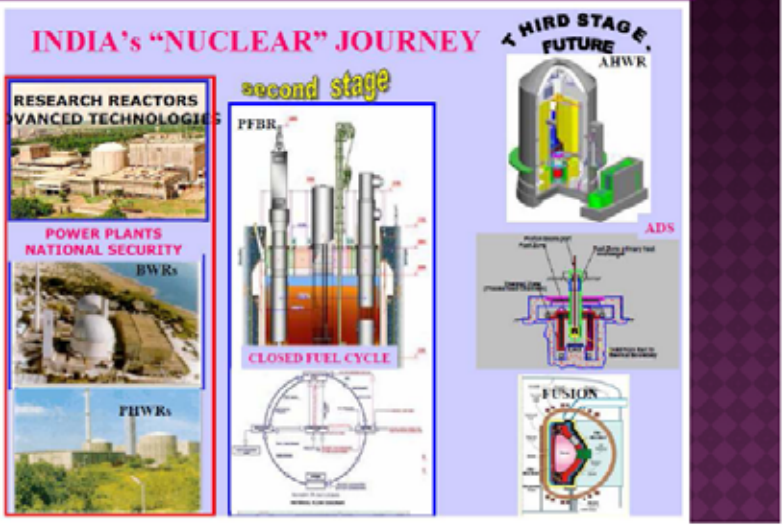
Breeding ratio: " . . . it obviously must be greater than one ".

" The serious objection to these fast chain piles is the removal of heat ".

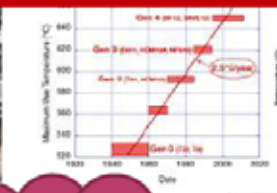
" The coolant for this type of pile would be a bismuth-lead alloy and would flow downward through the pile between the static and rotating rods. The possibility of using liquid sodium in place of bismuth-lead should also be looked into ".

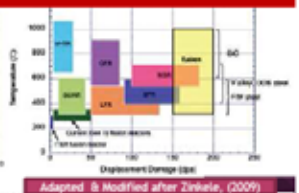
NUCLER OPTION FOR SUSTAINABLE ENERGY

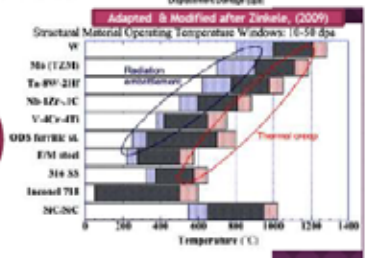
A SOLUTION FOR CLEAN AND AFFORDABLE ENERGY: INDIA'S NUCLEAR OPTION



NUCLRAR OPTION NEEDS ADVANCED MATERIALS TECHNOLOGY : CHALLENGES & OPPORTUNITIES FOR MATERIALS SCIENTISTS AND TECHNOLOGISTS ARE IMMENSE

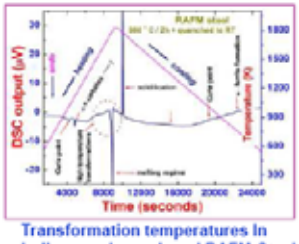




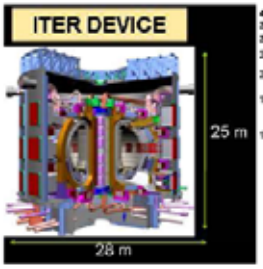


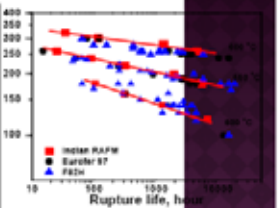
India has a strong in-house Nuclear Materials R&D. Over the years, it has fostered excellent collaboration with industrial partners. This advantage should not be lost sight of in the coming exponential expansion plan of Indian Nuclear Energy Scenario

Indian Fusion Programme: Material Science-based Indigenous Development of RAFM Steel and Fabrication Technologies

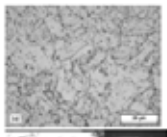


Transformation temperatures in indigenously produced RAFM Steel

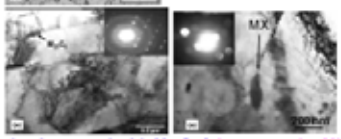




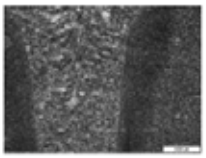
Creep rupture strength comparable to that of internationally developed RAFM steels

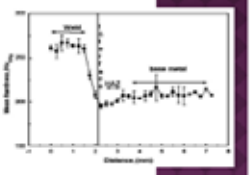


9Cr-1.4W-0.6 Ta RAFM steel - Tempered martensitic structure



Laths decorated with $M_{23}C_6$ & intragranular MX

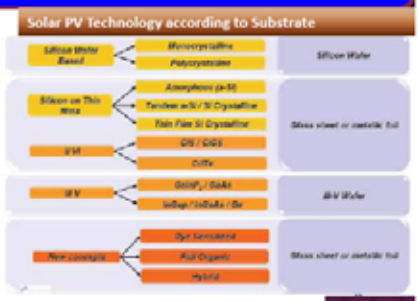




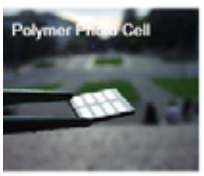
Electron beam welding of RAFM steel

Toughness of the weld metal (115 J) is as good as that of base metal (120-140 J)

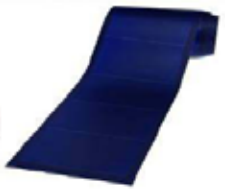
Solar Photo Voltaic Technology



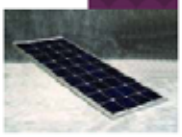
Thinner flexible solar modules for integration into building



Future trend: Flexible organic solar modules



Protective back sheets for solar cells



WIND POWER: Technology Challenges

Challenges

- Mfg capability has to increase with demand … annual 20-25% increase
- Drive towards more local mfg content

Opportunities

- New designs and advanced technology
- Permanent magnet manufacturing capacity
- Carbon fiber and fiberglass manufacturing
- Large gearboxes
- Large steel casting & alternatives
- High-power T&D

Design & Technology Advances: Key Enabler . . .

Off- Shore Wind Energy : Potential Prospects, If Materials Challenges are addressed

Materials Issues in Energy Saving Protocols Transmission, Distribution & Storage

Light Bulb….200 years of R&D; Yet Innovation on Materials for Energy savings in lighting- Still Continuing . . .

Proof of Principle				Prototype				Commercial			Cost Effective		
1809	1820	1835	1850	1854	1875	1878	1879	1880	1903	1906	1910	1925	1991
Demo Carbon	Demo Platinum	Demo Carbon	Demo Charcoal	Demo Bamboo	Demo Carbon	13.5 hrs Carbon	40 hrs carbon	1200 hrs Bamboo	1200 hrs tantalum	Costly Tungesten	cheap Tungesten	cheap Tungesten	60000 hrs Tungesten

Materials R&D associated with transmission of Oil and Gas will include development of:
Higher strength and toughness pipeline grades of steel - Clad / composite pipes

More economic corrosion-resistant pipes for corrosive gas mixtures

Lower cost cryogenic materials for Liquid Natural Gas (LNG) transmission and LNG / liquid hydrogen storage

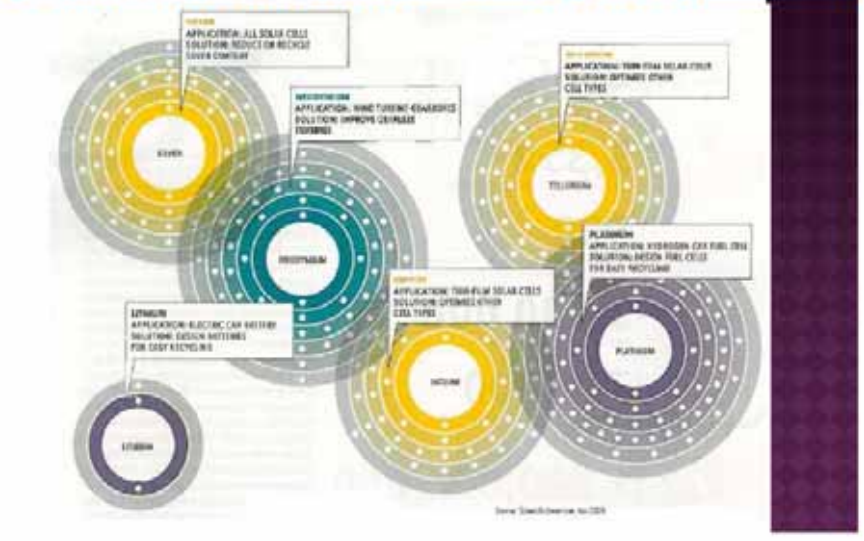
High Temperature/High strength conducting wires / cables would enable overhead cables to carry more power with shorter insulating strings and within a lower silhouette

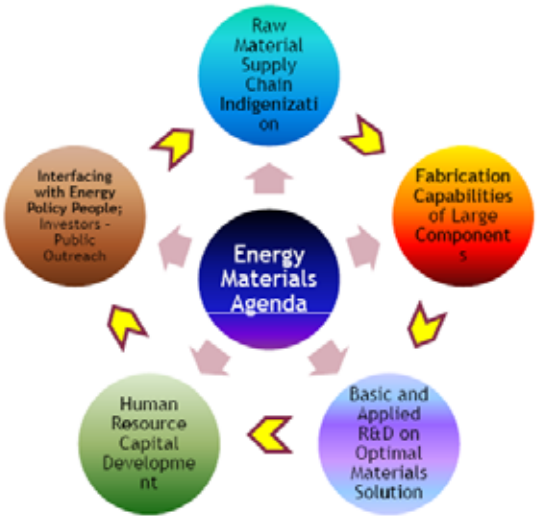
Advanced materials like High Temperature Superconducting Cables to enable future upgrading

Cost Effective and Green

2006 -
LED for Street Lighting

MATERIALS AVAILABILITY CONSTRAINING FUTURE ENERGY TECHNOLOGY: SCIENTIFIC AMERICAN (NOV. 2009)





Materials represent the common and ever present connecting link among all energy technologies. The future of sustainable energy campaign with a concurrent consensus on environmental concerns depends on constructive & cooperative interaction among all the components of Energy Materials Agenda

India's Energy Scenario: Diversity of Issues is actually the Strength: Indo-genus Model

India can adopt the Western Methodology to surmount Energy Deficit

Sequential adoption of all steps as outlined by Sustainable Energy Policy, India would take perhaps longer time than it took for Industrialized economies to arrive at a steady state

India can leapfrog – skipping some intermediate steps

Example: India can altogether opt out of fossil race, by deciding to go in for suitable mix of renewable and nuclear in a big way; placing solar + wind + biomass + small-hydro combination to effective use will largely reduce the dependency on thermal power for rural as well as non commercial applications. Innovative distribution technologies like off-grids and added grids can also be implemented

37

ENERGY & CULTURE

Energy Self-Sufficiency, the sole index of the quality of human life . . .

REMEDYING SOCIETAL DISORDER IS AS IMPORTANT AS ACHIEVING ENERGY SELF-SUFFICIENCY or registering high GDP growth

Traditional Indian Value System derives from Vedas & Scriptures that were centuries old; Advocates moderation in every thing. Spirituality subtly permeates all spheres of human activity.

Indian life style stresses on simplicity, energy intensive and consumption rich materialistic lifestyle is not advocated in oriental Indian culture. Energy conservation is inherent in oriental mindset.

Materialistic philosophy- led to inequalities in wealth generation and human satisfaction index.
Achievement - Yes; but, Contentment and Fulfillment - Not guaranteed
Self -Reliance - Yes
Self Realisation - No

INSPIRING LEADERSHIP

Nation requires the leadership of individuals, intellectuals and social scientists, who have the responsibility of devising the ethical vision of development. The need of times is enlightened human beings, who can remove disillusionment from public by infusing hope through their selfless commitment, and unflinching resolve to guide the course of sustainable development. Such a development would reflect our heritage, national pride and self-reliance. (Baldev Raj & Raju, *Energy & Culture*: in Science & Culture, July (2010))

The earth planet with over a population of more than six billion has witnessed highly segregated patches of societal advancement. The fact remains that more than two billions amongst us do not have proper access to basic life sustaining needs. Clean water, sustained energy availability, quality education and affordable health care etc have become matters of deep frustration for the low income strata of the society.

Baldev Raj & Raju (2010): Science Culture, July 2010

The disturbing fact is that the major share of the deprived section includes, expecting mothers and children living in underdeveloped parts of this globe. With the estimated projection of the growth in population to about 9 billion by 2050, the future means very little hope to the lower income group of the population

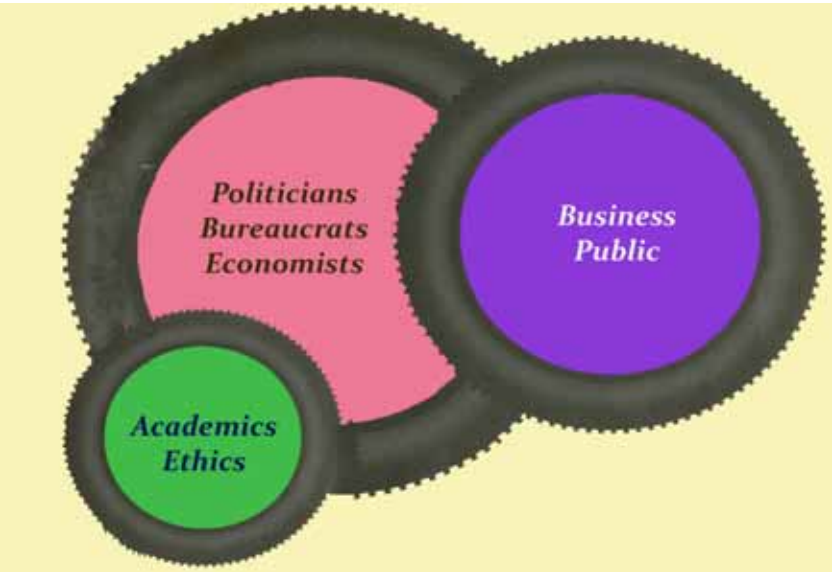
The human race now understands that the sheer celebration of science and technology towards enabling a high energy intense growth scenario has brought us to an extraordinary degree of *social insecurity*

The Earth is not a gift from our parents;

It is on a loan from our children - *Indian Proverb*

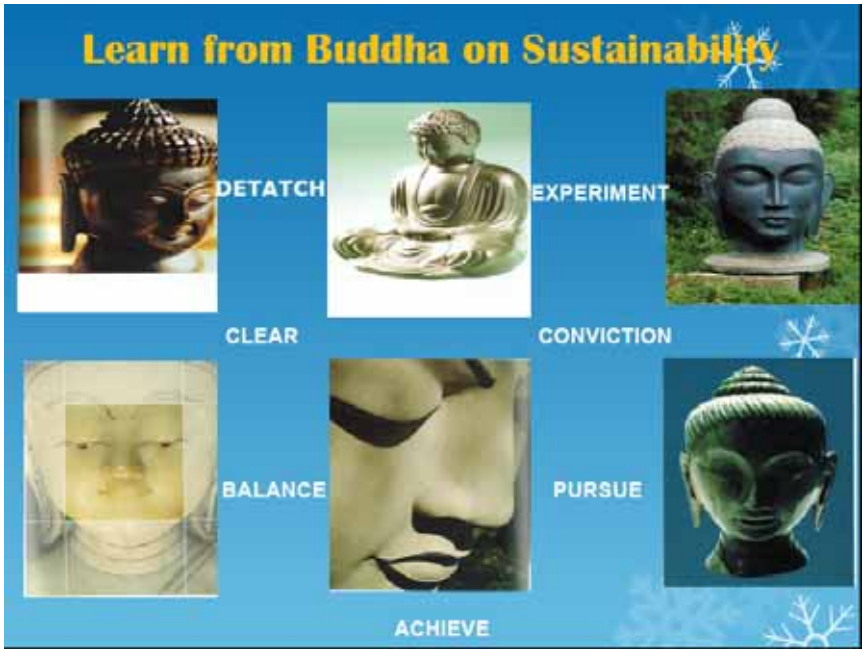
The best options for sustainable development - for meeting the needs of the present generation without compromising the ability of the future generation to meet their needs- lies in allowing all energy supply options to compete, improve and contribute on a level playing ground directly on the basis of cost effectiveness, environmental protection

Ethical & Sustainable model



A developed civilization scenario

Energy, water, health, land, food are to be considered in a comprehensive and interlinked fashion for sustainable options with better quality of life to all the citizens of the Planet


Learn from Buddha on Sustainability
DETATCH
EXPERIMENT
CLEAR
CONVICTION
BALANCE
PURSUE
ACHIEVE


Incredible India