Future Energy Demand and Supply in China, India, and Korea.

Based on talks given at a meeting at the Max Planck Institute for Plasma Physics, Garching, Germany, December 10-12, 2003:

"Development in Fusion Power: What role could fusion power play in transitional and developing countries."

Coordinated by Thomas Hamacher (IPP Garching) with support from the EFDA. Additional support provided by John Sheffield (JIEE at the University of Tennessee) with support from the US-DOE-OFES.

Summary

- The objective of the workshop was to investigate the possible role of fusion in transitional countries like China and India.

- These countries are experiencing a dynamic development of their economies and an associated rapid increase in energy demand and electricity production that is expected to continue throughout this century.

- International collaboration is viewed as important. Fusion energy is considered as a potential option in the latter half of this century.

Agenda

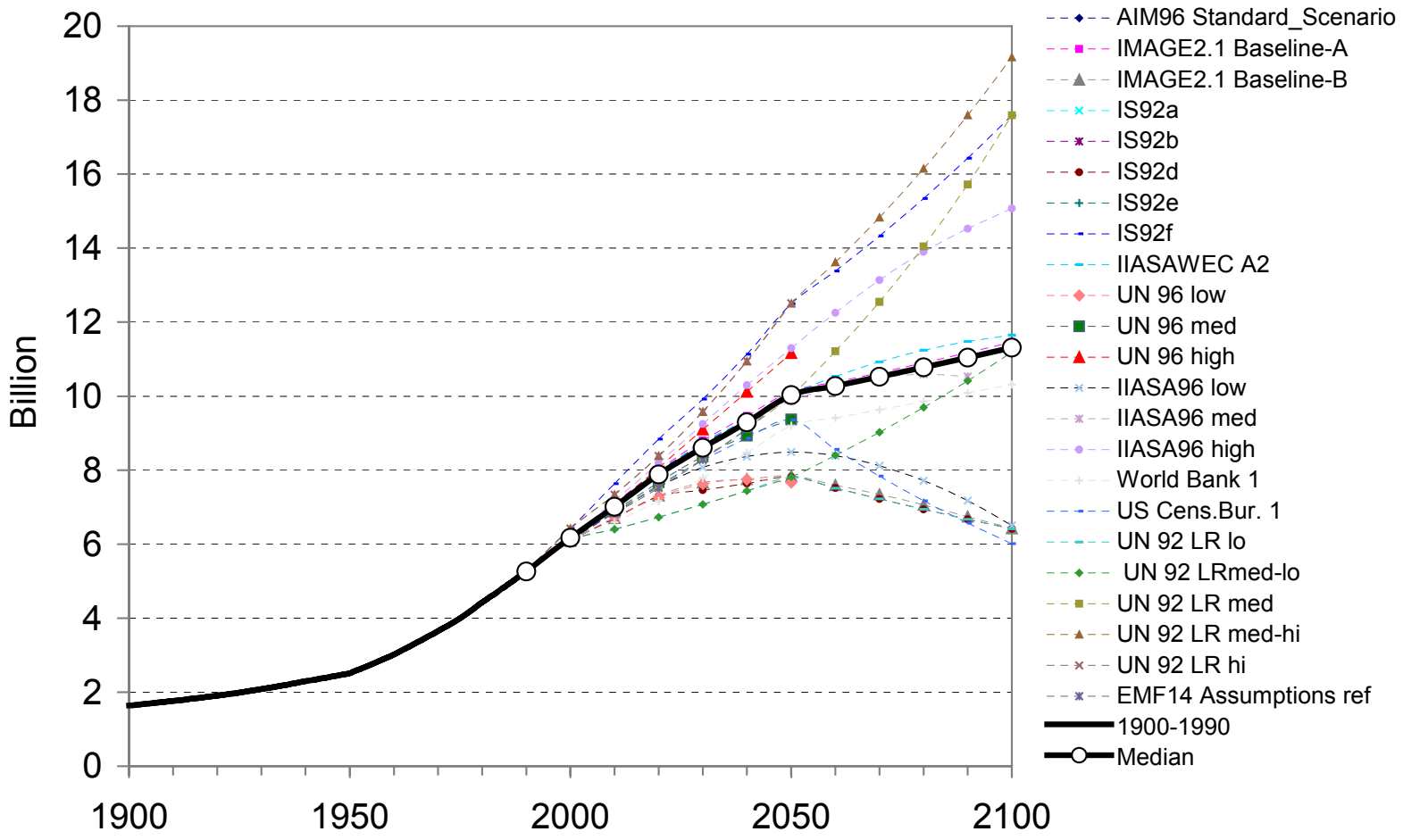
- The global energy situation and outlook: Nakicenovic IIASA
- Future energy demand in China: Huo, Zheng Zhou Univ.
- Future energy demand in India: Shukla, IIM Ahmedabad by Hamacher.
- Opportunities for nuclear (fission) power in a 'carbon-free' future: Clarke, PNNL-GTSP.
- Evolution of fission power in Korea: Shin KAERI, by Han.
- Investment issues during 2003 to 2030: Kato, IEA.
- The future availability of oil: Greene ORNL, by Sheffield..
- Fusion energy and ITER: Kallenbach (IPP), Spears (ITER).
- Energy and geopolitics in Asia in the 21st Century: Muller, SWP, Berlin.
- Proliferation: Can fusion energy be applied everywhere? Richter, Julich.

World Population and Energy Demand

- From1800 to 2000, population increased 6x, world income 70x, and energy use 35x.
- Over the next century the population will probably rise to around 11 billion people.
- An increase in per capita energy use will be needed to raise the standard of living in the developing and transitional countries.
- In the period 2003 to 2030, the IEA predicts that 70% of demand growth will be in non-OECD countries, 20% in China alone.
- New and carbon-free energy sources important to meet demand and lower emissions - there will be a large increase in electrical capacity.

Population Projections

Range Across Emissions Scenarios



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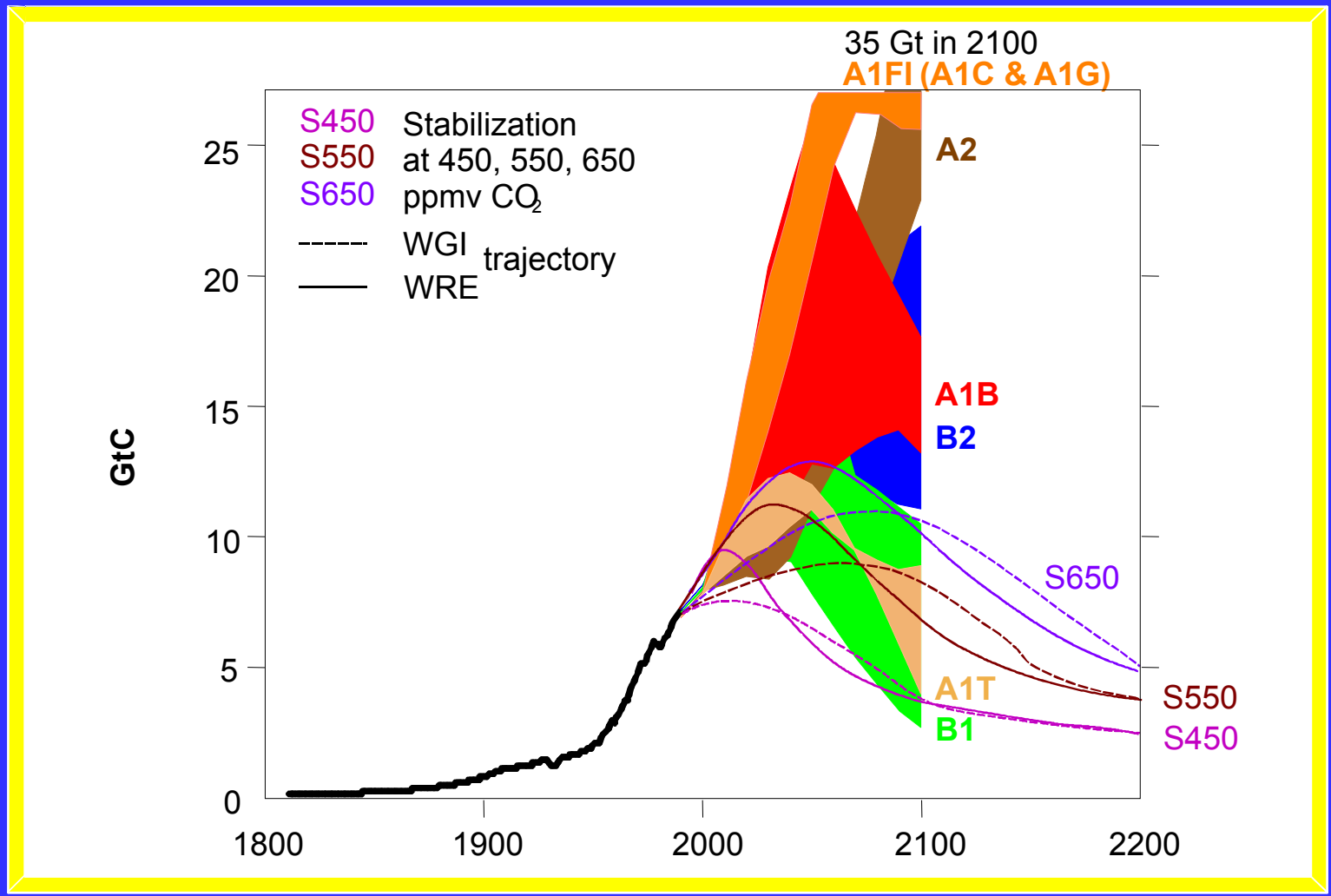
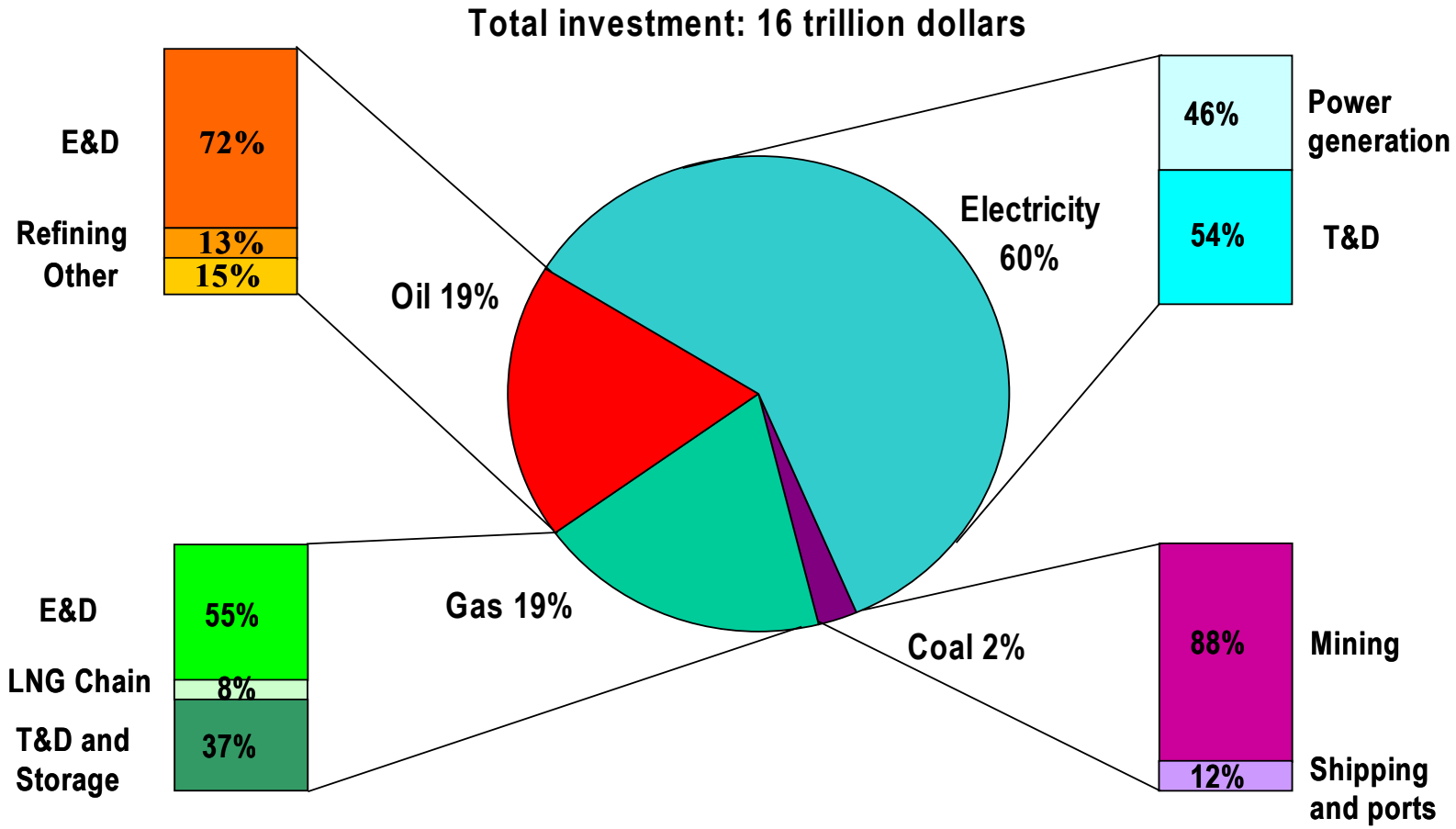
Carbon Emissions: Scenarios and Stabilization Profiles



World Energy Investment

2001-2030



Electricity investment will dominates. In each sub-sector, production accounts for the majority of investment – except for electricity

Global Hydrocarbon Reserves and Resources in GtC

	Consumption		Reserve	Resource	Resource Base	Addit'l Occur.
	1860-1998	1998				
Oil						
Convent'l	97	2.7	120	120	240	
Unconvent'l	6	0.2	120	320	440	1200
Gas						
Convent'l	36	1.2	90	170	260	12200
Unconvent'l	1	--	140	530	670	12200
Coal	155	2.4	530	4620	5150	3600
TOTAL	295	6.5	1000	5760	6760	17000

Source: Nakicenovic et al., 1996; Nakicenovic, Grubler and McDonald, 1998;
WEC 1998;
Masteres et al., 1994;Rogner et al., 2000

Renewable energy resource base in EJ (10^{18} J) per year (Nakicenovic [1])

Resource	Current Use in 2000 (a)	Technical Potential	Theoretical Potential
Hydropower	9	50	
Biomass energy	50	>276	2
Solar energy	0.1	>1,575	3,900
Wind energy	0.12	640	6
Geothermal energy	0.6	[5,000] (b)	[140,000] (b)
Ocean energy	n.e.	n.e.	7
Total	**56 (c)**	**>2,600**	>3,900,0

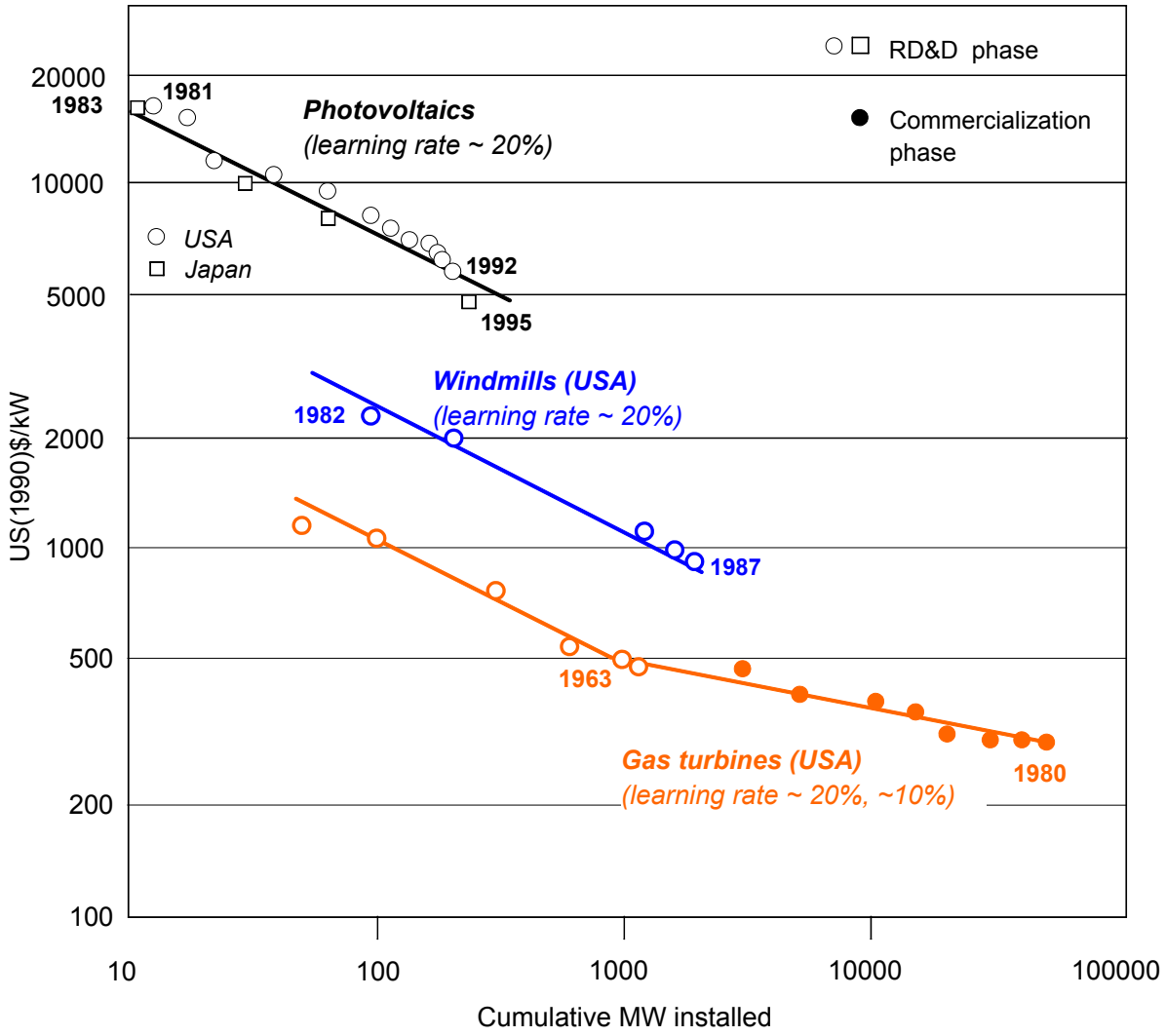
n.e. not estimated

a. The electricity part of the current use is converted to primary energy with an average factor of 0.385

b. These numbers are stored energy in EJ. The EJ/y will be much smaller than the fraction of solar energy

c. Current world annual energy use is about 400 EJ/yr.

Learning Curves



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Energy Efficiency

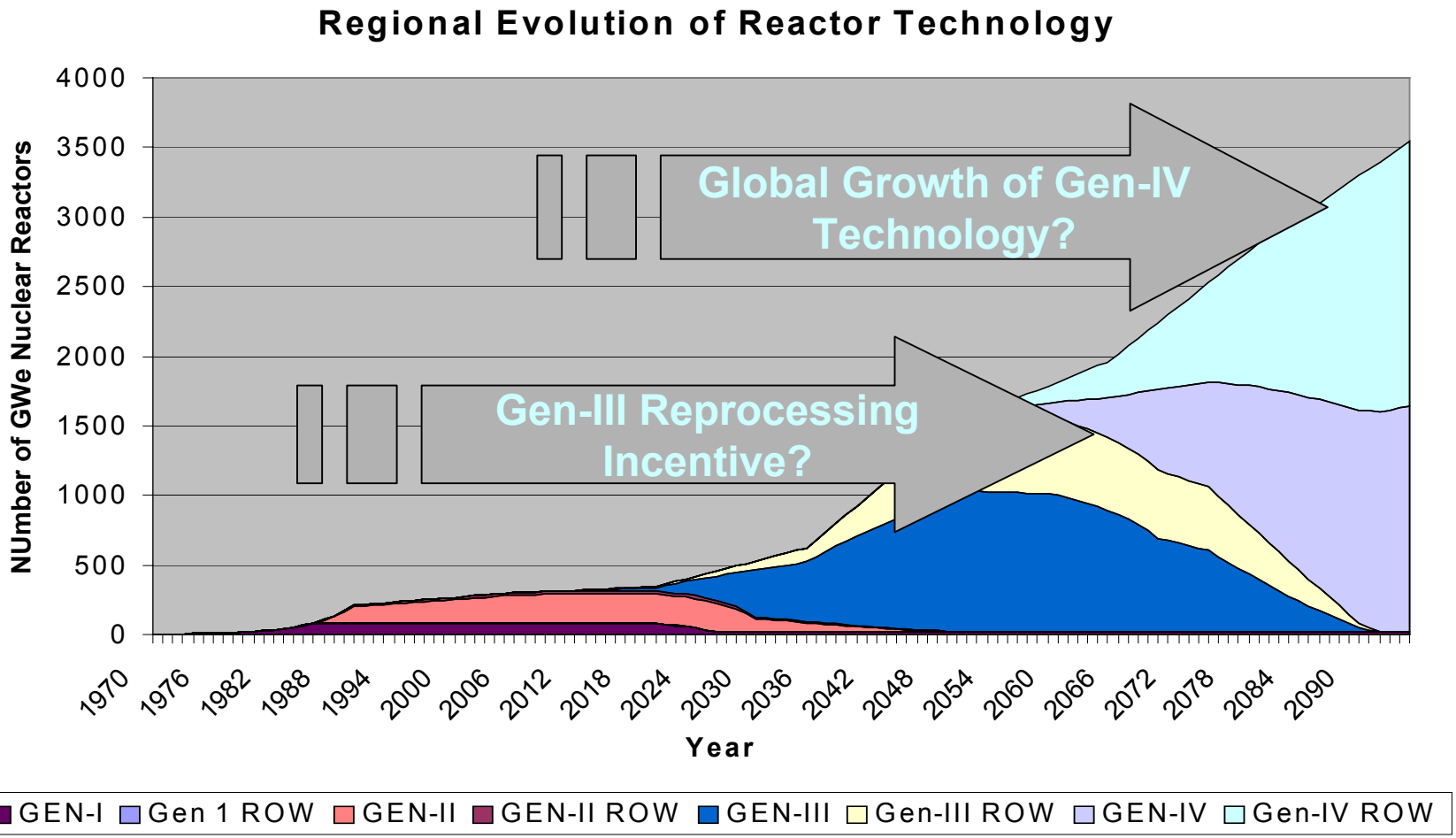
- It is commonly assumed, consistent with past experience and including estimates of potential improvements, that energy intensity (E/GDP) will decline at around 1% per year over the next century.
- As an example of past achievements, the annual energy use for a 20 cu.ft. refrigerator was 1800 kWh/y in 1975 and the latest standard is 470 kWh/y in 2001. It uses CFC-free insulation and refrigerant.

Fission Energy

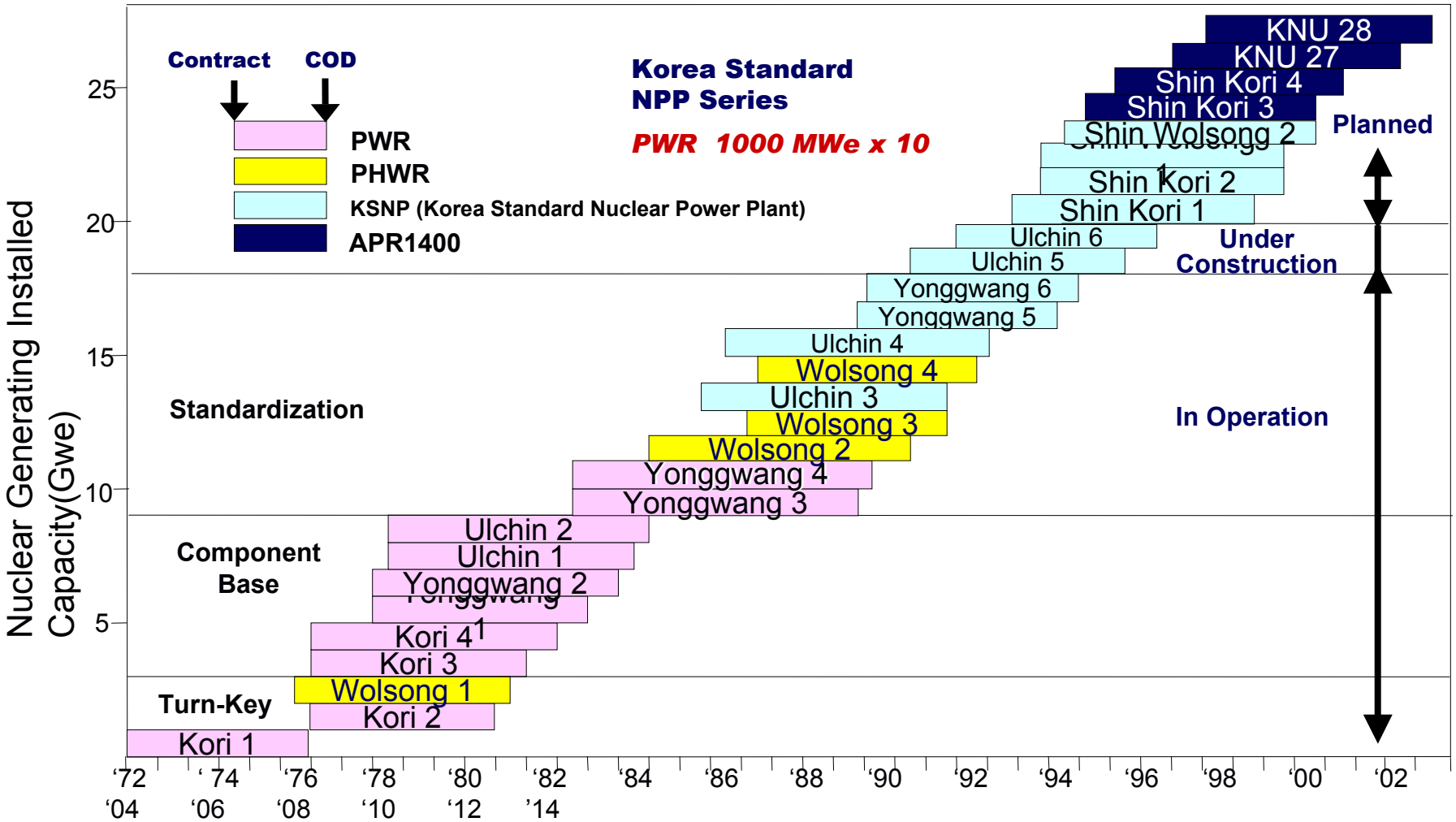
- Studies by the Global Energy Technology Strategy Project (GSTP) found that stabilizing CO_2 will require revolutionary technology in all areas e.g., advanced reactor systems and fuel cycles.

- A globally integrated system, encompassing the complete fuel cycle, waste management, and fissile fuel breeding is necessary for fission to make a major contribution.

An International Nuclear Regime May Also Be Essential To Assure Sustainable Nuclear Power After 2050!



Status of Nuclear Power Plant Construction



So, what is the problem?

- There are enormous untapped energy resources - fossil, nuclear, and renewables - but they are not uniformly distributed!
- All energy use causes pollution.
- Nuclear proliferation is a concern.
- Financing is an issue.
- These raise substantial geopolitical concerns.

- Worldwide collaboration is a key to success.

China and India: Growth to 2050 and 2100

	CHINA	INDIA
	by 2050	by 2100
Population billions	1.6 - 2.0	1.65
Per capita energy (STCE)	2 - 3	2.3
Annual energy (billion STCE)	4 - 5	3.8
Electricity GWe	300 - 900 - 1300	100 - 900
year	(2004) (2050) (2100)	(2004) (2100)

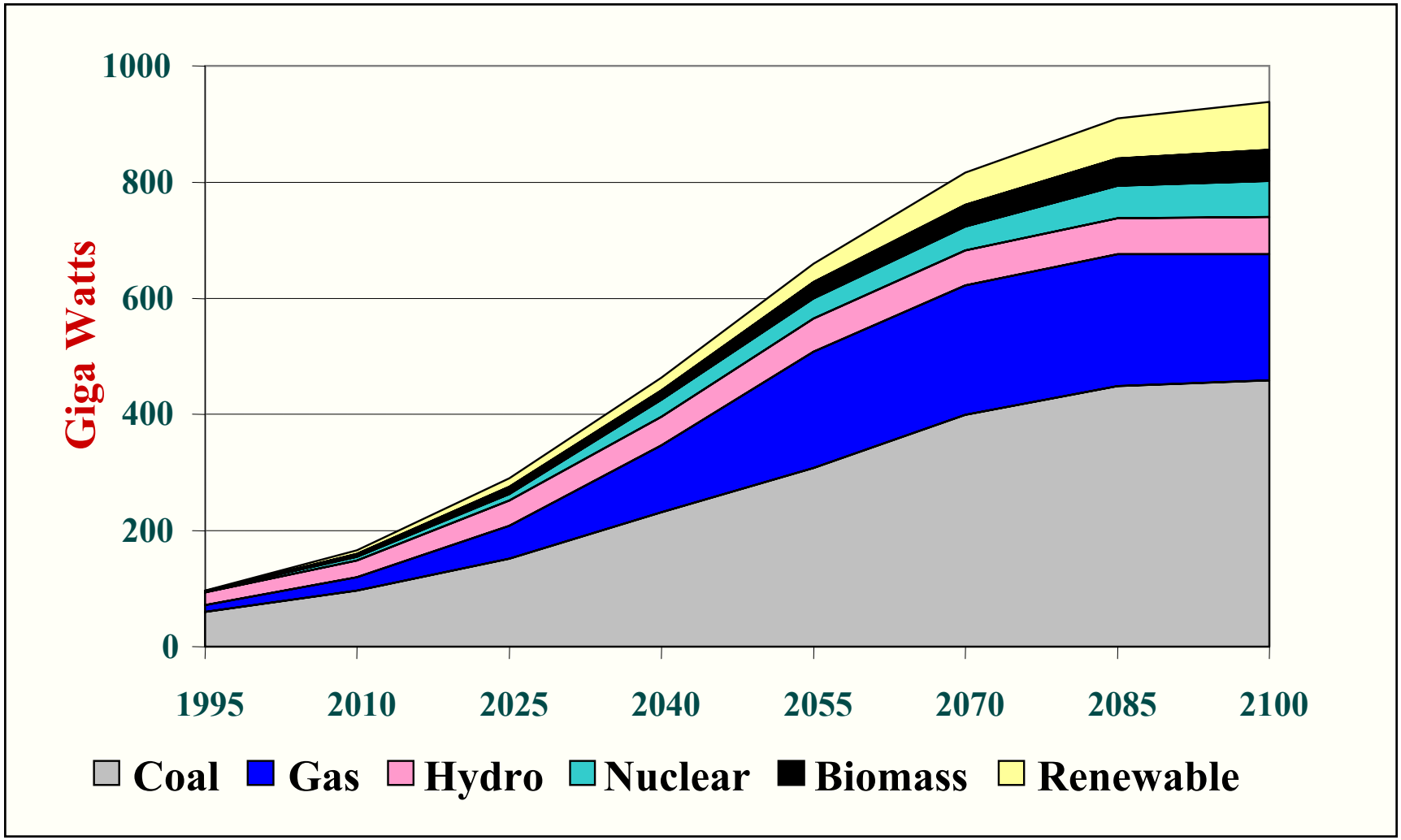
Potential Energy Supply in China

- In the absence of massive other sources, much of this energy will come from coal - up to 3 billion STCE/a.
- China will need to deploy Gen-IV power plants in an integrated nuclear system. Deployment of 100's GW_e will require capability to build in-house - see Korean example.
- Fission development, like fusion (ITER), will require world collaborative effort so that China can build sustainable systems - low emission scenarios essential.
- A broad portfolio of non-fossil energy sources is being considered to meet the needs. **In this regard, fusion energy is viewed as having a role to play in the latter half of this century**.

Potential Energy Supply in India

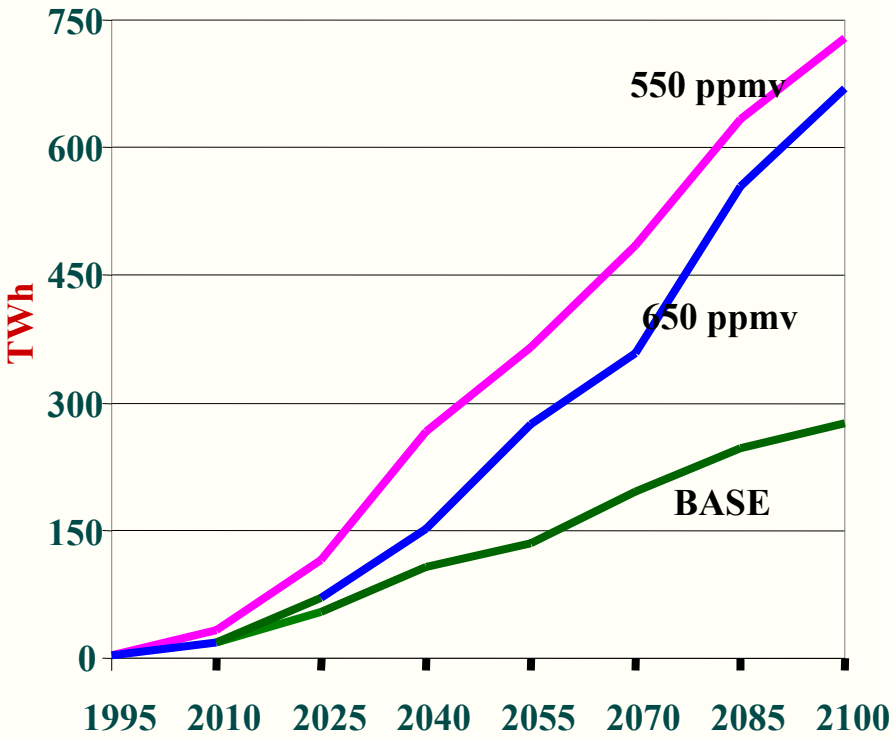
- In the absence of massive other sources, much of this energy will come from coal - including imports.
- Thorium-based nuclear plants are being developed.
- Apparently India has expressed an interest in joining ITER.
- A broad portfolio of non-fossil energy sources is being considered to meet the needs. **Scenarios including fusion energy have been developed.**

Electricity Generation Capacity

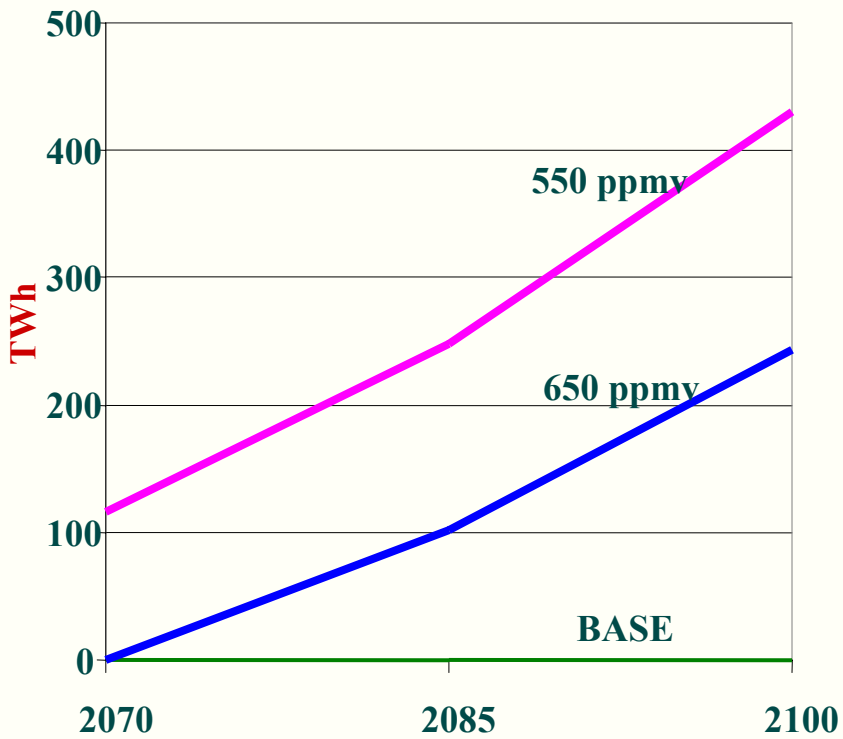


Stabilization: Impact on Electricity Sector

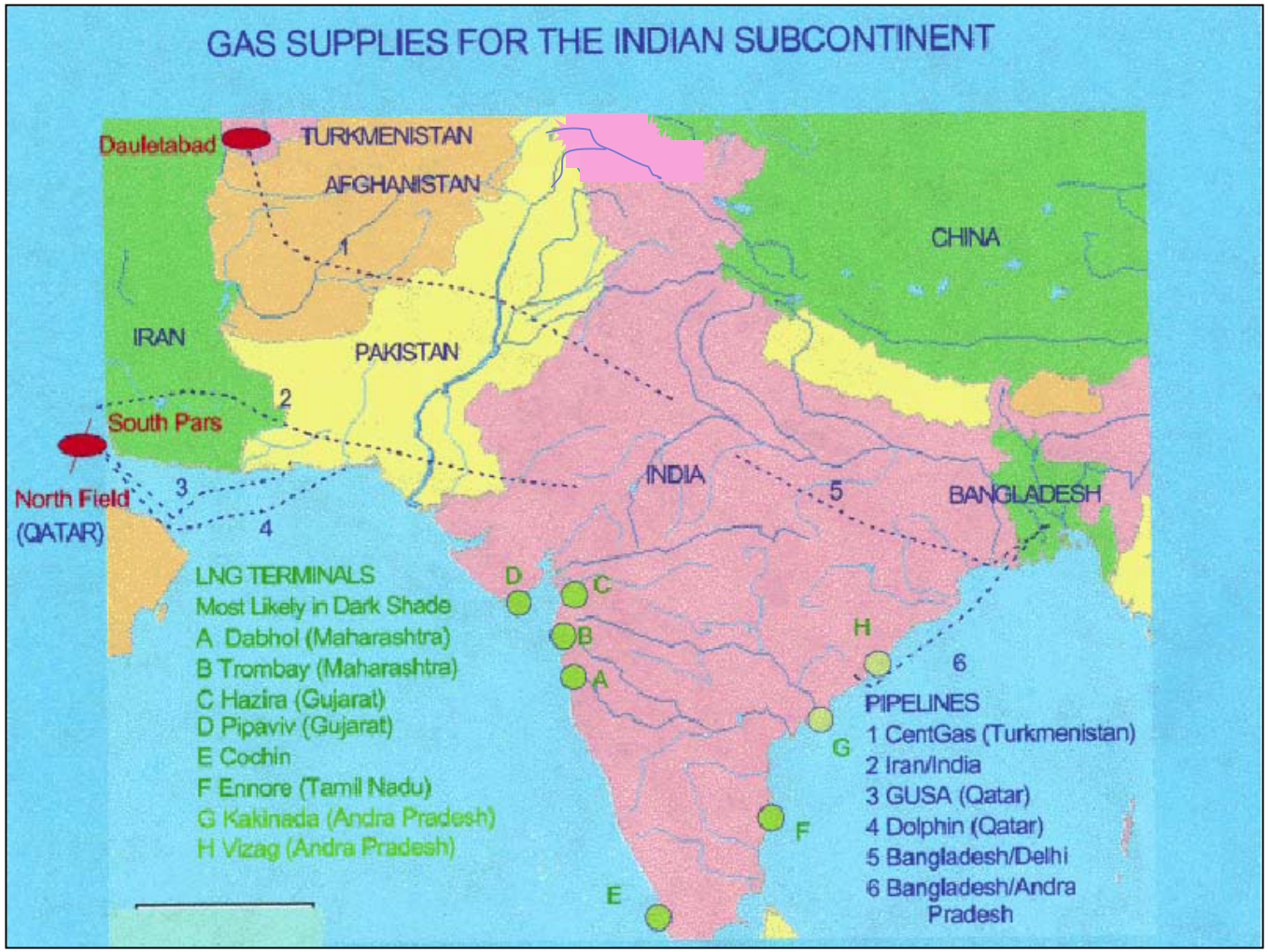
Renewable Technologies



Nuclear Fusion



South-Asia Regional Energy Market Development



Conclusions

- Energy demand due to population increase, and the need to raise standards of living in developing and transitional countries, will require new energy technologies on a massive scale.
- Climate change considerations make this need more acute.
- The extensive deployment across the world will require global development in all cases. ITER is an interesting model for how to do this.
- All energy sources will be required to meet the varying needs and resources of each country and to enhance their security against energy crises. Non-GHG-emitting sources will be particularly important.
- New plants will be required both to meet the increased demand and to replace outdated equipment.
- In this situation, fusion energy is regarded as an interesting potential option for the latter part of this century in many countries, including China, India and Korea.

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Units

	KJ	kWh	kgoe	kgCe	m^3 NG
KJ	1	$2.78x10^{-4}$	$0.24x10^{-4}$	$0.34x10^{-4}$	$0.32x10^{-4}$
KWh	3600	1	0.086	0.123	0.113
Kgoe	41,868	11.63	1	1,428	1.319
Kgce	29,308	8.14	0.7	1	0.923
m^3 NG	31,736	8.816	0.758	1.083	1

1 barrel (bbl) = 159 l oil

7.3 bbl = 1 t oil