Science and Technology in India: A focus on energy innovation

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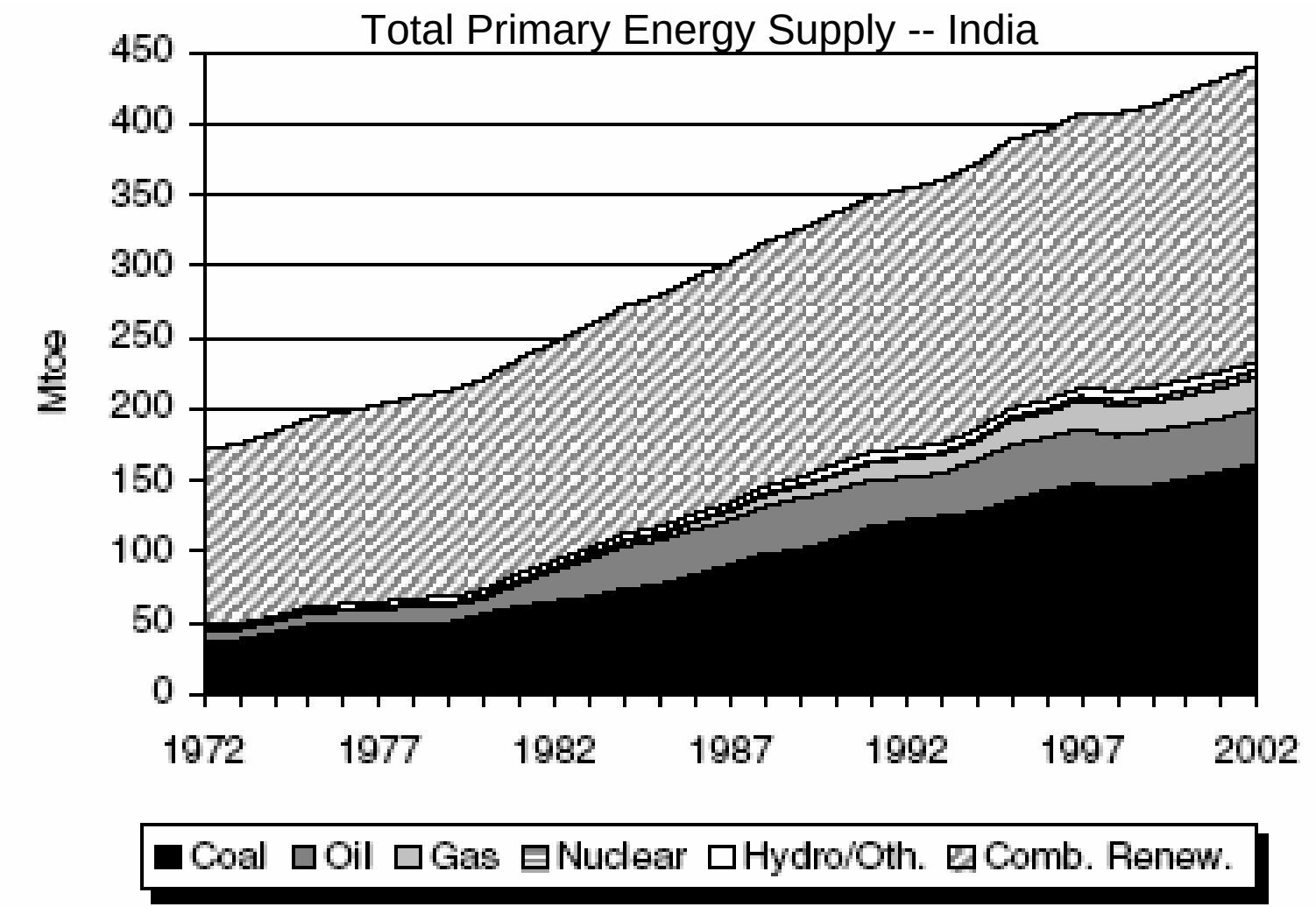
Outline

1. Indian Energy Sector Overview
2. Science and Technology (S&T) in India
3. Energy R&D/Innovation
4. Towards better a energy innovation system in India

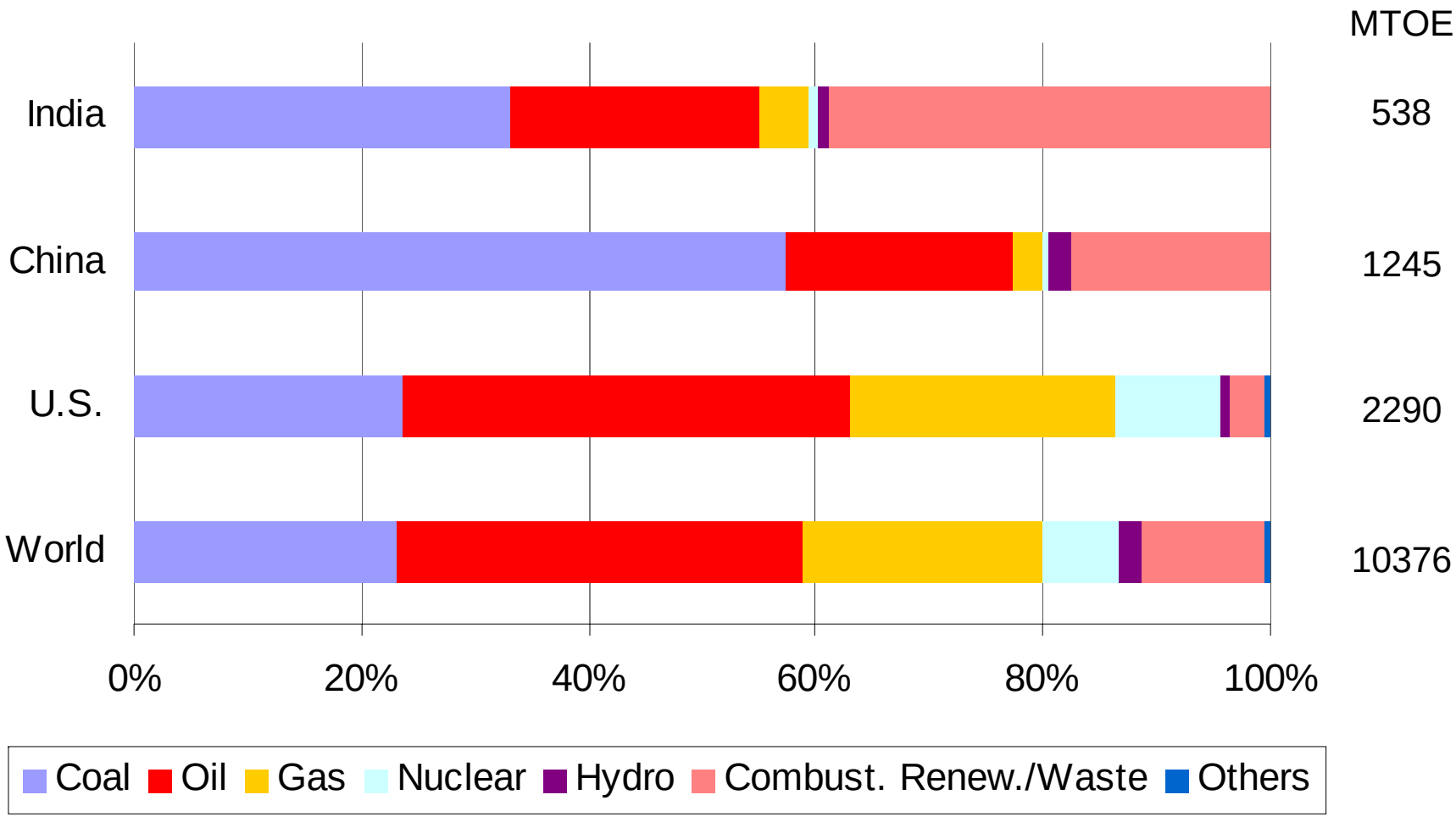
1.0 Energy Supply Trends



About 40% of TPES is from biomass, dung, and waste
Dominant energy source for rural and low-income population

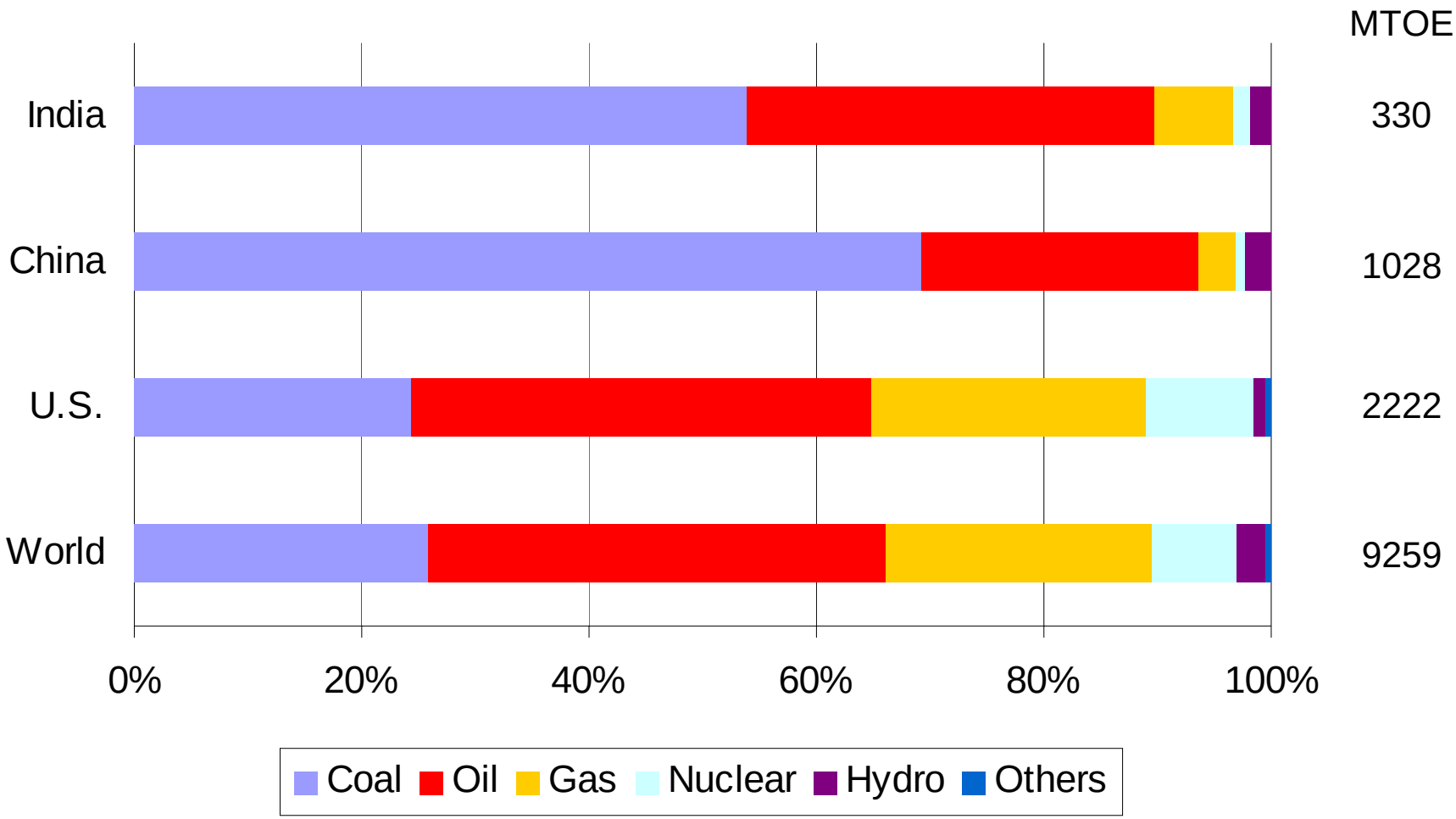
IEA 2005

1.1 TPES Comparison (2002)



IEA 2005

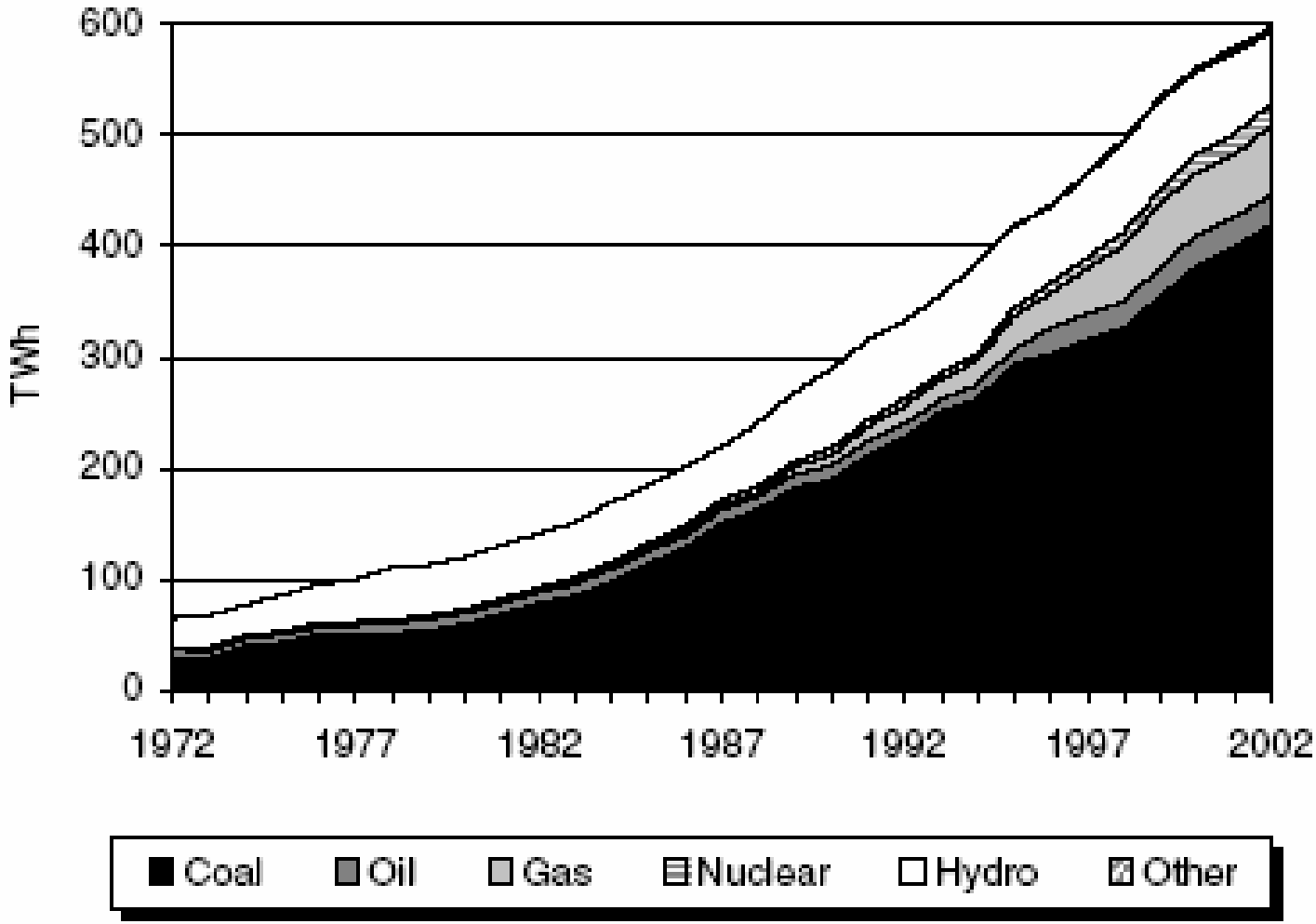
1.2 TPCES Comparison (2002)



Coal dominates the commercial energy sector in India (similar to China)

IEA 2005

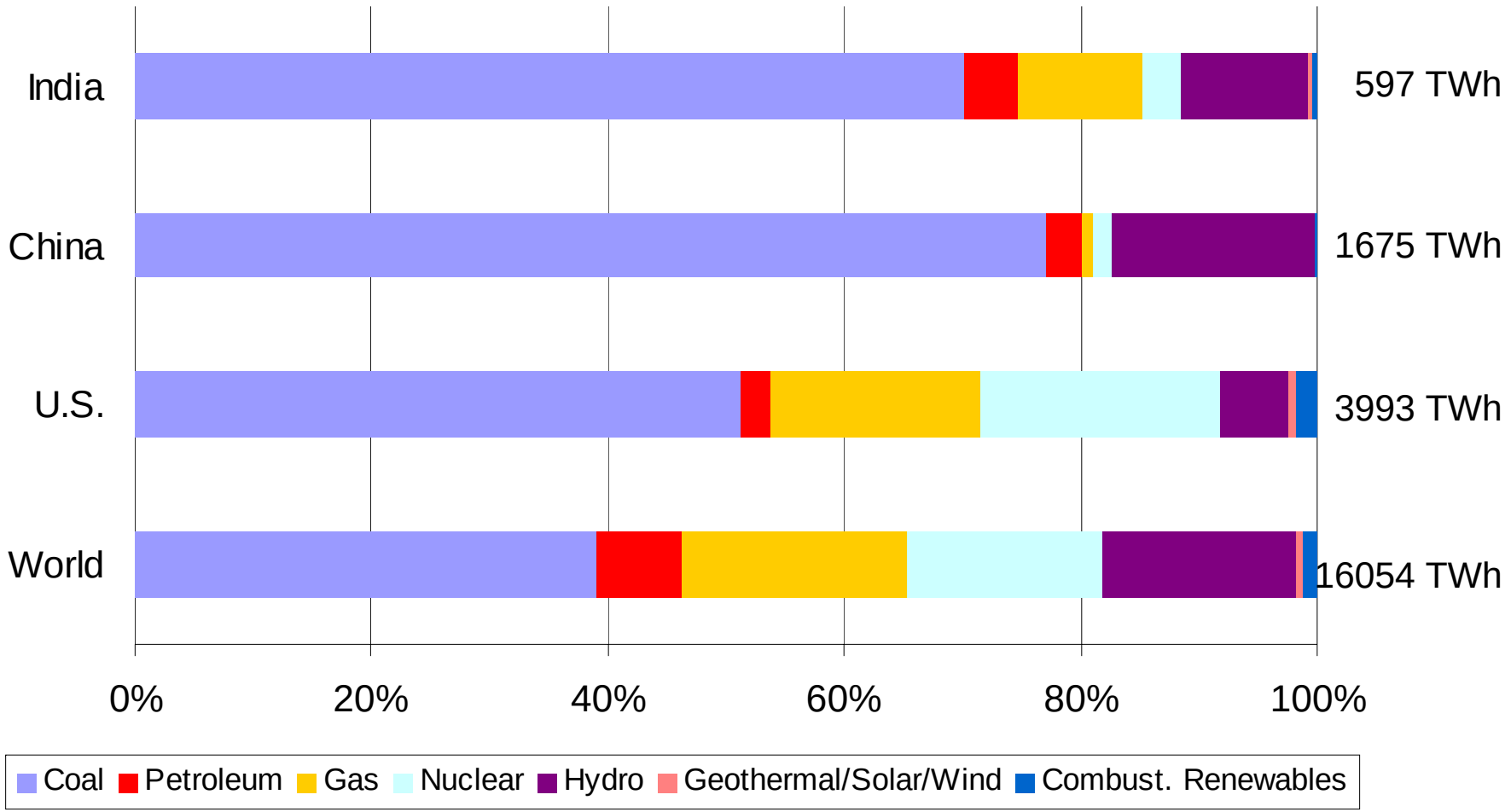
1.3 Electricity Production



Electricity is often equated with energy
Coal dominates electricity sector

IEA 2005

1.4 Electricity Comparisons (2002)



IEA 2005

1.5 Government Dominance

- Government dominates the overall energy sector
  - Key source for investment in the energy sector
  - Owns key corporations in production and conversion of energy
    - *Coal:* Coal India Limited, Neyveli Lignite Corporation
    - *Oil and Gas*: Oil and Natural Gas Corporation, Indian Oil Corporation, Gas Authority of India
    - *Electricity*: NTPC, BHEL, Power Grid Corporation, State-owned utilities
    - *Atomic Energy*: Department of Atomic Energy, Nuclear Power Corporation, Uranium Corporation
- Private Sector dominant only in transport, cement, and renewable energy, and end-use manufacturing sector

1.6 Key Future Energy Challenges

- Increase infrastructure and economic growth
  - Developing Countries: need to increase standards of living
- Energy security and access to energy resources
  - Oil security/Peak Oil
  - Cooking fuels, Electricity
  - Affordability
- Basic amenities and energy services to all citizens
  - Rural energy needs
  - Poverty reduction
- Local environmental protection (pollution control)
- Global Climate Change

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- Bas
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  - Poverty reduction
- Local environmental protection (pollution control)
- Global Climate Change

Science and Technology is a crucial element for meeting these challenges

2.0 S&T actors in India

- S&T – part of Indian culture, but government involved only after independence
- S&T viewed as crucial for India's development & industrialization
- Several departments and institutions were created to promote S&T
- 1942 – Council of Scientific and Industrial Research was created

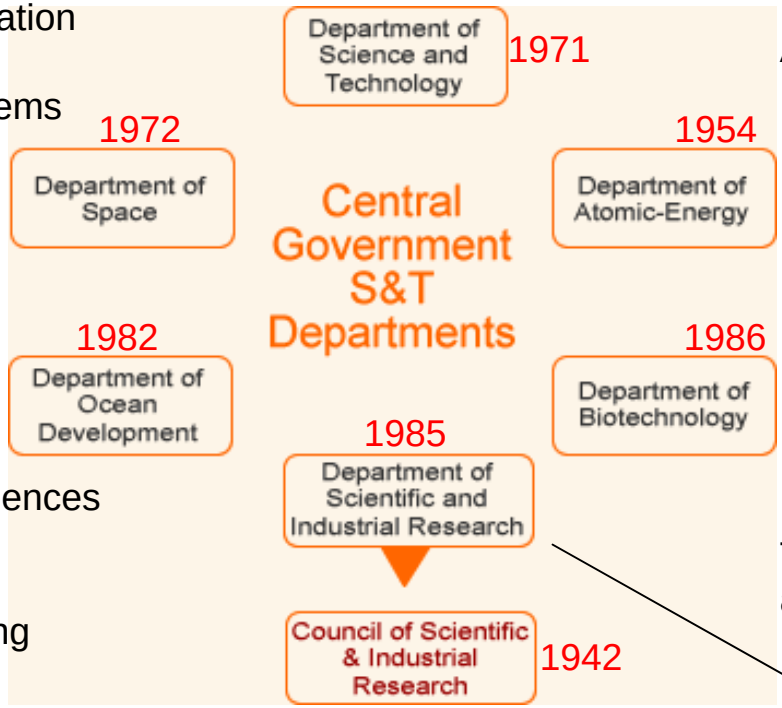
2.1 S&T Policies

- Defense, atomic energy and space given utmost priority
- 1958 Scientific Policy Resolution
  - Mobilization of S&T personnel for industrialization
  - Scientists given a “honored” status
- 1983 Technology Policy Statement
  - Attain technological self reliance
  - Make maximum use of indigenous resources
  - Develop competitive technologies to reduce energy demand
  - Education policies reoriented to increase academic research
- 2003 Science and Technology Policy
  - Use of S&T for poverty alleviation and increase in employment
  - Creation of national system of innovation (focus on BT and ICT)
  - Increase interactions between public and private sector R&D institutions
- Scientific Advisory Committee to Prime Minister and Cabinet
  - Creation and implementation of national S&T policies and plans

2.2 Key S&T Departments in India

Policy formulation
Coordination of R&D activities
Promotion of R&D in specific S&T areas
Technology information and assessment
International collaboration

Indian Space Research Organization
Execute Indian space program
Develop satellites & launch systems
Space-based research



Atomic Energy Commission (1958)
Production of nuclear power
Multi-disciplinary R&D Centers
Building research reactors
Basic nuclear energy research

Merged with Ministry of Earth Sciences
Policies for marine R&D
Survey of resources
Exploration of deep seabed mining

R&D in biotechnology
Biotechnology-related products
Training of young scientists
at various universities

38 R&D Laboratories/institutes
~50 Extension centers
14,000 S&T staff
Link between academia and industry

Promote R&D by industry (SME)
Focus on indigenous technologies
Technology transfer
National Information System for S&T

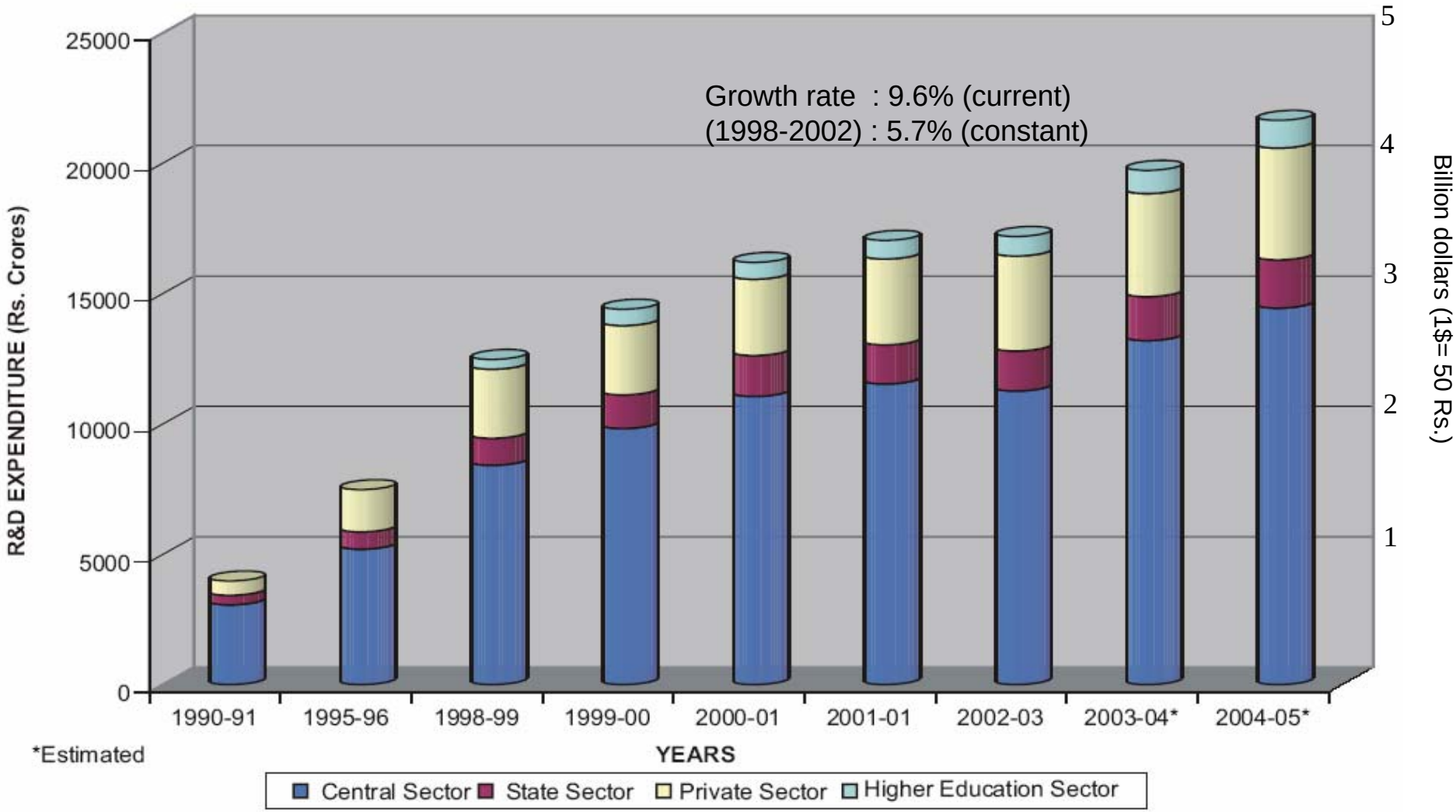
2.3 Number of institutions

Central Government: R&D Institutions/laboratories	545
State Government: R&D Institutions/Joint Sector Companies/ Research Stations	777
Universities (including 39 Deemed Universities; 11 Institutions of national importance)	226
In-house R&D units of Private Sector and Non-Profit Research Institutions	1351
Total	**2899**

SCIENTIFIC AGENCY	# INST
Indian Council for Agriculture Research (ICAR)	84
Defence Research & Development Organisation (DRDO)	53
Council for Scientific & Industrial Research (CSIR)	38
Indian Council for Medical Research (ICMR)	27
Department of Science & Technology (DST)	17
Department of Atomic Energy (DAE)	14
Department of Electronics (DOE)	14
Department of Space (DOS)	8
Department of Biotechnology (DBT)	5

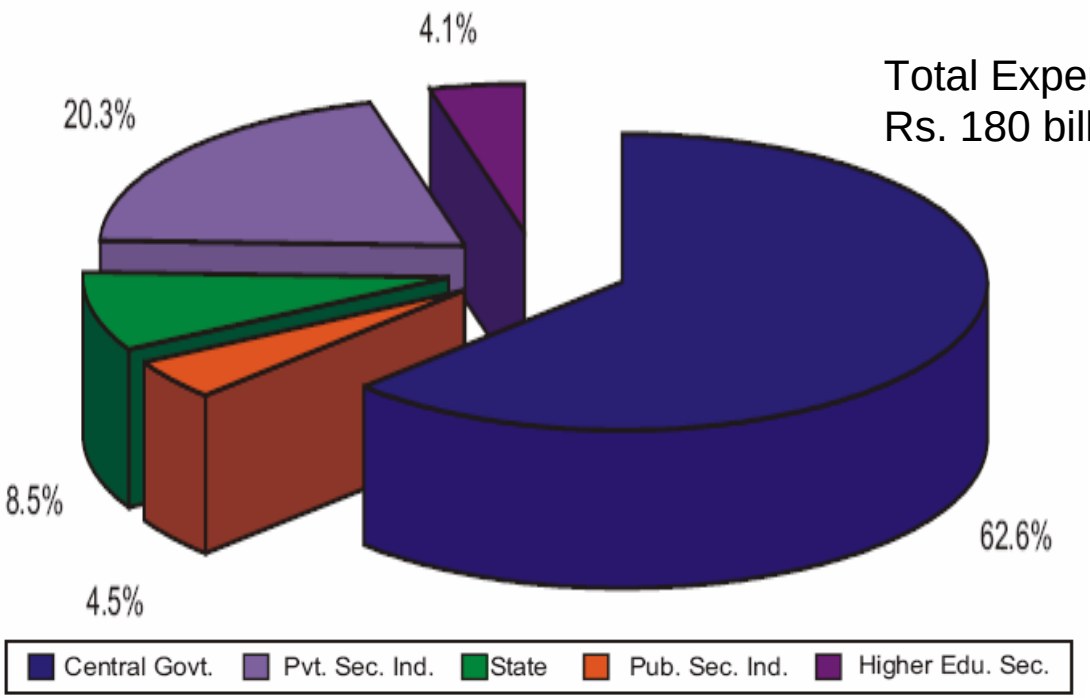
Source: S&T Data Book 2000

2.4 National R&D Expenditure



Source: DST, *R&D Statistics 2004-05*

2.5 Sectoral Distribution (2002-03)

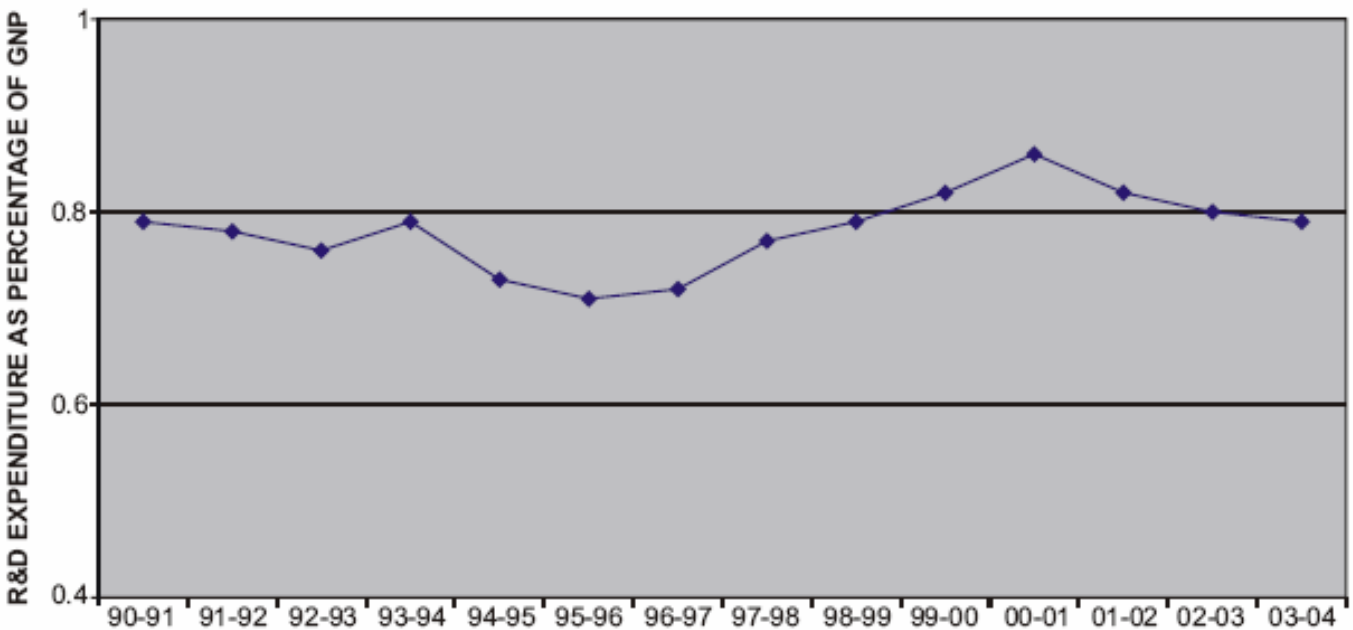


Total Expenditure
Rs. 180 billion ($3.7 billion)

Type	Percentage
Applied Research	41.7
Experimental Development	34.0
Basic Research	17.8
Other Activities	6.5

Source: DST, *R&D Statistics 2004-05*

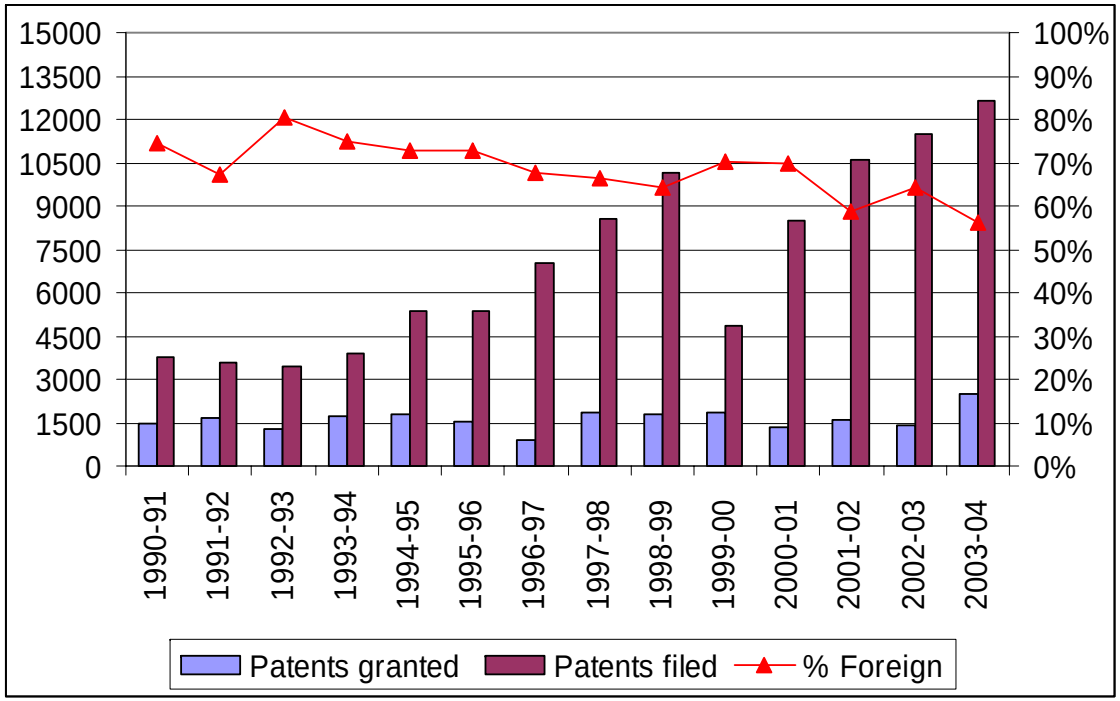
2.6 R&D relative to GDP



2002 Data		India	China	U.S.	Japan	U.K.
R&D	(% of GDP)	0.80	1.22	2.65	3.12	1.90
GDP per Capita	(2000 PPP$)	2500	4589	34669	26106	27897
Energy/GDP	(goe/2000 PPP$)	200	207	230	158	142
Energy use per capita	(kgoe)	509	947	7936	4093	3853

Source: DST, *R&D Statistics 2004-05*
: World Development Indicators

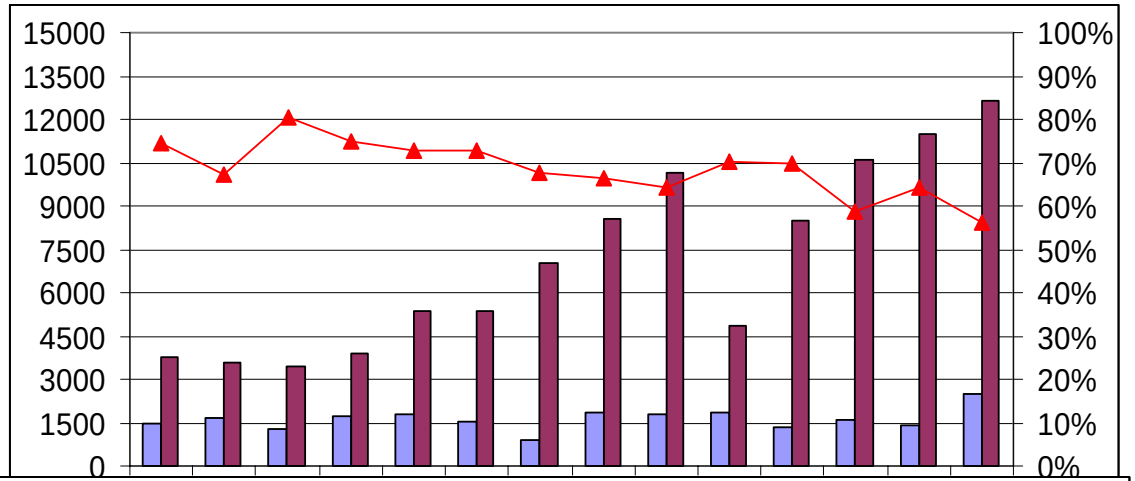
2.7 Output -- Patents



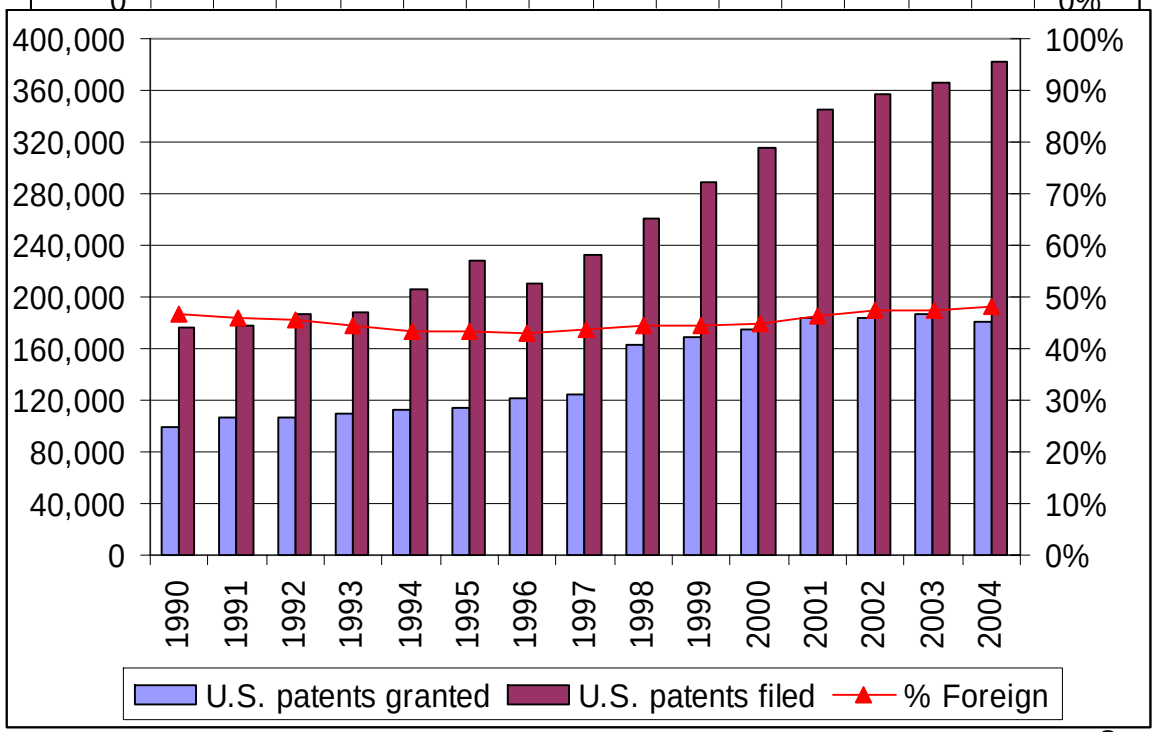
Patents in India

Source: DST, *R&D Statistics 2004-05*

2.7 Output -- Patents



Patents in India



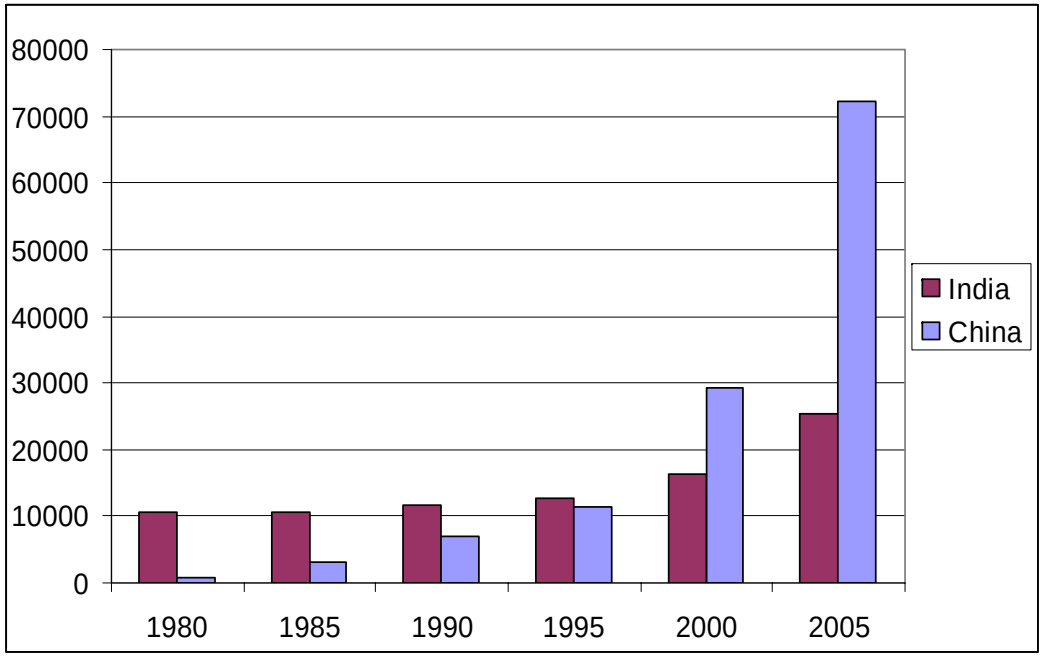
U.S. Patents

Source: DST, *R&D Statistics 2004-05*

2.8 Bibliometrics

Articles in Science Citation Index with at least one author with Indian/Chinese address

2005
Brazil: 17086
South Korea: 27397



Top 5 Institutions

INSTITUTION	PAPERS
Indian Inst Tech.	1752
Indian Inst. Sci.	669
Bhabha Atom. Res. Ctr.	365
Univ. Delhi	308
Tata Inst. Fund. Res.	298

Median Impact factor
U.S : 4.7
China : 0.6
India : 0.4

	JACS		Phys. Rev. Lett		J. Bio. Chem.	
YEAR	INDIA	CHINA	INDIA	CHINA	INDIA	CHINA
1995	**5**	2	**34**	14	**9**	2
1996	**17**	5	**49**	33	**13**	2
1997	**17**	11	**52**	31	**17**	7
1998	**23**	12	**66**	56	**10**	7
1999	**11**	13	**51**	39	**23**	16
2000	**19**	35	**54**	70	**17**	25
2001	**15**	49	**59**	85	**42**	46
2002	**14**	45	**49**	82	**31**	56
2003	**19**	89	**55**	134	**60**	83
2004	**15**	99	**50**	151	**54**	110
2005	**27**	142	**52**	158	**44**	124

Highest ranking journals
India:
chemistry, veterinary, agriculture, physics

China:
Physics, materials, chemistry

Source: Kostoff et al. 2006

3.0 R&D Expenditure by Objective

OBJECTIVE	Total	Central Government	State Government	Public Sector	Private Sector
Total	Rs. 180 billion	66.7%	8.5%	4.5%	20.3%
Defence	18.3%	93.2%	0.0%	6.0%	0.8%
Development of Agriculture,Forestry and Fishing	17.7%	46.7%	44.6%	0.9%	7.8%
Promotion of Industrial Development	12.1%	34.5%	0.7%	13.5%	51.3%
Space	12.1%	99.7%	0.0%	0.0%	0.3%
General Advancement of Knowledge	11.6%	96.2%	0.1%	1.4%	2.2%
Development of Health Services	8.6%	28.1%	2.1%	0.7%	69.1%
Production, Conservation, and Distribution of Energy	6.0%	85.0%	0.9%	2.7%	11.3%
Development of Transport and Communication	5.3%	19.1%	0.5%	8.5%	71.9%
Other aims	3.1%	57.7%	4.6%	0.7%	37.1%
Exploration and Assesment of Earths,Seas,Atmosphere	2.2%	68.6%	1.2%	29.9%	0.3%
Environment	1.8%	95.9%	0.5%	0.5%	3.2%
Social Development and other Socio-Economic Services	0.8%	34.1%	6.6%	0.2%	59.1%
Urban and Rural Planning	0.3%	33.9%	0.0%	25.1%	41.1%

Source: DST, *R&D Statistics 2004-05*

3.1 Share of Energy in National Plans

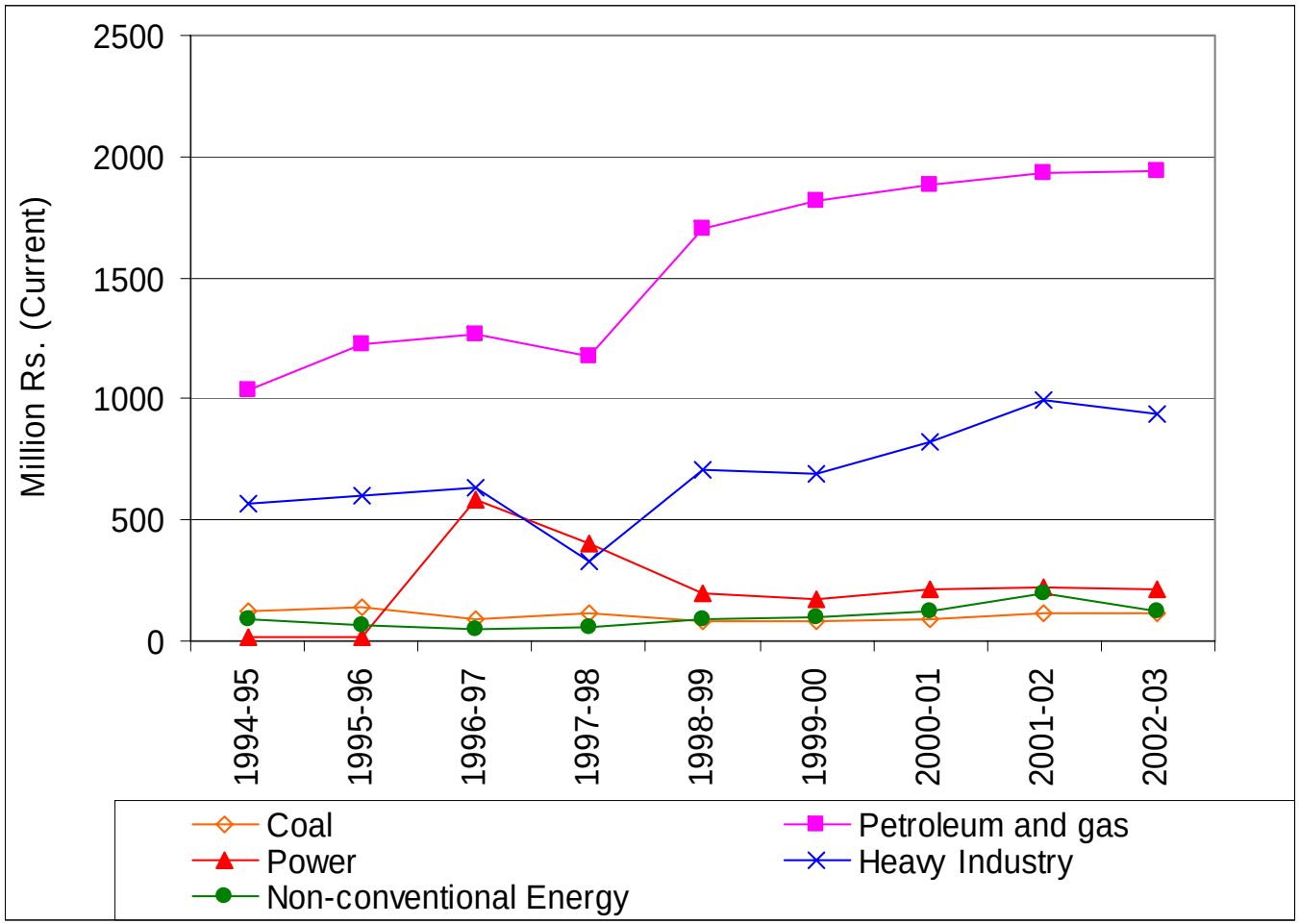
Plan and period	Plan Expenditure† (billion rupees)	Share of energy sector (%)				
		Power	Oil/Gas	Coal	NRSE§	Total
1st (1951-56)	19.6	---	---	---	---	19.7
2nd (1956-61)	46.7	9.7	0.8	1.9	---	12.4
3rd (1961-66)	85.8	14.6	2.6	1.3	---	18.5
4th (1969-74)	157.8	18.6	1.9	0.7	---	21.2
5th (1974-79)	394.3	18.7	3.6	2.9	---	25.2
6th (1980-85)	1092.9	16.7	7.8	3.5	0.1	28.1
7th (1985-90)	2202.2	17.4	7.3	3.2	0.3	28.2
8th (1992-97)	4854.6	15.8	8.3	2.3	0.2	26.6
9th (1997-2002)	8592.0*	14.5	8.6	2.3	0.4	25.8

§ New and renewable sources of energy
† Expenditure at current price at base year of the respective Plans.
* Plan outlay
Source: Planning Commission 1997, 2001a.

Source: Sagar 2002

- Energy sector occupies a significant fraction (~25%) of national investment
- However, energy does not play a significant role in R&D expenditure (6%)

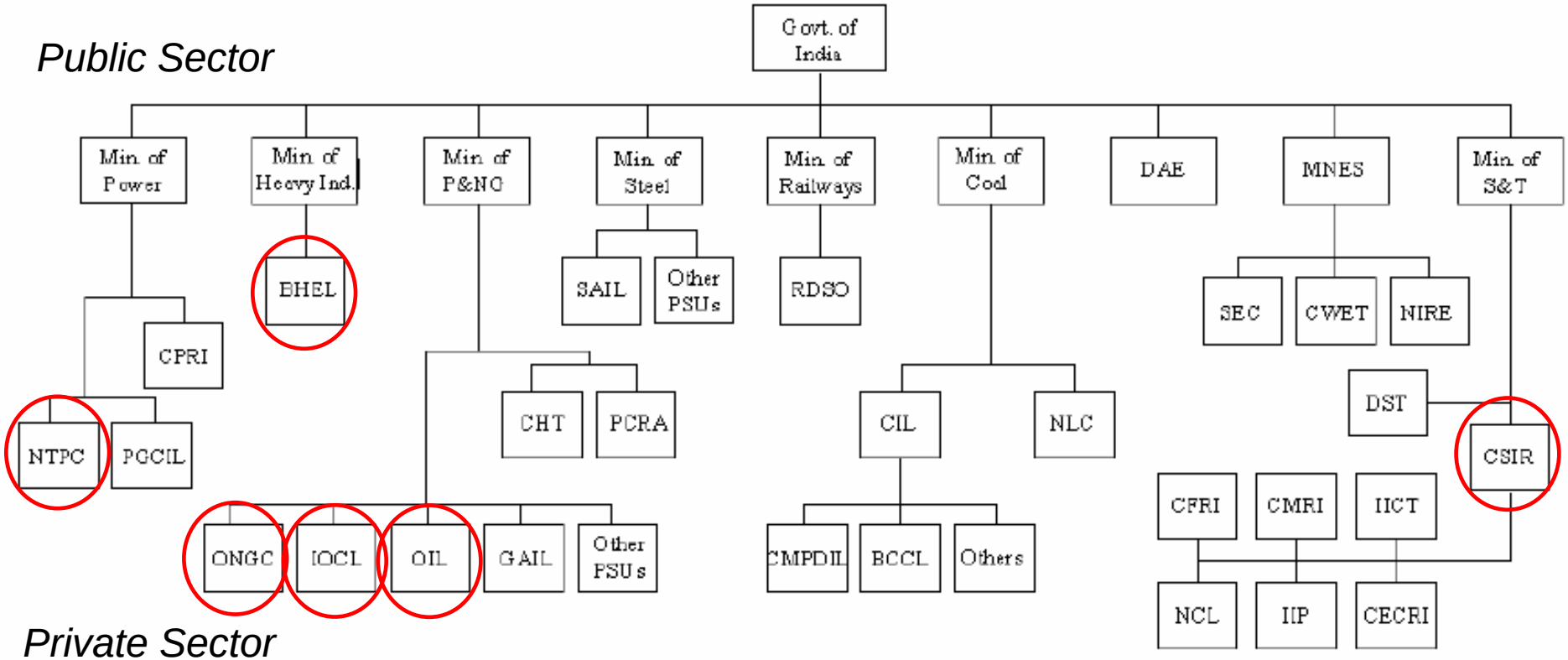
3.1 Expenditure by Energy Ministries



- Significant R&D in electrical manufacturing and oil/gas sectors
- Low expenditure levels on R&D in the power and coal sectors
- Mismatch between R&D spending and TPES

3.2 Key ER&D organizations

Public Sector



Private Sector

Power

- Alstom
- Siemens
- Cummins
- Thermax

Oil and Gas

- Reliance

Transport

- Tata Engineering
- Bajaj Auto
- Mahindra and Mahindra
- Automotive Research Association

Renewable

- Indian Institute of Science
- TERI

Source: Sagar 2002

3.3 R&D funding of selected orgs.

	R&D spending† (million Rupees)	R&D Intensity (% of sales)	R&D spending trend§
COAL			
CMPDIL	23[a]	2.50	
BCCL	10[a]	0.06	
Neyveli Lignite	36[a]	0.27	
PETROLEUM AND NATURAL GAS			
ONGC	577[b]	0.39	+
Indian Oil	780[c]	0.07	+
Oil India	110[a]	1.14	
GAIL	21[c]	0.03	=
Reliance Petroleum	451[d]	0.50	
Major Multinationals		0.3-0.6[e]	
POWER			
NTPC	45[a]	0.05	
BHEL	808[d]	1.30	+
ABB	51[e]	0.63	-
Cummins	100[c]	1.15	=
Thermax	35[d]	0.80	=
Major Multinationals		~ 3[e]	
Dept. of Atomic Energy	5300[a]		
Min. of Non-conventional Energy Sources	46[a]		
ROAD TRANSPORT			
Ashok Leyland	231[d]	0.89	+
Bajaj	610[d]	2.20	+
Mahindra & Mahindra	882[d]	2.00	+
Maruti Udyog	51[a]	0.12	
TELCO	905[d]	1.10	-
Major Multinationals		3-4[e]	

† year of R&D expenditure
a – 1996-97, b – 1997-98
c – 1999-00, d – 2000-01
e – 2000

§ Trend of R&D growth
+ increasing
– decreasing
= little or no change

Source: Sagar 2002

3.4 Key characteristics of ER&D orgs.

- Coal power
  - Technologies have been licensed from outside
  - Main focus on manufacturers has been to adapt technologies to meet local conditions
  - R&D mainly focused on adaptation, rather than new technology development
  - Indigenous technologies often cannot compete with international technologies
- Oil and gas
  - Focus on exploration, drilling, production technology, development of lubricants, refining technologies, etc.
- Road Transport
  - Infrastructure (road) development is in public sector
  - Vehicle manufacturing dominated by private sector

3.5 Landscape of Indian ER&D

- Diverse, large number of organizations
- System of national laboratories
- Fragmented energy innovation system in India
- Low ER&D expenditure, dominated by few organizations
- Focus on technology acquisition through licensing and technology adaptation and upgradation
- Public sector enterprises dominate energy sector (incl. R&D)
- Little/no competition in many sectors (power, coal, oil and gas)
- Sectoral R&D investment patterns do not match with energy consumption patterns
- Weak linkage between industry, academia and national laboratories
- Strong government influence on academia and industry

4.0 Indian Energy Innovation System

Characteristics	Status in India
Science becoming a national institution (government support of science education)	Yes
Strong technical education and training	Yes
Strong links between scientists and entrepreneurs	Limited
Development of strong institutional linkages between R&D and industry actors	Limited
Presence of firm-level in-house professional R&D	Yes
Support for indigenously developed technologies	Support of domestic industries, not necessarily technologies
Support for continuous technology improvement by domestic actors	Limited
Profits fed back into investment (technologies, new factories, etc.)	Limited (PSU profits fed back into government; planned growth)
Competitive environment	Limited (Government-owned monopolies)
Opportunities for partnerships (inter-firm relationships, even across sectors)	Limited
Access to finances for capital-heavy investments	Yes
Appropriate economic policies for encouraging innovation	Limited
Development of support infrastructure	Yes

4.1 Approaches to better E-innovation planning

- Better matching of ERD^3 activities and funding to energy-use patterns
  - Enhance ERD^3 in coal and power sectors
  - Create and increase ERD^3 for biomass-based technologies
  - Policy focus on deployment of cleaner technologies
  - Focus on energy efficiency technologies/practices (particularly end-use)
- Ongoing critical assessments of new technologies and technology-acquisition/domestic-RD^3 strategies
  - Historical and institutional context
  - Context and impact of decisions taken in other sectors
- Inclusion of multiple stakeholders in technology decision-making (greater transparency)
- Critical role of public policy in shaping ERD^3 activities
  - Importance of domestic policy research
  - Improved data collection and data analysis

4.2 Need for better overall innovation planning

- Understanding that technology innovation is not just development of *hardware* (machines, products, etc.), but also enhancing of *software* (human resources, skills, practices, tacit knowledge, institutions)
- S&T development needs government support
  - Role for government to inject societal priorities
    - Energy security, environment protection, climate change, etc.
  - Make best use of limited S&T capabilities
- Need for more financial inputs for innovation
- Need to improve “balance of system”
  - Physical investment, human capital and technological capacity
  - Institutions
  - Encourage continuous learning-by-doing
- Provision of innovation spurring incentives
  - Linked to output; competitive bidding

Acknowledgement

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Assistant Dean (School of Engineering, Harvard U.)

Funding:

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