Governmental Energy Innovation Investments, Policies, and Institutions in the Major Emerging Economies: Brazil, Russia, India, Mexico, China, and South Africa

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Governmental Energy Innovation Investments, Policies and Institutions in the Major Emerging Economies: Brazil, Russia, India, Mexico, China, and South Africa

Abstract

Over the past decade, countries with emerging economies like Brazil, Russia, India, Mexico, China and South Africa (the BRIMCS countries) have become important global players in political and economic domains. In 2007, these six countries consumed and produced more than a third of the world's energy and emitted about 35% of total greenhouse gas (GHG) emissions. The changing global energy landscape has important implications for energy technology innovation (ETI) nationally and internationally. However, there is limited information available about the energy research, development, and demonstration (RD&D) investments and ETI initiatives that are taking place by the national governments within these countries.

This paper presents the information available on energy RD&D investments in these emerging economies between 2000 and 2008. The results show that, in 2008, governments and 100% government-owned state-owned enterprises (SOEs) in the BRIMCS countries invested a minimum of $13.8 bln PPP international dollars in energy research, development, and demonstration (RD&D), with around 90% of these funds coming from SOEs. The data from governments and SOEs upon which this total is based, however, have not been reported in any systematic way, and definitions of what constitutes RD&D vary widely between different data sources. Despite these limitations, the results suggest that governments in the BRIMCS may have control over larger amounts of energy RD&D funding than the governments from countries that are members of the IEA[1], whose total government investments in energy RD&D were $12.7 bln PPP international dollars in 2008.

This working paper also provides a comparative systemic analysis of government-initiated ETI activities in these six major emerging economies. The aim of this analysis is to allow the identification of opportunities for collaboration within the governments of the BRIMCS countries and between the governments of the BRIMCS countries and those of other countries. These collaborations could take the form of cooperation or could involve coordination of activities in different countries. The analysis distinguishes between three analytically separate, but interrelated components of a country's innovation system: (1) the administrative entities and procedures that set the direction of government support for ETI activities; (2) the allocation mechanisms for energy RD&D support; and (3) the most important energy technology innovation institutions (ETIIs) and policies (ETIPs) that the government puts in place to accelerate ETI. Each country analysis concludes with a comparative framework that

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[1] The International Energy Agency (IEA) includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. Due to missing data, the Czech Republic, Poland and the Slovak Republic are not included in the Estimated IEA total.

provides a simple and systematic overview of the number of policies that each country uses to support the different stages, actors, and functions of its energy technology innovation system.

On the basis of these comparative frameworks and the data gathered, the study concludes with three high-level recommendations for areas where the BRIMCS countries can cooperate or coordinate with each other to accelerate ETI.

Acronym List

ABC	Brazilian Academy of Science, Brazil
AEC	Atomic Energy Commission, DAE, India
AEC	Atomic Energy Corporation, South Africa
ANEEL	Brazilian Electricity Regulatory Agency, Brazil
APDRP	Accelerated Power Development and Reform Program, Planning Commission, India
ASES	Mexican Solar Association, Mexico
BARC	Bhabha Atomic Research Centre, DAE, India
BEE	Bureau of Energy Efficiency, MOP, India
BHEL	Bharat Heavy Electricals Limited, India
BRIMCS	Brazil, Russia, India, Mexico, China, and South Africa
CAS	Chinese Academy of Sciences, China
CBCEE	Commercialization for Emerging Power, Brazil
CCS	Carbon Capture and Storage
CEA	Central Electricity Authority, MOP, India
CEF	Clean Energy Fund Group Limited, South Africa
CENPES	PetroBras Institute for Research and Development, Brazil
CEPEL	Research Center on Electric Energy, EletroBras, Brazil
CESAR	Centre for Energy Systems Analysis and Research, South Africa
CFE	Federal Electricity Commission, Mexico
CFRI	Central Fuel Research Institute, MST, India
CGEE	Management Center for Strategic Studies, Brazil
CHP	Combined Heat and Power
CHT	Centre for High Technology, MPNG, India
CIAE	Chinese Institute of Atomic Energy, CNNC, China
CICOP	Research and Development Corporate Integration Committee, Brazil
CIL	Coal India Limited, India
CINVESTAV	Research and Advanced Study Center, IPN, Mexico
CMPDI	Central Mine Planning and Design Institute, CIL, India
CNEN	National Commission of Nuclear Energy, Brazil
CNNC	Chinese National Nuclear Corporation, China
CNPq	National Council for Scientific and Technological Development, Brazil
CO_2	Carbon Dioxide
COFER	Advisory Council for Renewable Energy Development, CONUEE, Mexico
COMIA	Mexican Council for Municipal Infrastructure, Mexico
CONACYT	National Council on Science and Technology, Mexico
CONAE	National Commission for Energy Saving, Mexico
CONUEE	National Commission for the Efficient Use of Energy, Mexico
CORDs	Research and Demonstration Centers, South Africa
COSTIND	Nuclear Power Administration, China
CPRI	Central Power Research Institute, MOP, India
CRE	Energy Regulatory Commission, Mexico
CPRM	Research Company for Mining Resources, MME, Government of Brazil
CRMI	Central Mining Research Institute, MST, India
CRESESB	The Brazilian Solar and Wind Energy Reference Center, CEPEL, Brazil

CRSES	Centre for Renewable and Sustainable Energy Studies, South Africa
CSEP	China's Sustainable Energy Program, China
CSIR	Council for Scientific and Industrial Research, MOC, India
CTA	Technical and Administrative Committee, Mexico
CWET	Center for Wind Energy Technology, MNRE, India
DAE	Department of Atomic Energy, India
DEAT	Department of Environmental Affairs and Tourism, South Africa
DME	Department of Mines and Energy, South Africa
DOE	Department of Energy, South Africa
DSIR	Department of Scientific and Industrial Research, India
DST	Department of Science and Technology, India
DST	Department of Science and Technology, South Africa
EDC	Energy Development Corporation, South Africa
EE	Energy Efficiency
EEDSM	National Hub for Postgraduate Programme in Energy Efficiency and Demand Side Management, South Africa
EPE	Energy Research Company, MME, Brazil
ERI	Energy Research Institute, NDRC, China
ESMAP	Energy Sector Management Assistance Program of the World Bank
ETI	Energy Technology Innovation
ETII	Energy Technology Innovation Institution
ETIP	Energy Technology innovation Policy
FE	Fossil Energy
FINEP	Brazilian Innovation Agency
FNDCT	Scientific and Technological Development Fund, Brazil
FTP	Federal Targeted Programs, Russia
GDP	Gross Domestic Product
GE	Generic Energy Technologies (unspecified)
GW	Giga Watt
GWh	Giga Watt hour
HCF	Hydrogen Corpus Fund, MPNG, India
ICCC	Interministerial Commission on Climate Change, Brazil
ICCC	Interministerial Commission on Climate Change, Mexico
IEA	International Energy Agency
IES	Higher Learning Institutes, Mexico
IGCAR	Indira Gandhi Centre for Atomic Research, DAE, India
IGCC	Integrated Gasification Combined Cycle
IICT	Indian Institute of Chemical Technology, MST, India
IIE	Electrical Research Institute, CFE, Mexico
IMP	Mexican Institute of Petroleum, PEMEX, Mexico
ININ	Research Institute for Nuclear Research, CFE, Mexico
IPN	National Polytechnic Institute of Mexico
IREDA	Indian Renewable Energy Development Agency, MNRE, India
JNNSM	Jawaharlal Nehru National Solar Mission, MNRE, India
LACTEC	Institute of Technology for Development, Brazil
LAERFTE	Renewable Energy Development and Financing for Energy Transition Law, Mexico

LAFRE	Law for Sustainable Use of Energy, Mexico
LEDs	Light Emitting Diodes
LSPEE	Law for the Public Supply of Electricity, Mexico
LTMS	Long-Term Mitigation Scenarios, South Africa
MCT	Ministry of Science and Technology, Brazil
MDIC	Ministry of Development, Industry and Foreign Trade, Brazil
MEC	Ministry of Education, Brazil
MED	Ministry of Economic Development, Russia
MES	Ministry of Education and Science, Russia
MIE	Ministry of Industry and Energy, Russia
MME	Ministry of Mines and Energy, Brazil
MNRE	Ministry of New and Renewable Energy, India
MOC	Ministry of Coal, India NGO
MOE	Ministry of Energy, Russia
MOF	Ministry of Finance, China
MOP	Ministry of Power, India
MOST	Ministry of Science and Technology, China
MPNG	Ministry of Petroleum and Natural Gas, India
MST	Ministry of Science and Technology, India
MW	Mega Watt
MWh	Mega Watt hour
NDRC	National Reform and Development Commission, China
NE	Nuclear Energy
NEA	National Energy Administration, NDRC, China
NEAA	national Energy Efficiency Agency, South Africa
NEC	National Energy Commission, China
NECSA	South Africa's Nuclear Energy Corporation, South Africa
NEEPCO	North Eastern Electric Power Corporation Limited, MOP, India
NGHP	National Gas Hydrate Program, MPNG, India
NGO	Non-Governmental Organization
NHPC	National Hydroelectric Power Corporation Limited, MOP, India
NTC	New Technology Group, MNRE, India
NEF	National Energy Fund, India
NLC	Neyveli Lignite Corporation Limited, India
NOM-ENER	Official Mexican Standards for Energy Efficiency, Mexico
NPTI	National Power Training Institute, MOP, India
NSFC	National Natural Science Foundation of China
NSCC	National Strategy on Climate Change, Mexico
NTPC	National Thermal Power Corporation Limited, MOP, India
OECD	Organisation for Economic Co-operation and Development
OIDB	Oil Industry Development Board, MPNG, India
ONGC	Oil and Natural Gas Corporation Limited, MPNG, India
OPCSA	Oil Pollution Control South Africa, South Africa
PAESE	Program for Energy Saving in the Electric Sector, CFE, Mexico
PBMR	Pebble-Bed Modular Reactor
PECiTI	Special Program for Science, Technology and Innovation 2008-2012, Mexico

PEMEX	Petroleos Mexicanos, Mexico
PND	National Development Plan 2007-2012, Mexico
PNI	National Program for Infrastructure 2007-2012, Mexico
PROCEL	National Program for Electric Power Conservation, Brazil
PRODEEM	National Program for Energy Development of States and Municipalities, Brazil
PROINFA	Program of Incentives for Alternative Electricity Sources, Brazil
PSE	Sectoral Energy Program 2007-2012, Mexcio
R&D	Research and Development
RD&D	Research, Development and Demonstration
RDPAC	RDD&D Project Appraisal Committee, MNRE, India
RE	Renewable Energy
RECORD	Renewable Energy Research and Demonstration Center, South Africa
RGIPT	Rajiv Gandhi Institute of Petroleum Technology, India
Rosatom	Federal Agency for Nuclear Energy, Russia
ROSATOM	State Atomic Energy Corporation, Russia
Rosenergo	Federal Agency for Energy, Russia
Rosnano	Russian Corporation of Nanotechnologies (see also Rusnano)
Rusnano	Russian Corporation of Nanotechnologies (see also Rosnano)
SACCCS	South Africa's Centre for Carbon Capture and Storage, South Africa
SANEDI	South Africa's National Energy Development Institute, South Africa
SANERI	South Africa's National Energy Research Institute, South Africa
SEC	Solar Energy Center, MNRE, India
SEMARNAT	Ministry for the Environment and Natural Resources, Mexico
SENER	Ministry of Energy, Mexico
SFF	Strategic Fuel Fund Association, South Africa
SMEs	Small and Medium Enterprises
SMMEs	Small, Micro and Medium Enterprises
SOE	State-Owned Enterprise
SRC	Solar Research Council, MNRE, India
SSRC	Standing Scientific Research Committee, MOC, Government of India
SSS-NIRE	Sardar Swaran Singh National Institute for Renewable Energy, MNRE, India
S&T	Science and Technology
TDPAC	Technology Demonstration Project Appraisal Committee, MNRE, India
TDS	Transmission, Distribution and Storage
TRI	Technology Research and Investigations division, Eskom Ltd., South Africa
UNAM	National Autonomous University of Mexico

1. Introduction

Over the past decade, countries with emerging economies like Brazil, Russia, India, Mexico, China, and South Africa (which will be referred to as BRIMCS countries from this point onwards) have become important global players in political and economic domains. Since 1985 (and probably already before that time) the six BRIMCS countries together consumed more energy than any single country in the world (the single country with the largest energy use in 1985 was the United States). The rapid growth in energy use in the BRIMCS countries since the year 2000 has largely been driven by China. In 2010 it was announced that China has become the single largest energy consumer in the world (Swartz and Oster 2010). In 2007, the BRIMCS countries accounted for 44% of world's population, 32% of the world's energy consumption, and 35% of the world's global energy production[2] (World Bank 2009).

The BRIMCS countries also contribute significantly to global environmental problems. The International Energy Agency (IEA) estimated that in 2005 the BRIMCS countries had emitted 33% of global CO_2 emissions; their contribution had increased to 35% in 2007[3] (IEA 2009a). China became the country with the largest CO_2 emissions in 2007, contributing to 21% of global emissions (IEA 2009a). Part of these emissions, however, can be attributed to the production of goods for foreign markets (Wang and Watson 2007).

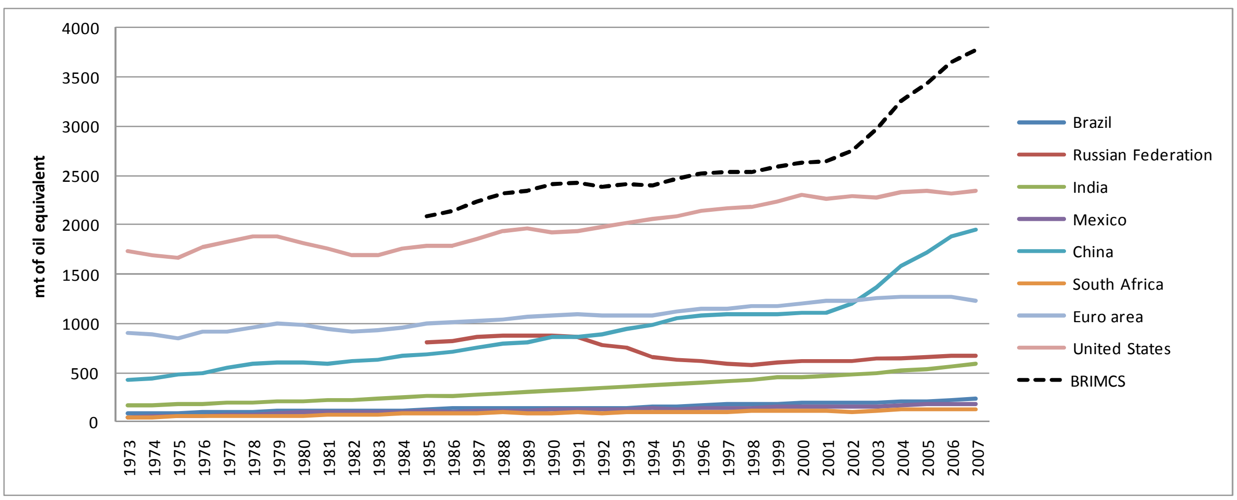

Figure 1. Energy consumption in the BRIMCS countries, the United States, and the European Union between 1973 and 2006 (BP 2009; The World Bank Group 2009).[4]

This trend of increased prominence of the BRIMCS countries in the world energy landscape is expected to continue. Looking ahead, the IEA forecasts a 40% increase in global energy use between 2007 and 2030, with the non-OECD countries accounting for more than 90% of this rise under their reference scenario. China and India together are expected to account for 30% of global primary energy demand in

[2] Energy production includes energy from renewable resources and waste and primary electricity production. Energy consumption is based on primary energy use (indigenous production plus stock and imports and minus exports) before transformation to other end-use fuels.

[3] These estimates only include energy-based CO_2 emissions and not emissions from industrial processes.

[4] Data on Russia's energy consumption between 1985 and 1989 based on BP; before 1985 no data available for the Russian Federation.

2030. Of the projected global annual CO_2 emissions of 40 Gt in 2030, China is expected to emit 11.6 Gt, and India 3.3 Gt (IEA 2009b).

Besides the BRIMCS countries significance in terms of their energy use and and greenhouse gas emissions, the BRIMCS group of countries also contains some of the world's largest net energy importers and exporters. After the United States and Japan, China and India are the largest single country importers of oil in the world. The Russian Federation and Mexico are both major oil exporters—e.g., in 2008, Russia produced 3.5 times as much oil as it consumed. In terms of natural gas, Russia is the largest gas exporter in the world. In contrast, the United States and the European Union are both net oil importers; in 2008 they imported 61% and 83% of their total oil consumption, respectively. In addition, the European Union relied on imports for 45% of its gas needs in that same year (BP 2010).

This changing global energy landscape has important implications for energy technology innovation (ETI) nationally and internationally. From a national perspective, ETI in the BRIMCS countries can be expected to be affected through: (1) increases in energy RD&D investments associated with increasing gross domestic product (GDP) and with increasing fossil energy production revenues in several of the BRIMCS countries; and (2) the increased demand for energy, which provides more opportunities to deploy new energy technologies and learn from experience. These national developments have important consequences for ETI activities elsewhere around the world. The increased exchange of knowledge, scientists, and technology between the BRIMCS countries and other countries directly impacts the comparative advantage of other countries in different areas of innovation. There are several indirect consequences of the increased global role of the BRIMCS countries. First, if a greater number of countries becomes more concerned about energy security, there will be a greater demand for new technologies thereby promoting the generation of energy from domestic resources and/or energy efficiency. Second, if more countries are interested in reducing their GHG emissions, there will also be more demand for innovation in energy technologies that do not contribute to climate change. Third, the positive impacts of innovation on economic growth in one or several countries or regions, might spark innovation activities elsewhere around the world. Fourth, the diverse environmental and geological characteristics of the BRIMCS countries could provide opportunities for other countries to learn from the technical and policy experiences in the BRIMCS.

The international and interdependent nature of ETI provides public policymakers with a complicated puzzle: they not only need to anticipate the consequences of their energy technology innovation policies (ETIPs) and energy technology innovation institutes (ETIIs) on the pace of ETI; but they also need to understand how other countries' initiatives might affect the effectiveness of their own initiatives. In addition, information about ETIPs and ETIIs in other countries might provide opportunities to identify gaps and overlaps or to determine commonalities or complementarities in the policies of two or more countries (Kempener and Anadon in preparation).

Despite their increasing significance in the world's energy sector, very little is known about ETIPs and ETIIs in the BRIMCS countries. None of the six BRIMCS countries is a member of the International Energy Agency (IEA), which is one of the few agencies that has been collecting data on energy technology research development and demonstration (RD&D) budgets for its members.[5] The majority of analyses focus on energy RD&D policies in industrialized countries and, more specifically, on funding

[5] Mexico is a member country of the OECD, but not of the IEA. The IEA is an autonomous intergovernmental organization associated with the OECD.

levels (Sagar and Holdren 2002). Even though a more extensive R&D policy categorization process has been developed (IEA 2007), it is mainly applied to IEA member countries. The emerging economies have received more attention from industrialized countries over the past five years. The G8 Gleneagles Plan of Action in 2005 initiated intensified dialogue with Brazil, India, Mexcio, China, and South Africa (the so called outreach countries referred to as "O5" countries) (Lesage, Van de Graaf et al. 2009), but none of these actions involves reporting on their energy RD&D activities. Finally, some initiatives attempted to provide overviews of ETI-related policies in the BRIMCS countries by both international organizations (IEA 2010a; REN21 2010b; WRI 2010) and policy consultants (Dahlman 2009; Leggett, Lattanzio et al. 2009; Nielson 2009). These efforts, however, do not present a systematic analysis of the role of the central government in the ETI system of each country.

This working paper provides data on energy RD&D investments in the BRIMCS countries and applies the comparative framework developed by Kempener and Anadon (in preparation) to compare ETIIs and ETIPs in these emerging economies. Section 2 describes the research methodology, the comparative framework, and the data collection procedure. Section 3 presents the results of the analysis of ETIIs and ETIPs in the six countries under investigation, while section 4 discusses these results. Section 5 concludes.

2. Methodology

2.1. Data

Two sets of data have been collected for this comparative analysis. The first data set consists of national government funding on energy RD&D projects within the period between 2000 and 2008. National government funding is defined as (1) funding directly provided by a national government to university, industry, national laboratories, or other national or international organizations engaged in or supporting energy RD&D; (2) funding through state-owned enterprises (SOEs) that are 100% owned by a national government; and (3) national government mandates requiring that state-owned enterprises spend a particular fraction or amount of their revenues on energy RD&D. Energy RD&D investments from sources "other" than the national government include investments from state-owned enterprises that operate independently, energy technology R&D&D investments by state or local governments, investments by non-governmental organizations (NGOs), foundations, and private industry.

As mentioned in the introduction, there is no international effort that systematically collects information on energy RD&D spending in the BRIMCS countries. Therefore, this report has drawn on a large range of data sources. Some data sources provide only aggregate values for energy RD&D funding, which is not broken down by the type of energy technologies. Conversely, some data sources only provide information about energy RD&D funding for specific energy technology programs, without indicating what additional government resources may be dedicated to similar technology areas. Consequently, there are three important considerations that one should bear in mind when interpreting the data of energy RD&D investments presented. First, in those countries where aggregated energy RD&D investments are reported separately from energy RD&D investments on specific energy technologies, the sixth category ("generic energy technologies") is used as a residual category for any energy RD&D investments that cannot be considered to fall into any of the other energy technology categories. Second, some years and categories of energy technology R&D without data are left empty. This does not mean that the country does not provide any RD&D funding for that particular energy technology area, but instead that data is unavailable. Third, it should be noted that all other data points only represent energy technology RD&D data as far as available. This means that there might be additional funding for energy technology RD&D in the countries under consideration that are not included. For additional explanations, see the notes on each country in Appendix 1.

The second data set consists of an overview of energy technology innovation institutions (ETIIs) and energy technology innovation policies (ETIPs) that support ETI in the BRIMCS countries and which were in place in 2009. ETIPs and ETIIs are defined as those policies and institutions created by a national government "specifically" aimed at shaping the direction and pace of ETI (Anadon and Holdren 2009). Considering the important role of SOEs in some of the BRIMCS countries, the definition of ETIPs and ETIIs includes R&D, demonstration and deployment activities by SOEs that are 100% owned by the national government as long as these activities impact the development, introduction and diffusion of "new" energy technologies into the market. For the purpose of this paper, this definition excludes (1) those national policies or institutions that focus on other technologies and indirectly impact ETI (i.e., nanotechnology or information and communications technology); or (2) those that shape generic innovation activities and therefore might impact ETI (i.e., tax credits that affect all private R&D activities). Consequently, the overview does not include universities or research centers that are not directly under the responsibility of a national government. A complete list of the different kinds of energy technology innovation policies included in this analysis can be found in Kempener and Anadon (Kempener and Anadon in preparation). Data has been collected through online databases (in particular IEA 2010d; REN21 2010b; WRI 2010). However, these databases mainly contain policies focused on renewable energy technologies and are poorly maintained. Therefore, these databases are augmented with the Clean Coal Projects database of the IEA Clean Coal Center (IEA 2010b) and the World Nuclear Association's country briefings (World Nuclear Association 2010). Subsequently, these databases are cross-referenced with secondary literature, academic papers and national policy reports. After the data had been compiled, it was reviewed by energy technology experts from each of the countries under investigation. The full overview of ETIPs and ETIIs and their classifications can be found in Appendix 2.

2.2. The Comparative Framework

The comparative framework developed by Kempener and Anadon (in preparation) has been used to quantitatively analyze data on national ETIIs and ETIPs compiled from several sources. The intention for using this framework in this paper is to identify opportunities for cooperation and coordination, although it can also be used to identify areas in which governments have competing objectives. The policies and institutions are categorized according to three levels: macro-level, micro-level, and system-level policies.

- The macro-level policies and institutions are subsequently categorized according to the different *stages* in which energy technology innovation activities take place: R&D, demonstration, and deployment (Gallagher, Holdren et al. 2006).
- Micro-level policies are categorized based on the *actors* that are directly affected by the ETIPs and ETIIs. Five categories of actors are distinguished: supply-side actors, demand-side actors, intermediary infrastructure actors, support infrastructure actors or international actors (Smits and Kuhlmann 2004; Sarewitz and Pielke 2007).

- System-level policies are categorized based on the different *functions* within the innovation system that they impact (Johnson and Jacobsson 2001; Hekkert, Suurs et al. 2007).

Furthermore, the policies and institutions are also categorized according to the different energy technologies that they impact. The six categories are fossil energy (coal, gas and oil including carbon capture and sequestration (CCS)), nuclear energy (fission and fusion technologies), renewable energy technologies, transmission, distribution and storage (TDS) technologies (including hydrogen) and energy efficiency technologies in industry, agriculture, buildings and appliances. There is a sixth category, "generic energy technologies," that is used to encompass those ETIPs and ETIIs that directly affect more than one energy technology category.

The aim of this classification is to provide a basis for identifying opportunities for cooperation and coordination of ETIPs and ETIIs between different countries. To this extent, the analysis will only include those ETIPs and ETIIs that are in force and active in 2009. After classifying the ETIPs and ETIIs according to the stages, actors, functions and energy technologies they impact, the comparative framework provides an overview of the total number of ETIPs and ETIIS in each category. The number of ETIPs and ETIIs provides an indication of where and to what extent a government attempts to support innovative activities within a particular area and technology within its country. These insights can subsequently be used for a more thorough analysis to identify specific opportunities for cooperation and coordination. With this objective in mind, the following considerations need to be taken into account when interpreting and comparing the comparative frameworks between multiple countries:

1. A policy or institution is counted multiple times if it affects multiple stages, actors or functions at the same time. Similarly, a policy or institution is counted multiple times if its description specifies that it applies to multiple energy technology categories. However, if a policy or institution does not specify which energy technologies it is supposed to impact or if a policy or institution affects all energy technology categories (for example, research on energy systems analysis), it will be classified under the category "generic energy technologies."
2. A policy or institution can have multiple sub-policies or sub-programs and can result in multiple individual projects affecting ETI activities, which makes it difficult to determine when to count a policy or institution as a single intervention. Two different methods, one for policies and one for RD&D programs and institutions, have been used to address this challenge. The rational for these methods is to reflect within the counting the number of times that a government intentionally puts an intervention in place to impact ETI within its country. For policies or laws, the method is that each time a new policy is announced at separate points in time, the policy is counted as a separate policy. For RD&D programs and RD&D institutions, the method is that each program or institution is counted separately, but that different R&D projects within a program or institution are not counted separately. For example, using this method, the Chinese Renewable Energy Law introduced in 2006 is counted as one specific policy, although it provides a framework for establishing a range of measures to support renewable energy technologies. Only when the actual measures with this framework were introduced, we counted them as separate measures because they were established at different points in time and the time and specifics of the measures has affected ETI activities within the country. On the other hand, China's 863 program on carbon capture and storage finances a range of different R&D projects, but we have only counted the program and not the individual projects.

3. Energy technology categories include those policies and institutions that are specific to the category as well as specific to energy technologies within that category. For example, the RD&D budget with which India's Ministry of New and Renewable Energy (MNRE) supports RD&D proposals in each of its energy technology priority areas is counted as one ETIP, while each of MNRE's specialized RD&D centers for solar, wind and bio-energy are counted as a separate ETII. For this specific example, this means that in the comparative framework a general RD&D budget for renewable energy technology and a specific research center for wind technology are represented as two equally weighted ETIPs or ETIIs impacting supply actors in the R&D stage of renewable energy technologies.
4. The comparative framework does not consider policies or institutions that have an adverse affect on ETI nor does it include innovative activities that take place without any support through ETIPs or ETIIs. In other words, the number of policies or institutions in each category does not provide an indication of the number of innovative activities, but instead it provides an indication of where and how the government is attempting to support innovative activities within its country.
5. Finally, the comparative framework does not provide any information about the relative effectiveness of each individual policy or institution, but instead provides a quantitative landscape of the stages, actors, and functions that are intended to be affected by the policies and institutions.

3. Country Characteristics

This section presents a summary of the data available on the energy RD&D investments of central governments and "other" sources in the BRIMCS countries. It also presents for the first time a comparative analysis of other ETIPs and ETIIs.

Each country description includes an overview table for energy RD&D investments and an overview table of the ETIPs and ETIIs. The references for these overview tables are provided in the appendices to this working paper. Appendix 1 provides the details on the data sources for energy RD&D investments and Appendix 2 provides an overview of the details and classification of ETIPs and ETIIs in each country.

The introduction to this section includes a generic overview of the current energy situation in the BRIMCS countries. Subsequently, each of the BRIMCS countries is discussed separately but within an identical format. This format consists of: a brief discussion of the administrative entities and procedures through which ETI strategies are shaped; an overview of the institutions that are involved in the actual allocation of energy RD&D funds; an overview of the most important institutions and policies determining ETI activities within a country; and, an analysis of these ETIIs and ETIPs using the comparative framework developed by Kempener and Anadon (in preparation).

3.1. The Energy Landscape in the BRIMCS Countries

As mentioned in the introduction, the BRIMCS countries consumed and produced around one third of the world's energy (31 percent and 34 percent, respectively). As a group, they have been important players in the energy sector since the early 1980s, but with their economic rise their importance is growing. They are, however, a diverse group including some of the largest energy exporters and largest energy importers and their sources of energy vary considerably. Table 1 provides an overview of the energy sources for electricity production in each of the BRIMCS countries, the United States and the Euro area.[6]

Table 1. Overview of energy sources for electricity production in the BRIMCS countries, the United States, and the Euro area (The World Bank Group 2009).

2007 data	U.S.A.	Euro area	BRIMCS	Brazil	Russia	India	Mexico	China	S. Africa
% from coal	49%	25%	60%	2%	17%	68%	12%	81%	95%
% from gas	21%	22%	12%	3%	48%	8%	49%	1%	0%
% from oil	2%	4%	2%	3%	2%	4%	20%	1%	0%
% from nuclear	19%	31%	5%	3%	16%	2%	4%	2%	4%
% from hydro	6%	9%	20%	84%	17%	15%	11%	15%	0%

The main source of electricity in the BRIMCS countries is coal, which accounted for 60 % of their total power production in 2007. While nuclear energy is the main source of electricity in Euro Area, most BRIMCS countries have a higher contribution of hydro-electric power than the Euro area and the United States. Natural gas makes up a similar fraction of electricity production in the Euro Area and the United States, but its contribution to electricity production in the BRIMCS varies widely— it makes up 48% of total electricity generation capacity in Russia versus 0%, 1%, and 3% in South Africa, China, and Brazil.

Without including power generated in hydroelectric plants, the contribution of renewable energy resources to electricity production has been limited, although the installed capacity in BRIMCS countries, the United States, and the Euro area has been growing quickly since 2005. The use of renewable energy sources for heat production is larger, although there are also large differences in renewable energy heat and power generation capacities in the BRIMCS countries, the United States, and the Euro area. Individually, BRIMCS countries have lower renewable energy power generation capacities than the Euro area and the United States, but combined they make up large fractions of global renewable energy capacity. The European Union is the frontrunner in terms of installed wind power and solar photovoltaic (PV) capacity with 46-47% and 70-76%, however China and India's share of the world's installed wind power and solar PV capacity is rapidly increasing (BP 2010; REN21 2010a). In addition, the combined wind power and biodiesel production capacity in China and India has already surpassed that of the United States; the same is true of their installed small hydro and solar thermal capacity (REN21 2010a).

Arable land and fresh water sources are two important inputs for biomass-based electricity generation and heat production. The BRIMCS countries had 37 % of the world's arable land and with 11%, 10%, and 9% of the world's arable land, India, China, and Russia have large areas of arable land at their disposal. In contrast, only 12% and 4% of the world's arable land is in the United States and the Euro area, respectively. Similarly, a third of the world's total renewable internal freshwater resources were located in the BRIMCS countries. Two BRIMCS countries alone, Brazil with 12% and Russia with 10%, accounted for almost a quarter of the world's renewable freshwater resources. The United States houses 6% of freshwater resources, three times more than the Euro area (World Bank 2009).

[6] The Euro Area includes those European countries in the euro zone. In 2007, this included Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Slovenia and Spain. Data on renewable energy and refining capacities is based on the European Union (E.U.), which also included Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Sweden in 2007.

Finally, the BRIMCS countries are also becoming more important energy users in the transportation sector. In 2005, 11% of all motor vehicles[7] worldwide were located in BRIMCS countries. This fraction pales in comparison to the 38% in the United States and 36% in the European Union. The use of gasoline for road transportation in the BRIMCS countries consumed 15% of global gasoline and diesel fuel production; the United States and the European Union consumed 35% and 14%, respectively (World Bank 2009).[8] Finally, the refining capacity for crude oil is more evenly distributed among the United States, the European Union and the BRIMCS countries with 20%, 17% and 24% of the world's capacity (BP 2010). China has the largest refining capacity among the BRIMCS countries with 10% of the world's capacity.

In conclusion, there are significant differences between the BRIMCS countries in terms of their reliance on energy resources and energy production. However, there are also similarities in that most BRIMCS countries have significant land and water resources, they have more limited penetration of renewable energy technologies than the European Union and the United States, and they all can expect increasing demands for energy in the transport sector.

3.2. Brazil

Administrative entities and procedures

In Brazil, the Ministry of Mines and Energy (MME) coordinates energy policy and the Ministry of Science and Technology (MCT) is responsible for defining and implementing the National Policy of Science and Technology. MME is responsible for the Energy Research Company (EPE), formed as a subsidiary in 2004, which has published its National Energy Plan 2030 and its National Energy Balance 2030, which sets out its planning activities including a greater share of cane sugar and gas as domestic energy sources and a reduction in imported gas and hydroelectricity (Guerreiro 2009). This policy has been translated into guidelines for the ten year Electrical Energy plan 2008-2017, in which reliance on hydropower is reduced to 78% and plan are announced to increase nuclear power capacity, beginning with the completion a 1,000-megawatt nuclear plant scheduled to come on line in 2014. Brazil also has plans to construct four additional 1,000-megawatt nuclear plants beginning in 2015. Furthermore, the plan calls for a dramatic increase in production from small hydroelectric and waste-to-energy projects.

MCT is responsible for Brazil's innovation policy and it has identified a number of strategic RD&D areas for energy R&D in its "Science, Technology and Innovation Platform for National Development 2007-2010," which includes science, technology and innovation funding for biofuels, transmission, distribution, end use and optimization of the electrical system, hydrogen, renewable energies, oil, gas, coal, and nuclear (Rezende 2008). Furthermore, MCT administrates three sectoral funds for the energy sector. These funds were created to ensure solid and permanent investments in R&D:

- CT-Energy finances projects and programs in the energy sector with emphasis in energy efficiency. Generation, transmission and distribution companies contribute with 0.75% to 1% of their net sales for this fund.
- CT-Petro is in charge of stimulating innovation in the production chain of the oil and gas industry. Its source of finance comes from 25% of the value of the royalties that exceed 5% of the production of oil and natural gas.

[7] Including cars, buses and freight vehicles, but excluding two-wheelers

[8] Gasoline and diesel fuel consumption figures are from 2003.

- CT-Infra provides funds for infrastructure R&D including support for hydrogen and fuel-cell technology.

Other entities that play an indirect role in shaping Brazil's innovation policy are the Ministry of Education (MEC) which funds universities and the Ministry of Development, Industry & Foreign Trade (MDIC).

Finally, Brazil set up the Interministerial Commission on Climate Change in 1999, which has developed a "National Plan on Climate Change" (ICCC 2008) with the following policies:

- Increase energy efficiency to decrease electricity consumption by 10% in 2030 compared to current levels
- Maintain high levels of renewable electricity supply
- Increase the use of biofuels in the transport sector
- Reduce de-forestation by 70% by 2017 and eliminate net loss of forest coverage by 2015 by re-forestation.

RD&D allocation
Energy RD&D in the electricity sector is monitored, evaluated and allocated by the electricity regulator ANEEL (Act 9,991/2000). The funds are provided by mandatory contributions by the electric energy utilities (Eletrobrás has a state-ownership that ranges from 52 – 58%). The amount of yearly energy RD&D funding is based on a minimum percentage of their net operating income (1%) and consists of R&D and energy efficiency projects, but the exact allocation of these funds depends on whether the utilities are generators, transmission companies or distribution companies. R&D funding goes to the search for innovations to address technological and market challenges in the electricity sector, while energy efficiency funds go to the demonstration projects in the market. Some of the R&D funds go to national R&D programs like the Brazilian scientific and technological development fund (FNDCT) and the sectoral CT-Energy program, while another percentage goes to projects assessed and evaluated according to guidelines by ANEEL (Soares, Melo Junior et al. 2008).

Similar mandatory regulation is in place for Brazil's oil company Petrobras (in 2008 the Brazilian government owned a 55.7% of Petrobras). Energy R&D funding comes for a share of the royalties of oil and natural gas production and these funds are redistributed to CT- energy and CT-Petro (in 2008, the allocation was based on 25% of the share of royalties that exceed 5% of production of oil and natural gas). CT-Energy specifically funds research on energy-efficiency in end-use and is linked to industry R&D. The goal of CT-Petro is to encourage innovation in the production chain of oil and natural gas.

Furthermore, MCT is supported in its R&D allocation decisions through the Brazilian Academy of Science (ABC), the National Council for Scientific and Technological Development (CNPq) and the Management Center for Strategic Studies (CGEE).[9]

[9] With regard to energy innovation, CGEE mainly focuses on biofuels (ethanol and biodiesel and climate change.

Table 2. Energy RD&D funding in Brazil by government and others for different energy technologies between 2000 and 2008.

Brazil Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government	170	129	79	76	64	68	89	101	79
	other	352	361	453	571	595	745	1192	1240	1167
nuclear energy (incl. fusion)	government		9	4	9	9	9	10	7	8
	other									
renewable energy sources	government	7	40	36	50	46	44	66	46	15
	other									
energy-efficiency	government	9	35	40	47	41	40	67	46	3
	other									
transmission, distribution & storage	government	22	94	104	125	111	106	175	122	14
	other									
energy technologies (unspecified)	government		13	6	14	14	14	16	11	12
	other		224	203	178	165	199	218	209	184
total	**government**	**208**	**319**	**270**	**321**	**286**	**281**	**424**	**333**	**131**
	other	**352**	**585**	**656**	**750**	**760**	**945**	**1410**	**1449**	**1351**

ETIIs and ETIPs

Brazil's energy sector is dominated by two state-owned companies called PetroBras (57% state-owned) and EletroBras (52% state-owned), which dominate the exploration and production of oil and 69% of transmission lines and 40% of installed electricity generation respectively. The majority of R&D investments in Petrobras are directed towards exploration, supply, gas and energy, and corporate. CENPES is PetroBras' R&D center for petroleum research and CT-Gas funds PetroBras' gas research (Castello Branco 2007). The funds collected through Eletrobrás are used to support internal R&D as well as research through CEPEL (Research Center on Electric Energy) and CICOP (Research and Development Corporate Integration Committee). The Institute of Technology for Development (LACTEC) is another technological research center that supports energy RD&D in the electricity sector, however it operates independently from either MME or MCT.

Within the MME, there are two publicly owned companies that conduct research; the Research Company for Electric Power (EPE) and the Research Company for Mining Resources (CPRM) (the Commercialization for Emerging Power (CBCEE) no longer exists). There are also three research institutions under MCT that play a role in energy R&D. The National Council for Scientific and Technological Development (CNPq) coordinated the first stages of R&D, the Brazilian Innovation Agency (FINEP) coordinates the latter stages of R&D and nuclear R&D takes place within the National Commission of Nuclear Energy (CNEN). CNEN directs five nuclear research centers that work on fuel cycle, reactor technology, radioisotopes, and related R&D (IAEA 2003). In 2006, 15 percent of the total CT-Energy budget funded work on nuclear energy R&D, 29% on renewable, 19% on electricity and the rest on basic industrial technology research, hydrogen, human resources, cooperation activities and other areas of research. Table 2 assumes that these allocations are constant over the 2000-2008 timeframe.

Large number of energy innovation policies supporting the deployment of renewable energy technologies both in electricity generation and fuel production. In 2002, PROINFA was announced to increase electricity generation from wind, biomass and small-scale hydropower with guaranteed prices for 15 years, which has led to an increase in wind power projects around 2003/2004. PRODEEM is another program which installed PV systems in off-grid areas, however due to poor maintenance and technical problems many of these systems do not operate properly (Geller, Schaeffer et al. 2004).

Furthermore, there are several policies promoting the demand for energy efficient technologies through norms and standards. PROCEL is a national electricity conservation program that has had varied success, but energy efficiency standards in industrial processes, equipment, buildings and vehicles are still low by international standards (Geller, Schaeffer et al. 2004). Furthermore, ANEEL introduced a policy in 1998 that required to invest 1% of revenues of distribution utilities into energy efficiency programs, but only 50% of this money goes into energy R&D (Geller, Schaeffer et al. 2004).

Besides energy policy and innovation policies, rural electrification is an important policy area affecting energy innovation. There are three large programs: (a) 'Luz para Todos' focuses on universalisation of electricity access through grants, preferential loans, project-based programs and infrastructure investment; (2) the National Program of Efficient Public Lighting or 'Reluz'; and (3) National Program for Electric Power Conservation or 'Procel' that focus on providing electricity (often decentralized) to rural areas.

Table 3 and Table 4 show the number of institutions and policies that impact the R&D, demonstration and deployment stage of ETI and the different functions of innovation. It shows that Brazil has a large number of policies and institutions in place that affects the suppliers of renewable energy technologies through loan programs, tax incentives and feed-in tariffs. Furthermore, it has several policies in place that affect the use of renewable energy technologies through subsidies for ethanol use, targets for use and policies for mandatory targets for solar heaters. On R&D, the Brazilian government has several institutions that act as national laboratories for the creation of new knowledge and has mechanisms in place for mandatory R&D expenditure within private energy companies.

Table 3. Number of Brazilian governmental policies and institutions affecting different stages and actors in the innovation process within each of the energy technology categories.

Brazil	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	1	1	1	0	1	0	0	0	1	1	0	0
NE	1	1	0	0	0	0	0	0	1	0	0	0
RE	2	1	0	0	1	0	0	0	10	3	4	4
EE	1	0	2	0	0	0	0	0	4	1	2	1
TDS	1	2	0	0	0	0	0	0	1	0	1	0
GE	0	2	4	0	0	0	0	0	0	3	1	2

Table 4. Number of Brazilian governmental policies and institutions affecting different functions in the innovation process within each of the energy technology categories.

Brazil	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	2	0	1	0	0	0	1
NE	1	1	0	0	1	1	0
RE	2	2	3	2	0	3	13
EE	3	0	2	0	0	2	6
TDS	1	2	1	0	0	1	0
GE	1	2	1	0	2	2	2

3.3. Russian Federation

Administrative entities and procedures

The Ministry of Energy (MOE) was established in 2008 when the responsibility of energy policies was split up from the Ministry of Industry and Energy (MIE). Before the establishment of MOE, the formation of a highly competitive energy market was a priority for MIE, while innovation was earmarked as a priority after 2000-2010 (MIE 2003). MOE, however, is responsible for organizing implementation of activities to stimulate technological innovation in the energy sector. The former Federal Agency for Energy (Rosenergo) was also merged into this new ministry, while the responsibilities of the Federal Agency for Nuclear Energy (Rosatom) are taken over by the State Atomic Energy Corporation (ROSATOM)[10]. MOE recently presented its *Energy Strategy for Russia until 2030* (Makarov 2009; Shmatko 2009)[11], which calls for the creation of a sustainable national innovation system in the energy sector. Its initial target is a 20% share of domestic production of world class energy technologies through the import of key technologies, establishment of R&D centers and public-private partnerships. Recognizing fiscal and other restraints in innovation and energy innovation in particular, Russia agreed in 2006 to focus on a list of 34 critical technologies for their feasibility and relevance to the domestic economy and these remain the technical areas of focus.[12] These critical priority technologies related to energy include (Klimenko 2008):

- Nuclear power technologies, including fuel cycle, safety aspects and spent fuel treatment
- Hydrogen energy technologies
- New and renewable energy sources
- Power generation and fuel production from fossil fuels
- Energy saving systems for transportation, distribution and consumption of heat and electricity
- Creation of energy efficient engines and propulsion devices for transport systems

In recent addresses by President Medvedev and Putin, they argued that Russia should move away from an economy that is dependent on extracting resources to one that is based on innovation. Two of the five technological development priorities mentioned are: 1) energy, including energy efficiency, energy conservation and new fuels (39% of total government R&D expenditure) and 2) nuclear technology (7% of total government R&D expenditure) (Dezhina 2010; Smith 2010).

Another energy policy that might affect energy R&D is the current restructuring of Russia's electricity system (Engoian 2006; Pittman 2007). Under the electricity restructuring program, national transmission would be turned over to a new state-owned company called Federal Grid Company, thermal generation plants would be privatized and nuclear plants as well as most hydro plants would be transferred to separate state-owned companies. The rationale is to create a deregulated market in which these enterprises compete to operate, to invest efficiently, and to provide low cost electricity (Pittman 2007). Simultaneously, a Federal Law was passed that enabled the restructuring and reorganization of Russia's Nuclear Energy Industrial Complex by delegating the responsibility of state policies and management to ROSATOM. AtomEnergoProm, 100% controlled by ROSATOM, became the vertically-integrated company responsible for making Russia's nuclear energy industry more competitive.

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[10] Although ROSATOM and Rosatom have the same name, they are two different entitities.

[11] Developed with assistance of the Russian Academy of Sciences.

[12] See Перечень критических технологий Российской Федерации (The list of critical technologies of Russia), 21 May 2006 accessed at http://www.sci-innov.ru/law/base/99/ on 30 Nov 09.

In terms of innovation policy, there are several ministries involved. The Ministry of Education and Science (MES) has overall responsibility for the co-ordination of the "Development Strategy of science and Innovation in Russia for the Period up to 2015" (MES 2006). Furthermore, the Ministry of Economic Development (MED) has developed an "Innovation Scenario for Russia" (Makarov 2009). On the basis of this Innovation Scenario, several Energy Strategies up to 2030 have been developed to help Russia's energy policy development. Within this Energy Strategy, reducing Russia's GDP energy intensity, a long-term strategy for efficient natural gas production and the efficient development of the national power sector are main priorities.

RD&D allocation

The Federal Agency for Science and Innovation (FASI) manages a significant part of the Federal civil R&D budget and is therefore one of the most important actors in the Russian R&D and innovation spheres (MES 2006). Furthermore, FASI manages the biggest state program on the development of Russian applied science called "Research and development on priority areas of the development of the Russian scientific & technological complex for 2007-2011". This program has five priority areas, from which the budget for "Energy & Energy Efficiency" has increased from 6,960m RUB ($238m) in 2004 to 23,567m RUB ($805m) in 2008, with over 80% invested in the government's "Federal Targeted Programs" (FTPs) (ERAWATCH 2010). Research grants are allocated to scientific research organizations and industry on the basis of tenders and for energy projects FASI received more than 600 applications.

Energy R&D is also addressed through another program of FASI called "Nanosystems and materials". This area of research includes projects on gas flaring, membranes and material science. R&D on nanotechnologies is managed by the Russian Corporation of Nanotechnologies, Rosnano.

In general, Russia has lower R&D expenditures than other science-leading world states and R&D expenditure in business enterprises is considerable lower (MES 2009). However, the production, transfer and distribution of electricity, gas, steam and hot water supply is a significant part (>10%) of Russia's economic activities (MES 2009) and there are a variety of private and state-owned energy companies that carry out significant innovation activities. For example Gazprom's research and development companies spent 2.2bn ($75m) RUR on research and development in 2007 (Gazprom 2007).

In July 2009, a new Federal Program "Nuclear Power Technologies of the New Generation for 2010-15 and Prospectively to 2020" was approved. The total funding from the Federal budget for this program is limited to 110.4 billion RUB between 2010 and 2020 (Government Directive 2009). The start data for this program is after 2008, and thus, its budget information was not included in Table 5.

Table 5 shows data on energy RD&D expenditure in Russia. This overview is largely based on an overview of federal energy R&D and energy RD&D funding between 2002 and 2008 (Klimenko 2008) and on data about Russia's gross domestic expenditure on energy R&D (Gokhberg 2010). Gokhberg's data is not broken down by funding source. We have categorized any expenditure that could not be traced back to government expenditure under the category 'other' sources of funding. As a consequence, Table 5 seems to suggest that 'other' sources of funding for energy R&D are much higher than government sources of funding, although qualitative descriptions suggest that government is still the main funding source for innovation activities (Dezhina 2010).

Table 5. Energy RD&D funding in the Russian Federation by government and others for different energy technologies between 2000 and 2008.

Russia Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government								23	20
	other	*339*		263	256	280	399	152	261	411
nuclear energy (incl. fusion)	government									
	other									
renewable energy sources	government								16	14
	other									
energy-efficiency	government								29	25
	other									
transmission, distribution & storage	government						1	1	26	22
	other	*34*	*64*							
energy technologies (unspecified)	government			28	25	20	16	14	52	45
	other	183		378		398		587		508
total	**government**			**28**	**25**	**20**	**17**	**15**	**145**	**126**
	other	**555**	***64***	**642**	***256***	**677**	***399***	**739**	***261***	**918**

ETIIs and ETIPs

Russia's innovation system was radically changed after the fall of the Soviet Union, between 1991 and 1998, when the number of R&D researchers halved. In 1997, some new financial support was created through tax concessions and the promotion of science parks to accelerate commercialization of new technologies (Kihlgren 2003). However, the institutional structure of Russian science remains archaic with approximately 2900 state-owned scientific organizations (compared to 39 in the U.S. in 2003) which account for 70-80% of all personnel and R&D investments (Gokhberg 2003). More recently, however, foreign companies have been increasing their R&D in Russia to take advantage of the relatively low costs of scientists. The share of foreign funding in Russian R&D has increased from 2% in 1994 to nearly 10% in 2006 (Dahlman 2009).

Specific energy innovation policies are limited in Russia. In particular, Russia's innovation system lacks adequate legal forms for investment funds, small innovative companies and entrepreneurs (Dezhina 2010). Recently, a State Policy Guidelines for Promoting Renewable Energy in the Power Sector has been accepted, which includes strategic planning, regulation and improvement of monitoring energy RD&D (IEA 2010c). Furthermore, Russia has established building codes and energy audits for buildings and in 2006 it established jointly with UNESCO an International Centre of Sustainable Energy Development, which attempts to play a central role in providing research, technical expertise, dissemination of information and develop institutional and organizational capacity.

Table 6 and Table 7 show the number of institutions and policies that impact the R&D, demonstration and deployment stage of ETI and the different functions of innovation. The tables show that Russia's Federal energy innovation policies have mainly supported the deployment of energy efficient technologies through standards, codes and long-term targets for energy efficiency, however there is only one specific program focused on promoting the supply of energy efficient appliances (a program stimulating district heating efficiency). Furthermore, the federal government has policies to deploy innovative nuclear reactor designs and it significantly supports the development of new knowledge on nuclear energy technologies.

Table 6. Number of Russian governmental policies and institutions affecting stages and actors in the innovation process within each of the energy technology categories.

Russia	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	0	0	0	0	0	0	0	0	1	0	0	0
NE	18	1	2	0	0	1	0	0	4	1	0	0
RE	1	1	1	0	0	0	0	0	4	4	1	1
EE	2	1	1	0	0	0	1	0	1	7	1	0
TDS	0	0	1	0	0	0	0	0	0	0	0	0
GE	1	0	1	0	0	0	0	0	0	0	0	1

Table 7. Number of Russian governmental policies and institutions affecting functions in the innovation process within each of the energy technology categories.

Russia	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	0	0	0	0	0	1	0
NE	18	0	0	0	3	3	0
RE	2	1	1	1	3	5	4
EE	2	1	1	0	1	4	3
TDS	0	0	0	0	1	0	0
GE	0	0	0	0	0	0	0

3.4. India

A large number of governmental bodies is involved in administrating and developing India's energy policy, in conducting and allocating RD&D and in developing and managing ETIPs and ETIIs. Their subsequent roles will be discussed in each of three sections below.

Administrative entities and procedures

The Planning Commission is the central institution, which formulates India's Five-Year Plans. In its 11th Five-Year Plan it provides recommendations for improvements in energy efficiency, auditing, labeling standards and procurement policies. Furthermore, it proposes a number of R&D initiatives and policies to establish National Innovation Policies (Planning Commission 2008a).

The planning commission also developed an "Integrated Energy Policy," which calls for three approaches for energy R&D: 1) technology development missions that require coordinated R&D of all stages of the innovation chain to reach a targeted goals; 2) technology roll out mission to develop and roll out commercial or near commercial technology; 3) broad based R&D support to research institutions, universities and project funding (Planning Commission 2006).

India's government has also developed a "National Action Plan on Climate Change", which was published in 2008 by the Prime Minister's Council on Climate Change (Prime Minister's Council on Climate Change 2008). In this report, improved energy technologies feature in four of the eight national missions (Shukla 2009):

1. Solar energy (100 MW PV/yr; 1000 MW Thermal by 2017)
2. Enhanced energy efficiency (1000 MW saving by 2012)
3. Water sector (20% water use efficiency improvement)
4. Strategic knowledge for climate change

Finally, a Group on Climate Change Adaptation will be established which cuts across departments in two ministries and has the task to proactively prepare for providing technology required to comprehensively address issues related to climate change (Sibal 2008).

The executing of India's energy policy and energy RD&D activities takes place in five different ministries: (1) Ministry of Power (MOP); (2) Ministry of Coal (MOC); (3) Ministry of Petroleum and Natural Gas (MPNG); (4) Ministry of New and Renewable Energy (MNRE); and (5) Department of Atomic Energy (DAE). Furthermore, the Ministry of Science and Technology (MST) runs R&D programs through the Department of Science and Technology (DST) and the Department of Scientific and Industrial Research (DSIR).

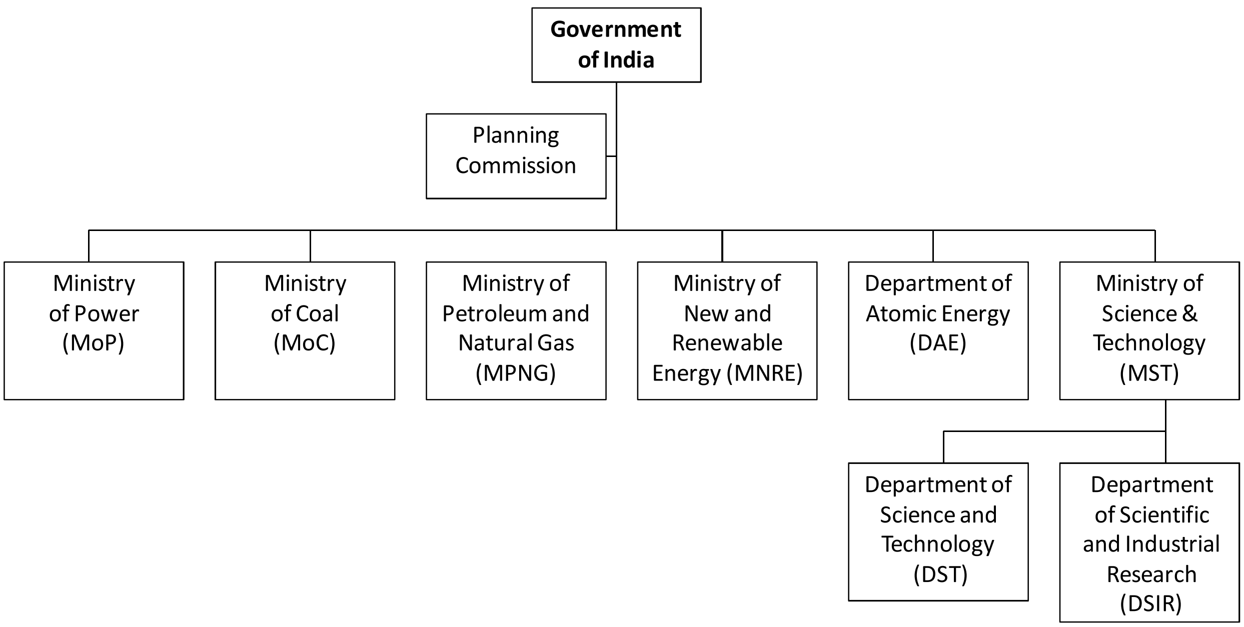

Figure 2. Energy policy administration in India's energy sector.

RD&D allocation

The allocation of energy RD&D is complicated, because of the different layers within the government. The Planning Commission proposes R&D initiatives, but the ministries and departments have to execute the allocation. Furthermore, the ministries and departments include both organizations responsible for allocating energy RD&D funds as well as organizations that receive energy RD&D funds. For example, MPNG includes both the Oil Industry Development Board (OIDB) and the Centre for High Technology (CHT). Within MPNG, the OIDB is responsible for the allocation of research grants to CHT.

To avoid duplication, this section will only discuss the organizations' role in allocating energy RD&D investments, while the next section will focus on national institutions and policies that conduct or affect energy RD&D activities. The guidelines for energy RD&D allocation come from the Planning Commission, which proposes new R&D initiatives within the 11th Five-Year Plan (see Table 8). These proposed budgets were not incorporated into the overview presented in Table 8.

Table 8. Proposed R&D Initiatives in the 11th Five-Year Plan (2007-2012) (Planning Commission 2008b).

S. No	Items	Amounts Projected (in Rs Crore)	Percentage
1	Development and production of new material	400	7.5%
2	R&D in biofuels	200	3.8%
3	Combustion research initiative	200	3.8%
4	Energy R&D in India railways	45	0.8%
5	Hydrogen as a source of clean energy	350	6.6%
6	Advanced coal technologies		
	(i) Setting up of first 100 MWe IGCC demonstration plant	350	6.6%
	(ii) In situ coal gasification of coal and lignite	30	0.6%
	(iii) Coal to oil conversion	200	3.8%
	(iv) Coal bed methane	35	0.7%
	(v) Carbon capture and storage (incl. climate change issues)	125	2.4%
7	Ultra supercritical technologies	30	0.6%
8	Energy storage systems	400	7.5%
9	Futuristic energy sources		
	(i) Gas hydrate	350	6.6%
	(ii) Oil shale	15	0.3%
10	Energy efficiency	205	3.9%
11	Technologically important crystals - facilitate to manufacture polysilicon for production of single crystals of silicon	1200	22.6%
12	Light-emitting diodes (LEDs) - a viable alternative to fluorescent lighting	1000	18.8%
13	Evs and hybrid electric vehicles - viable alternate propulsion systems	175	3.3%
	Grand total	5310	100% *

* Due to rounding issues, the percentages do not exactly add up to 100%

In this proposal, there is an almost even distribution of funds among the technology categories of fossil fuels, energy efficiency, renewable energy, and transmission, distribution, and storage. Each of those categories would receive between 21% and 26% of the funding. Most striking is that 85% of the funding for renewable energy R&D would be directed towards the development of solar PV manufacturing technology, and 70% of the budget for energy efficiency R&D would be directed towards the development of light emitting diodes (LEDs). Furthermore, it should be noted that this proposed budget does not include any specific projects focused on nuclear energy.

MOC's R&D budget is currently administered through an Apex body: the Standing Scientific Research Committee (SSRC) of the Ministry of Coal with its Secretary (Coal) as its Chairman. This body also includes directors of state-owned coal companies, the Central Mine Planning & Design Institute, the Directors of the Council for Scientific and Industrial Research (CSIR) laboratories, representatives of the Department of Science and Technology, the Planning Commission, and 35 educational institutions amongst others. The main functions of the SSRC are to plan, program, budget, and oversee the implementations of research projects and to seek application of the findings of the R&D work done. The Central Mine Planning and Design Institute (CMPDI), the research organization of the largest state-owned coal company called Coal India Ltd. (CIL), also provides an administrative task by coordinating the research activities in the coal sector (Sagar 2002).

MPNG has several institutional organizations that deal with R&D, however the Oil Industry Development Board (OIDB) is most important in the allocation energy RD&D budgets. They provide loans and grants for R&D projects to state-owned enterprises and research centers and approve other energy R&D projects as well.

MOP runs the Central Power Research Institute (CPRI), a national level lab that conducts R&D activities including infrastructure improvements, solving operational problems of the network, developing new materials for transmission, power system planning, and reliability improvements and support for technology development. However, it also administers R&D funds for activities in utilities and other R&D programs.

MNRE allocates RD&D funds to seven different programs: (1) Solar Energy Programme; (2) Biogas Programme; (3) Wind Energy Programme; (4) Biomass Programme; (5) Others Sources of Energy; (6) Small Hydel Programme; and (7) National Institute of Renewable Energy. The majority of the R&D allocation went to the Biogas and Biomass programs (70%) and the wind program (23%). Furthermore, MNRE runs a Research, Design, Development and Demonstration (RDD&D) and Manufacturing program, which is governed by the RDD&D Project Appraisal Committee (RDPAC), the RDD&D Sectoral Project Appraisal Committee (RDSPAC) and the Technology Demonstration Project Appraisal Committee (TDPAC). The RDD&D program financially support R&D projects in different institutions across the country, provides guidelines and direction and focuses on projects that lead to the manufacturing of complete energy systems (MNRE 2009). The Ministry is also home to the New Technology Group, which each year promotes R&D and demonstration projects in different energy areas (NTC 2009).

Nuclear energy R&D takes place at DAE and DSIR. Within DAE, the Atomic Energy Commission and the Strategic Planning Group provide input into the allocation of energy R&D.

Table 9. Energy RD&D funding by government and others for different energy technologies between 2000 and 2008.

India Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government	53	58	72	224	146	96	307	186	106
	other			1	3320	2389	1564	559	1378	694
nuclear energy (incl. fusion)	government	207	289	298	296	295	738	866	987	965
	other									
renewable energy sources	government	38	52	43	43	38	18	31	45	57
	other									
energy-efficiency	government									
	other									
transmission, distribution & storage	government	12	12	19	8	11	12	27	30	35
	other									
energy technologies (unspecified)	government									
	other									
total	**government**	**311**	**410**	**431**	**570**	**491**	**865**	**1231**	**1248**	**1163**
	other			**1**	**3320**	**2389**	**1564**	**559**	**1378**	**694**

ETIIs and ETIPs

Similar to the allocation of energy RD&D resources, the planning commission provides guidelines and proposes initiatives for energy RDD&D, while the ministries and departments are each responsible for their own research institutes and their own state-owned enterprises. Furthermore, the ministries and departments include organizations and boards running demonstration and deployment programs for energy technologies.

In the 11th Five-Year Plan, the planning commission proposed improvements in the efficiency of the electricity system through the Accelerated Power Development and Reform Programme (APDRP) and placed rural electrification as highest priority. Furthermore, they mentioned that auditing, benchmarking, labeling, standards and changes in procurement policies are required to improve energy-efficiency and clean coal, in-situ gasification, solar PV and solar thermal, cellulosic extractions of ethanol and yield improvements for bioenergy crops are R&D priorities. In terms of innovation policy, the 11th Five-Year Plan calls for the establishment of a National Innovation Policy which includes the promotion of basic sciences, mega science projects, cross-disciplinary technology areas, strengthening academia-industry interface including public-private partnerships and science and technology for small and medium enterprises. In its overall strategy, nuclear research remains one of the top priorities.

The 2006 Integrated Energy Policy recommendations were: (1) The creation of a National Energy Fund (NEF) to finance energy R&D; (2) The establishment of an independent board of government officials and outside experts to govern NEF and fund energy research consortia; (3) The proposal of a mandate for energy companies to spend 0.4% of their turnover on R&D; and (5) The creation of initiatives to increase efficiency, seeking substitutes to fossil fuels, shift to efficient transport modes, augmenting domestic energy resources and adopt a leading commercial low carbon technology to extract and use coal. Furthermore, it suggested that India's energy and carbon path between 2005-2050 consist of annual improvements in energy intensity (3.14%), carbon intensity (3.07%) and decarbonization of energy (-0.07%). Finally, the Integrated Energy Policy projects that direct investments in energy projects to be US$ 1.2 trillion for 2010-2030 and US$ 2.3 trillion for 2030-2050, from which 75% will go to energy infrastructure (distribution, transmission and power) and 25% to coal, oil and gas.

The actual R&D activities of MOC occur in the research organizations of the state-owned enterprises. CMPDI, the research organization of Coal India Ltd. (CIL), plays a central role, but several other CIL subsidiaries and R&D organizations of other state-owned enterprises, for example Neyveli Lignite Corporation (NLC) and Singrauli Collieries Company Ltd, have R&D activities as well. (Sagar 2002).

Besides MOP's role in RD&D allocation, it also controls two other bodies of interest to energy innovation: (1) National Power Training Institute (NPTI) and (2) the Bureau of Energy Efficiency (BEE). NPTI is the designated autonomous institute for training. BEE, established under the Energy Conservation Act in 2001, runs the Standards & Labeling program, the accreditation of energy auditors, the national energy conservation awards and the national awareness campaign on energy conservation. Furthermore, the Central Electricity Authority (CEA) has established a Chair at IIT, Delhi to which the officers of the MOP (since extended to officers of NPTI and CPRI) and CEA are appointed to executive education programs to keep their base of knowledge and skills up to date. Furthermore, there are several state-owned electricity companies (such as NHPC Ltd., NTPC Ltd., and NEEPCO Ltd), which have also individual R&D budgets on transmission, distribution and storage projects. While most state-owned manufacturers of electrical systems and equipments largely depend on the R&D of international organizations, Bharat Heavy Electricals Ltd. (BHEL) has an R&D department of their own.

MPNG has three important institutions for energy R&D. Besides OIDB's role in allocating energy R&D budgets as discussed in the previous section, OIDB also runs two energy R&D programs: the National Gas Hydrate Programme (NGHP) maps gas hydrates as a future alternative energy sources and the Hydrogen Corpus Fund (HCF) establishes hydrogen as a future energy source for the transport sector. The Centre for High Technology (CHT), coordinates and funds research work in refining and marketing areas, and coordinates the exchange of information and technology assessments. The Petroleum Conservation Research Association (PCRA) conducts energy studies, R&D, awareness and education programs and provides soft loan schemes to help improve energy efficiency in transport, industry, agriculture, and households. Furthermore, the Ministry has set up the Rajiv Gandhi Institute of Petroleum Technology (RGIPT) to establish a single training and education institution that can render expert training to the petroleum industry. State-owned companies that have independent R&D programs are: Oil India Ltd., Gail India Ltd., Hindustan Petroleum Ltd., and ONGC Ltd.

MNRE combines its RD&D support for its renewable energy programs with a host of different ETIPs and ETIIs. The "Biogas Programme" includes support for popularization of family type plants and R&D in biogas, while the "Biomass Programme" promotes biomass conversion and utilization. The "Wind Programme" includes support for demonstration projects, R&D and provision for Center for Wind Energy Technology (CWET). Other support mechanisms include the Solar Energy Centre (SEC) for the "Solar energy" and "Solar thermal Programme" and support for feasibility studies, detailed reports and subsidies in the "Small Hydel Programme". Besides CWET and SEC, MNRE has a third technical specialized institutions for renewable energy called the "Sardar Swaran Singh National Institute for Renewable Energy" (SSS-NIRE). Finally, the Indian Cabinet approved MNRE plans for the "Jawaharlal Nehru National Solar Mission," aiming to install capacity of 20,000 MW by 2022 (Deshmukh, Gambhir et al. 2010). The Mission includes a focused R&D program to address India-specific challenges in solar energy, overseen by a Solar Research Council. The estimated cost is Rs 4,337 crores ($933m) (Anonymous 2009).[13] Furthermore, since 1987 Indian Renewable Energy Development Agency (IREDA), a 100% government owned company, promotes and develops new renewable sources of energy through loans for wind, hydro, biomass, solar and energy efficiency projects.

India's "Nuclear Power Programme" took off in the sixties and aims to install 20 GWe of nuclear power capacity by 2020. The program consists of three stages, each based on different technology developments. The first stage comprises setting up technological capabilities for Pressurized Heavy Water Reactors (PHWRs), the second stage envisages setting up Fast Breeder Reactors (FBRs) and the third stage is based on the thorium-uranium-233 cycle (Government of India 2010). DAE runs two large research institutes that support these different technological development stages: (1) The Bhabha Atomic Research Centre (BARC); and (2) the Indira Gandhi Centre for Atomic Research (IGCAR). BARC is the largest center and it pursues R&D programs in the fields of nuclear sciences, engineering & technology. BARC focuses on applications of nuclear energy in power generation, agriculture, health care and industry. IGCAR mainly supports stage 2 of the "Nuclear Power Programme" and is engaged in design and development of liquid sodium cooled fast breeder reactors in the country.

DSIR and DST run R&D programs in engineering, chemistry, physics, mathematics, earth and atmospheric sciences and life sciences, but no specific program is dedicated to energy. For example, the Council for Scientific and Industrial Research (CSIR) runs laboratories like the Central Fuel Research Institute (CFRI), Central Mining Research Institute (CRMI) and the Indian Institute of Chemical Technology (IICT) that perform energy RD&D related activities (Sagar 2002). Furthermore, several research institutes in molecule, material science and technology forecasting are useful for energy research. DST (along with DAE) funds India's participation at the collider at CERN. A National Energy Fund, called for in the 2006 Integrated Energy Policy and governed by DST, has not yet been established.

[13] It is unclear over what time period this cost is reported for.

Although none of the recommendations of the planning commission have been installed yet, this overview shows that there are a large range of ETIIs and ETIPs in each of the different ministries and departments. Table 10 shows the number of institutions and policies that impact the R&D, demonstration and deployment stage of ETI. Most policies focus on either providing information on energy efficiency, awareness and labeling programs or financial support for renewable energy projects through subsidies and feed-in tariffs. Furthermore, there are a large number of policies and institutions that provide incentives for renewable energy R&D (through funding) and renewable energy demonstration projects (through loans, credits and other incentives). Table 10 and Table 11 also show that the Indian government provides a large number of policies and institutions to support the development of knowledge through research centers and R&D budgets.

Table 10. Number of Indian governmental institutions and policies affecting stages and actors in the innovation process within each of the energy technology categories.

India	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	8	4	0	0	3	0	2	0	5	1	2	1
NE	3	0	1	0	1	0	1	0	3	0	1	0
RE	8	0	0	0	4	0	1	0	13	6	3	1
EE	1	2	0	0	3	1	0	0	2	2	6	5
TDS	5	2	0	0	0	0	0	0	1	2	0	2
GE	0	1	1	0	0	0	0	0	0	1	1	0

Table 11. Number of Indian governmental institutions and policies affecting functions of the innovation process within each of the energy technology categories.

India	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	10	1	1	1	0	0	0
NE	3	0	0	0	1	1	0
RE	8	2	5	1	2	2	7
EE	1	2	1	0	1	4	4
TDS	4	1	0	1	1	1	2
GE	0	1	0	0	1	1	0

3.5. Mexico

Administrative entities and procedures

The Ministry of Energy (SENER) is responsible for the country's energy policy, including the planning of sector development and applying the regulatory framework. Since 2001, these six-year Sectoral Energy Programs define the main objectives of the energy sector and align it with the National Development plan. Currently, Mexico has the following plans and programs related to the energy sector (OECD 2009):

- National Development Plan 2007-2012 (Plan Nacional de Desarrollo, PND)
- Sectoral Energy Program 2007-2012 (Programa Sectorial de Energía, PSE)
- National Program of Infrastructure 2007-2012 (Programa Nacional de Infraestructura, PNI)
- Special Program for Science, Technology and Innovation 2008-2012 (Programa Especial de Ciencia, Tecnología e Innovación, PECiTI)

The main impact of these plans and programs on ETI are summarized below:

Table 12. Overview of Mexico's energy policies and implications for energy innovation.

Program	**PND**	**PSE**	**PNI**	**PECiTI**
Description	Energy infrastructure, efficient energy use and diversity are primary strategies to tackle poverty	Save 43 TWh through energy efficiency, increase renewable electricity sources from 23.6 to 26% and avoid 28 mln tns of CO2 emissions	Includes 200 infrastructure projects representing $141 bln investments through public-private partnerships with $76 bln for oil and gas production	Aims to strengthen the links between science, technology and innovation and set up the new sectoral funds for energy R&D

Besides SENER, an Interministerial Commission on Climate Change was established in 2007 to develop a National Strategy on Climate Change (NSCC) (ICCC 2007). As part of the NSCC, a new "Law for the Better Use of Renewable Energy and the Financing of Energetic Transition" was passed. This law opens the door to private investment in the generation of electricity derived from renewable energy. Furthermore, an Energy Reform was approved in Oct. 2008 which includes a new Law for the Sustainable use of Energy, which promotes better use of renewable sources of energy and sustainable use of energy. Furthermore, it created the National Commission for the Efficient Use of Energy (CONUEE), which is discussed in more detail below.

RD&D allocation

Two organizations are central to energy RD&D allocation: the Ministry of Energy (SENER) and the National Council on Science and Technology (CONACYT).

SENER allocates almost its entire S&T budget to finance the public research centers under its responsibility (OECD 2009):

- The Electrical Research Institute (IIE) ~ founded 1975
- Mexican Institute of Petroleum (IMP) ~ founded in 1965
- Research Institute for Nuclear Research (ININ)

CONACYT has three sectoral funds for energy research with and funds postgraduate research and regional centers. Two of these funds are administered together with SENER, while the third is administered together with the Federal Electricity Commission (CFE). The allocation of research funds to these three sectoral funds is as follows (CONACYT 2010a):

- SENER– Energy Sustainability (19%);
- SENER Sectoral fund – Hydrocarbons (29%);
- CFE - Research and Technological Development in Energy (52%).

Figure 3 shows the relationship between CONACYT, SENER and PEMEX in the sectoral fund for Hydrocarbons. The sectoral fund consist of RD&D grants for research projects as well as initiatives to create human capital

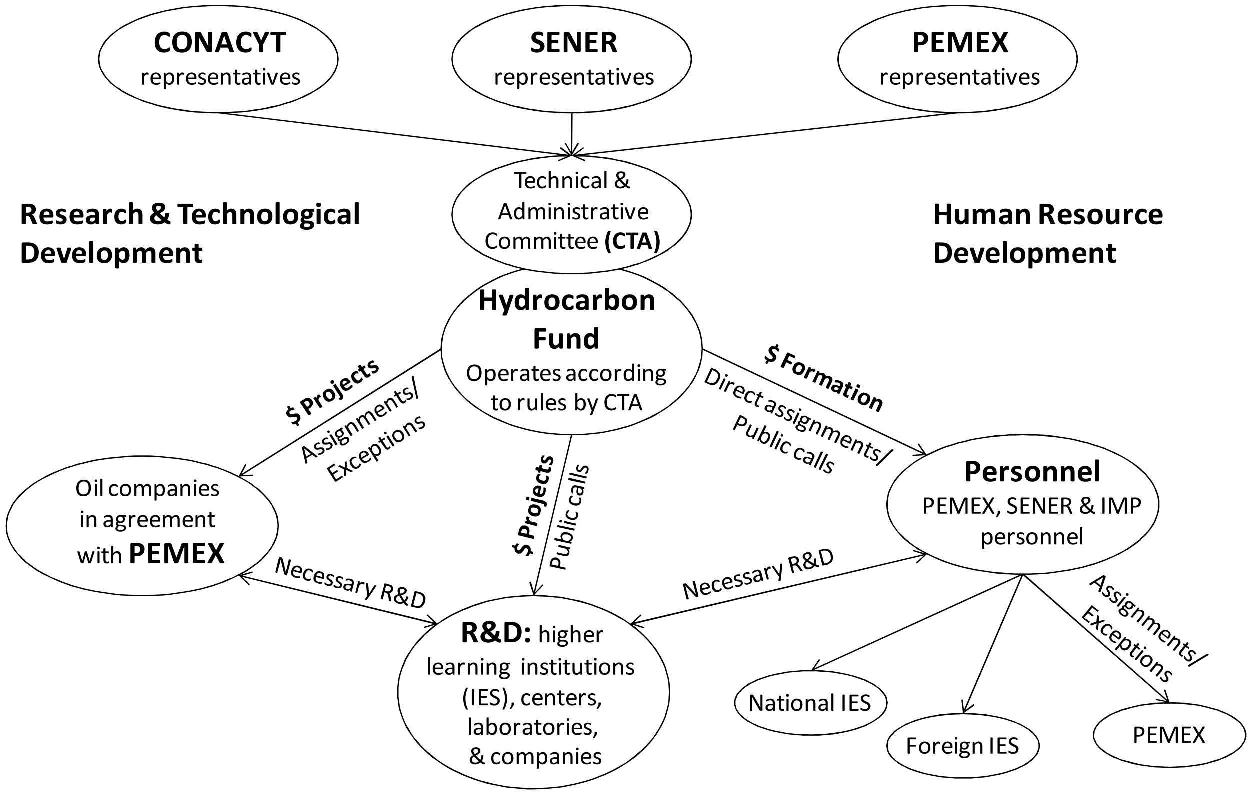

Figure 3. Schematic overview of the relationships between CONACYT, SENER, PEMEX and research institutions within CONACYT's sectoral Fund SENER-Hydrocarbons (CONACYT 2010b).

Part of the funding for these programs comes from PEMEX's duty for the "Fund for Scientific and Technological Research on Energy," which is based on a percentage of the total value of the crude oil and natural gas produced in the year (0.15% in 2008, 0.05% in 2006/07). 55 % of the funds raised by PEMEX goes to SENER-Hydrocarbons, 35% to CFE-R&D in energy and 10% to SENER- Energy Sustainability. Furthermore, it provides the funding for IMP (Pemex 2008).

Table 13. Energy RD&D funding in Mexico by government and others for different energy technologies between 2000 and 2008.

Mexico Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government	230	183	203	218	97	78	62	140	
	other							0.1	0.1	0.2
nuclear energy (incl. fusion)	government	54	45	40	22	33	35	33	32	
	other									
renewable energy sources	government									
	other									
energy-efficiency	government									
	other	213	0	662	566	219	263			
transmission, distribution & storage	government	55	56	83	74	79	82	73	79	
	other									
energy technologies (unspecified)	government									
	other	26	24	21	23	18	19			
total	**government**	**339**	**284**	**326**	**314**	**209**	**194**	**167**	**252**	
	other	**239**	**24**	**684**	**589**	**237**	**282**			

ETIIs and ETIPs

In Mexico energy extraction, generation, and transportation (transmission & distribution) is by law restricted to the state. [14] PEMEX is Mexico's state-owned oil company, while the Federal Electricity Commission (CFE) generates, distributes and sells electricity to Mexico City and the rest of Mexico. [15] Although generation of electricity is state-owned, 22% of the installed capacity comes from plants that were built in partnership with the private sector through so-called "independent producers."

The central role of the government in Mexico's energy system is reflected in its energy RDD&D activities. The Mexican Institute of Petroleum (IMP), the Electric Research Institute (IIE) and the National Institute of Nuclear Research (ININ) are the main research institutes in Mexico. [16] IMP is directly associated with PEMEX and its research programs include basic research and industrial applications in areas including securing hydrocarbons production, production of deep water oil fields, molecular engineering, pipe integrity, applied mathematics and computation, processes of transformation and hydrocarbon recovery. IIE and ININ are research institutes associated with CFE. IIE serves also as R&D contractor to other users of power-related technology (e.g. transformer producers), although CFE dominates as "client." Public research and technological development in the electricity sector is primarily achieved through the IIE, which operates under four main technical areas:

- Energy sources (including geothermal, nuclear energy and non-conventional energy)
- Control systems (including simulations, information systems and processes supervision)
- Electric system (including power network analysis, electric equipment and transmission and distribution)
- Mechanical systems (including civil engineering and materials, chemical and thermal processes).

The National Commission for Energy Efficiency (CONUEE) is a decentralized administrative agency of SENER, with technical and operative autonomy. CONUEEE was created after the enforcement of the "Law for Sustainable Use of Energy" (LAFRE) in Nov. 2008, and includes the previous National Commission for Energy Saving (CONAE) (Tudela 2009). Besides the provision of information, CONUEE sets the Official Mexican Standards for Energy Efficiency (NOM-ENER), certifies bodies, verifies accreditation and is responsible for energy labeling. Furthermore, CONUEE is home to the Advisory Council for Renewable Energy Development (COFER), which analyzes the implementation of renewable energy projects and identifies, promotes and coordinates opportunities, mechanism, conditions and funding sources for renewable energy projects and consults to organizations like the Mexican Solar Association (ASES) (Huacuz 2005).

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[14] The Energy Regulatory Commission (CRE) is since 1995 an autonomous institution in charge of regulating natural gas and electricity. It grants permits to foreign-based energy producers, approves frameworks of contracts and also provides the methodologies used to calculated the prices received by private sector energy suppliers. The Law for the Public Supply of Electricity (LSPEE) regulates the electricity supply in Mexico; the law forbids free trade of energy between individuals and it requires generating permits from CRE for companies that generate energy through co-generation or for self-supply.

[15] Until November 2009, the state-owned company Luz y Fuerza del Centro supplied electricity to Mexico City, but because of excessive spending allegations it has been placed under the control of CFE.

[16] Besides these three institutes, there are two large public university systems that contribute to energy RD&D: the National Autonomous University of Mexico (UNAM) through its engineering institute (Instituto de Ingeniería) and the National Polytechnic Institute of Mexico (IPN) through its Research and Advanced Studies Center (CINVESTAV).

Another organization that is concerned with the introduction of renewable energy projects is the Mexican Council for Municipal Infrastructure (COMIA), which is an advisory board for SENER and the Ministry for the Environment and Natural Resources (SEMARNAT) on energy supply in municipalities (ESMAP 2006).

In the same year that the Sustainable Use of Energy Law was passed, Mexico also approved the Renewable Energy Development and Financing for Energy Transition Law (LAERFTE).[17] The aim of LAERFTE is the development of a renewable energy program that regulates the usage of renewable energy sources to generate electricity, however the exact mechanisms to be introduced or the objectives with which to regulate electricity generation remain unclear (Ruiz-Mendoza and Sheinbaum-Pardo 2010).

Table 14 and Table 15 provide an overview of how different Mexican policies and institutions impact ETI. Most policies are clustered around measures to support the deployment of and increase the demand for renewable energy and energy efficiency. For example, LAFRE has introduced a framework to introduce minimum of 8% of renewables into the electricity system, the "Renewable Energy Initiative" is a large procurement policies for renewable energy technologies and the government provides fiscal credits up to 30% of investments (Ruiz-Mendoza and Sheinbaum-Pardo 2010). Furthermore, in 2008 Mexico has established the "Biofuels Law", which develops an independent legal framework for biofuels and allows private entities to enter the biofuels market and work alongside PEMEX and the state-owned gas sector (Felix 2008).

This overview also shows that there is a substantial amount of policies and institutions providing support for the deployment of new energy technologies. For example, SENER has published the National Development Plan, the Sectoral Energy Plan, the National Program of Infrastructure and the Special Program for Science, Technology and Innovation, which all provide incentives and policy support for deployment. Furthermore, there exists policy support provided by the Interministerial Committee on Climate Change and by the Energy Savings Program (PAESE) of CFE to promotes the acceleration of construction and entrance of electric power systems.

Table 14. Number of Mexican governmental policies and institutions affecting stages and actors in the innovation process within each of the energy technology categories.

Mexico	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	3	0	0	0	0	0	0	0	0	1	0	0
NE	1	1	0	0	0	0	0	0	1	0	0	0
RE	2	1	0	0	0	1	1	0	6	6	2	0
EE	0	0	0	0	0	0	0	0	1	7	4	2
TDS	1	0	0	0	0	0	0	0	0	1	0	0
GE	0	0	0	0	0	0	0	0	0	0	0	0

[17] A second renewable electricity bill called the Mexican Renewable Energy Sources Bill proposed to generate 8% of Mexico's gross electricity generation from renewable energy sources, but was rejected.

Table 15. Number of Mexican governmental policies and institutions affecting functions in the innovation process within each of the energy technology categories.

Mexico	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	3	1	0	0	0	1	0
NE	1	0	0	0	0	1	0
RE	2	1	0	0	2	4	8
EE	1	1	1	0	0	4	1
TDS	1	1	0	0	0	0	0
GE	0	0	1	0	2	2	0

3.6. China

Administrative entities and procedures

The National Energy Commission (NEC) is the top administrative authority in China for energy deployment (Gao 2010). The National Reform and Development Commission (NDRC) established the idea for a NEC in 2008, but it took until January 2010 before it was established to replace the National Energy Leading Group. The NEC is chaired by the Premier and its General Office is concurrently run by the Director of NDRC. Furthermore, NEC is established directly under the State Council and not within the Central Committee of the party indicating the rise of power of the government and the importance of energy (Bo 2010). The 21 members of NEC consist of Ministers from central government departments (Science & Technology, Industry and Information, Finance, Land and Resources, Environmental Protection, Communication & Transport, Water Resources, Commerce and State Security) and representatives of regulators and military. NEC is responsible for the investment of large energy production projects, energy prices, commercialization of RD&D, and international cooperation.

The General Office of NEC is supported by the State's Energy Administration (NEA), which is housed within NDRC. NEA has replaced NDRC's energy bureau and it includes the Office of the National Energy Leading Group and the nuclear power administration COSTIND. NEA handles NEC's daily affairs and its responsibilities include managing the energy sector, drafting energy policies, negotiating with international energy agencies, and approving foreign direct investments. According to Downs, the NEA is almost certainly a transitional institution in place until the discussion around the establishment of a Ministry of Energy (opposed by the NDRC and the state-owned companies) are resolved (Downs 2008).

Although NEC has only been established recently, China has centrally planned energy policies through its Five-Year Plans by NDRC (which since 2003 includes the Energy Research Institute (ERI)). Although the 11th Five-Year Plan does not contain a chapter dedicated to energy specifically (NDRC 2006), the Chinese government did released a "11th Five-Year Plan for Energy Development" in 2007 (Hu 2007). The plan calls for the construction of energy bases in coal, oil and gas and for the development of a nuclear power base through high-temperature gas-cooled reactors, the development of transportation and storage facilities for coal and oil, the development of a coal-based bio-liquid based oil industry and the development of renewable and rural energy.

Besides the Five-Year Plans, NDRC also issued a "Medium and Long term National Planning of Renewable Development," which was ratified by the National Congress in 2007 (NDRC 2007; State Council 2007). According to these plans, the installation capacity of renewable energy generation is targeted to reach 15% of total energy consumption by 2020, of which hydro, wind, solar, and biomass generation should account for 300GW, 30GW, 1.8GW and 30GW respectively. More recently, China's national renewable energy targets are 1000 GW for wind, 20 GW for PV and 15% or more for total energy consumption. The targets for 2030, 2040 and 2050 are respectively 20%, 30% and 40% (Li 2009). Furthermore, four technology priorities were identified:

- Turbine design, blade design, bearing production technologies and equipment and special materials for wind energy
- Silicon manufacturing technologies with low emission and tin film production technologies for solar PV
- Non-food liquid fuel production technologies for bio-fuels
- R&D capability, such as national center and laboratory (Li 2009).

In 2007, China also released its "National Climate Change Program" outlining GHG mitigation and adaptation policies, which included goals to double renewable energy use by 2020, to displace coal-fired power production with nuclear, gas, and renewable energy sources and increase energy efficiency through standards and closure of inefficient industrial facilities. According to the NDRC, implementation of the Climate Change Program has reduced energy consumption per unit of GDP in China with 10.1% in 2008 (NDRC 2009).

The Chinese Academy of Sciences (CAS) and the Ministry of Science and Technology (MOST) have also political impact on energy innovation policy. CAS has recently released its China Sustainable Development Strategy Report, which calls for a 40~60% reduction of energy consumption per unit of GDP over 2005 levels in 2020 with large investments in energy efficient projects, speeding up the development in coal gasification and IGCC and diversifying the energy supply through renewables (Wang 2009). MOST affects energy innovation policies through its role in the development of international cooperation policies (MOST and NDRC 2007), patent law regulations, and the administration of China's science and technology programs.

Another important part of China's energy policy is its rural energy policy. Rural energy commercialization provides environmental benefits, which is in line with its state policy to shut down small coal mines, promote new energy developments and strengthen the reform of rural power grid and rural power administration (Peng and Pan 2006).

Energy policy is also influenced by the charitable foundation China Sustainable Energy Program (CSEP). Founded in 1999 and funded by international NGOs, its mission is to assist in China's transition to a sustainable energy future by promoting energy efficiency and renewable energy. CSEP is politically connected to the Ministers through their Advisory Council and Dialogue Partners. The program sets up regional demonstration projects, which if successful, can be developed into national policies and has as such, important impact on the development of the Renewable Energy Law and the Fuel Efficiency standards for cars.

RD&D allocation

China's energy innovation system is very complex. There are some overlaps among central government ministries, commissions and other administrations. The energy R&DD budget is allocated first by the Ministry of Finance to the Ministry of Science and Technology (MOST), NDRC, the National Natural Science Foundation of China (NSFC) and the Chinese Academy of Sciences (CAS). MOST, NDRC and NSFC will allocate their funds by their missions to research institutes (including national labs), higher education institutions and enterprises (all kinds of, not only state-owned). CAS has its own funds from the Ministry of Finance, and CAS can also get contract funds from MOST, NDRC and NSFC. NSFC mainly supports basic research. CAS mainly performs basic and applied research. MOST support RD&D through its four large R&D programs for basic research (called the “973 program”), pre-commercial high-tech projects with co-funding from enterprises (the “863 program”), industry technology developments and upgrading (the “National Key Technologies R&D Program”) and 16 major programs. Steering committees, which consist of experts from research institutes, universities and industrial enterprises, choose the technologies that are supported by these programs (Jiang 2010). NDRC has little money for RD&D. Major parts of their fund goes to deployment, demonstration and diffusion (Gao 2010). Enterprises will finance and perform energy R&DD according to their market strategy. Besides the national programs and support for industries, the Chinese government runs, since 1984, a State Key Laboratories program to support basic research (Jin, Dake et al. 2006). Several State Key Laboratories do energy technology related research, such as the laboratories for superconductivity, high energy materials information, nuclear analysis techniques, coal conversion, clean energy utilization, combustion of coal, and power systems and generation equipment. However, these State Key Laboratories only receive a small amount of direct funding from the government (~ 10%) and have to apply for funding for the majority of their research[18].

The overview in Table 16 is based on data provided by the China Statistical Yearbook on Science and Technology[19], which provides a yearly update of research and development expenditure in Chinese R&D institutions, industries, and institutions of higher education and per national R&D program (State Statistical Bureau 2009). The data on R&D expenditure in R&D institutions, funding of S&T activities in industry, and funding for S&T activities in higher education is further broken down by funding source (central or local government, self-raised, bank loans, or funds from overseas) and by industry. Furthermore, industry data is broken down into funding for energy-related S&T activities by state-owned enterprises and by “other” enterprises. In Table 16, funding for S&T activities by state-owned enterprises is categorized under government investments. Table 16 shows that, since 2004, government investments are increasing rapidly. Most of this growth takes place through increased R&D investments in state-owned enterprises operating in the following sectors: (1) mining and washing of coal; (2) extraction of petroleum and natural gas; (3) production and distribution of gas; (4) processing of petroleum, coking and nucleus fuels; (5) and, production and supply of electric power and heat power. Government funding for energy-related S&T activities in “other” enterprises in these industries actually declined over the same period. Furthermore, Table 16 shows that between 30-50% of China’s total energy RD&D funding takes place in the fossil energy sector. The overview also shows that, except for fossil energy, there is hardly any breakdown of the data for other energy technology categories. Except for some data on “new fuel vehicles” projects within the 863 program (Siegler 2009), some data on nuclear energy S&T activities in institutions of higher education, and some sporadic data points suggesting large R&D investments in the transmission network (Delman and Chen 2008), there is no systematic data on energy RD&D expenditure in any of the other energy technology categories except fossil energy.

[18] Personal communication, March 2010.
[19] We are indebted to Kelly Sims Gallagher for her help in locating and collecting this data.

Table 16. Energy RD&D funding in China by government and others for different energy technologies between 2000 and 2008

China Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government	1004	684	999	563	3499	3760	4586	5541	6755
	other	767	1101	1028	1873	40	55	46	105	289
nuclear energy (incl. fusion)	government		24	6	5	19	23	25	41	12
	other		17	4	3	14	16	18	27	7
renewable energy sources	government									
	other									
energy-efficiency	government		63	75	86	87	75	114	144	136
	other			4	3	17	15	12	6	26
transmission, distribution & storage	government									
	other									
energy technologies (unspecified)	government	1631	1140	913	976	2609	2637	3257	3320	4900
	other	554	845	780	938	745	575	704	725	985
total	**government**	**2634**	**1911**	**1992**	**1629**	**6214**	**6496**	**7983**	**9045**	**11803**
	other	**1321**	**1963**	**1816**	**2818**	**816**	**661**	**779**	**863**	**1307**

ETIIs and ETIPs

Energy RD&D takes place in universities, national research institutes on both national and provincial level and in state-owned and private enterprises. China's MOST actively supports energy RD&D in state-owned enterprises and the different national programs support energy RD&D in national institutes, universities and companies. National energy technology budgets are distributed among science programs, local governments and state-owned enterprises. For example, Gao (2006) identified eight R&D programs that contribute to energy R&D: the 973 and 863 programs, the National Program for Key S&T projects, the Torch program, the Spark program, the National S&T Results Dissemination program, the S&T program for social development and the National Natural Science foundation. In the 10th Five-Year Plan, the 863 program contained a 880 mln RMB program on fuel cells. In the 11th Five-Year Plan, there are R&D projects on enhanced oil recovery (36 mln RMB), carbon storage and sequestration (30 mln RMB), IGCC & co-production (350 mln RMB), fuel efficient and new fuel vehicles (1.1 bln RMB) and oxy-fuel combinations (Liu 2009; Zhang 2009; Chen and Xu 2010).[20]

China enacted its "Renewable Energy Law" early in 2005 and it entered into effect on 1 January 2006. This law mandates that 15% of all electricity is produced from renewable resources in 2020. Policies currently in place consist of financial, tax and price incentives policies for Wind Power generation (partly funded by a levy on electric power sales nation-wide), applications of PV solar in buildings, and the use of straw for energy and the implementation of renewable energy in buildings in rural areas (NDRC 2009). The law also authorized feed-in tariffs for wind and biomass. The law was updated in 2009 to include grid-related provisions, a provision to purchase all renewable power generated a strengthening of the Renewable Energy Fund (Martinot and Li 2010).

[20] In 2008, 1 bln RMB equates to 220 mln dollar (PPP) (World Bank 2009).

Box 1. China's data on energy R&D investments

The China Statistical Yearbook of Science and Technology provides an annual update of intramural expenditure on R&D for R&D institutions and funds for science and technology (S&T) activities in industries and institutions of higher education in China. The data is presented on the basis of R&D performing organizations (R&D institutions, enterprises, institutions of higher education, and others) and by national S&T programs (national basic research program, key technologies R&D program, basic S&T construction program and several innovation and industrialization programs). The data presented in Table 16 is based on R&D expenditure and funding for S&T activities by R&D performer.

The China Statistical Yearbook also reports energy R&D investments on the basis of China's national R&D programs. Table 17 provides China's energy R&D investments based on funding for energy S&T activities as reported by the national R&D program.

Table 17. Data on funding for energy-related S&T activities in China's national R&D programs.

in million 2008 PPP $Int.		2000	2001	2002	2003	2004	2005	2006	2007	2008
Energy activities in the Key Technologies R&D Program	government funds *	*no data*	*27*	*31*	*29*	*19*	*36*	*56*	*50*	*63*
	industry	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*
	total	*no data*	27	31	29	19	36	56	50	63
Energy Science in the National Basic Research Program	government funds *	*no data*	*28*	*24*	*31*	*28*	*30*	*27*	*44*	*44*
	industry	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*	*no data*
	total	*no data*	28	24	31	28	30	27	44	44
Promotion of Energy Generation, Distribution, and Rational Use in the "973" program	government funds	39.13	*no data*	48	49	31	47	3	83	74
	industry ^	2.41	*no data*	3	3	2	3	0	5	5
	total	41.54	*no data*	51	52	33	50	3	88	79
Promotion of Energy Generation, Distribution, and Rational Use in the "863" program	government funds	18.85	*no data*	136	215	162	173	51	264	305
	industry ^	25.50	*no data*	184	291	220	234	70	357	412
	total	44.34	*no data*	320	507	382	407	121	621	717
Promotion of Energy Generation, Distribution, and Rational Use in the Key Technologies program	government funds	50.70	*no data*	77	133	98	78	28	795	317
	industry ^	82.02	*no data*	124	214	158	126	45	1287	513
	total	132.72	*no data*	201	347	256	204	73	2082	829
New Energy and Energy Efficiency in the Torch program	government funds	*no data*	*no data*	29	37	27	6	21	293	25
	self-raised funds ^	*no data*	*no data*	505	847	1746	486	1046	15051	2186
	bank loans ^	242	*no data*	430	370	413	2501	996	9787	2602
	total	738	*no data*	965	1253	2185	2993	2062	25131	4813
Total	*government funds*	109	>> 54	345	495	364	370	186	1530	828
	industry	352	*no data*	1247	1725	2538	3350	2157	26488	5717
	total	460	>> 54	1592	2220	2903	3719	2343	28018	6545

* It is assumed that the Key Tecnologies R&D program and the National Basic Research Funding Program consist of 100% government funding, although the China Statistical Yearbook on Science and Technology does not provide a breakdown of the funding between government and industry.
^ The China Statistical Yearbook only provides data on the total funding within the "973", "863" and "Key Technologies program. Based on data by Su, Huang et al. (2010), we have assumed that respectively 94.2%, 42.5% and, 38.2% of the total funding comes from government and the rest from industry. Furthermore, we have assumed that this allocation is constant over the 2000-2008 period. Finally, we have assumed that all industry funding comes from non-state-owned enterprises.

A comparison of total funding in Table 16 and 17 shows that the total energy S&T expenditure through national programs ranges between 25% and 50% of the total R&D investments and S&T expenditure by R&D performers. In 2007, however, total S&T funding for 'New Energy and Efficient Energy Use' in the Torch program is 2.5 times larger than the total (government plus 'others') energy R&D expenditure by R&D institutions, enterprises, and institutions of higher education ($25.1 bln versus $9.9 bln). We are unsure how to interpret this large increase in energy-related S&T funding associated with the Torch program in 2007 and have not included this data in the overview table in section 4.

In 2009, the NDRC provided an overview with progress on its climate change strategy, which among others, includes China's National Climate Change Strategy. Other policies that indirectly promote energy innovation are "The Opinions on Implementing the Policies and Measures for Accelerating the Development of the Service Industry" by the State Council, which actively phases out backward production capacities, and enhances technological levels and energy conservation in 10 major industries (NDRC 2009). Furthermore, China formulated a stimulus package with 370 bln RMB for technology renovation and adjustment in the energy-intensive industrial sectors. Furthermore, the NDRC issued the "Notice on Implementing Pilot Projects of Car Component Manufacturing" with 57.1 mln RMB to increase the technological standards for car components (NDRC 2009). This policy augments the "Fuel Efficient and New Fuel Vehicle Project" under the 863 program, which consists of 1.1 bln RMB of science and technology funding for the 2006-2010 period (Zhang 2009).

Furthermore, the amended "Energy Conservation Law" came into effect in 2008, which includes heightened liabilities, administration and supervision of energy efficiency standards in civil buildings and public institutions. It also contains increased mandatory energy efficiency standards and mandatory labeling for end-use products and the energy-intensity of production. Furthermore, NDRC has organized together with the Ministry of Finance financial subsidies for energy efficient products, including subsidies for demonstration and promotion of energy-efficient and new vehicles (NDRC 2009).

Finally, China has established a large number of institutes that coordinate and are involved in nuclear energy R&D. The Chinese National Nuclear Corporation (CNNC) manages China's nuclear efforts (including planning, procurement, operations and R&D). CNNC includes four key national labs and the Chinese Institute of Atomic Energy (CIAE), which is the main research organization of CNNC (NTI 2010).

Table 18 provides an overview of currently existing institutions and regulations that have a direct impact on R&D, demonstration and deployment of energy technologies within the China. The table shows that there are 20 different regulations and/or institutions that impact on those actors that supply renewable energy technologies to the market (for example, renewable energy companies can receive low interest loans and tax incentives from the "3-Self Program" (Tong 2009), can receive loans from the "Program on New and Renewable Energy Development" (Chang, Leung et al. 2003) and can benefit from feed-in tariffs through "Interim Management Measures for Renewable Power Tariff and Cost allocation" (REN21 2009)). Furthermore, Table 18 and Table 19 show that China has a large number of policies that promote the creation of knowledge, especially for nuclear energy and fossil energy. Furthermore, international agreements play an important role in supporting the diffusion of knowledge on these energy technologies into China.

Table 18. Number of Chinese governmental policies and institutions affecting stages and actors in the innovation process within each of the energy technology categories.

China	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	8	5	1	0	11	3	10	0	13	4	4	0
NE	5	3	0	0	3	1	3	0	3	1	0	0
RE	2	2	0	0	1	1	0	0	20	7	2	2
EE	1	0	0	0	0	0	0	0	3	5	13	2
TDS	3	0	0	0	0	0	0	0	2	1	0	0
GE	4	0	6	0	1	0	0	0	0	0	0	0

Table 19. Number of Chinese governmental policies and institutions affecting functions in the innovation process within each of the energy technology categories.

China	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	8	7	0	0	0	0	2
NE	5	3	0	0	1	4	0
RE	3	1	3	0	1	6	14
EE	1	2	0	0	1	6	7
TDS	3	0	0	0	0	0	0
GE	5	1	1	0	7	3	0

3.7. South Africa

Administrative entities and procedures

South Africa's energy policy is the responsibility of the Department of Energy (DOE), which split up from the Department of Mines and Energy (DME) in 2009. DOE executes the National Energy Act (Act 52 of 2008), which was established by DME in 2008 and which primarily focuses on accelerating the uptake of sustainable energy projects through selective state interventions. Furthermore, it revised its National Energy Efficiency Strategy in 2008 (DME 2008), partly in the light of increasing energy shortages in the country. The strategy sets a long-term target of 12% energy efficiency improvements by 2015, which has to be achieved alongside South Africa's "Power Conservation Program" for electricity.

The Department of Environmental Affairs and Tourism (DEAT) plays a central role in South Africa's climate change policy. In 2006, the SA government initiated a Long-term Mitigation Scenario (LTMS), which was concluded in 2007 (Scenario Building Team 2007). On the basis of LTMS, four technology priority areas have been identified:

1. solar water heating; standardization of technology, the training of local installers and rebates for households. However, the development of local capacity is lacking.
2. green transport revolution; development of alternative propulsion systems for public transport, development of a Centre for Green Transport and introduction of own electric vehicle (Joule).
3. tax incentives for EE in industry; introduced by the National Treasury whereby industry may claim benefits after purchasing EE equipment through accelerated depreciation, tax rebates or covering of audit costs.
4. carbon capture and storage; identification of carbon storage sites, development of Centre for Carbon Capture and Storage and a commercial pilot project for CO_2 storage from (possibly) SASOL plant in 2016. A carbon tax is being investigated by the National Treasury as part of the Environmental Fiscal Reform and there is currently a tax of $0.003/kWh on non-renewable energy sources (Nassiep 2009).

Furthermore, a policy development process was launched to develop a national Climate Change Response Policy, in which DEAT will play a central role. This policy is due in 2010 and calls upon a systems approach for new technologies building on the Department of Science and Technology's (DST) climate change R&D strategy. Furthermore, the DST has developed a Foresight Energy Report that employed a comprehensive analysis for South Africa's energy RD&D activities (DST 2007). It identified a range of medium and medium to long-term priorities based on attractiveness (benefits/rewards) and feasibility (effort, risk and time). The medium term priorities are the use of coal discards, solar water heating, PV systems and paraffin use for households, buildings options like energy efficiency and insulation and energy simulation and modeling, metering and energy applications for gas. The long term priorities are energy efficiency in industry, generation and transmission, hydrogen production, large-scale energy storage, biotechnology for energy, bulk solar thermal and alternate energy delivery for rural SMME's.

RD&D allocation

South Africa has limited governmental funding for energy R&D. DST has a small budget for "energy resources" and "energy supply" and some energy related R&D budgets in: (1) natural resources; (2) transport; and (3) natural sciences, technology and engineering.

A large fraction of the government's support on energy RD&D was carried out or funded through South Africa's National Energy Research Institute (SANERI), a government research institute on energy RD&D (in 2007 SANERI received 40 mln ZAR, while the budget of the Department of Science and Technology for energy research was 2 mln ZAR). It has an array of projects and was funded at about 10-40 mln ZAR per year between 2005 and 2008. The National Energy Act of 2008 included a provision to establish a National Energy Development Institute (SANEDI), which is expected to be launched sometime in 2010. This new body will merge SANERI and the National Energy Efficiency Agency (NEEA). NEAA was established in March 2006 and coordinated many of the government-funded energy efficiency projects in South Africa. SANEDI´s mandate is to develop renewable energy resources, support energy efficiency programs, carry out research on energy technologies and energy supply security, and develop and coordinate necessary energy infrastructure (Merwe 2009).

The South African government funds energy R&D on nuclear power indirectly through a 69% share in PBMR Ltd., which is a company that develops Nuclear Pebble Bed Modular Reactors, and through the establishment of the Nuclear Energy Corporation (NECSA), which is a state-owned company responsible for R&D on nuclear energy technology. In 2010, the South African government announced that they would withdraw their support for PBMR Ltd. (DPB 2010).

Table 20. Energy RD&D funding in South Africa by government and others for different energy technologies between 2000 and 2008.

South Africa Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government									
	other	125	96	117	117	116	63	65	165	164
nuclear energy (incl. fusion)	government	146	126	105	451	217	209	211	263	133
	other	26	25	22	118	43	41	38	35	31
renewable energy sources	government									
	other	8	11	12	19	7	12	8	11	7
energy-efficiency	government									
	other									
transmission, distribution & storage	government									
	other	63	91	94	154	59	61	38	38	26
energy technologies (unspecified)	government			0.3		0.5	0.5	0.5	10	9
	other									
total	**government**	**146**	**126**	**106**	**451**	**217**	**210**	**211**	**273**	**142**
	other	**223**	**223**	**245**	**409**	**225**	**178**	**148**	**248**	**229**

ETIPs and ETIIs

The National Energy Act in 2008 introduced a new entity called South Africa's National Energy Development Institute (SANEDI), which combined the national research institutes SANERI and NEAA (SANERI 2008). As part of this transformation, two hubs for research have been established: a hub for renewable research at the University of Stellenbosch (CRSES) and a hub for energy efficiency and demand side management (lighting, sustainable buildings and motors/drives) at the University of Pretoria (EEDSM) funded for ZAR 4,5 mln and ZAR 3 mln p.a. respectively (Davenport 2007; Anonymous 2008). Furthermore, to bridge the gap between R&D and demonstration and implementation several Research and Demonstration Centers (called CORDs). The role of CORDs is to fund energy innovation projects from the design stage through the pilot-stage and demonstration projects. Four of the research centers have been established (RECORD for renewable energy, SACCCS for CCS, CESAR for systems analysis and the green transport CORD), while the others are in the process of being established (see Figure 4).

CORDs are seen as central agencies between SANEDI, industry, the research hubs and foreign donor organizations. CORDs will receive their base funding and strategic direction through SANEDI. In return, they will provide product royalties and will have the responsibility to achieve energy technology development and implementation goals. Donors (often international energy agencies) can provide specific projects and consulting support to the CORDs and in return they can receive specific support for SA government policies or promotion of products by donor countries within South Africa. Industry will receive specific project development, consultancy and product royalties from the CORDs and in return the CORDs will receive basic funding and international affiliation from industry. Finally, CORDs will cooperate with research hubs through academic exchange and permanent postgraduate staff and will contract out research to the research hubs. It is expected that SANEDI will provide around 50% of the funding for education and around 30% of the funding for promotion and product R&D activities. Industry is expected to contribute around 40% of the funding for education, 70% for promotion activities, 30% for production R&D and 100% of the funding for consultancy activities. The rest of the funding should come from donors (SANERI 2008).

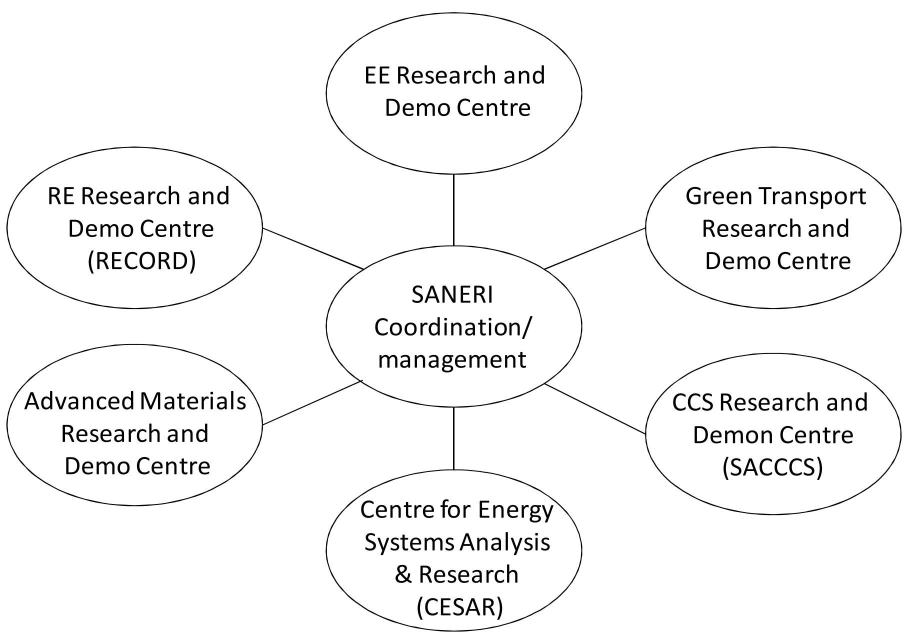

Figure 4. The research and demonstration centers (CORDs) coordinated by SANEDI (SANERI 2008).

South Africa's government has established a private company called CEF Group to execute South Africa's "Central Energy Fund". The CEF Group is controlled by DOE and is involved in the search for appropriate energy solutions to meet the future energy needs of South Africa, including oil, gas, electrical power, solar energy, low-smoke fuels, biomass, wind and renewable energy sources. Its purpose is to finance and to promote the acquisition, generation, manufacturing, marketing, distribution of coal products and research associated with any of these stages. The CEF group operates in the energy sector and controls entities with commercial, strategic, regulatory and developmental roles. The CEF group consists of seven operating subsidiaries:

- PetroSA; exploration and production of crude oil and natural gas off the southeast coast of South Africa.
- iGas; the official State agency for the development of the hydrocarbon gas industry in Southern Africa.
- Petroleum Agency SA; promotes exploration for oil and gas resources and their optimal development on behalf of the government.
- Oil Pollution Control SA (OPCSA); provides oil prevention, control and clean-up services
- SANERI; focuses on research and development within the energy sector.
- The National Energy Efficiency Agency (NEEA); oversees the implementation of DSM and Energy Efficiency projects within the country.
- The Strategic Fuel Fund Association (SFF); manages South Africa's strategic inventory of crude oil on behalf of the State.
- Energy Development Corporation (EDC); invests in renewable energy and alternative energy fields through support of commercial, developmental and social projects.

The relationship between SANEDI's activities, the CORDs activities and the activities of CEF is straightforward. Concept, pre-feasibility, feasibility and detailed design studies are funded by SANEDI, detailed design and pilot & demonstration projects take place within the CORDs and commercialization takes place in the private sector (PS) and State-Owned Enterprises (SOE) (SANERI 2008).

Nuclear energy R&D mainly takes place within the Atomic Energy Corporation (AEC). The activities of the AEC constitute the largest item on DOE's budget, although this is decreasing. These resources are used for institutional nuclear activities carried out for the government, nuclear enrichment research, high technology nuclear-based commercialization activities and the decommissioning of uneconomic plants. Furthermore, until 2010 the South African government had a stake in PMBR Ltd., which does research and demonstration projects in the area of Pebble Bed Modular Reactors.

Finally, there are some private enterprises that undertake energy R&D with indirect support from the South African government. Eskom Ltd. is South Africa's main electricity generator and supplier and conducts energy R&D. Although Eskom Ltd. is not under control of the South African government, it is responsible for achieving a renewable energy target of 10000 GWh of green electricity in 2013 (DME 2003). SASOL is another large energy company in South Africa, which conduct some of South Africa's energy technology innovation. For example, the Industrial Development Corporation (IDC)[21] finances activities at Optimal Energy, a company founded through the Innovation Fund (IF) from DST, which is

[21] IDC is a self-financing state-owned finance institution, which provides loans and financing to entrepreneurial activities in South Africa.

developing South Africa's first electric vehicle and together with SASOL is developing commercial pilot projects for CO_2 storage.

There are several ETIPs that have been introduced in South Africa. SANERI has introduced the Renewable Energy Feed-in Tariff (REFIT) in 2009, which set feed-in tariffs for wind (~0.15 $/kWh), small hydro landfill gas (~0.11 $/kWh) and concentrated solar (2.10 $/kWh). A further set of tariffs has been developed for Solar PV, biomass and SWH. Furthermore, the "National Energy Efficiency Strategy" of the DME introduces mandatory energy efficiency standards, mandatory labeling of household appliances, the establishment of inspectors and the education and training on energy efficiency issues. Finally, sectoral approaches for industry and mining, commercial and public buildings, residential sector and the transport sector are established (DME 2008).

Table 21 and Table 22 show the number of institutions and policies that impact the R&D, demonstration and deployment stage of ETI and on the functions of innovation. The tables include the proposed changes in the National Energy Act, which was re-enacted in 2008 and has resulted in significant changes in South Africa's energy innovation systems. As such, it shows that there are several policies and institutions promoting the deployment of renewable energy technology and energy efficiency and providing support for funding and coordination of R&D and demonstration projects on renewable energy, energy efficiency and clean coal (specifically CCS). However, the institutions that support the coordination have only been in place since 2009, so it is too early to determine whether they can fulfill the intentions with which they have been established.

Table 21. Number of South African governmental policies and institutions affecting stages and actors in the innovation process within each of the energy technology categories.

South Africa	R&D				Demonstration				Deployment			
	supply	interm.	demand	support	supply	interm.	demand	support	supply	interm.	demand	support
FE	1	1	0	0	0	1	0	0	0	0	0	0
NE	1	0	0	0	0	0	0	0	0	0	0	0
RE	1	1	1	1	0	2	0	0	3	5	2	1
EE	1	1	0	1	0	1	0	0	0	0	4	0
TDS	0	0	0	0	0	0	0	0	0	0	0	0
GE	3	2	0	1	0	1	1	0	0	1	0	1

Table 22. Number of South African governmental policies and institutions affecting functions in the innovation process within each of the energy technology categories.

South Africa	knowledge creation	knowledge diffusion	resource allocation	entrepreneurial activities	guidance of search	creation of legitimacy	market formation
FE	1	1	0	1	0	0	0
NE	1	0	0	0	0	0	0
RE	3	1	4	2	0	3	3
EE	1	1	1	1	1	2	2
TDS	0	0	0	0	0	0	0
GE	4	2	0	1	0	1	0

4. Discussion

The results in section 3 show heterogeneities in the national initiatives to accelerate ETI. The aim of this section is to provide a brief comparison of the different organizational structures for allocating energy RD&D funds, the size of energy RD&D and ETIIs and ETIPs in place in 2009. The section will conclude with identifying three areas in which governments in the BRIMCS countries have opportunities to cooperate and coordinate energy innovation policies either among themselves or with other governments around the world.

4.1. Administrative Entities and Procedures

The description of administrative entities and procedures shows that in most BRIMCS countries energy technology policy is developed through an interplay between four different types of institutions: (1) an intergovernmental organization; (2) one or more energy ministries; (3) one or more science and technology institutions; and (4) state-owned enterprises. However, the combination and extent of interplay between these institutions differs substantially between the countries and affects the way in which countries can coordinate and cooperate on energy technology innovation activities.

The national government energy RD&D investments in Brazil, Russia, Mexico, and South Africa are coordinated by dedicated energy ministries, although in each of these countries science and technology organizations (either in the form of ministries or science councils) also contribute to the coordination of ETI activities. In Brazil and Russia, the energy ministries set energy RD&D priorities, while in South Africa the environmental ministry is also involved. India and China do not have one overarching or dedicated energy ministry, but rely on inter-governmental commissions that provide direction and set priorities for energy innovation activities. However, since the installation of the Chinese National Energy Commission (NEC) there is an important difference between China's and India's approaches for setting energy RD&D priorities. In China, the NEC is specifically dedicated to energy issues and the Ministry of Science and Technology plays a central role in coordinating energy technology activities. In India, energy policy is only one of a range of activities of the Planning Commission and there is a large number of dedicated energy ministries (Coal & Power, Nuclear Energy, etc.) involved in coordinating the energy technology activities.

The allocation of national government energy RD&D investments varies also by country and does not necessarily take place in the ministry or organization that sets the priorities for energy RD&D. On the one hand, in Brazil, Mexico, and India state-owned enterprises play an important role when making decisions about allocating energy RD&D funds, because they either provide the funds through their revenues or because they are related to the most important energy research institutions. On the other hand, in Russia, China, and South Africa, the allocation of energy RD&D investments seems more influenced by scientific institutions, although state-owned enterprises receive significant amounts of research funds.

Finally, the overview shows that most BRIMCS countries (except Russia) have established intergovernmental organizations on climate change which have important consequences for ETI through target setting and the development of different future energy scenarios. However, it is interesting to observe that these intergovernmental organizations mostly focus on the deployment of energy technologies and less on RD&D.

4.2. Energy RD&D Investments

Table 23 provides an overview of energy RD&D investments in the BRIMCS countries and compares this with the latest data with energy RD&D investments in the United States. Table 23 shows that, in 2008, governments and 100% government-owned SOEs in the BRIMCS countries invested a minimum of $13.8 bln PPP international dollars in energy RD&D with around 90% of these funds coming from SOEs.

Table 23. Overview of energy RD&D investments in the BRIMCS countries and the United States.

*in Million 2008 PPP $Int**	**Fossil (incl. CCS)**	**Nuclear (incl. fusion)**	**Electricity, transmission, distribution & storage**	**Renewable energy sources**	**Energy Efficiency**	**Energy technologies (not specified)**	***Total***
United States - Gov't	659	770	319	699	525	1160	*4132*
United States - Other ~	1162	*34*	*no data*	*no data*	*no data*	1350	*2545*
Brazil – Gov't	79	8	122	46	46	12	*313*
Brazil – Other	1167	*no data*	*no data*	*no data*	*no data*	184	*1351*
Russia – Gov't	20	*no data*	22	14	25	45	*126*
Russia – Other	411	*no data*	*no data*	*no data*	*no data*	*508*	*918*
India – Gov't	106	965	35	57	*no data*	*no data*	*1163*
India – Other	694	*no data*	*no data*	*no data*	*no data*	*no data*	*694*
Mexico – Gov't	140	32	79	*no data*	*no data*	*no data*	*252*
Mexico – Other	0.1[1]	*no data*	*no data*	*no data*	263[3]	19[4]	*282*
China – Gov't	6755	12	*no data*	*no data*	136	4900	*11803*
China – Other	289	7	*no data*	*no data*	26	985	*1307*
South Africa- Gov't	*no data*	133	*no data*	*no data*	*no data*	9	*142*
South Africa - Other	164	31[2]	26	7	*no data*	*no data*	*229*
BRIMCS - Gov't	**7100**	**1149**	**> 259**	**> 117**	**> 208**	**> 4966**	***> 13799***
BRIMCS - Other	**2724**	**>> 38**	**>> 26**	**>> 7**	**>> 289**	**> 1696**	***> 4781***
BRIMCS - GRAND TOTAL	**9824**	**> 1187**	**> 285**	**> 124**	**> 497**	**> 6662**	***> 18580***

* Data from United States, Brazil, Russia, India, China and South Africa based on 2008, Mexico on 2007.
'Other' includes (w henever available) funding from state and local governments, partially state-ow ned enterprises, NGOs, and industry.
~U.S. data on industry expenditure is from 2004 (NSF 2008).
[1]Based on PEMEX's fund for Scientific and Technological Research on Energy
[2]Based on total non-governmental investments into PBMR Ltd.
[3]Based on 2005 R&D expenditure in car manufacturing industry (CONACYT 2008)
[4]Based on 2005 R&D expenditure in utilities sector (CONACYT 2008)
> These cumulative values are based on data from only three to four BRIMCS countries, so actual expecteditures are likely to be higher.
>> These cumulative values are based on data from tw o BRIMCS countries or less, so actual expenditures are expected to be much higher.

The data from governments and SOEs upon which this total is based, however, have not been reported in any systematic way, and definitions of what constitutes RD&D vary widely between different data sources. Despite these limitations, the results suggest that governments in the BRIMCS may have control over larger amounts of energy RD&D funding than the governments from countries that are members of the IEA[22], whose total government investments in energy RD&D were $12.7 bln PPP international dollars in 2008.

[22] The International Energy Agency (IEA) includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, the Netherlands, New Zealand, Norway,

Four conclusions can be drawn from this overview. First, there is limited data available. The BRIMCS countries collect data yearly or bi-annually, however information about energy RD&D funds for renewable energy sources, energy efficiency, and transmission, distribution and storage is limited and the level of aggregation differs. For example, Russia provides details on aggregated energy RD&D funding, while India breaks down its energy RD&D expenditure per ministry. Furthermore, the overview shows that neither the BRIMCS countries nor the United States has systematically collected information about energy RD&D in the private industry.

Second, fossil fuel and nuclear energy receive the highest level of RD&D expenditure in both the United States and the BRIMCS countries. Despite the efforts of governments to allocate part of their 2009 stimulus packages to low-carbon and clean technologies, data on energy RD&D funds show that yearly energy RD&D funds to renewable energy resources and energy efficiency remains significant lower than fossil and nuclear energy.

Third, despite incomplete data on energy RD&D funds in the BRIMCS countries, the data shows the significant levels of energy RD&D expenditure in the BRIMCS countries and points to the need to include the BRIMCS countries into a comprehensive global strategy to accelerate ETI.

Fourth, state-owned enterprises play an important role in energy RD&D investments in the BRIMCS countries. A comparison of government funded energy RD&D investments between the BRIMCS countries and IEA member countries cannot take place without considering the dominant role of SOEs in funding energy RD&D in the BRIMCS countries.

4.3. ETIIs and ETIPs

It is to be expected that a country's overall strategy for promoting innovation in energy technologies would provide the context in which the objectives and content of ETIIs and ETIPs are formulated. Consequently, a comparison of ETIIs and ETIPs requires a comparison of a country's overall energy technology strategy.

Despite similarities in at least the direction of national energy technology priorities, section 3 has shown that there are both similarities and significant differences in the number, content, and extent to which national governments have formulated and introduced ETIIs and ETIPs to accelerate ETI. Differences exist in the number, extent, and aggressiveness of ETIIs and ETIPs that are employed, but they are similarities with regard to the stages, actors, and functions that they target.

Table 24 provides a brief overview of the BRIMCS countries' energy technology priority areas that they have identified in their national energy policies. The overview shows that despite the fact that most technology priority areas differ at a detailed level, they all seek to promote a mixture of fossil, nuclear, and renewable technologies and energy efficiency measures.

Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. Due to missing data, the Czech Republic, Poland and the Slovak Republic are not included in the Estimated IEA total.

Despite similarities in at least the direction of national energy technology priorities, section 3 has shown that there are both similarities and significant differences in the number, content, and extent to which national governments have formulated and introduced ETIIs and ETIPs to accelerate ETI. Differences exist in the number, extent, and aggressiveness of ETIIs and ETIPs that are employed, but they are similarities with regard to the stages, actors, and functions that they target.

Table 24. Renewable energy targets and energy technology priority areas in the BRIMCS countries (priorities are not listed in order of importance or emphasis).

Country	**Energy technology priorities**
BR	Biofuels; electricity generation; hydrogen; renewable energy; oil, gas and coal; and nuclear (Rezende 2008).
RU	Nuclear power technologies (including fuel cycle, safety aspects and spent fuel treatment); hydrogen energy technologies; new and renewable energy sources; fossil fuels; energy efficiency and conservation; and creation of energy efficient engines and propulsion devices for transport systems (Klimenko 2008).
IN	New materials; R&D in biofuels; combustion research; energy R&D for railway transportation; hydrogen; advanced coal technologies; ultra-super-critical technologies; energy storage systems; gas hydrates and oil shale; energy efficiency; silicon crystals for PV applications; LEDs; electric vehicles (Planning Commission 2008a).
MX	Energy efficiency and energy savings; energy efficiency standards; secondary oil recovery by CO_2 injection; CCS; CHP in the cement, steel, and sugar industries; biofuels production; CO_2 mitigation measures in maritime and air transport (ICCC 2007).
CN	Advanced coal, high-temperature gas-cooled reactors, smart grid, wind energy, silicon manufacturing technologies, bio-fuels and R&D capability (Hu 2007; Li 2009); key energy saving technologies, 2-3 MW wind turbine commercialization and high quality transmission technology & equipment (Tan 2010).
SA	Solar water heating, green transport revolution; energy efficiency in industry and carbon capture and storage (Nassiep 2009).

The BRIMCS countries show similarities in that most countries have a large number of ETIIs and ETIPs that support deployment activities for renewable energy technologies and energy efficiency technologies, but that nuclear energy, fossil fuels, and transmission, distribution, and storage technologies are supported on the R&D side. Furthermore, in there are less national government activities (ETIIs and ETIPs) supporting the demonstration stage of energy technologies than supporting energy R&D and energy deployment.

However, there are also differences in: (a) the number of ETIIs and ETIPs that are employed to accelerate the deployment of renewable BRIMCS countries; (b) the specificity of energy R&D activities towards particular energy technologies; and (c) the extent in which government provide intermediary infrastructures or support infrastructures for R&D, demonstration and deployment activities. India and China have the largest number of ETIIs and ETIPs targeting supply and demand actors in the deployment stage of renewable energy technologies and energy efficiency, while countries like Russia and South Africa have a relative small number of specific ETIIs and ETIPs to accelerate renewable energy and energy efficiency. However, in contrast to Russia, South Africa has many more ETIIs and ETIPs that support R&D, demonstration and deployment activities by providing intermediary and supportive functions.

Second, there are differences in the specificity of their policies. For example, China and India differ in the extent to which their energy R&D activities are specific to particular technologies. China has large funds for R&D, but does not a priori allocate these funds into specific energy technology categories. Instead, they develop specific energy technology programs within more generic innovation programs targeting basic, applied, and experimental development (Tan 2010). India, on the other hand, has R&D funds that are specific to particular ministries and therefore are earmarked for specific energy technology categories from the point when final budget decisions are made.

Finally, we have defined three different models to distinguish between the intermediary and support functions in the BRIMCS countries.

- *Academy and SOE model.* In this model, academies play an important role in coordinating the allocation of R&D funding to national labs or universities. State-owned enterprises play an important role in coordinating and implementing deployment projects. Both China and Russia fit this model with many national labs and research institutes conducting R&D, while deployment takes place in SOEs.
- *SOE and ministry model.* In this model, SOEs are much more involved in the coordination of R&D activities, but the government provides additional support for deployment activities through ministry-related institutions. In Brazil and Mexico, the R&D institutions are mostly associated with SOEs, but the different ministries have established autonomous institutions that facilitate access to and deployment of new energy technologies by private industry. India has a hybrid model in which it has established several institutions and agencies to facilitate the deployment of new technologies, but also provides independent research centers for the development of new technologies.
- *University and private sector model.* In this model, energy R&D funded by the government is mainly conducted at universities and private industry, but where the government provides support through centers that, although coordinated by a government organization, are embedded within scientific institutions rather than ministries or SOEs. The coordination and support for the deployment of new energy technologies is independent from either ministries or SOEs. South Africa is an example of this third model.

4.4. Opportunities for Cooperation and Coordination of ETIPs and ETIIs

The previous three sections have shown that there are institutional differences that should be taken into account if governments are planning to cooperate with BRIMCS countries or if they consider coordinating policies with those of a BRIMCS country. The next step consists of identifying opportunities for cooperation and coordination between countries using the comparative framework. Kempener and Anadon (in preparation) have identified four types of opportunities for cooperation and coordination, which are illustrated with a comparison of the opportunities for coordination and cooperation between Brazil and India in Figure 5.

The first step is to identify energy technologies that are of shared interest to governments of two or more countries. Since we specifically focus on government-to-government cooperation and coordination activities, we assume that whenever a government has policies or institutions in place to support an energy technology, such government is also interested in cooperation or coordination on ETIPs or ETIIs for that particular technology.

The second step is to examine where cooperation and coordination activities might provide shared value for the governments involved. We have identified four potential avenues for cooperation and coordination: gaps, overlaps, commonalities, and complementaries. *Gaps* and *overlaps* in policies and institutions arise wherever two or more countries both lack or emphasize support for, respectively, a particular stage, actor, or function of the innovation system. For example, to the best of our knowledge, the central governments in India and Brazil do not provide support for intermediate infrastructure actors in the deployment phase of nuclear energy technologies (gaps), while they both have a large number of ETIPs and ETIIs in place to support supply actors of renewable energy technologies (overlap). *Commonalities* occur wherever patterns (or sets) of ETIPs in two or more countries show similarities along one of the analytical dimensions. For example, Figure 5 shows that both Brazil's and India's government provide a full range of different deployment mechanism for renewable energy technologies and provide a large number of different ETIPs and ETIIs focusing on supply actors. As such, there are opportunities to cooperate on policies that address common objectives or coordinate policies that match. *Complementarities* between countries arise wherever the set of ETIPs in one country could complement the set of ETIPs in another country. For example, the difference in deployment support for energy efficiency in Brazil and India indicate that Brazil has a larger number of ETIPs to stimulate suppliers of energy efficient technologies, while India has a larger range of ETIPs to support the demand for energy efficient technologies.

Brazil	Deployment			
	supply	interm.	demand	support
FE	1	1	0	0
NE	1	0	0	0
RE	10	3	4	4
EE	4	1	2	1
TDS	1	0	1	0
GE	0	3	1	2

India	Deployment			
	supply	interm.	demand	support
FE	5	1	2	1
NE	3	0	1	0
RE	13	6	3	1
EE	2	2	6	5
TDS	1	2	0	2
GE	0	1	1	0

Figure 5. Identification of gaps, overlaps, commonalities, and complementarities between ETIPs and ETIIs in the deployment stage in Brazil and India (based on Kempener and Anadon in preparation)

Each gap, overlap, commonality, and complementarity provides opportunities for both cooperation and coordination between countries. *Cooperation* is defined as collective action by two or more governments pursuing a shared objective, while *coordination* is defined as two or more governments developing policies in consideration of each other's individual objectives and interdependency (Snidal 1985). In the context of ETIPs, governments can cooperate by developing shared or complementary policies to address a particular shared objective. In other words, even though two countries may want to pursue the same objective, their approaches may differ in the extent to which the ETIPs are designed to be similar or complementary. Coordination takes place wherever governments pursue individual but interdependent objectives. In this case, governments can develop matching policies or policies in consideration of each other.

The analysis of gaps, overlaps, commonalities, and complementarities, together with the insights from the comparison of administrative entities, allocation mechanisms for energy RD&D funding, and the set of the most important ETIPs and ETIIs provides a systematic and practical starting point for identifying and developing opportunities for cooperation and coordination. Here it is important to note that a comprehensive list of cooperation and coordination opportunities, would require a systematic country-by-country comparison between each of the BRIMCS countries or any other country of interest to the analyst, which is beyond the scope of this paper.

Nevertheless, the comparative frameworks do point to some areas of opportunity for cooperation and coordination at a macro-level. On this basis, we have identified three areas where the BRIMCS countries could cooperate to fill important gaps, make more effective use of the overlaps, and address their commonalities and complementarities. The three areas are:

1. Gaps in support for demonstration projects;
2. Overlaps and commonalities in deployment policies for RE and EE;
3. Gaps and complementarities in support for entrepreneurial activities.

A glance at the comparative analyses shows that there is a lack of ETIIs and ETIPs that support demonstration projects in all five energy categories. Except for funding mechanisms for renewable energy and energy efficiency demonstration projects in India and support for demand-side actors in South Africa, there is little support for actors that operate in the demonstration stage of ETI for any of the energy technology categories. In particular, none of the countries has systematic support in place to connect those actors that are interested in undertaking demonstration projects (the suppliers) with those actors are interested in or need for demonstration projects (the demand actors). If there are particular energy technologies that two or more countries are interested in, this area would provide opportunities for cooperation through complementary demonstration projects. Similarly, countries could coordinate their support activities to allow supply actors to get in touch with demand actors in other countries and vice versa. Since demonstration projects provide playgrounds for experiments and learning, coordination of demonstration projects could benefit multiple governments simultaneously. Furthermore, the coordination of demonstration projects, combined with a sharing of the insights from each project, would provide a more diverse environment in which new energy technologies could be tested and improved.

Second, the comparative analyses show that most countries have a large number of ETIPs and ETIIS in place to support the deployment stage of renewable energy and energy efficiency technologies in their country. For example, Brazil, India and China have respectively 10, 13 and 19 different ETIPs and ETIIs in place to support the supply actors of renewable energy technologies in the deployment stage. Similarly, almost all of the ETIPs and ETIIs in place in South Africa and Mexico supporting the deployment stage of renewable energy and energy efficiency technologies. The BRIMCS also have a large number of ETIPs and ETIIs supporting the formation of markets and the creation of legitimacy for these two energy technology categories. The overlap and commonality between government support for renewable energy and energy efficiency provides opportunities for cooperation and coordination. For example, countries can cooperate on the development of standards or coordinate their economic incentives. There might also be interesting opportunities for cooperating and coordinating those deployment activities that involve SOEs or ministerial agencies. For example, an SOE in a BRIMCS country could cooperate with the government of an industrialized country to deploy houses with more efficient insulation systems, providing opportunities for a fast deployment of technologies in foreign markets. The liberalized energy markets of industrialized countries often provide fewer opportunities to directly test new technologies within energy companies, so collaboration with BRIMCS countries might provide different ways of deploying new technologies.

Third, the comparative analysis shows that there are a relative small number of policies and institutions in place in the BRIMCS countries that support entrepreneurial activities and that the extent to which entrepreneurial activities are supported differs between countries. Based on the data available, the analysis suggests that are no interventions supporting entrepreneurial activities in China and Mexico, limited support for entrepreneurial activities in renewable energy technologies in Russia and Brazil and a larger, but still limited, range of policies available to support entrepreneurial activities in India and South Africa. Also, the policies itself differ. In India, there are several activities that support entrepreneurial activities in the context of rural electrification, while South Africa has developed specific research and demonstration centers to attract and support entrepreneurial activities. In Russia and Brazil, on the other hand, the policies consist of specific support for entrepreneurial activities by small- and medium enterprises. The identification of these different approaches and the extent to which they are applied in each of the countries can provide a basis for developing new ways of coordinating and cooperating these innovation policies.

These three examples provide a first step in developing more detailed proposals for cooperation and coordination, however it shows that a systematic analyses of existing government support mechanisms provides a sound basis for identifying opportunities.

5. Conclusions

The BRIMCS countries are major players in the global energy sector and their activities have important implications for ETI worldwide. Each of the BRIMCS countries has an extensive set of national government initiatives in place to accelerate the development of energy technologies. Despite the fact that the BRIMCS countries face similar challenges as other countries around the world, and despite the interdependence of federal initiatives between countries, there is little structured collaboration or cooperation on government policies for ETI.

This working paper aimed to identify opportunities for collaboration and coordination through a comparative analysis of governmental interventions to support ETI activities in the BRIMCS countries. As such, it had to overcome two challenges: (1) the lack of data on ETI activities; and (2) the lack of a coherent framework to allow a systematic comparison between the policies of different countries.

Data gathering has been particularly difficult for national government funded energy RD&D because none of the BRIMCS countries are members of the IEA and because their methods of collecting and reporting information differ substantially. Furthermore, each country has different structures in their energy sector, which makes it difficult to determine which energy RD&D activities are funded by the national government and which are funded through private industry or local and state councils. The structure that eventually was adopted aggregates energy RD&D funding for five energy technologies and separates national government from ”other” sources of energy RD&D expenditures to provide a first step towards comparing energy RD&D budgets and identifying gaps. However, on their own, data on energy RD&D expenditures does not provide sufficient information for developing cooperative or coordinative activities among different governments.

The second challenge involved the development of a systematic comparison of ETI activities. The paper has focused on three aspects of national government interventions to support ETI activities: the administrative entities and procedures that set the direction of government support, the allocation mechanisms for energy RD&D, and the ETIIs and ETIPs in place. The first two comparisons provide some insights in how each country has similar actors involved in developing government support for ETI, but that their interactions and structure differs quite substantially. In other words, the fact that two countries have a Ministry for Energy does not necessarily imply that the roles of these ministries are comparable. Similarly, the overview of ETIIs and ETIPs has shown that there are substantial differences in: (a) the number of ETIIs and ETIPs that are employed to accelerate the deployment of renewable BRIMCS countries; (b) the specificity of energy RD&D activities towards particular energy technologies; and (c) the extent in which government provide intermediary infrastructures or support infrastructures for R&D, demonstration and deployment activities. These differences make it difficult to compare the effectiveness of individual ETIPs and ETIIs and emphasize the need for a simple comparative framework to identify opportunities for cooperation and coordination.

This paper has illustrated the use and applicability of a comparative framework to identify opportunities for cooperation and coordination. The results show both the advantages and disadvantages of such approach. The disadvantage of using this comparative framework is that it does not explore how ETIIs and ETIPs have evolved over time or the extent of their impact on accelerating ETI, and therefore does not provide any lessons with respect to what ETIIs and ETIPs do and do not work. On the other hand, the simplicity of this approach does provide some advantages as well. First, this comparative framework has covered a large number of different energy technologies, while other comparative analyses either limit themselves to specific energy technologies or do not provide systematic comparisons. The second advantage of this approach is that although it provides a simple summation of government initiatives, it does categorize these initiatives along a range of different dimensions (stages, actors and functions) and, as such, provide a simple first-order comparison of the similarities and differences between the approaches of different countries. These similarities and differences form the first step for identifying collaborative activities.

Finally, this paper has provided some insights into future research challenges and provides three specific recommendations. First, this paper explored and compared administrative, institutional, and procedural structures of governments and provided a comparison of the application of ETIPs and ETIIs in each of the countries. One next step would be to combine the results of these two analyses in order to develop an understanding of how different structures impact on the development and evolution of ETIPs. A second recommendation for future research would incorporate the dynamic nature of innovation. So far, the comparisons of ETIPs and ETIIs have been static and have not considered how different administrative structures might impact the development of new or the abolishment of old ETIPs and ETIIs. Further research is required to take these dynamics in consideration. Third, this paper has not touched upon the possibility to use these comparative frameworks to learn from other countries' experiences. Future work is required to measure and compare the effectiveness of different ETIPs and ETIIs and use these insights for learning within, between and among governments.

Despite these limitations, the paper has illustrated that there are ample opportunities for cooperation and coordination among different governments. Furthermore, it has demonstrated that opportunities of cooperation can not only be found in particular technology areas, but that analyzing ETIPs and ETIIs using the dimensions of stages, actors and functions provides new insights into opportunities for cooperation and coordination. The method provides practitioners with a more systematic and structured approach to think about cooperation and coordination, to communicate their needs and wants, identify opportunities, and understand each others' perspectives.

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ABOUT THE ENERGY TECHNOLOGY INNOVATION POLICY GROUP

ENERGY TECHNOLOGY INNOVATION POLICY RESEARCH GROUP

The overarching objective of the Energy Technology Innovation Policy (ETIP) research group is to determine and then promote adoption of effective strategies for developing and deploying cleaner and more efficient energy technologies, primarily in three of the biggest energy-consuming nations in the world: the United States, China, and India. These three countries have enormous influence on local, regional, and global environmental conditions through their energy production and consumption. ETIP researchers identify and promote strategies that these countries can pursue, separately and collaboratively, to accelerate the development and deployment of advanced energy options that can promote economic growth while reducing conventional air pollution, greenhouse-gas emissions, dependence on oil, and poverty. ETIP's focus on three crucial countries rather only one not only multiplies our leverage on the world scale and facilities the pursuit of cooperative efforts, but also allows for the development of new insights from comparisons and contrasts among conditions and strategies in the three cases.

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ENERGY RESEARCH, DVELOPMENT, DEMONSTRATION AND DEPLOYMENT (ERD3) PROJECT

The ERD3 Project is a three-year effort within ETIP funded by the Doris Duke Charitable Foundation aimed at producing a set of comprehensive recommendations for the Obama administration to accelerate energy technology innovation (ETI). ERD3 Project members are working in three main areas: (a) identifying the opportunities for government-funded energy research development and demonstration (RD&D), and developing a portfolio of U.S. government investments in energy RD&D as components of a coordinated ETI strategy; (b) understanding the private sector's current role in carrying out and funding energy RD&D in the United States and drawing conclusions about effective structures of public-private undertakings and other incentives to promote private sector innovation; and, (c) analyzing the global picture of ETI to make recommendations on a strategy and priorities for international cooperation on ETI for the United States.

http://belfercenter.ksg.harvard.edu/project/10/energy_technology_innovation_policy.html?page_id=213

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