Historical Case Studies of Energy Technology Innovation

CASE STUDY 19: RD&D INVESTMENTS (EMERGING ECONOMIES).

ENERGY RD&D INVESTMENTS IN THE MAJOR EMERGING ECONOMIES AND THE UNITED STATES

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AUTHORS' SUMMARY

This case study provides an overview of energy research, development and demonstration (RD&D) investments in six major emerging economies: Brazil, the Russian Federation, India, Mexico, China and South Africa (referred to as 'BRIMCS' countries). RD&D expenditures are differentiated by technology category (fossil fuel, nuclear, electricity, renewables, efficiency, and other) and by funding source (government, state-owned enterprises, private industry, not-for-profit organisations), based on the most recent published data available in each country. For comparison purposes, corresponding data for the US are included. This data synthesis draws on a wide array of sources that have not been systematically compiled and compared to-date. Various key findings emerge. First, energy RD&D in BRIMCS countries is substantial, amounting to some $14 billion (in PPP terms), which is slightly greater than the entirety of the public energy RD&D budget of all IEA countries combined ($12.7 billion). The relative RD&D effort in BRIMCS compared to IEA countries is, however, sensitive to the comparison metric (e.g., GDP, energy use, energy production). Second, the significance of energy RD&D expenditure in BRIMCS countries challenges the traditional view that new energy technologies are predominantly developed within IEA countries, and highlights the need to include BRIMCS countries in a comprehensive global strategy to accelerate energy technology innovation. Third, the highest level of RD&D support in BRIMCS countries is for fossil fuel and nuclear energy. Renewables and energy efficiency are strongly under-represented both in expenditures as well as in statistical reporting.

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1 INTRODUCTION

In the 1970s, concerns about the vulnerability of countries to shocks in energy supply, primarily oil, prompted the largest energy-consuming countries to create the International Energy Agency (IEA). Besides working on operational measures such as sharing of oil reserves, the IEA has the long-term objective of reducing oil dependence by implementing energy conservation programs, enlarging available fossil energy resources through exploration and development, and developing new forms of energy (Lantzke 1975). These have been pursued through joint energy research, development and demonstration (RD&D) projects, and regular reporting and analysis of national energy technology policies and research activities (Keohane 1978).

Thirty-five years later, the global energy system has changed. Emerging and some large non-IEA countries like Brazil, Russia, India, Mexico, China and South Africa (referred to as the 'BRIMCS' countries) have become important players in both energy production, conversion, and use. Yet scant information is available about energy RD&D activities outside the IEA members. The IEA does provide energy statistics for non-members, but the collection of data on energy technology policies is restricted to its 28 member countries which do not include BRIMCS and other developing countries. Although other international institutions have been established to promote information exchange on energy policy issues, including the International Renewable Energy Agency and the Clean Energy Ministerial, no institution has the mandate to systematically collect information on energy RD&D investments across different energy technologies and across all countries.

In this chapter, we collate and analyze data on energy RD&D investments in the BRIMCS countries, and compare them with energy RD&D investments in the US, a major IEA member country. Our aim is to deepen understanding of energy RD&D efforts outside developed countries in the IEA, and to identify and prioritize opportunities for RD&D cooperation, coordination of national policies and innovation activities.

2 METHODOLOGY

There is no international effort that systematically collects information on energy RD&D investments in the BRIMCS countries. To fill this gap we collected data on public and private investments in energy RD&D for the period 2000 to 2008 from a wide range of data sources including annual reports of ministries and state-owned enterprises ('SOEs'), databases provided by regulators or statistical organizations and interviews with local experts. Data were collected in local currencies, but for comparative purposes are reported in million 2008 purchasing power parity (PPP) adjusted international dollars (World Bank 2010). For details on the compiled database, see: Kempener, Anadon et al. (2010).

RD&D investment data were categorized according to funding source and technology. Funding sources distinguish central government from other sources (Kempener et al. 2010). Central government funding is defined as: (1) funding directly provided by a central government to universities, industry, national laboratories, or other national or international organizations for energy RD&D activities; (2) funding for energy RD&D from state-owned enterprises (SOEs) that are 100% owned by the central government; or (3) funding for energy RD&D resulting from government mandates that require SOEs to spend a particular percentage or amount of their revenues on energy R&D or energy RD&D. Funds specifically targeted to support RD&D projects on energy technologies are also considered to be energy RD&D

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investments. Energy RD&D funding categorized as "other" includes funding from state or local governments, from SOEs that operate independently, from industry, or from non-for-profit organizations.

Five categories of energy technology are used to differentiate the targets of RD&D investment (see Table 1). A sixth category of "general energy technologies" is included as a residual to capture investments that could not be linked to a particular energy technology. For further details, see: Gallagher, Anadon et al. (2010). RD&D investments that target other research areas (such as information and communications technologies, nanotechnology, or behavioral studies) which might have indirect impacts on energy resources, infrastructure or use are not included unless funded through an energy RD&D program.

TABLE 1. DEFINITION OF ENERGY TECHNOLOGY CATEGORIES.

Categories	Technologies
Fossil energy	Oil & gas (excluding exploration), both conventional & non-conventional
	Coal (including carbon capture and storage or 'CCS')
Nuclear energy	Fusion
	Fission
Renewable energy	Solar energy (heating, PV and solar thermal applications)
	Wind energy
	Ocean energy
	Biomass and waste energy
	Geothermal Energy
	Hydropower
Energy efficiency (all end-use technologies)	Industry
	Appliances
	Residential & commercial buildings
	Transportation (including vehicles)
	Agriculture
Transmission, distribution & storage	Transmission & distribution (including pipelines, smart grids)
	Stationary energy storage
	Hydrogen
General energy technologies	Unspecified and/or insufficient information to disaggregate RD&D data by technology

Some of the available data sources provide only aggregate values for energy RD&D funding. As a result, in some cases it was not possible to determine how much support was directed toward different types of energy technologies. Conversely, some data sources only contain information on specific energy RD&D projects or programs, and do not provide an overview of all sources of funding. Consequently, there are three important considerations to keep in mind when interpreting the data. First, aggregate energy RD&D investments reported separately from energy RD&D investments in specific energy technologies are included under the sixth "general energy technologies" category. Second, years and energy technology categories for which no data on energy RD&D investments are available are left blank. Third, available data on energy RD&D investments may be incomplete. Totals should therefore be treated as lower bounds.

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3 RD&D INSTITUTIONS & EXPENDITURES BY COUNTRY

The next seven sections provide brief descriptions of the main funding agencies and funding allocation mechanisms for energy RD&D in the United States and the BRIMCS countries, followed by an overview of energy RD&D investments in those countries between 2000 and 2008.

3.1 United States

3.1.1 RD&D Institutions

The U.S. Department of Energy (DoE) is a major funder for government energy RD&D and is also responsible for a large range of national laboratories conducting energy RD&D. The DoE Office of Science conducts basic energy RD&D in areas including high energy physics, nuclear physics, and basic energy sciences. Other DoE Offices covering Energy Efficiency and Renewable Energy, Electricity Delivery and Energy Reliability, Nuclear Energy, and Fossil Energy, are responsible for promoting innovation in a range of energy technologies in association with the network of eleven National Laboratories. Most of these laboratories also receive funding from other Offices.

DoE is also responsible for the loan guarantee program which issues loan guarantees to reduce the borrowing rate of qualifying energy technology projects, and the Advanced Research Projects Agency – Energy (ARPA-E). ARPA-E was created in 2007, and in April 2009 received US$400 million for two years to fund high risk, high payoff transformational energy research to bridge the gap between basic energy research and industrial innovation. Since the loan guarantee program is focused on deployment and ARPA-E started after 2008, neither programs are included in this synthesis.

3.1.2 RD&D Investments

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Table 2 provides an overview of U.S. energy RD&D investments. Technology categories are explained in Table 1. The data on federal government energy RD&D are based on a database developed by Gallagher & Anadon (2010). Industry data are based on an industry R&D study by the National Science Foundation (NSF 2008). Government fossil energy RD&D includes coal, gas, petroleum, and carbon capture R&D projects, and a carbon capture and storage project (FutureGen). Government renewable energy RD&D includes international renewable energy programs, energy efficiency RD&D includes policy and management issues, and general energy technologies (unspecified) includes the budget for Basic Energy Sciences. The "other" category of funding source includes industry funding.

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Table 2 shows that energy RD&D investments in fossil energy, nuclear energy, and renewable energy have doubled between 2000 and 2008 in real terms. The fastest growth rate in investments between 2000 and 2008 has been in the area of transmission, distribution and storage, while energy efficiency investments have been slowly declining.

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TABLE 2. AVAILABLE DATA ON ENERGY RD&D INVESTMENTS IN THE UNITED STATES BETWEEN 2000 AND 2008.

U.S. Energy RD&D Expenditure (in mln 2008 PPP $Int)		2000	2001	2002	2003	2004	2005	2006	2007	2008
fossil energy (incl. CCS)	government	308	633	713	633	610	420	577	583	659
	other	986	867	863	1067	1162				
nuclear energy (incl. fusion)	government	354	365	466	461	480	529	583	678	770
	other		27	25		34				
renew able energy sources	government	346	410	415	326	292	306	272	579	699
	other									
energy efficiency	government	624	671	549	567	535	486	467	442	525
	other									
transmission, distribution & storage	government	30	32	89	202	252	286	314	286	319
	other									
energy technologies (unspecified)	government	924	1163	1150	1152	863	924	980	1120	1160
	other	285	535	784	728	1350				
total	**government**	**2586**	**3274**	**3382**	**3341**	**3031**	**2951**	**3193**	**3688**	**4132**
	other	**1271**	**1430**	**1671**	**1794**	**2545**				

3.2 Brazil

3.2.1 RD&D Institutions

Energy RD&D funding in Brazil comes from mandatory contributions by the SOEs in the oil and gas industry and the electricity sector. In 2008, the Brazilian government owned 56% of Petrobras, the state oil company. Between 2002 and 2008, the government owned 52-58% of Electrobras, the state electricity company.

Energy RD&D in the electricity sector is monitored, evaluated, and allocated by the electricity regulator. Annual energy RD&D funding is based on a minimum of 1% of utilities' net operating income. This funding is directed toward energy R&D or energy efficiency demonstration projects in the market with the exact allocation depending on whether the utilities are generators, transmission companies, or distribution companies. Some RD&D funds support national R&D programs, such as the Brazilian scientific and technological development fund and the sectoral CT-Energy program which funds research on end-use energy-efficiency in industry. Remaining funds are used for in-house R&D projects assessed and evaluated according to guidelines by the regulator (Soares et al. 2008).

Similar regulation is in place to collect energy R&D funds from Brazil's state-owned oil company, Petrobras. In 2008, Petrobras was mandated to redistribute 25% of royalties that exceed 5% of oil and natural gas production to fund energy R&D in the CT-Energy and CT-Petro programs. CT-Petro supports innovation in the production chain of oil and natural gas.

Brazil's Ministries of Science and Technology, Mines and Energy, Education, and External Affairs, all fund nuclear energy RD&D. The National Nuclear Energy Commission within the Ministry of Science and Technology is Brazil's nuclear energy regulator and also the most important organization supporting nuclear technology and innovation with an R&D budget supporting health, agriculture, environment, and industry applications of nuclear energy (Obadia 2010).

3.2.2 RD&D Investments

Table 3 provides an overview of Brazil's energy RD&D investments. Technology categories are explained in Table 1. Data come from RD&D investments from CT-Energy, CT-Petro, regulator-mandated R&D investments in energy efficiency, and the annual reports of Petrobras and Eletrobras. Central government funding for fossil energy RD&D includes funds in CT-Petro (which supports exploration, production, supply, gas/energy, management & centers). "Other" funding includes Petrobras' R&D

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investments in exploration and production, supply, distribution, and gas. Central government funding for nuclear energy RD&D includes a proportion of CT-Energy funds (15% in 2006) which is assumed to be constant over time. According to ERAWatch (2010a), in 2008 the Nuclear Energy Commission and the Brazilian Nuclear Industries also have R&D budgets of R$ 511.8 million (2008 PPP $ 350 million) and R$ 432.8 million (2008 PPP $ 296 million) respectively, but these are not included in this synthesis as further details are unknown. Central government funding for renewable energy RD&D includes a proportion of CT-Energy funds as well as regulator-mandated funding. The data available on energy efficiency RD&D includes CT-Energy's funding for R&D on basic industry technologies and regulator-mandated R&D investments in energy efficiency, thermoelectric generation, and environment. Central government transmission, distribution and storage RD&D includes CT-Energy's support for RD&D on electricity and hydrogen and regulator-mandated R&D on power system security, planning, control, optimization, reliability, and measurement. RD&D funding from Eletrobras is reported under "other" funding for the residual category of unspecified energy technologies since it includes funding for a range of areas from distribution management to wave energy to conductivity.

Table 3 shows that the majority of Brazil's energy RD&D investment is focused on fossil energy and transmission, distribution and storage. These funds are tied to the revenues generated by the oil and gas, and electricity SOEs. However, Table 3 does not include the Nuclear Energy Commission's budget as the proportion allocated to energy RD&D is not known. Since Table 3 assumes constant proportions of RD&D within CT-Energy and regulator-mandated R&D budgets, it is difficult to determine whether the government's energy RD&D funding priorities have changed, although it is clear that both budgets overall have remained fairly stable.

TABLE 3. AVAILABLE DATA ON ENERGY RD&D INVESTMENTS IN BRAZIL 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**

3.3 Russia

3.3.1 RD&D Institutions

The Federal Agency for Science and Innovation manages a significant part of the civil R&D budget and is therefore one of the most important institutions in Russian R&D and innovation (MES 2006). The current applied science program (2007-2012) has five priority areas of which one is "Power Engineering and Energy Efficiency" (Khlunov 2007). The RD&D budget for this area increased from RUB 6,960 million (2008 PPP 2008 $ 704 million) in 2004 to RUB 23,567 million (2008 PPP $ 1324 million) in 2008, with over 80% invested in the government's "federal targeted programs" (Aksenova 2009). Research grants are allocated to scientific research organizations and industry on the basis of tenders (ERAWATCH 2010b). Energy R&D is also supported through materials research including projects on gas flaring, solar

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panels, efficient lighting systems, and insulation materials (Aksenova 2009). In July 2009, a new federal program on nuclear power (Government Directive 2009) but this falls after the 2008 cut-off for this data synthesis.

Little information is available on energy RD&D funding from industry, although Gokhberg (2003) estimates that in 2001 about 33% of Russia's gross domestic investments in R&D came from the private sector.

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Table 4 includes the available R&D budgets from five Russian companies: Gazprom in the natural gas industry, Rosneft, Lukoil and Surgutneftegas in the oil industry, and Unified Energy System in the electricity sector.

3.3.2 RD&D Investments

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Table 4 provides an overview of Russia's energy RD&D investments. Technology categories are explained in Table 1. Data draws on statistical overviews provided by Gokhberg (2010b), augmented by Reutov (2007) and annual reports of five major national energy companies. Federal fossil energy RD&D funding is based on R&D programs for CCS, co-generation, oil & gas recovery, extraction of non-traditional resources (deep wells, bitumen sands & arctic shelf), and processing of gas including liquefied natural gas (LNG). "Other" funding of fossil energy RD&D are Gazprom's and Lukoil's R&D investments, which provide data only for selected years. Federal renewable energy RD&D funding represents biofuels and biomass programs, federal energy efficiency RD&D represents programs to improve lighting efficiency and system management programs, and federal energy RD&D on transmission, distribution and storage is based on a hydrogen program that includes work on storage and fuel cells. In this latter technology category, 'other' funding is from Unified Energy System's R&D investments in 2000 and 2001. Data on other federal energy RD&D programs are reported under the residual unspecified energy technologies category (Klimenko 2008). "Other" funding in this category reports the difference between the data points presented above and Gohkberg's bi-annual data (2010a) on Russia's gross energy RD&D investments from all central government, industry and non-governmental sources.

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Table 4 shows that there is little information about Russia's allocation of energy RD&D to the different energy technologies, although a qualitative analysis suggests that most energy RD&D is directed toward nuclear energy, fossil energy, and transmission, distribution and storage. A list of "critical priority technologies" released in 2006 (Klimenko 2008) sheds some light about these areas of focus by specifying: nuclear power technologies; hydrogen; new and renewable sources; fossil fuel power generation and fuel production; energy saving systems for transportation, distribution and consumption of heat and electricity; efficient engines and propulsion devices for transport systems. Two of five technological development priorities cited in a 2009 presidential address are energy (including efficiency, conservation and new fuels), and nuclear technology (Smith 2010).

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TABLE 4. AVAILABLE DATA ON ENERGY RD&D INVESTMENTS IN RUSSIA 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									
renew able 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**

3.4 India

3.4.1 RD&D Institutions

Gathering information about the allocation of energy RD&D in India is difficult because the central government has several layers, all active in energy RD&D. The Planning Commission proposes R&D initiatives, but the ministries and departments have to make decisions and implement programs. Each ministry includes both SOEs and institutions responsible for funding and allocating energy RD&D budgets. The Ministries of Power, Coal, Petroleum and Natural Gas, New and Renewable Energy, as well as the Department of Atomic Energy and the Ministry of Science and Technology through the Departments of Science and Technology, and Scientific and Industrial Research, are all involved in supporting or running energy RD&D programs.

3.4.2 RD&D Investments

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Table 5 provides an overview of India's energy RD&D investments. Technology categories are explained in Table 1. Data on RD&D investments from each of these ministries are included, augmented with data on R&D investments in SOEs. "Other" funding for fossil energy RD&D include R&D budgets of SOEs that are only partially-owned by the government and the loans for R&D activities that are provided to them by the Oil Industry Development Board. Central government funding for nuclear energy RD&D is based on the total R&D budgets of the Bhabha Atomic Research Centre and the Indira Gandhi Centre for Atomic Research, although it is possible that a large fraction of their budgets is used to investigate military applications. Central government funding for renewable energy includes ministry budgets and programs as well as the R&D budget of the National Institute of Renewable Energy. Central government funding for transmission, distribution and storage includes the budget of the Central Power Research Institute and the R&D budgets of two SOEs.

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Table 5 shows that India's energy RD&D investments are mostly directed towards fossil and nuclear energy technologies. Nuclear RD&D investments more than quadrupled between 2000 and 2008 (although it is not possible to determine the proportion allocated to military applications). The RD&D budgets for and renewable energy and for transmission, distribution and storage are substantially smaller, but have received a relatively stable level of support.

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TABLE 5. AVAILABLE DATA ON ENERGY RD&D INVESTMENTS IN INDIA 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									
renew able 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**

3.5 Mexico

3.5.1 RD&D Institutions

Two organizations are central to funding and directing energy RD&D in Mexico. The first is the Ministry of Energy which finances three public research centers (OECD 2009): the Electrical Research Institute; the Mexican Institute of Petroleum; and the Institute for Nuclear Research. The second is the National Council on Science and Technology (CONACYT) which has three sectoral funds for energy research (19% on energy sustainability, 29% on hydrocarbons, and 52% on research and technological development) and also supports postgraduate and regional research centers. Part of the funding for these programs comes from PEMEX, Mexico's state-owned oil and gas company. In 2006-7, PEMEX was mandated to allocate 0.05% of the total value of crude oil and natural gas production to RD&D programs. In 2008, this tripled to 0.15%, of which the majority went to hydrocarbon RD&D (Pemex 2008).

3.5.2 RD&D Investments

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Kempener, R., Anadon, L.D., Gallagher, K.S., & K. Jiang. (2012). Energy Rd&D Investments in the Major Emerging Economies and the United States. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

Table 6 provides an overview of Mexico's energy RD&D investments. Technology categories are explained in Table 1. Data draws on government and industry investments provided by CONACYT (2008) and PEMEX's annual reports. Federal government funding for fossil energy, nuclear energy, and transmission, distribution and storage RD&D are based on the RD&D budgets of their corresponding research institutes. Fossil energy R&D also includes R&D funds provided to PEMEX. "Other" funding for fossil energy R&D includes PEMEX's budget for Scientific and Technological Research and for energy efficiency include R&D investments by the motor vehicle and other transport industries. "Other" funding for unspecified energy technologies is based on R&D investments in two sectors reported by CONACYT (2008): (1) coal, oil derivatives, and nuclear energy; and (2) electricity, gas, and water supply.

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Table 6 shows broadly stable energy RD&D budgets for fossil energy, nuclear energy, and transmission, distribution and storage, through their respective government-funded research institutes. No information is available about energy RD&D investments on renewable energy sources or energy efficiency. From the data available, the extent to which Mexico's car manufacturing industry R&D investments relate to energy efficiency is also unclear.

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TABLE 6. DATA ON ENERGY RD&D INVESTMENTS IN MEXICO 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									
renew able 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**			

3.6 China

3.6.1 RD&D Institutions

China's energy innovation system is very complex. Central government ministries, commissions, and other agencies often have overlapping areas of responsibility and action. The Ministry of Finance distributes funds for energy RD&D to the Ministry of Science and Technology, the National Development Reform Commission, the National Natural Science Foundation of China, and the Chinese Academy of Sciences. These institutions then allocate funding according to their respective missions to different research institutes (including national laboratories), higher education institutions, and enterprises (all kinds of, not only state-owned) (Gao 2010).

Furthermore, industry data are broken down into funding for energy-related science and technology activities by SOEs and by "other" enterprises. The China Statistical Yearbook does not provide any breakdown of what percentage of funds for science and technology activities in industry is spent on R&D, nor on the respective allocations to 'new' versus 'commercially available' technologies. Here we assume that all funding for science and technology activities in enterprises relates to 'new' energy technologies and can therefore be included within China's energy RD&D investments.

3.6.2 RD&D Investments

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Table 7 provides an overview of China's energy RD&D investments. Technology categories are explained in Table 1. Funding for science and technology activities by SOEs is included under government investments.

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Table 7 shows that government investments have increased rapidly since 2004. Most of this growth has taken place through increased R&D investments in SOEs, while government funding for energy-related science and technology activities in "other" enterprises in these industries declined over the same period.

If referencing this chapter, please cite:
Kempener, R., Anadon, L.D., Gallagher, K.S., & K. Jiang. (2012). Energy Rd&D Investments in the Major Emerging Economies and the United States. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

Table 7 also shows that 30 - 50% of China's total energy RD&D funding is for fossil energy. There is hardly any breakdown of the data for other energy technologies except for some data on "new fuel vehicles" projects (Siegler 2009), on nuclear energy science and technology activities in institutions of higher education, and on some large R&D investments in the transmission network (Delman & Chen 2008).

If referencing this chapter, please cite:
Kempener, R., Anadon, L.D., Gallagher, K.S., & K. Jiang. (2012). Energy Rd&D Investments in the Major Emerging Economies and the United States. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

TABLE 7. AVAILABLE DATA ON ENERGY RD&D INVESTMENTS IN CHINA 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
renew able 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**

3.7 South Africa

3.7.1 RD&D Institutions

South Africa has limited government funding for energy RD&D. The Department of Science and Technology has a small budget for energy resources and supply, and some energy-related R&D funds for natural resources, transportation, and natural sciences, technology, and engineering. The South African Department of Energy also funds energy RD&D indirectly and largely through a subsidiary research institute which is involved in the search for technologies to meet the future energy needs of South Africa, both fossil and renewable. The main research organization under the umbrella of CEF Ltd. is South Africa's National Energy Research institute (SANERI), which in 2008 was merged with the National Energy Efficiency Agency to form SANEDI[1] of the majority of government support for energy RD&D in South Africa was either carried out or funded by SANERI (in 2007 SANERI received 40 million ZAR, while the budget of the DST for energy research was 2 million ZAR). The South African government funds nuclear energy R&D indirectly through the state-owned Nuclear Energy Corporation and through a 69% ownership share in a company that develops nuclear pebble bed modular reactors (which ended in 2010). In addition, two large companies conduct energy R&D in South Africa: Eskom, which is involved in nuclear, renewables, and transmission, distribution and storage; and Sasol, which produces liquid fuels.

3.7.2 RD&D Investments

Table 8 provides an overview of South Africa's energy RD&D investments. Technology categories are explained in Table 1. "Other" funding for fossil energy RD&D includes Sasol and for nuclear, renewables, and transmission, distribution and storage RD&D includes Eskom. Federal government funding for unspecified energy technologies is based on the Department of Science and Technology's annual R&D contributions to programs on "energy resources" and "energy supply."

Table 8 shows that South Africa's government has limited involvement in directing energy RD&D investments towards particular energy technologies, except for its indirect involvement in R&D activities in the nuclear energy industry. Furthermore, the energy RD&D budget of the national energy research institute is limited in comparison to the indirect funds provided to nuclear energy RD&D. Most energy RD&D in South Africa takes place in industry, dominated by the electricity-related activities of Eskom and the coal, oil, and gas activities of Sasol.

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TABLE 8. AVAILABLE DATA ON ENERGY RD&D INVESTMENT IN SOUTH AFRICA 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**

4 COMPARATIVE COUNTRY ANALYSIS

The previous sections provided a panel data set of energy RD&D investments in the BRIMCS countries and the United States. Table 9 presents a comparative synthesis of energy RD&D investments in each of these countries for the most recent year for which data was available. The results should be interpreted with caution as this synthesis is based on official data available (with the extent to which data is available differing between countries) which are subject to missing data and underestimation.

TABLE 9. COMPARISON OF LATEST ENERGY RD&D DATA IN THE UNITED STATES AND THE BRIMCS COUNTRIES.

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

* Data from United States, Brazil, Russia, India, China and South Africa mainly based on 2008, Mexico on 2007.
'Other' includes (whenever available) funding from state and local governments, partially state-owned 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 expenditures are expected to be higher.
>> These cumulative values are based on data from two BRIMCS countries or less, so actual expenditures are expected to be much higher.

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Two main conclusions can be drawn from this synthesis. First, fossil and nuclear energy receive the highest level of RD&D funding in both the United States and the BRIMCS countries. Even though support for renewable energy RD&D programs has increased substantially between 2000 and 2008 in the United States, Brazil, and India, absolute levels of funding remain small compared to fossil and nuclear energy. Energy RD&D funding in transmission, distribution and storage has gained substantial support in China, Brazil, and Mexico, which can be explained by the important role of SOEs in the electricity industry in these countries.

Second, governments and 100% government-owned SOEs in the BRIMCS countries invested a minimum of US$ 13.8 billion in energy RD&D in 2008, with around 90% of these funds coming from SOEs (see Table 9). Governments in the BRIMCS countries may thus control larger amounts of energy RD&D funding than the governments in IEA member countries whose total energy RD&D investments were US$12.7 billion in the same year. This finding is subject to data limitations, particularly the lack of systematic reporting, and definitions of what constitutes RD&D varying widely between different data sources.

Table 10 provides a comparison of energy RD&D investments in the United States and the BRIMCS countries relative to their GDP, energy use and energy production. The comparison is based on data from the most recent year for which the most complete aggregate data was available in each country. The results show significant differences between countries, with the relative amounts of energy RD&D investments highly dependent on the comparison metric. China's government investments in energy RD&D are higher than any other country based on any metric, but funding from "other" sources is lower than any other country. Conversely, "other" funding in Brazil is relatively large because of the R&D expenditure by Petrobras and Eletrobras. In Russia, government investments are relatively low if measured in terms of energy use and production due its abundant energy resources. South Africa's government energy RD&D investments relative to GDP are higher than in most other countries, although their absolute value is lowest (see Table 9). Similarly, the size of energy RD&D investments from India's government relative to India's GDP, energy production or energy use is higher than the United States, whereas their absolute value is less than 30% that of the United States. In general, therefore, energy RD&D investments of "governments" or "others" cannot be explained as a simple function of either GDP, energy consumption or energy production.

TABLE 10 ENERGY RD&D INVESTMENTS RELATIVE TO GDP, ENERGY USE AND ENERGY PRODUCTION.

Energy RD&D investments (% of GDP * 10^{-2})							
	United States	*Brazil*	*Russia*	*India*	*Mexico*	*China*	*South Africa*
government	2.9	1.8	0.5	3.5	1.7	14.9	5.7
other	2.0	7.7	3.9	2.1	2.0	1.7	5.2
Energy RD&D investments relative to energy use (mln 2008 PPP $int / mln tonnes oil equivalent)[1,2]							
	United States	*Brazil*	*Russia*	*India*	*Mexico*	*China*	*South Africa*
government	1.8	1.4	0.2	2.0	1.4	6.0	2.0
other	1.1	6.1	1.4	1.2	1.6	0.7	1.8
Energy RD&D investments relative to energy production (mln 2008 PPP $int / mln tonnes oil equivalent)[1,2]							
	United States	*Brazil*	*Russia*	*India*	*Mexico*	*China*	*South Africa*
government	2.5	1.5	0.1	2.6	1.0	6.5	1.7
other	1.6	6.7	0.7	1.5	1.1	0.7	1.6

[1] U.S. gov.= '08, U.S other = '04, Brazil gov. = '07, Brazil other = '07, Russia gov. = '08, Russia other = '08, India gov. = '08, India other = '08, Mexico gov. = '07, Mexico other = '05, China gov. = '04, China other = '04, South Africa gov. = '07, South Africa other = '07

[2] Data on energy production and energy use from the World Bank WDI (2010). Data for the year 2008 is not available, so energy RD&D investments in 2008 are relative to energy production and energy use in 2007.

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5 CONCLUSION

This chapter provides an overview of energy research, development, and demonstration (RD&D) investments in six major emerging economies: Brazil, Russia, India, Mexico, China, and South Africa (the 'BRIMCS' countries). Energy RD&D investments are categorized by funding source (government and other) and by technology category.

Analysis of available information shows that fossil fuel and nuclear energy have received the highest level of RD&D funding between 2000 and 2007 in the BRIMCS countries as well as the United States. In 2008, renewable energy RD&D funding in the United States exceeded fossil energy RD&D funding, but in the BRIMCS countries RD&D investments in fossil and nuclear energy RD&D remain the largest. The significant investments in energy RD&D made by the BRIMCS countries in absolute terms points to the need to include the BRIMCS countries into a comprehensive global effort to accelerate energy technology innovation and meet the world's energy challenges. The relative efforts of the different BRIMCS countries and the United States highly depend on whether GDP, energy use or energy production are used as measures for comparison.

Finally, this overview emphasizes that a more comprehensive and systematic effort is needed to collect information on energy RD&D investments by central governments and other institutions. Currently, governments in the BRIMCS countries still have limited information on their energy RD&D investments and to the extent information is available, it is often not categorized into different priority areas. This impedes effective policy making as well as the search for mutually beneficial international energy RD&D activities.

6 FURTHER READING

IEA (2011), "Clean Energy Progress Report," IEA input into the Clean Energy Ministerial, June 2011.

Anadon, L. (2011) Transforming U.S. Energy Innovation," Energy Research, Development, Demonstration and Deployment Project, Energy Technology Innovation Policy Group, Belfer Center of Science and International Affairs, November 2011.

7 REFERENCES

Aksenova, I., (2009), "Personal Communication: Energy R&D funding in Russia," email correspondence with M. Bunn, 2 November 2009.

Anonymous, (2008), "Statement of Katharine A. Frederiksen Acting Assistant Secretary Office of Policy and International Affairs U.S. Department of Energy," U.S.-China Economic and Security Review Commission, Washington D.C.: 10.

CONACYT (2008), "Informe General del Estado de la Ciencia y la Tecnología (in Spanish)," Consejo Nacional de Ciencia y Tecnologia, accessed 12/09 at, http://www.conacyt.mx/.

CONACYT (2010), "Difusion del Fondo CONACYT-SENER (antecedentes)," CONACYT; SENER, accessed 08/10 at, http://www.conacyt.gob.mx/Fondos/Sectoriales/SENER/Sustentabilidad-Energetica/2010/Difusion-del-fondo.ppt.

If referencing this chapter, please cite:
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Delman, J. and Y. Chen (2008), "Nordic Collaboration with China in Energy Research and Development," Nordic Institute of Asian Studies, commissioned by Nordic Energy Research, 127, accessed 10/10 at, http://www.nordicenergy.net/section.cfm?id=3-0&path=142.

ERAWATCH (2010a), "National Profiles: Brazil," ERAWATCH, accessed 08/10 at, http://cordis.europa.eu/erawatch/index.cfm?fuseaction=ri.content&topicID=329&countryCode=BR.

ERAWATCH (2010b), "Russian Federation; Federal Agency for Science and Innovation," ERAWATCH, accessed 08/10 at, http://cordis.europa.eu/erawatch/index.cfm?fuseaction=org.document&uuid=E45D3E10-043B-5E51-3526AADB9C2B6169.

Gallagher, K. S. and L. D. Anadon (2010), "DoE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy research group, John F. Kennedy School of Government, Harvard University, accessed at, http://belfercenter.ksg.harvard.edu/publication/20013/doe_budget_authority_for_energy_research_development_demonstration_database.html.

Gallagher, K. S., L. D. Anadon, et al., (2010), "Trends in Investments in Global Energy RD&D," Wiley interdisciplinary Reviews: Energy innovation, R. A. Pielke, Wiley.

Gallagher, K. S., J. P. Holdren, et al., (2006), "Energy-Technology Innovation," Annual Review of Environment and Resources, 31(1): 193-237.

Gao, C., (2010), "Personal Communication," email correspondence with R. Kempener, 19 June 2010.

Gokhberg, L., (2003), "S&T and Innovation in the New Economy: Search for Systemic Solutions," The First Globelcis Conference Innovation Systems and Development Strategies for the Third Millenium, Rio de Janeiro, Brazil, accessed at, redesist.ie.ufrj.br/globelics/slides/Leonid%20Gokhberg.pdf.

Gokhberg, L., (2010a), "Personal Communication: Gross domestic expenditure (GERD) on energy R&D," email correspondence with A. Grubler, 19 February 2010.

Gokhberg, L., (2010b), "Personal Communicationo: Gross domestic expenditure (GERD) on energy R&D," email correspondence with A. Grubler, 19 February 2010.

Government Directive (2009), "Nuclear Power Technologies of the New Generation for 2010-15 and prospectively to 2020," R.F. Government Directive Russia, Federal Targeted program, accessed at,

Kempener, R., L. D. Anadon, et al. (2010), "Governmental Energy Innovation Investments and Policies in the Major Emerging Economies: Brazil, Russia, India, Mexico, China, and South Africa," Energy Research, Development, Demonstration and Deployment Project, Energy Technology Innovation Policy Group, Belfer Center of Science and International Affairs, 1-61, accessed 11/10 at, http://belfercenter.ksg.harvard.edu/publication/20517/.

Keohane, R. O., (1978), "The International Energy Agency: State Influence and Transgovernmental Politics," International Organization, 32(4): 929-951.

Khlunov, A., (2007), "EU-Russia: New perspectives for S&T Cooperation for 2007-2013," International Conference EU-Russia Cooperation: Priorities for Science and Technology 2007-2013, moscow, accessed at, http://hse.ru/temp/2007/files/02_22_konf/Khlunov.pdf.

Klimenko, A., (2008), "Russian R&D Policy in the Field of Energy Technology," FASI-IEA NEET Workshop 'Cooperation in the field of energy technologies', Moscow, Russia, accessed at,

Lantzke, U., (1975), "The OECD and Its International Energy Agency," Daedalus, 104(4): 217-227.

MES (2006), "Strategy Development of Science and Innovation in the Russian Federation for the Period up to 2015," Ministry of Education and Science of the Russian Federation, 123, accessed 08/10 at, http://mon.gov.ru/work/nti/dok/.

If referencing this chapter, please cite:
Kempener, R., Anadon, L.D., Gallagher, K.S., & K. Jiang. (2012). Energy Rd&D Investments in the Major Emerging Economies and the United States. Historical Case Studies of Energy Technology Innovation in: Chapter 24, The Global Energy Assessment. Grubler A., Aguayo, F., Gallagher, K.S., Hekkert, M., Jiang, K., Mytelka, L., Neij, L., Nemet, G. & C. Wilson. Cambridge University Press: Cambridge, UK.

NSF (2008), "Research and Development in Industry: 2004," Division of Science Resources Statistics (SRS), National Science Foundation, 307, accessed 03/10 at, http://www.nsf.gov/statistics/nsf09301/.

Obadia, I. J., (2010), "Nuclear Energy RD&D Funding in Brazil," email correspondence with Personal Communication, 16 August 2010.

OECD (2002), "Frascati Manual: Proposed Standard Practice for Surveys on Resarch and Experimental Development," Organisation for Co-operation and Development, 254, accessed 08/10 at, http://www.lmt.lt/PROJEKTAI/TEKSTAI/Frascati.pdf.

OECD (2009), "OECD Reviews of Innovation Policy: Mexico," OECD, 1-220, accessed 08/10 at, http://titania.sourceoecd.org.ezp-prod1.hul.harvard.edu/vl=1699107/cl=17/nw=1/rpsv/cgi-bin/fulltextew.pl?prpsv=/ij/oecdthemes/99980134/v2009n16/s1/p1l.idx.

Pemex (2008), "Annual Report 2007/2008," Petróleos Mexicanos, accessed 12/09 at, http://www.ri.pemex.com/index.cfm?action=content&sectionID=135&catID=12320.

Reutov, B. F., (2007), "Implementation of Energy Efficiency Projects in Russia within the Framework of Public-Private Partnerships," eighteenth steering committee meeting on energy efficiency - 21 project, Geneva, Switerzland, accessed 02/10 at, http://www.unece.org/energy/se/pp/ee21_sc/18scMay07/31may/reutov_310507.pdf.

SANERI (2008), "South African progress on RE Activities; From the perspective of the SA National Energy Research Institute," SANERI, 21, accessed 03/10 at, http://www.ren21.net/presentations/SouthAfricanprogressonREActivities.pdf.

Siegler, A., (2009), "The European Green Cars Initiative," Info Day on the Research PPPs, Brussels, Belgium, accessed 10/10 at, http://ec.europa.eu/research/industrial_technologies/pdf/ppp-infoday-gc-01-a-siegler-the-european-green-cars-initiative.pdf.

Smith, M. A. (2010), "The Russian Chronologies: October - December 2009," Defence Academy of the United Kingdom, 128, accessed at,

Soares, L. R., A. C. d. Melo Junior, et al., (2008), "Overview of Brazilian R&D management: Electricity regulatory agency case," Proceedings of the R&D Management Conference 2008: Emerging and New Approaches to R&D Management, Ottawa, Canada, accessed at,

State Statistical Bureau (2009), "China Statistical Yearbook on Science and Technology," State Statistical Bureau, State Science and Technology Commission, v., accessed 10/10 at, http://hollis.harvard.edu/?itemid=%7Clibrary/m/aleph%7C005059969

World Bank, (2010), "World Development Indicators Online, 2010," online database by The World Bank Group, accessed 08/2010 at, http://go.worldbank.org/6HAYAHG8H0.

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