

→ Nuclear Power in Turkey, Egypt, and Saudi Arabia – how cost effective?

Nonproliferation Policy Education Center Conference

Prague, Czech Republic

18 March 2008

Agenda

- **Scope and framework for analysis**




- Saudi Arabia

- Egypt

- Turkey

- Preliminary conclusions

Interest in nuclear energy widespread throughout the Middle East / North Africa

-  **PROPOSED:** Expressions of interest have been made and/or studies have been carried out with an eye toward future development.
-  **PLANNED:** Agreements/contracts have been signed and operations are going ahead.
-  **UNDER CONSTRUCTION**



Economic reasons cited to support nuclear power development in the Middle East

*“Although a major oil producer, the UAE argues that it **needs nuclear energy to satisfy soaring demand for power and desalinated water**. With electricity demand soaring by 10 per cent a year, the UAE is expected to double its power capacity over the next decade to supply the rapidly-growing population and many industrial ventures. Officials say that **faster growth** as a result of economic diversification could **eat away at hydrocarbons exports**.”*

Financial Times January 21, 2008

*“But economics are also behind this new push to explore nuclear power, at least for some of the aspirants. Egypt's oil **reserves are dwindling**, Jordan has no natural resources to speak of at all, and **power from oil and gas has grown much more expensive for everyone**. Though the day has not arrived, it's conceivable that **nuclear power will be a cheaper option than traditional plants**.”*

Christian Science monitor, November 1, 2007

*“Demand for electricity is growing at more than 6 per cent annually, something which dictates doubling the capacity for electrical power generation in the GCC nations over the next 10 years. The **GCC members also wish to diversify the sources of energy** by adopting technically and **economically feasible technologies for power generation and water desalination**. This takes into consideration that the alternatives to oil and gas in the long run are nuclear energy, wind power, and solar energy, especially when we note the expected increases in oil and gas prices and rising demand, especially from the Asian region.”*

Abd-al-Rahman Bin Hamad al-Atiyyah,
Secretary General of the Gulf Cooperation Council

Three case studies are illustrative of the issues faced in the region



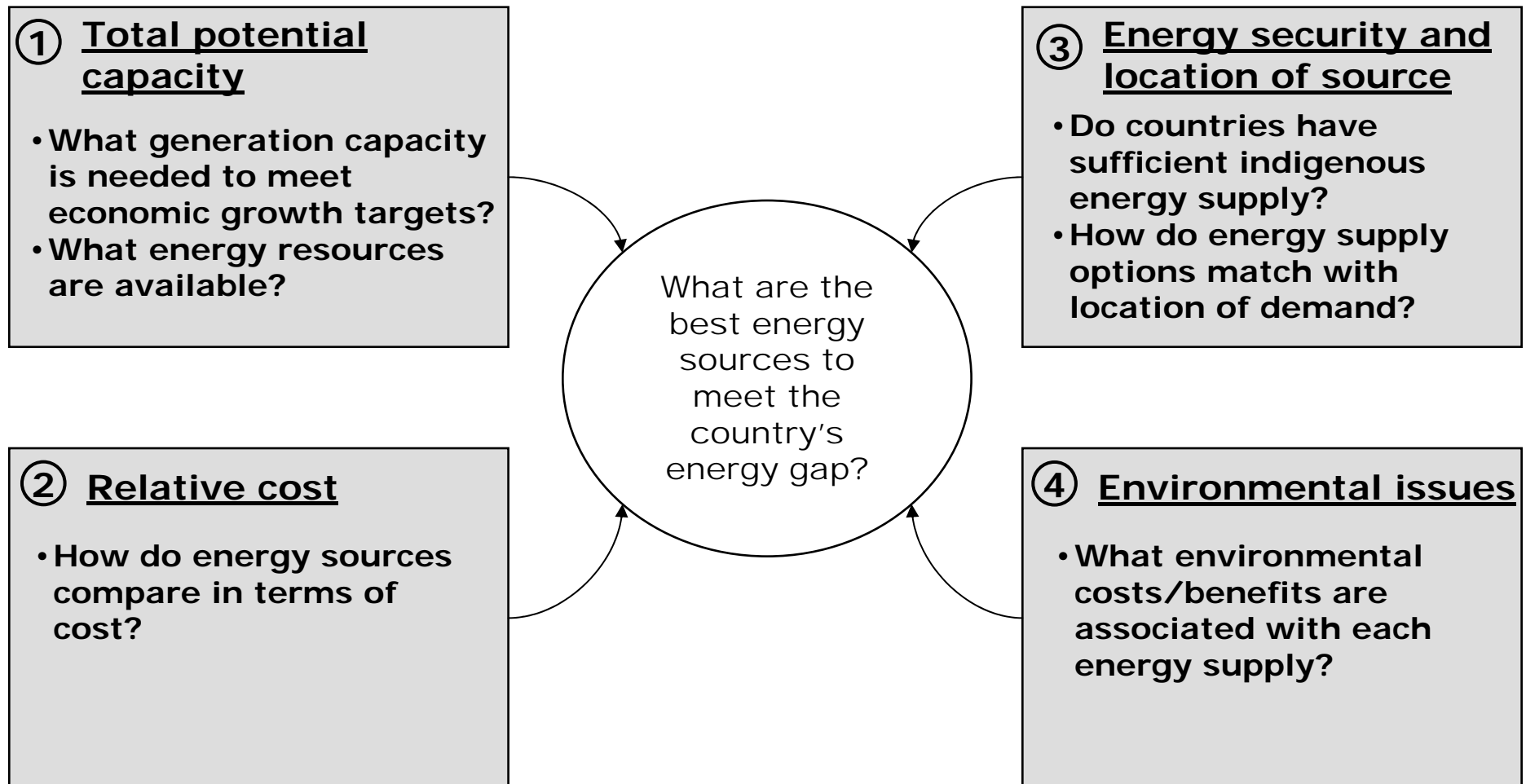
Representative characteristics

- | | | |
|--|--|--|
| <ul style="list-style-type: none"> • Large fossil fuel reserves, form base for economy • Strong sovereign credit rating • Fast rising electricity demand, partly driven by desalination needs | <ul style="list-style-type: none"> • Some domestic fossil fuel reserves • Poor credit rating | <ul style="list-style-type: none"> • No domestic fossil fuel reserve • Strong economy based on non-oil/gas sectors |
|--|--|--|

Comparable countries

- | | |
|---|--|
| <ul style="list-style-type: none"> • Libya • United Arab Emirates | <ul style="list-style-type: none"> • Algeria • Morocco • Tunisia • Yemen |
|---|--|

A framework for policy analysis for national energy strategies focuses on total potential capacity, relative costs, locations of sources, and environmental issues



Agenda

- Scope and framework for analysis

- **Saudi Arabia**

- Egypt

- Turkey

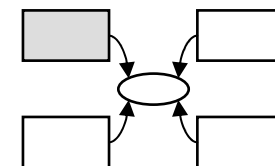
- Preliminary conclusions

Saudi Arabia relies on its tremendous fossil fuel reserves for its energy needs

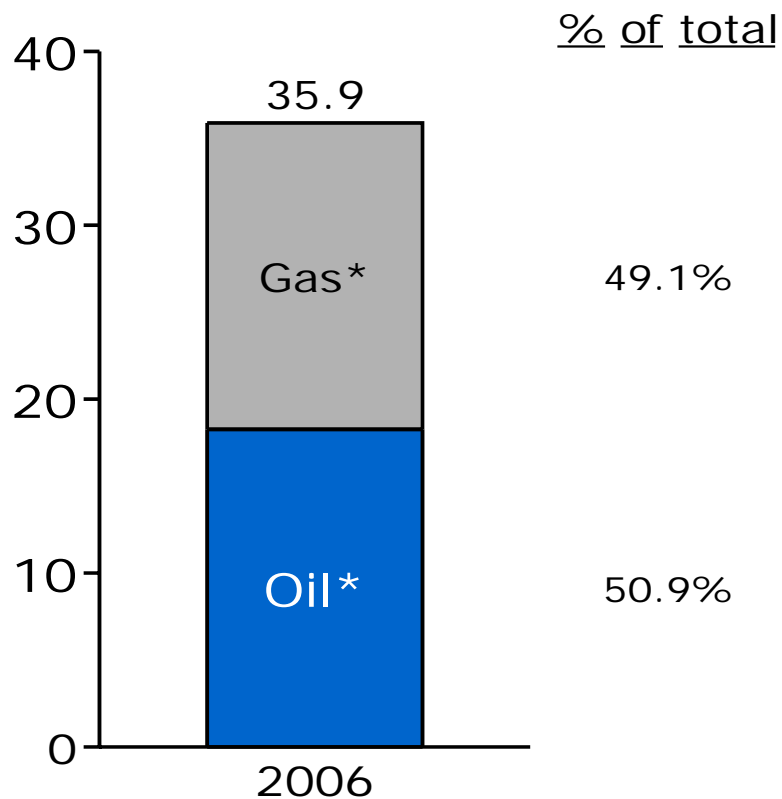


- **Key Country statistics**
 - Population: 27.6M
 - GDP: \$374.5B (2007 est, official FX rate)
 - GDP/Cap: \$20,700 (PPP)
- **Energy supply**
 - Large oil supply
 - Proven reserve: 266.8 B Barrels
 - Production: 11 million bbl/d
 - Export: 8.9 million bbl/d
 - Growing gas supply
 - Reserve: 6.6 Tcm
 - Production: 68.3 Bcm
 - Potential renewable energy sources: solar and wind
- **Energy infrastructure**
 - 35.9GW installed electricity generation capacity – most can run on both oil and gas
 - Master Gas System for domestic transport of natural gas
- **Energy demand**
 - Residential usage comprise ~53% of electricity demand, industry ~20%
 - Growth in electricity demand driven largely by requirements of new desalination plants

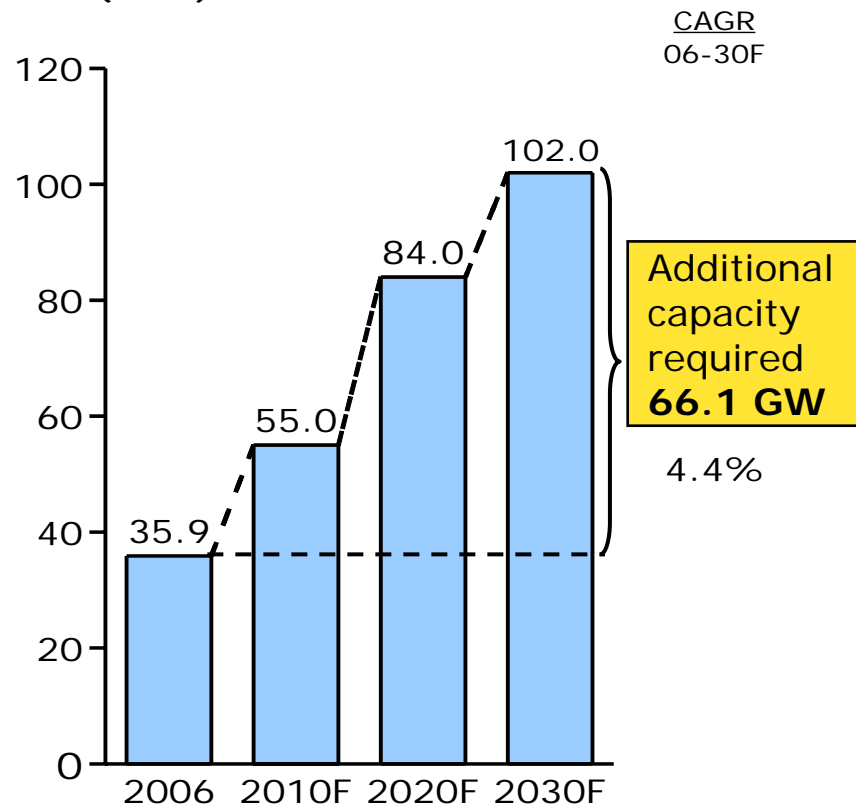
Saudi electricity generation dominated by oil and gas; need to almost triple by 2030 to meet demand



2006 Generation capacity (GW)



Generating capacity required (GW)



Drivers of demand growth

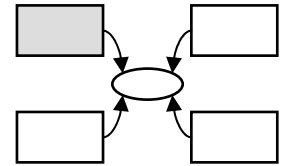
- 3.5% GDP growth **
- Large demand for water desalination

*Gas and Oil generation capacity split based on 2005 proportions

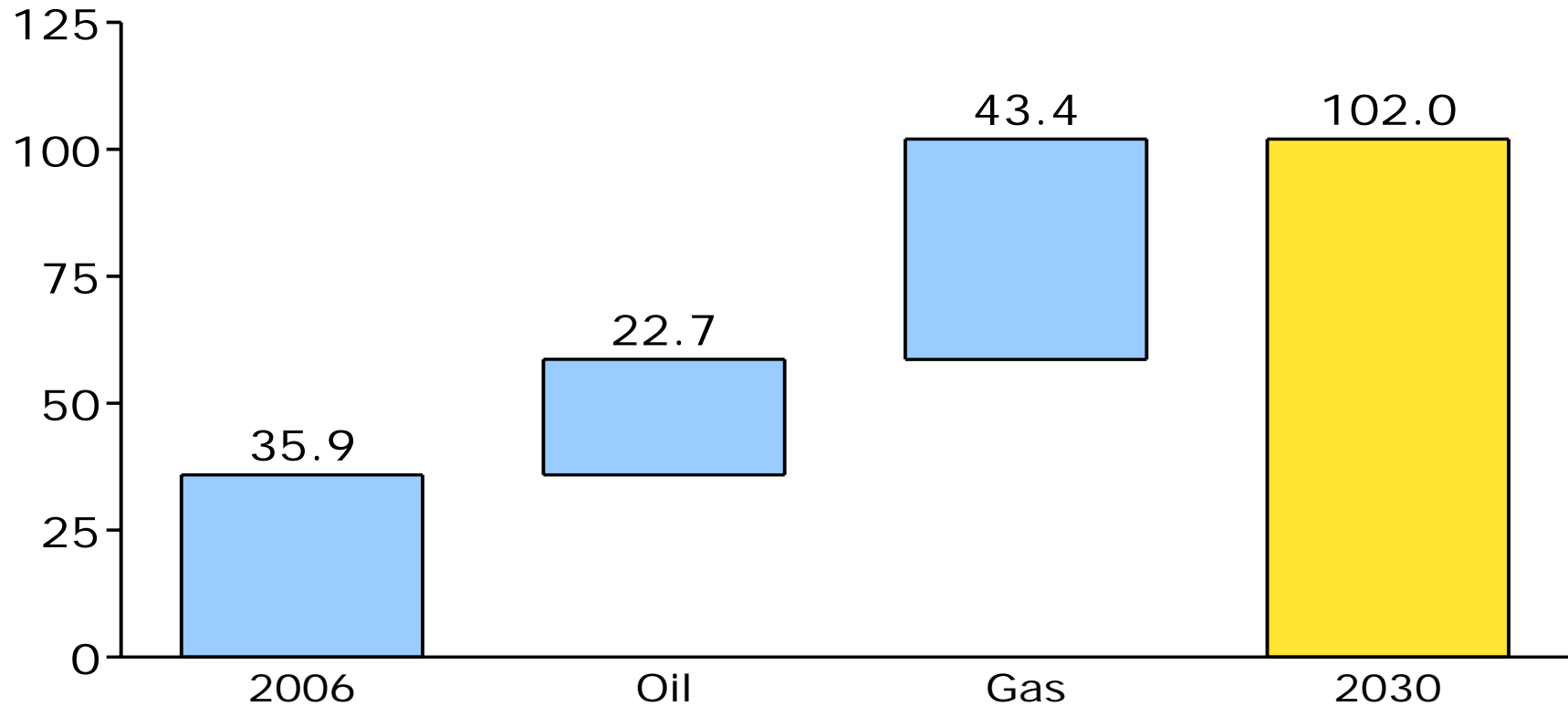
**GDP growth rate from 2003-2030

Source: Saudi Arabia Electricity and Cogeneration Regulatory Authority Annual Report 2006; International Energy Agency Statistics; World Energy Outlook 2005 – International Energy Agency

Oil and gas generators projected to fulfill the bulk of Saudi's future generation needs

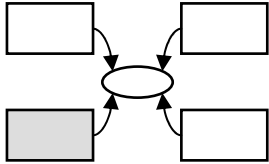


Generating capacity (GW)*



*“The Saudi government has **not seriously considered electricity generation from any source other than gas, supplemented by crude oil.** The abundance of the resource just means that there’s less economic need for anything else.”*

Global survey of comparative costs shows nuclear power highly sensitive to discount rate

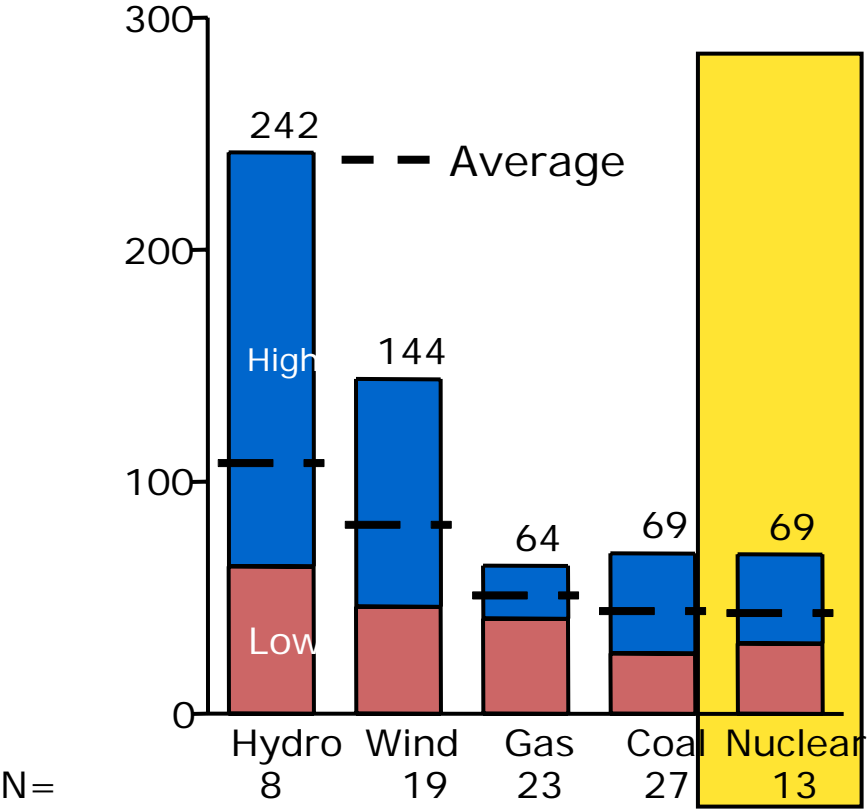
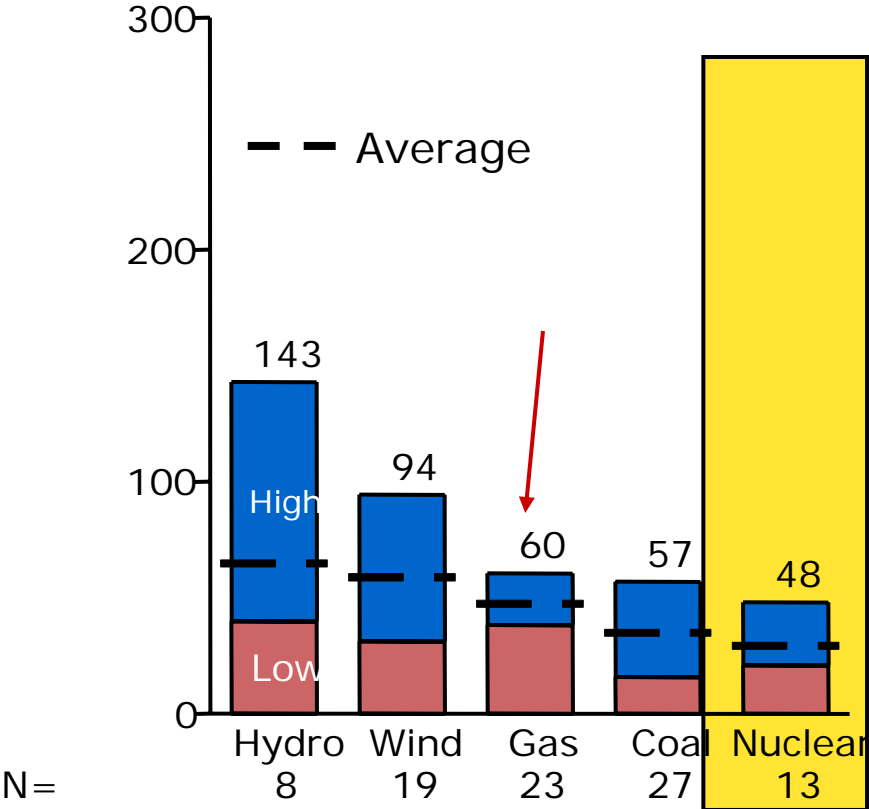


5% Discount Rate

10% Discount Rate

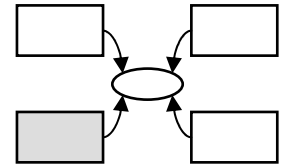
Levelized generation cost* (US\$/MWh)

Levelized generation cost* (US\$/MWh)



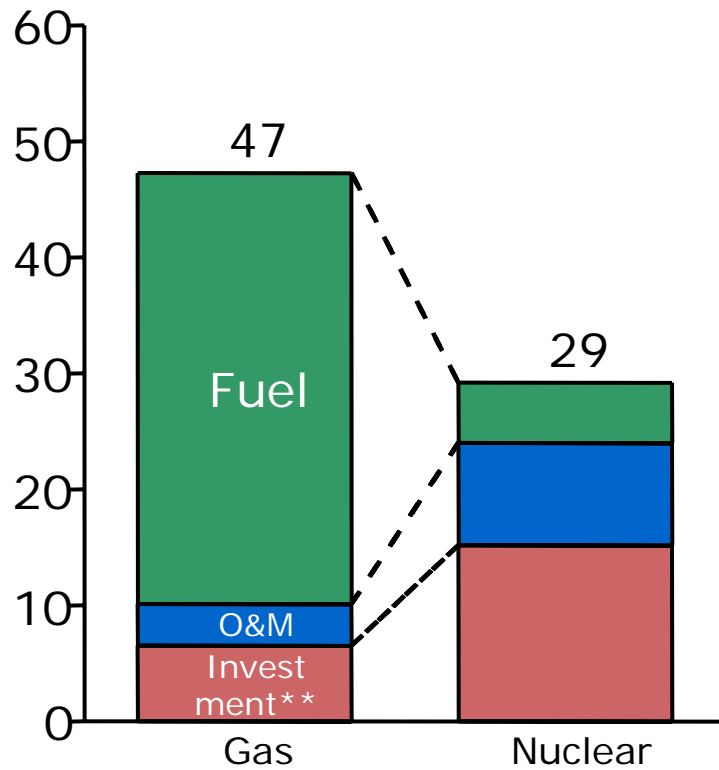
*Data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear, decommission cost; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models
 Source: Projected Cost of Generating Electricity 2005 Update – Nuclear Energy Agency / International Energy Agency

The relative capital costs drives the erosion of nuclear plants' cost advantage vs. gas plants



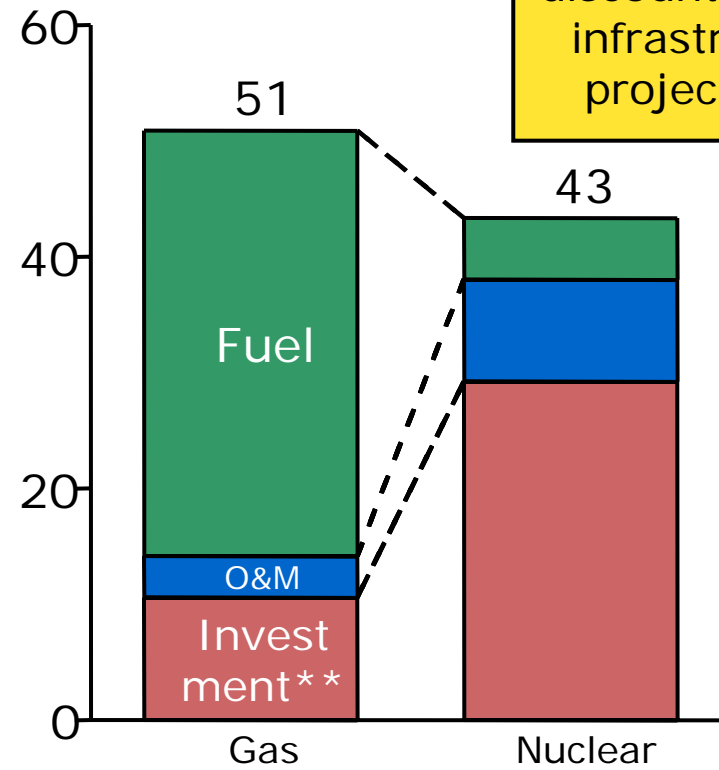
5% Discount Rate

Average levelized cost*
(US\$/MWh)



10% Discount Rate

Average levelized cost*
(US\$/MWh)



Estimated Saudi discount rate for infrastructure project: ?%

N=

23

13

N=

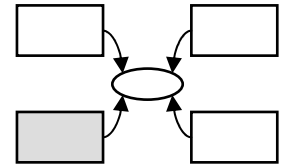
23

13

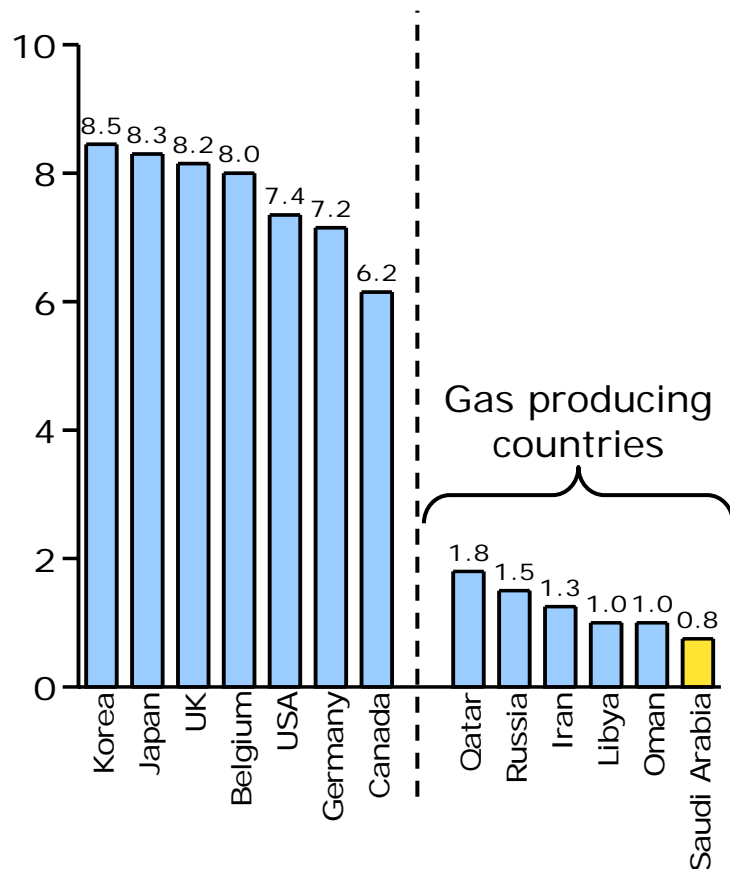
*Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models
**Investment cost for nuclear power includes decommission cost
Source: Projected Cost of Generating Electricity 2005 Update – Nuclear Energy Agency / International Energy Agency



In addition, Saudi's extremely low gas "cost" significantly reduces the cost of gas plants

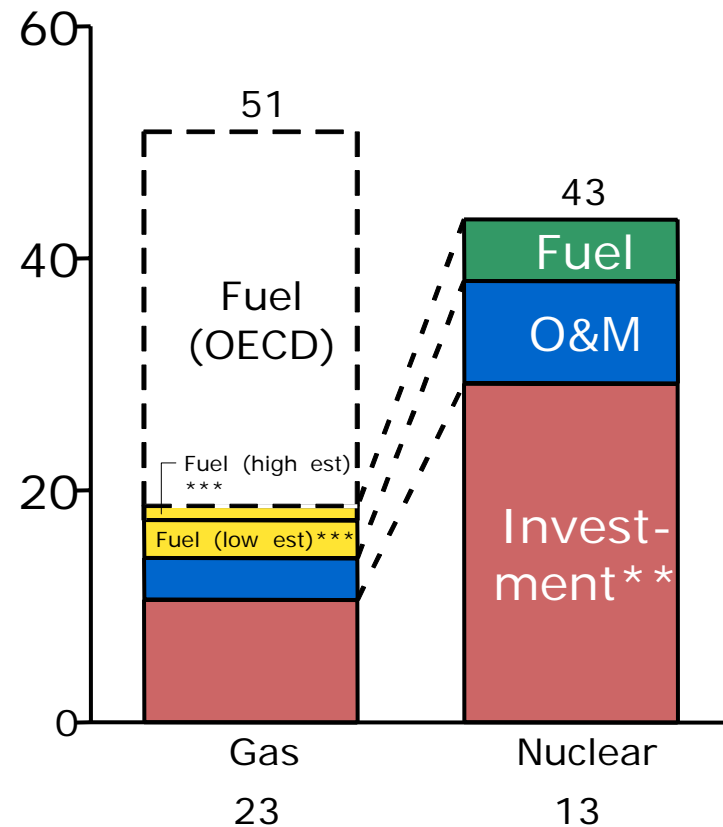


Natural Gas cost
(US\$ per million BTUs, 2007 Q2)



10% Discount Rate

Average Levelized cost*
(US\$/MWh)



*Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Levelized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models

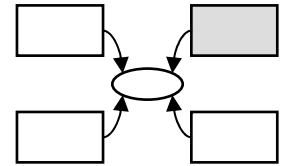
** Investment cost for nuclear power includes decommission cost

***calculated as Saudi's gas price as % of the lowest and highest price in the OECD gas price data available

Source: American Chemistry council; Projected Cost of Generating Electricity 2005 Update – Nuclear Energy Agency / IEA

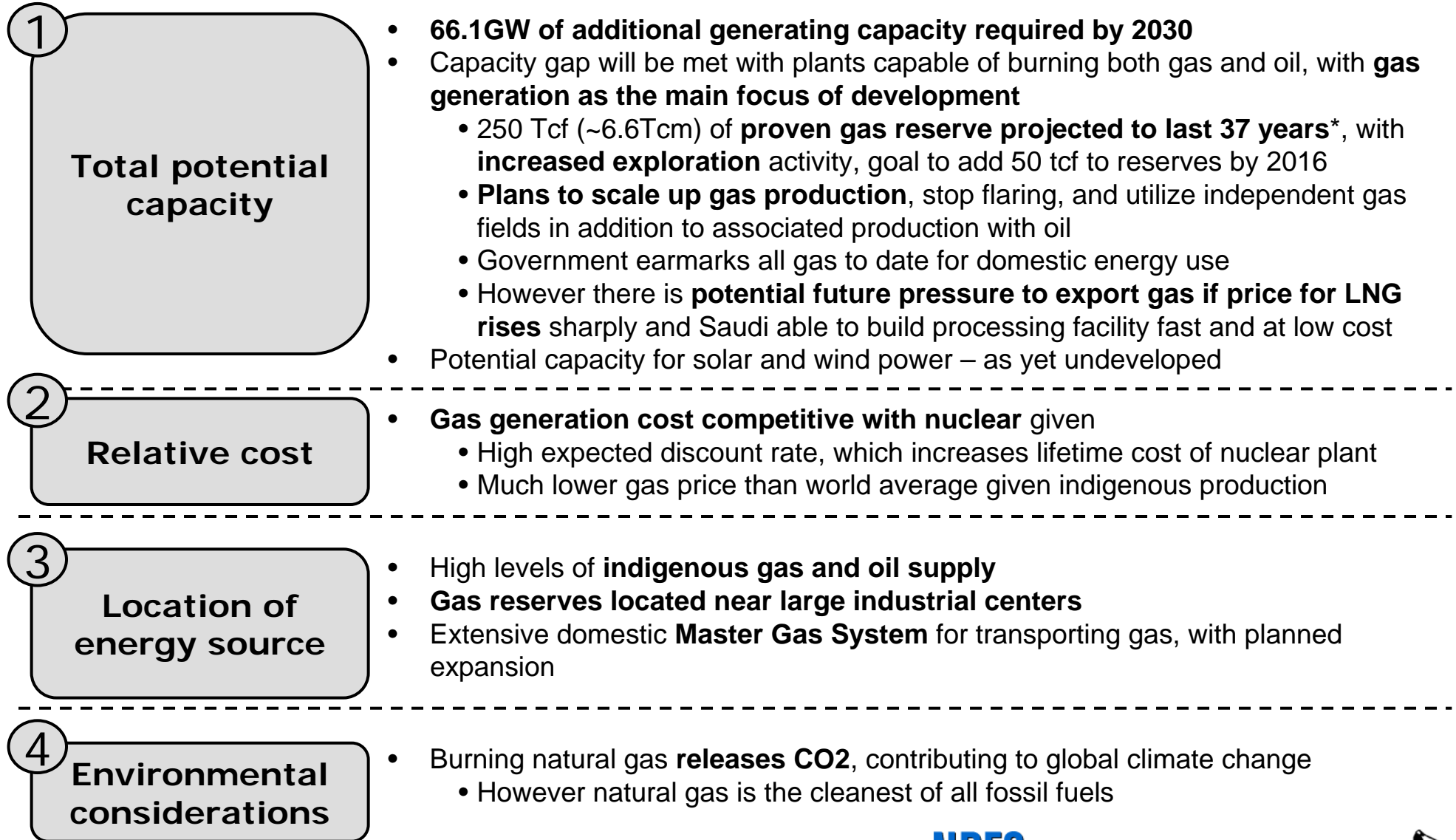


Saudi Arabia has an extensive fuel supply and infrastructure



Indigenous fuel supply and infrastructure for transporting fuel ensures energy security

Saudi can meet its electricity demand effectively through developing gas generation





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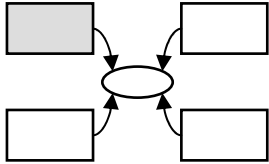


Egypt has many sources of indigenous energy supply including oil, gas, and hydro

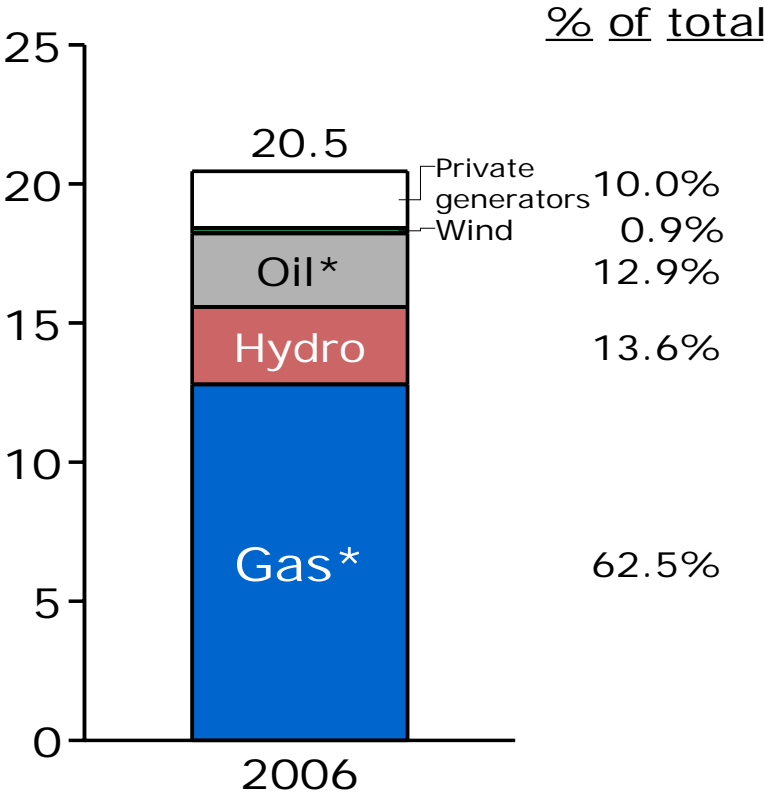


- **Key Country statistics**
 - Population: 80.3M
 - GDP: \$127.9B (2007 est, official FX rate)
 - GDP/Cap: \$5,400 (PPP)
- **Energy supply**
 - Dwindling oil supply
 - Reserve: 3.7 B Barrels
 - Production: 684K bbl/d
 - Export: 153K bbl/d
 - Growing gas supply
 - Reserve: 1.6 Tcm
 - Production: 40.8 Bcm
 - Export: 7.95 Bcm
 - Aswan Dam accounts 13.6% of electricity
 - Other potential sources: solar, wind, small hydro
 - 3 nuclear plant in planning/pre-feasibility stage
- **Energy infrastructure**
 - 20.5GW installed electricity generation capacity
- **Energy demand**
 - Residential and industrial sector account for 36% and 35% of electricity consumption, respectively
 - Demand growth slowing with slowing population and GDP growth

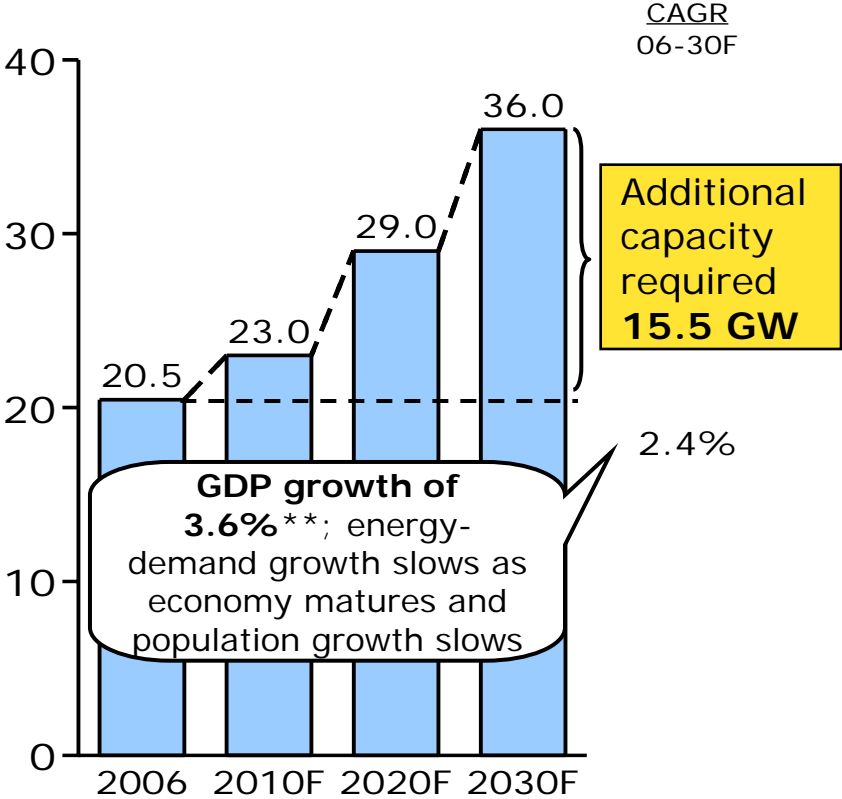
Egypt requires 15.5GW more generation capacity by 2030 to meet its slowing but growing demand



2006 Generation capacity (GW)

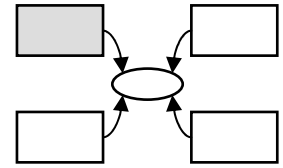


Generating capacity required (GW)

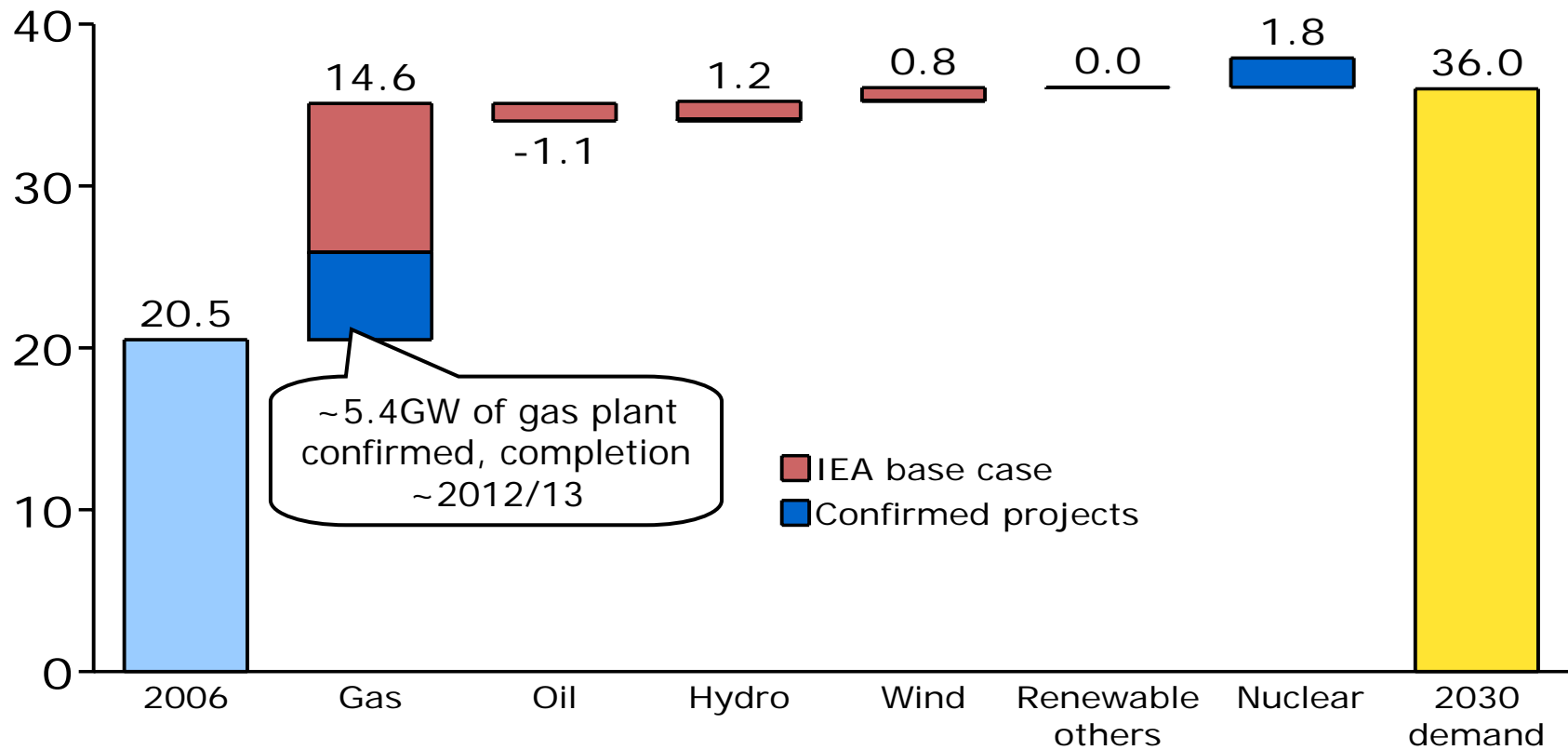


*Gas and Oil generation capacity estimated based on total "thermal" generation capacity in 2006 and average ratio of gas to oil generation capacity in 2003 and 2010F
 **GDP growth rate from 2003-2030
 Source: Egyptian Electric Holding Company Annual Report 2005-2006; Demand projection from World Energy Outlook 2005 – the Middle East and North Africa Insights, International Energy Agency

Gas power plants projected to fill most Egypt's electricity generation gap

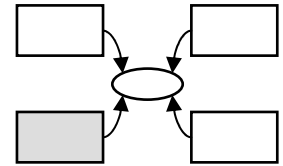


Generating capacity (GW)



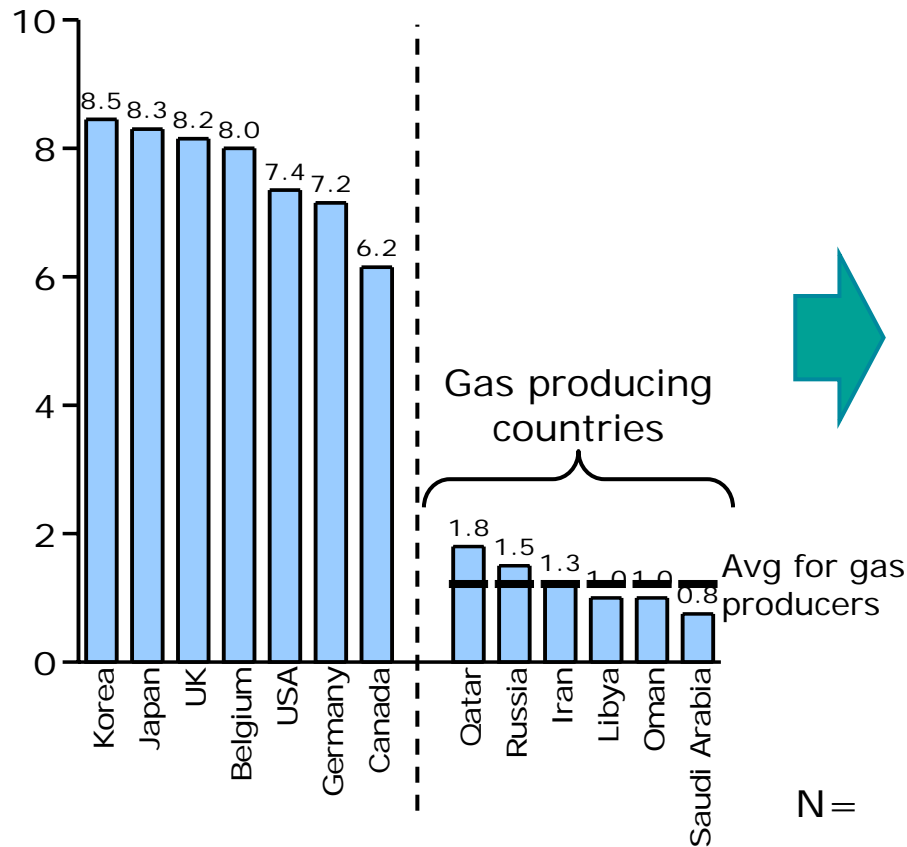
Source: World Energy Outlook 2005 – IEA; "US\$325 Million AfDB Loan for Abu Qir 1300 MW Steam Power Project" Africa News, November 14, 2007; "Egypt Approves plans to build three new nuclear power stations" BBC, September 26, 2006; Economic Intelligence Unit Country profile – Egypt: Egyptian electric Holding Co. AR 2005/06

Egypt's low gas price makes gas power plants cost competitive with nuclear



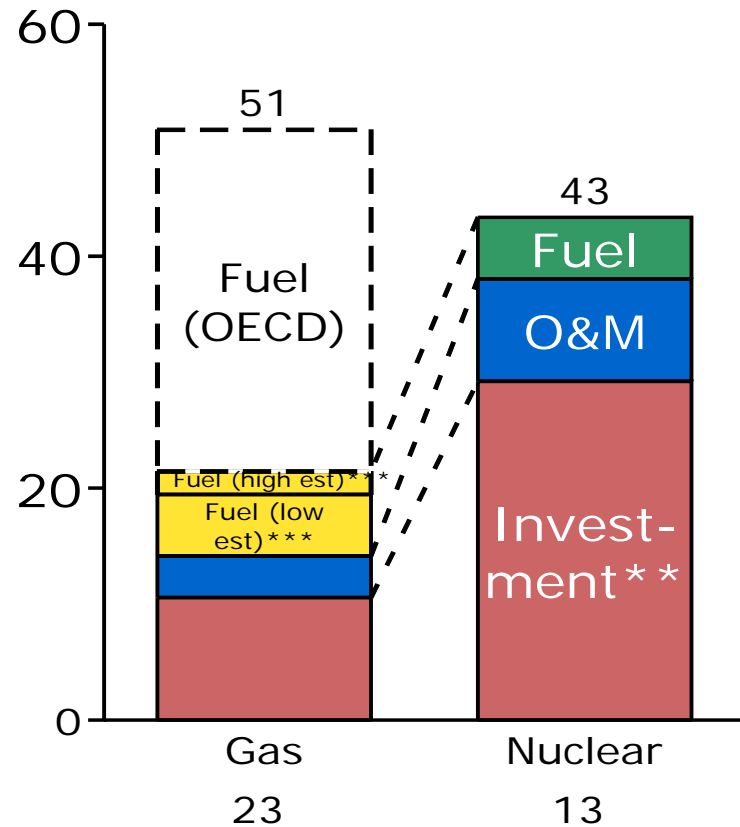
10% Discount Rate

Natural Gas cost
(US\$ per million BTUs, 2007 Q2)



N =

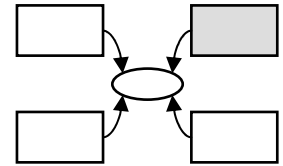
Average leverized cost*
(US\$/MWh)



*Average of data from survey of new facilities in 21 countries, mostly OECD but also include 4 developing countries. Leverized generation cost include initial investment cost, Operation and Maintenance cost, Fuel cost, and in the case of nuclear; main assumptions – 85% capacity factor for plants, 40 year lifetime for coal and nuclear plants, for other plants lifetime come from country level responses, fuel price projection based on each country's models
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 ***calculated as average gas producing country's gas price as % of the lowest and highest price in the OECD gas price data available
 Source: Projected Cost of Generating Electricity 2005 Update – Nuclear Energy Agency / International Energy Agency

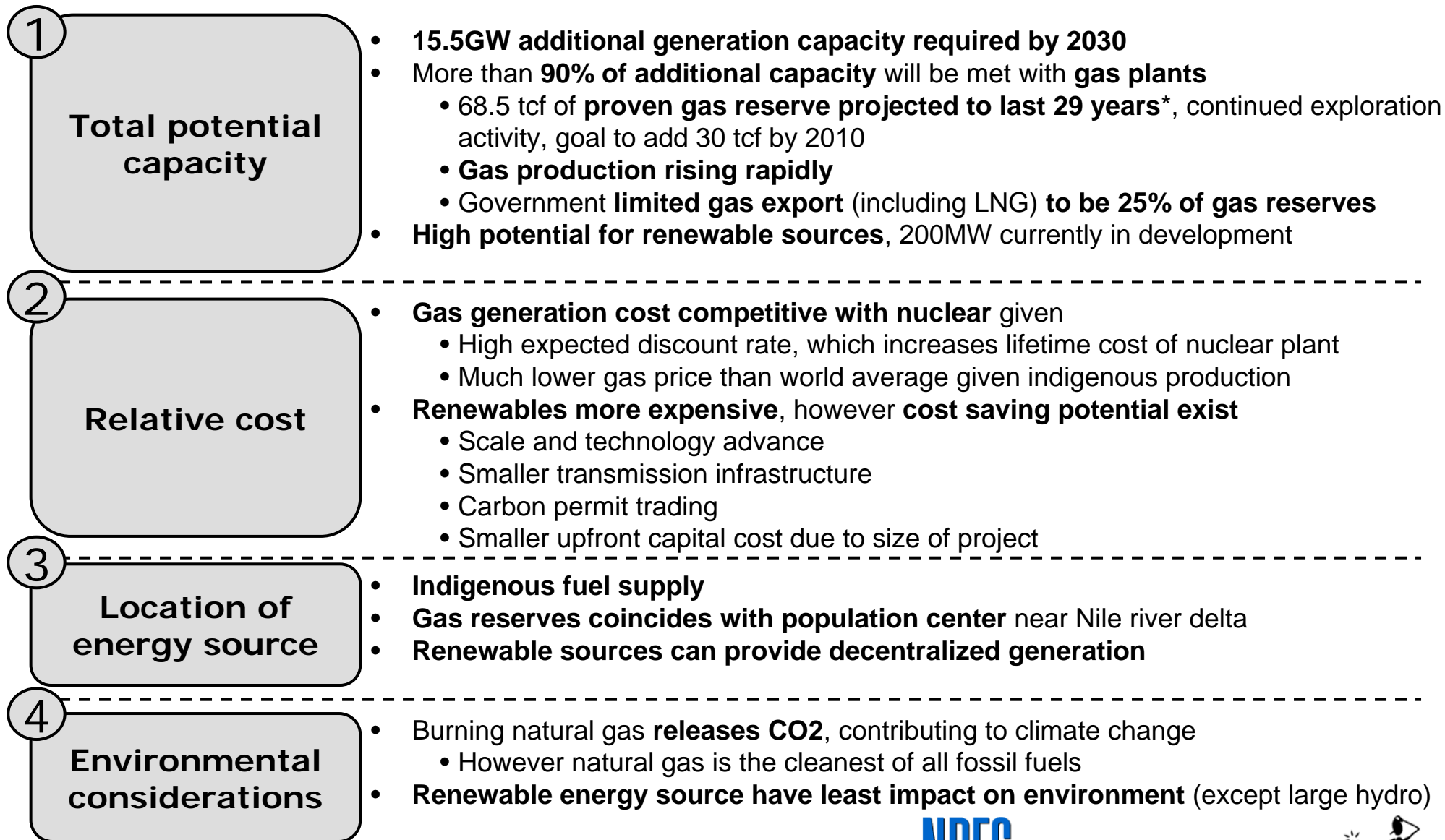


Egypt's gas reserves correspond with population centers; extensive transport infrastructure in place



Indigenous fuel supply sufficient to meet domestic energy needs

Egypt can meet its electricity demand effectively through development of gas and renewable fuels





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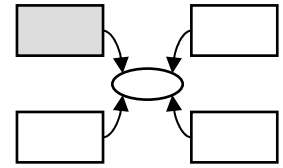


Turkey relies on imported oil, gas, and indigenous supply of renewable sources for energy

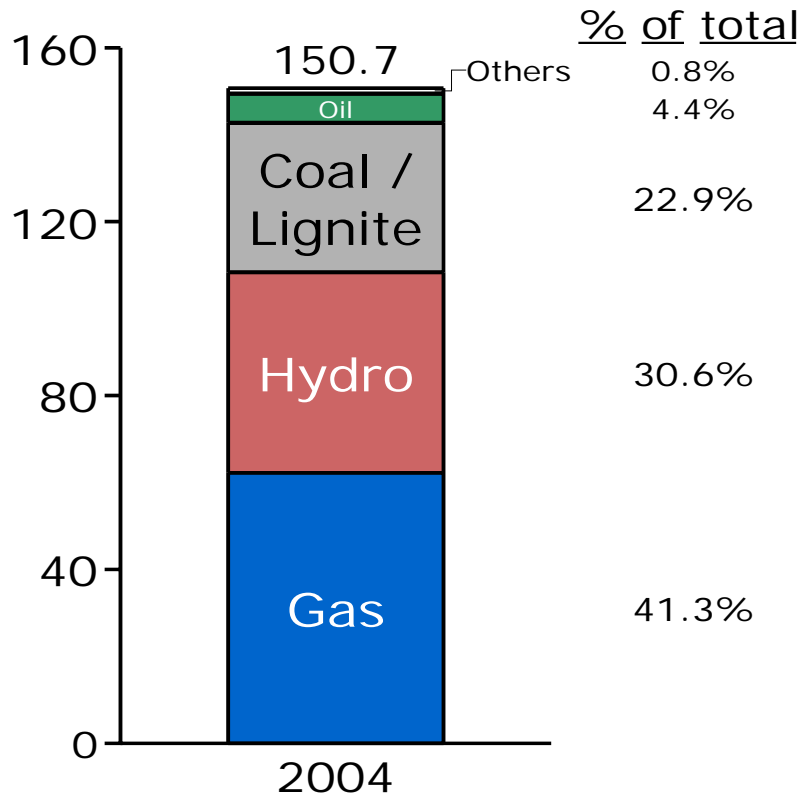


- **Key Country statistics**
 - Population: 71.2M
 - GDP: \$482B (2007 est, official FX rate)
 - GDP/Cap: \$9,400 (PPP)
- **Energy infrastructure**
 - 40.8GW installed electricity generation capacity
- **Energy demand**
 - Industry account for 56.9% of electricity demand
 - Residential account for 22.8% of electricity demand
- **Energy supply**
 - Small oil supply
 - Reserve: 300 M Barrels
 - Production: 45.5 bbl/d
 - Net import: 612K bbl/d
 - Small gas supply
 - Reserve: 8.1 Bcm
 - Production: 860 Mcm
 - Import: 25.5 Bcm
 - Some coal / lignite supply
 - Large hydro potential – currently supply 30.6% of total electricity
 - Estimated large wind and solar potential

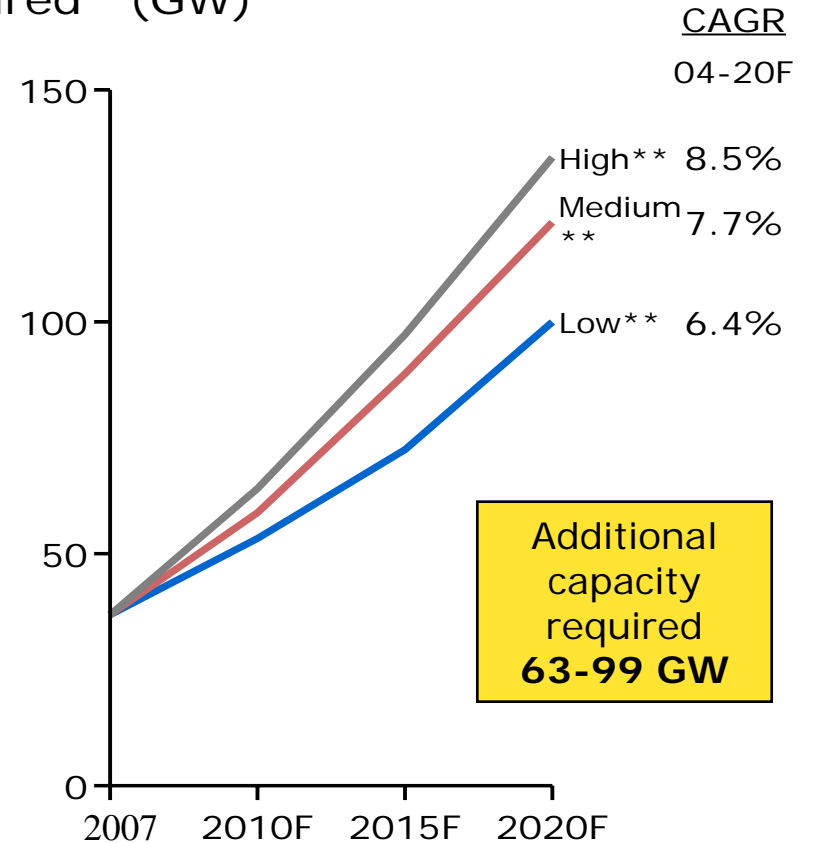
Turkey's main electricity fuel is fossil fuel and hydro – growth in demand projections vary widely



2004 Electricity generated (TWh)

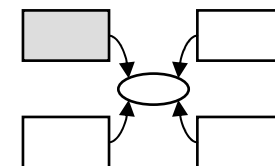


Generating capacity required* (GW)



*Generating capacity required projection based on growth rate in electricity generated projection
 **MAED-Model for Analysis of Energy Demand by the International Atomic Energy Agency – Scenario 1 is based on GNP growth by the Turkish Planning Organization (DPT) in May 2002, Scenario 2 based on GNP growth planned in Apr 2004, Scenario 3 assumes different production industry prediction than Scenario 2 (TBD), from Report of Turkey Long Term Electric Energy Demand, 2004. Ministry of Energy and Natural Resources
 Source: Turkey Statistical Yearbook 2006;

Turkey has long term contracts of natural gas until ~2020 at which time they would be renegotiated

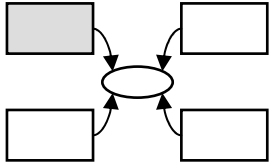


Natural Gas Import Contracts

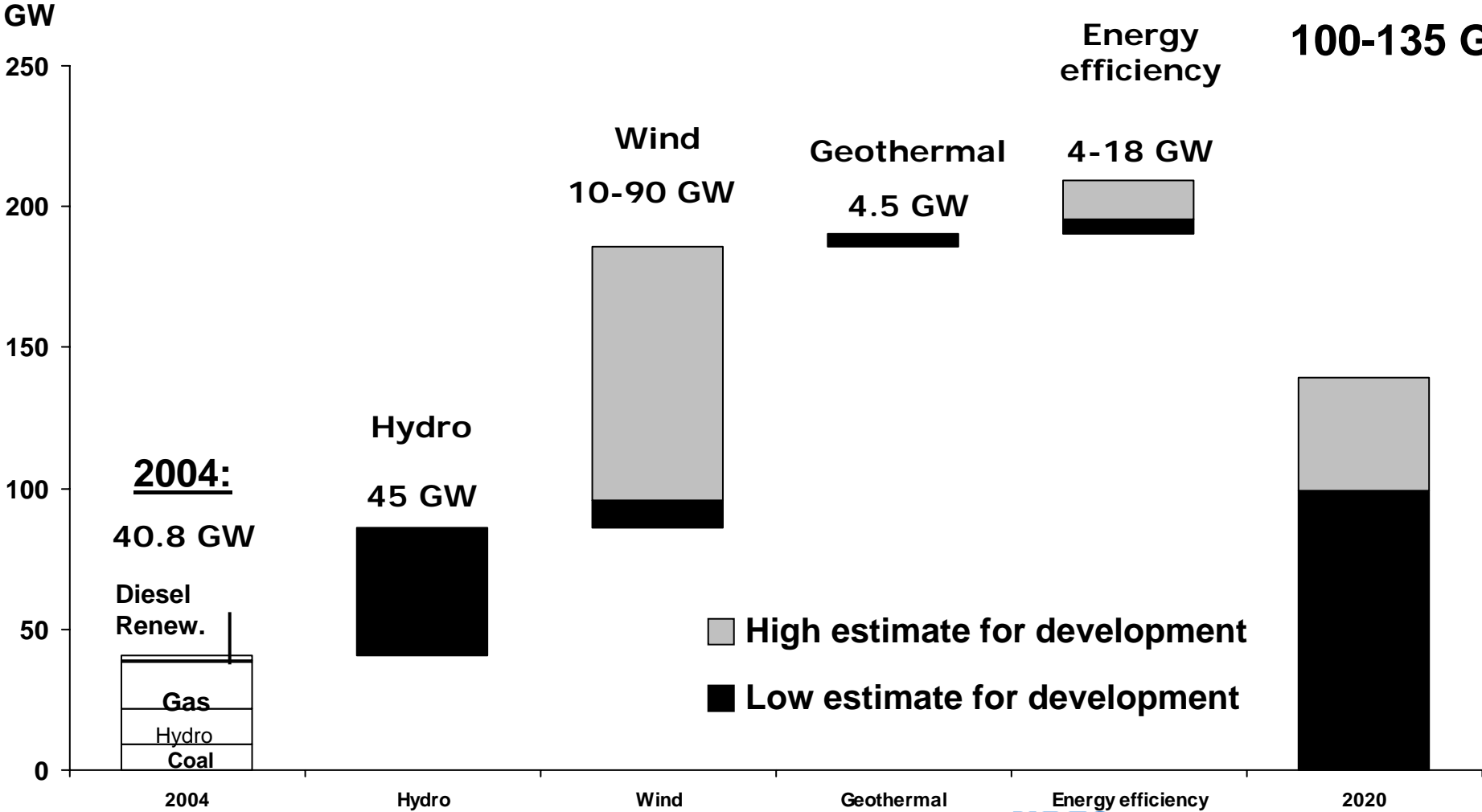
<i>Existing agreements</i>	<i>Volume (bcm/year)</i>	<i>Signature date</i>	<i>Length (years)</i>	<i>Operation date</i>	<i>Volumes delivered in 2003 (bcm)</i>
Russia (West)	6	February 1986	25	June 1987	11.4 (total Western pipeline)
Algeria (LNG)	4	April 1988	20	August 1994	3.8
Nigeria (LNG)	1.2	November 1995	22	November 1999	1.1
Iran	10	August 1996	25	December 2001	3.5
Russia (Black Sea)	16	December 1997	23	February 2003	1.2
Russia (West)	8	February 1998	23	March 1998	See above
Turkmenistan ¹	16	May 1999	30		0
Azerbaijan	6.6	March 2001	15	2006	0

¹ Contract suspended, among other things, for pending issue regarding the legal status of the Caspian Sea.

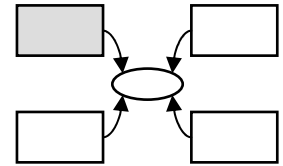
Even without natural gas, Turkey has a range of projected supply options that could potentially meet their energy gap



**2020 need:
100-135 GW**



Experts agree on large potential for renewable energy and efficiency technology in Turkey



Wind

*“Wind power could supply Turkey's electricity needs twice over within five to ten years if the government had the political will to develop this sector... We have **terrific geographic conditions for solar and wind power in Turkey**. Exploiting it is already **economically and technically possible**, but the problem is that the government favors fossil fuels and nuclear energy.”*

Tanay Sýdký Uyar, Vice President of the World Wind Energy Association and Associate Professor of Renewable Energy at Marmara University

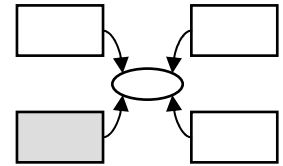
Hydro

*“Turkey has... abundant hydropower potential to be used to generate electricity... Turkey's hydropower potential can meet nearly **33%, 38% and 46%** of its electric energy demand in 2020 , according to Scenarios 1, 2, and 3, respectively.”*

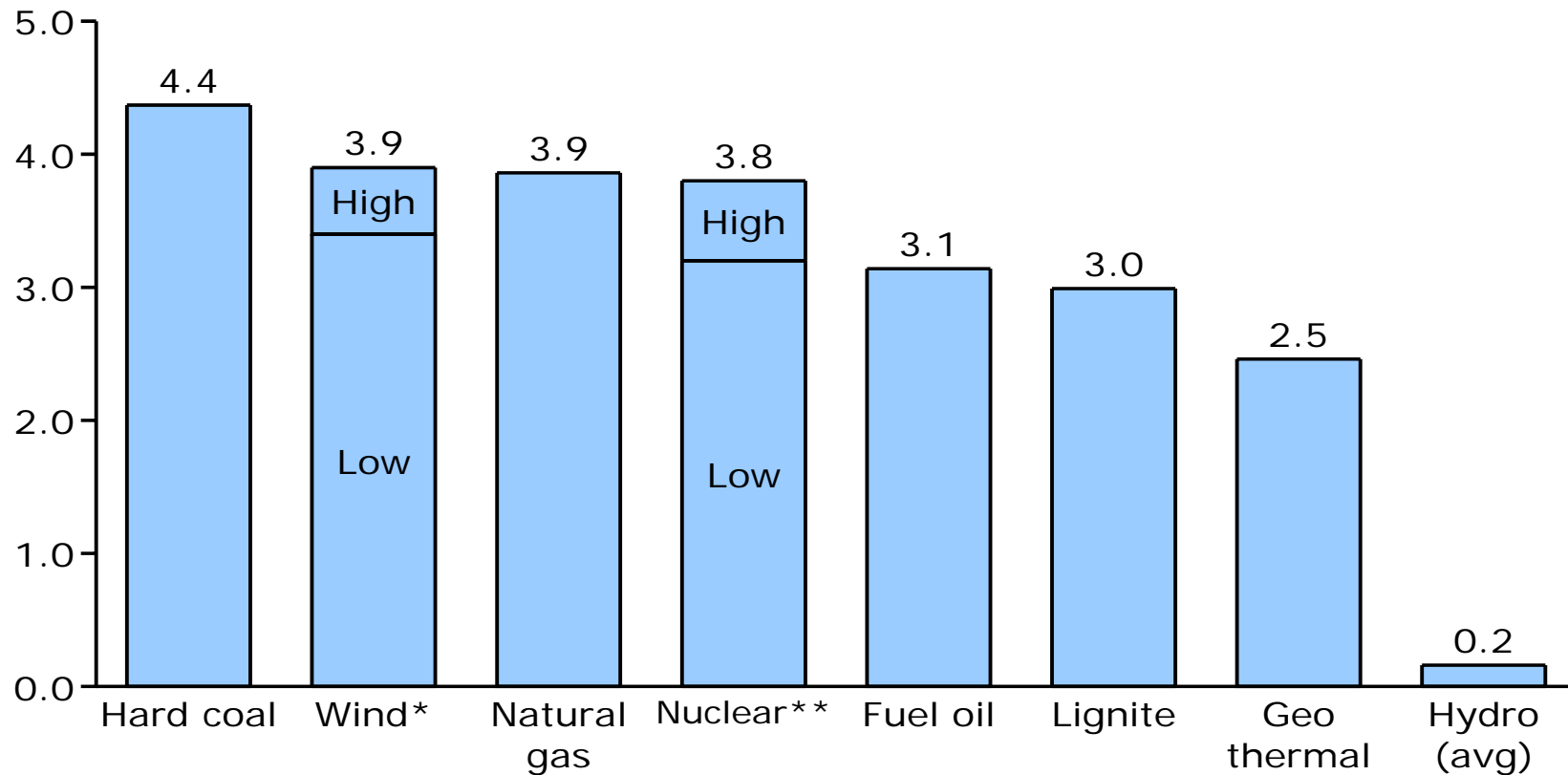
Energy Policy 2006



Cost of electricity in Turkey is lowest for hydro projects, other sources on par



Power generating cost in Turkey
(US cents / kWh)



*Best wind sites, from IEA, "Energy Policy in IEA Countries – Turkey" 2005

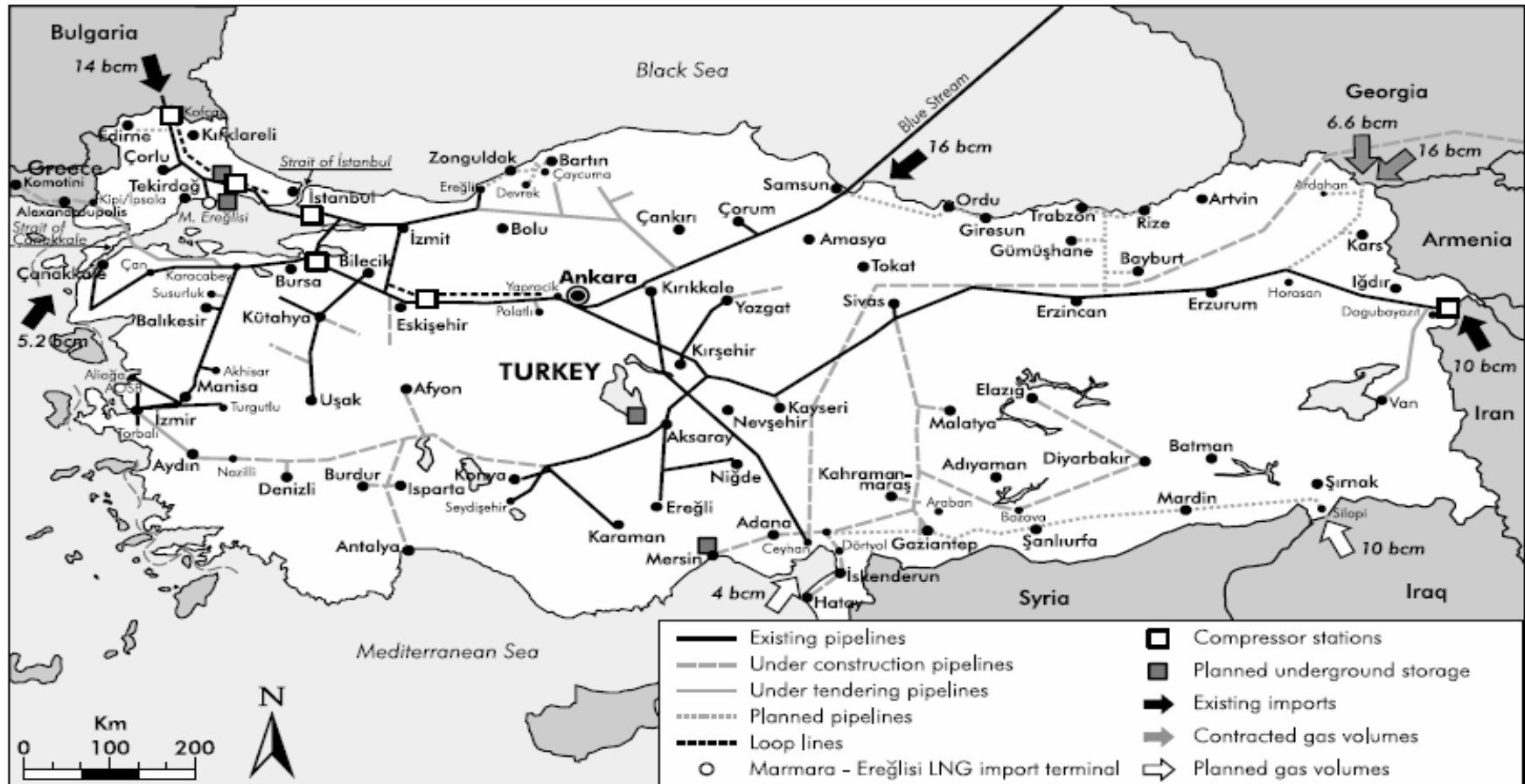
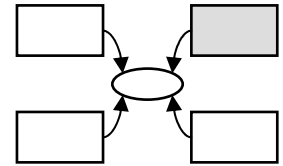
**Estimated cost by IEA

*** Natural gas cost similar to reported by Projected Cost of Generating Electricity 2005 Update – Nuclear Energy Agency / International Energy Agency

Source: IEA 2005 via Erdogdu, Erkan. "Nuclear power in open energy markets: A Case Study of Turkey" Energy Policy 35 (2007):3061-3073

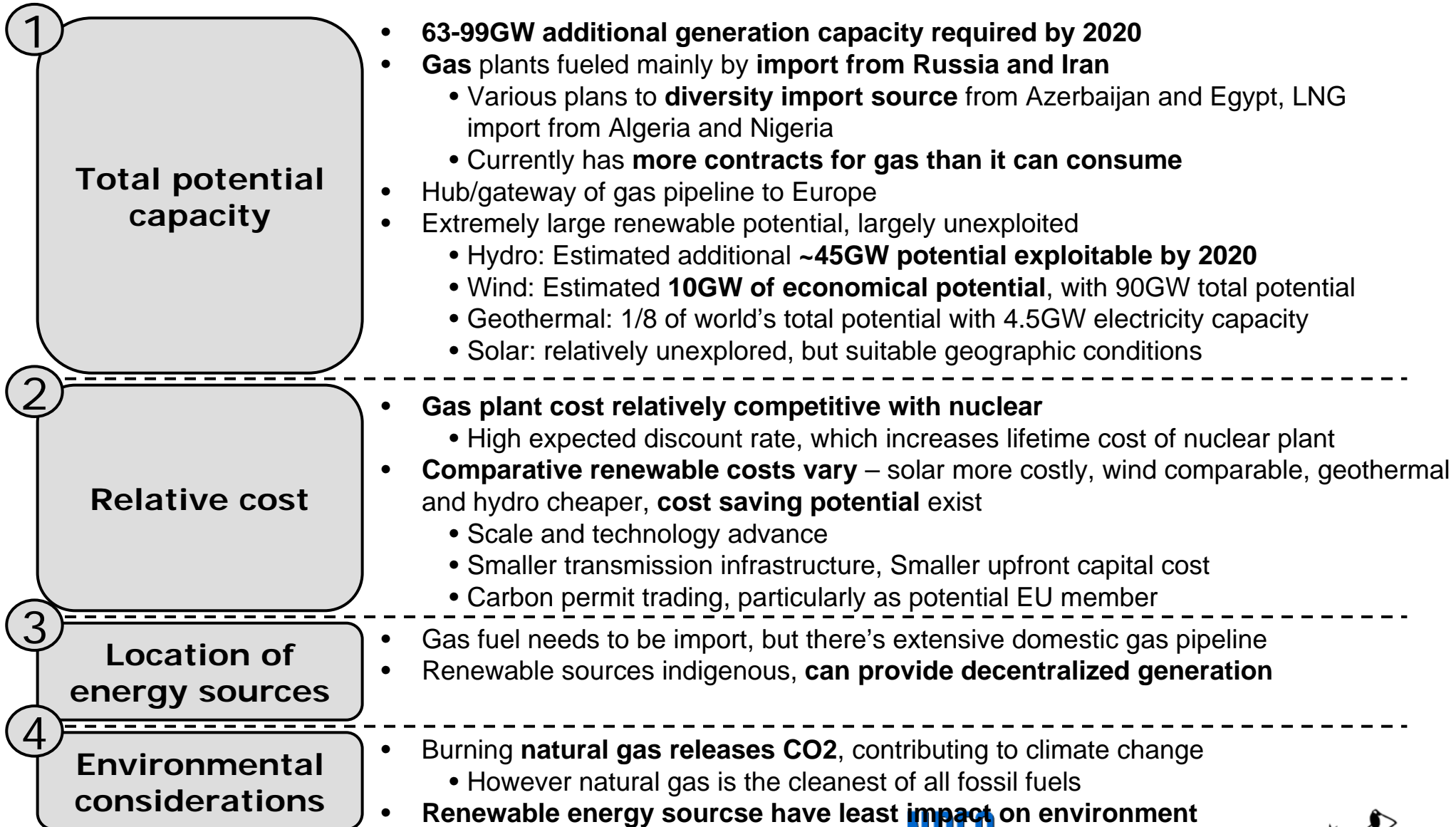


Though Turkey has little indigenous gas, it is the hub for extensive gas pipeline systems



Energy security issue is managed through position as pipeline hub and plans to diversify fuel sources

Turkey has a myriad of alternative fuels feasible to meet demand, pace of development uncertain



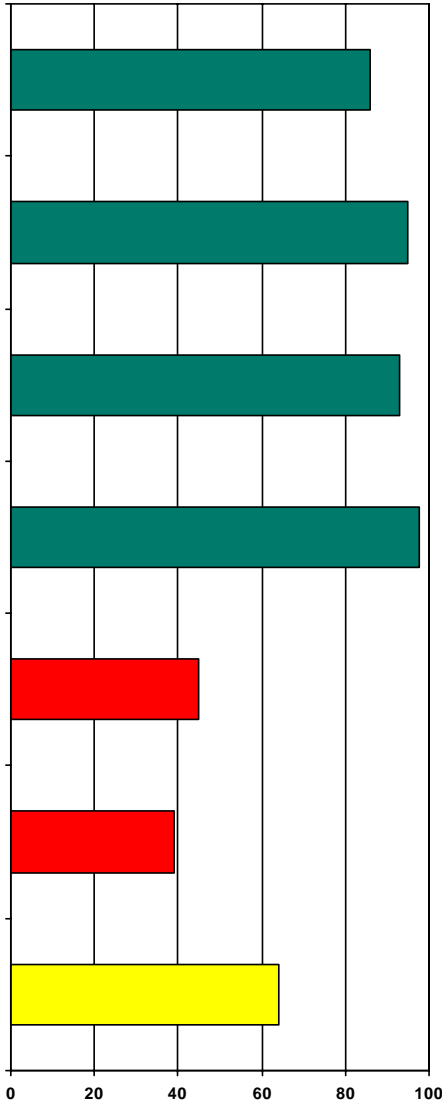
Preliminary conclusions

- Neither Saudi Arabia nor Egypt require nuclear power to meet their growing electricity demand in the medium term
 - **Indigenous supply of natural gas** as fuel that is **abundant, cost-effective**, with **established delivery infrastructure**
 - Government set aside significant quantities for domestic consumption, will only come under pressure if incentive to export gas rises significantly with LNG price and large reduction in cost of LNG infrastructure
 - **Underdeveloped / unexplored potential for renewable power sources**
 - Higher cost but potential savings in transmission infrastructure, upfront investment, and added benefits of environmental protection and meeting decentralized electricity needs
 - Hydro, wind, and solar for Egypt, wind and solar for Saudi
- Turkey can meet its growing electricity demand with a myriad of energy sources, need for nuclear power depends on natural gas negotiations and the pace of renewable energy development
 - **Gap in energy can be met with imported gas**
 - Current gas contracts ensures medium term supply security
 - Position as hub for pipelines and plans to diversify gas sources
 - Optimum geographic location for **hydro and wind potential**
 - Hydro most cost effective energy source
 - Development encouraged by Renewable Energy Law, pace uncertain
 - Nuclear could contribute to electricity portfolio if development of other sources hits barriers

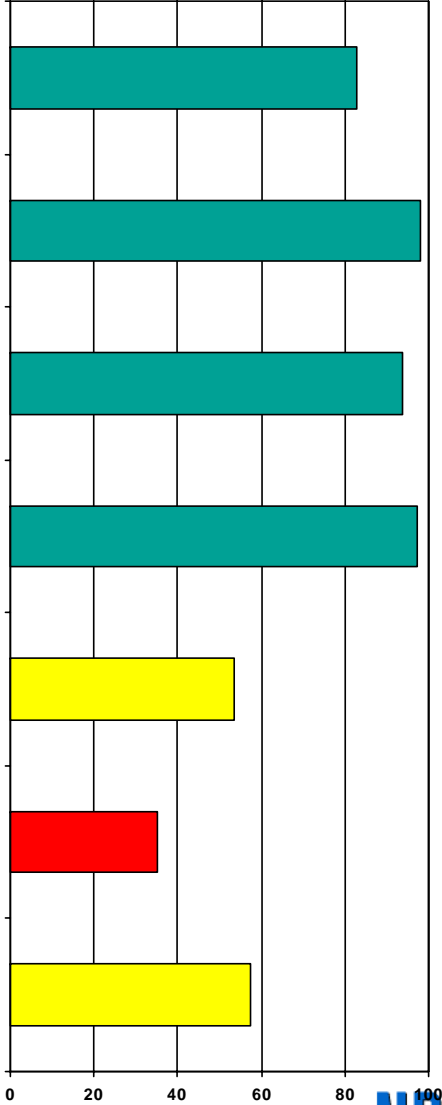
Governance indicators



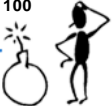
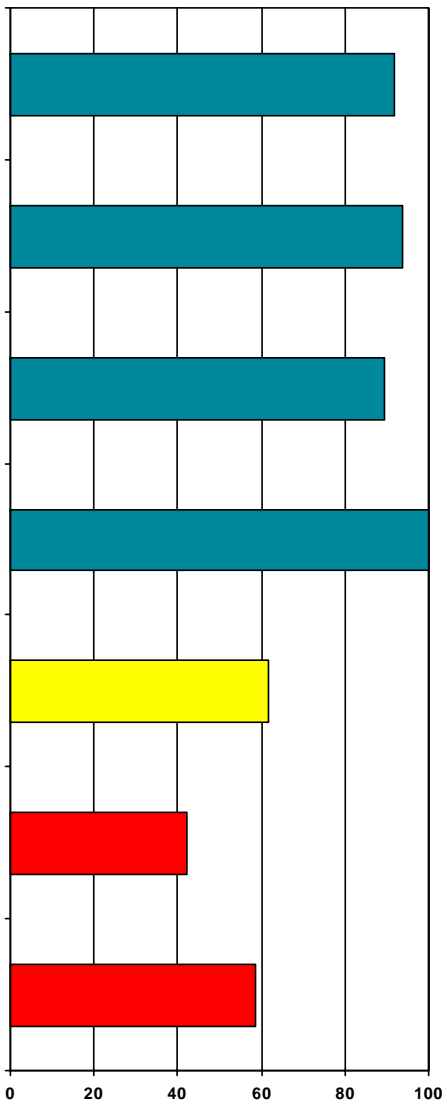
Government effectiveness



Regulatory quality



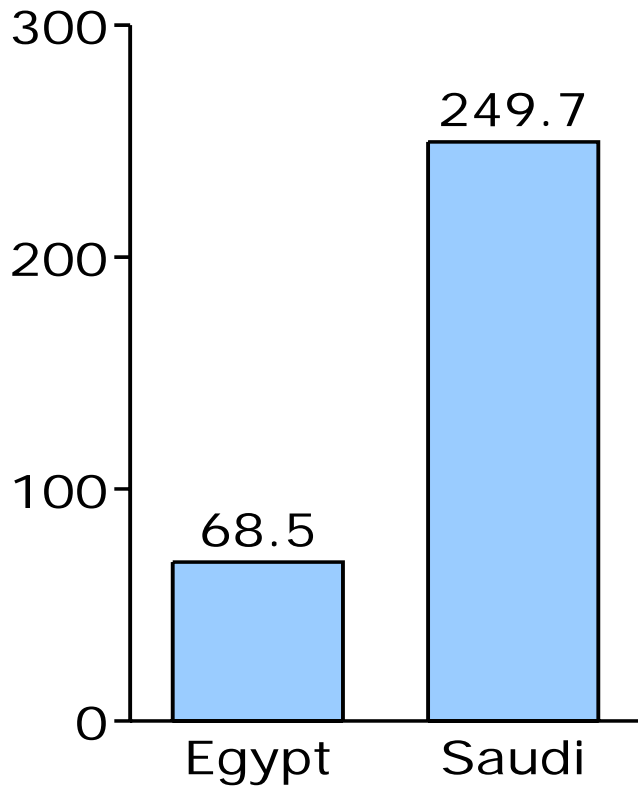
Control of corruption



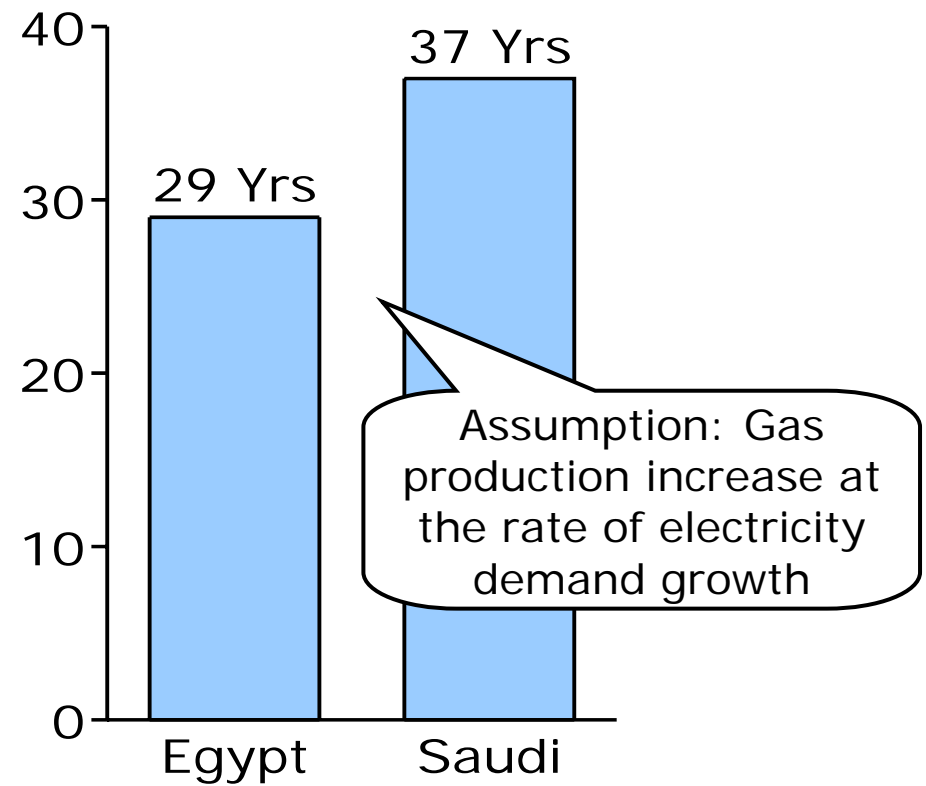
Backup slides

Current oil and gas reserves in Egypt and Saudi Arabia should last for next half century

Proven gas reserve
(T cubic ft)

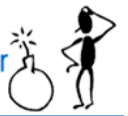
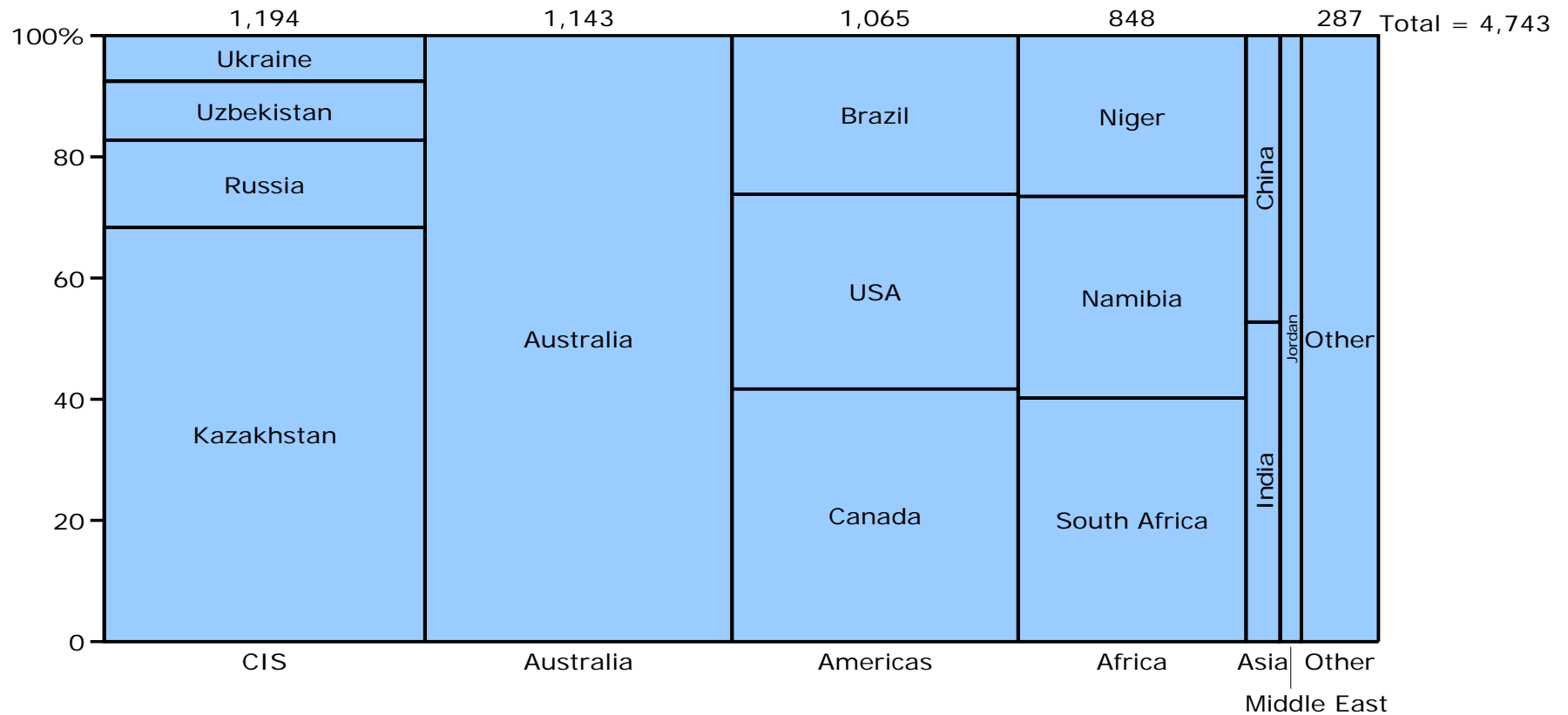


of years gas
projected to last



World uranium resources located in diverse locations

Known recoverable resources of uranium
(K tonnes)



Currently, projects worth ~24GW of generating capacity already licensed or authorized in Saudi

Entity	Status	Licence type	Licence date	Project site	Capacity (MW)	
Obaikan Group	Licensed	Generation	2003	Riyadh	60	
Tihama Power Generation	Licensed	Cogeneration	2004	Juaimah	308	
Tihama Power Generation	Licensed	Cogeneration	2004	Othmaniya	308	
Tihama Power Generation	Licensed	Cogeneration	2004	Shadgum	308	
Tihama Power Generation	Licensed	Cogeneration	2004	Ras Tanura	150	
Yanbu Cement	Licensed	Generation	2004	Yanbu	139	
Yamamah Cement	Licensed	Generation	2004	Riyadh	158	
Jubail Power	Licensed	Cogeneration	2005	Jubai	250	
Shoabih National Water and Electricity	Licensed	Cogeneration	2005	Shoabih	905	Desalination
Al-Shuqaiq Water and Electricity	Licensed	Cogeneration		Al-Shuqaiq	1,020	Desalination
Tayyabeh Power	Authorized	Generation	2005	Sudair	1,000	
Tayyabeh Power	Authorized	Cogeneration	2006	Rabigh	2,400	Desalination
MEES Power and Telecom	Authorized	Generation	2005	Rabigh	700	
Bahhar Trading	Authorized	Cogeneration	2005	Rabigh	1,650	Desalination
Mechanical Engineering & Electrical Systems	Authorized	Generation	2005	Jeddah	600	
National Tripartite Productoin Co	Authorized	Generation	2005	TBC	1,000	
Maaden	Authorized	Cogeneration		Ras Al-Zour	1,809	Desalination
Marafic/Public Investment fund / Saudi Electricity	Authorized	Cogeneration		Jubail	2,500	Desalination
Manafea International	Authorized	Cogeneration		Rabigh	500	Desalination
Hejaz Trading	Authorized	Generation		Rabigh	5,000	Desalination
European Middle East Project	Authorized	Cogeneration		Rabigh	2,882	
Ibrahim Zarea Mohammad Al-Rifae	Authorized	Generation		Jeddah	600	
Total					24,247	

Currently, projects worth 7.4GW of generating capacity already planned and approved in Egypt

	Power plant site	Planned Capacity (MW)	Scheduled completion	Notes
Gas	Abu Qir	1,300	TBD	2X650MW turbines
	al-Da'bah	4,000	2012/13	
	Kureimat	120	TBD	Combined solar
Nuclear	al-Da'bah #1	600	2015/16	
	al-Da'bah #2	600	2017/18	
	al-Da'bah #3	600	2019/20	
Wind	Suez Canal	60	TBD	Financed by Netherland
Hydro	Naga Hammadi	64	2008	
	New Aslut Barrage	32	2014	
	Kanater Delta Damietta	13	2010	
	Gabal Galala	TBD	TBD	
Solar	Kureimat	31	TBD	Combined gas; subsidized by GEF
Total		7,420		

Source: "US\$325 Million AfDB Loan for Abu Qir 1300 MW Steam Power Project" Africa News, November 14, 2007; "Egypt Approves plans to build three new nuclear power stations" BBC, September 26, 2006; Economic Intelligence Unit Country profile – Egypt; Egyptian electric Holding Co. AR 2005/06, Energy Information Administration – US Department of Energy

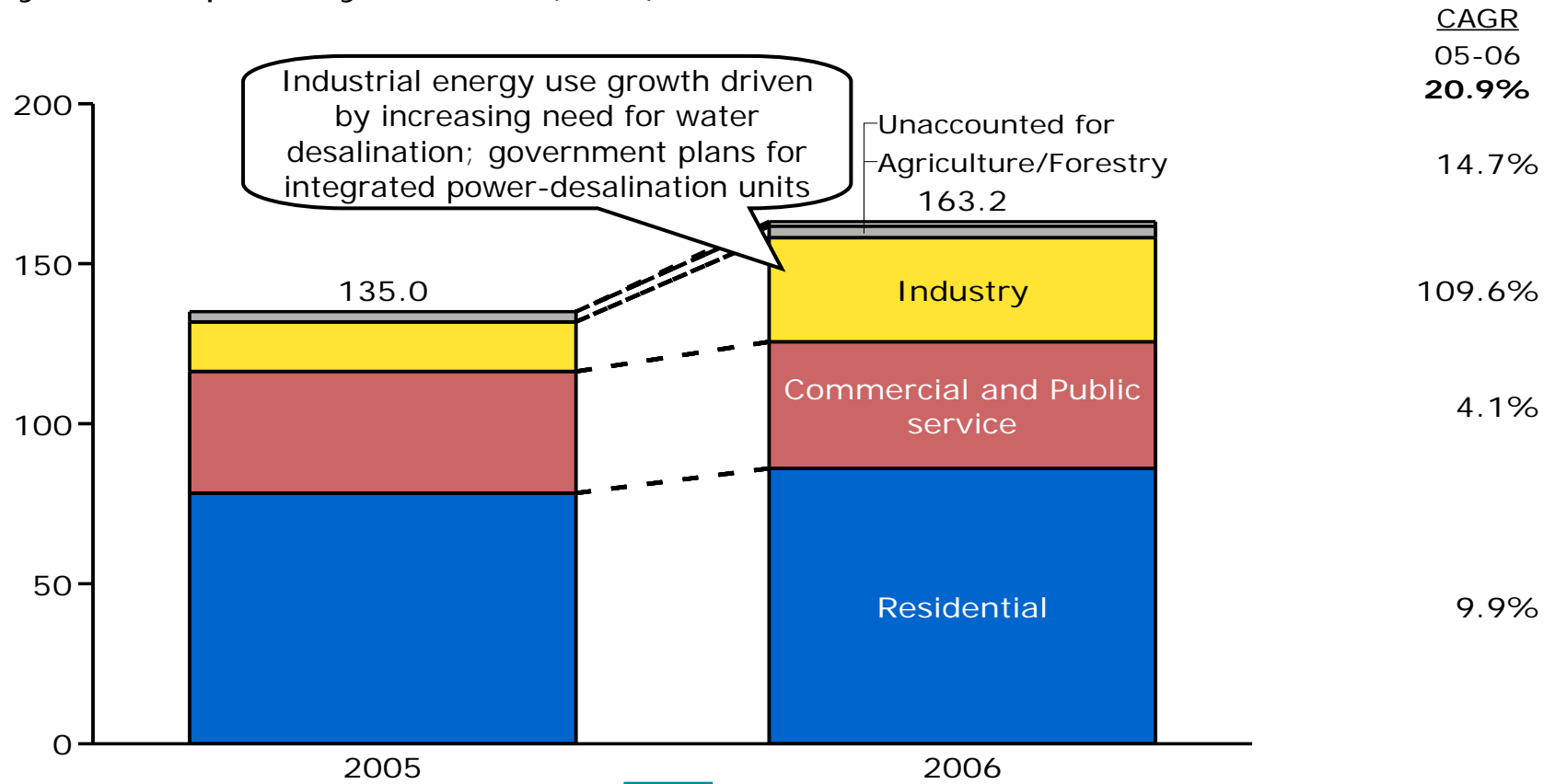


Currently projects amounting to 5GW of generating capacity already licensed in Turkey

Source	Generating capacity (MW)						Notes	
	2008	2009	2010	2011	2012	Total*		
Asphaltit		137.8					137.8	
Natural Gas	303						303	• Import from Russia and Iran
Fuel Oil	20						20	
Lignite								• Domestic supply • Low quality
Hydro	197.9	260.9	1714.8	904.4	292.5		3378.6	• Large potential in small hydro products
Waste							16.6	• Encouraged by Renewable Energy law
Geothermal		7.5					59.4	• Encouraged by Renewable Energy law
Wind	202	82.7					775.5	• Encouraged by Renewable Energy law
Total	722.9	488.9	1714.8	904.4	292.5		5094.4	

Saudi electricity use dominated by residential sector, growth driven by water desalination

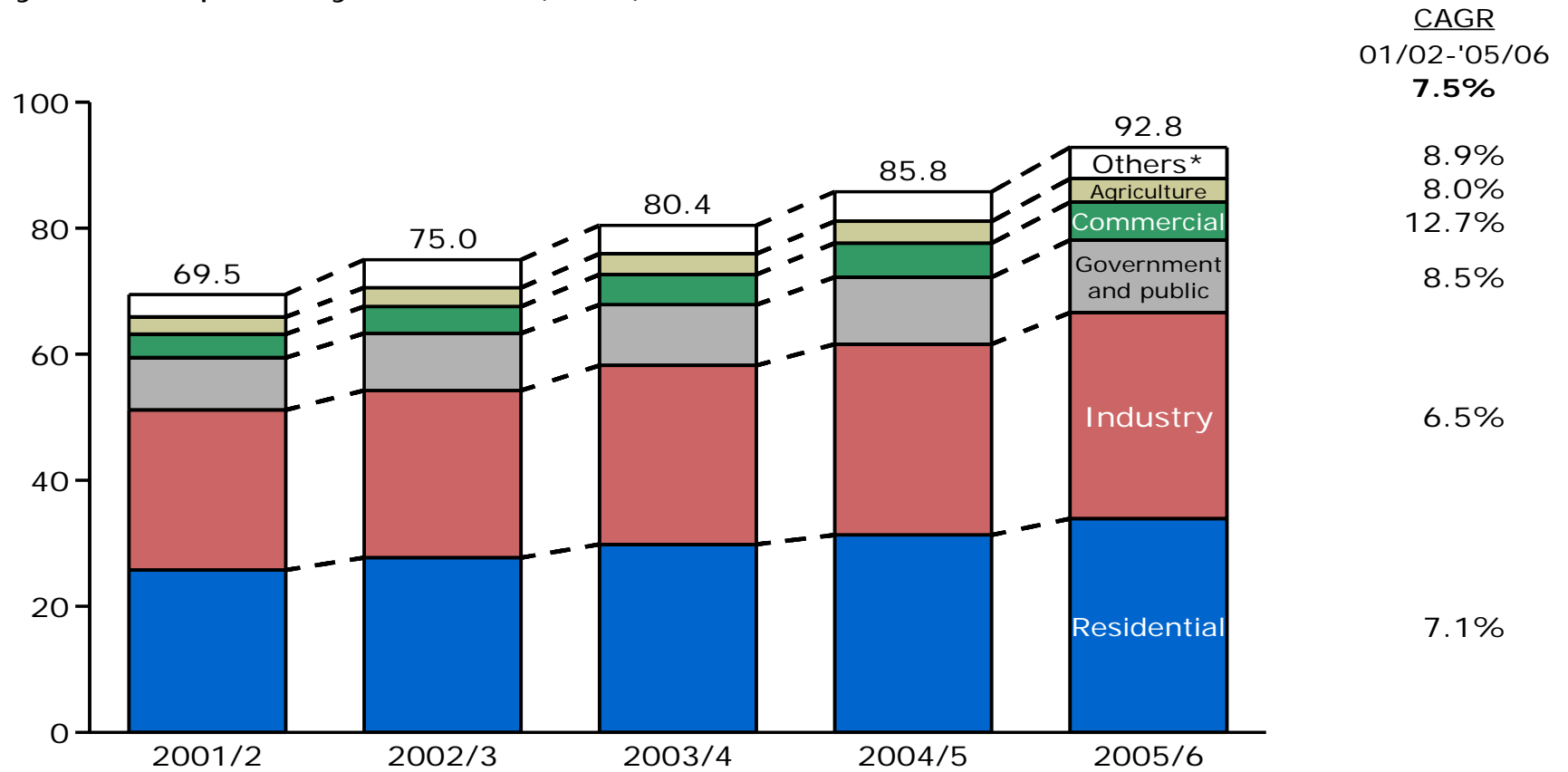
Electricity consumption by end use (TWh)



Need to assess compatibility of nuclear power plant with desalination units?

Egyptian electricity use dominated by residential and industrial; growth driven by commercial sector

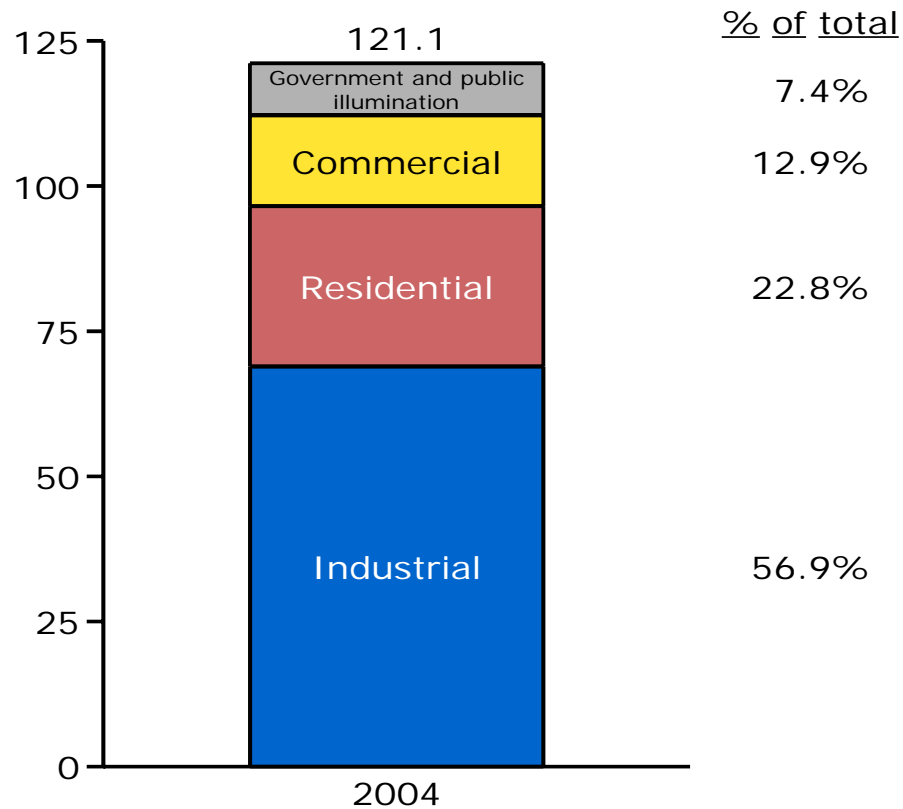
Electricity consumption by end use (TWh)



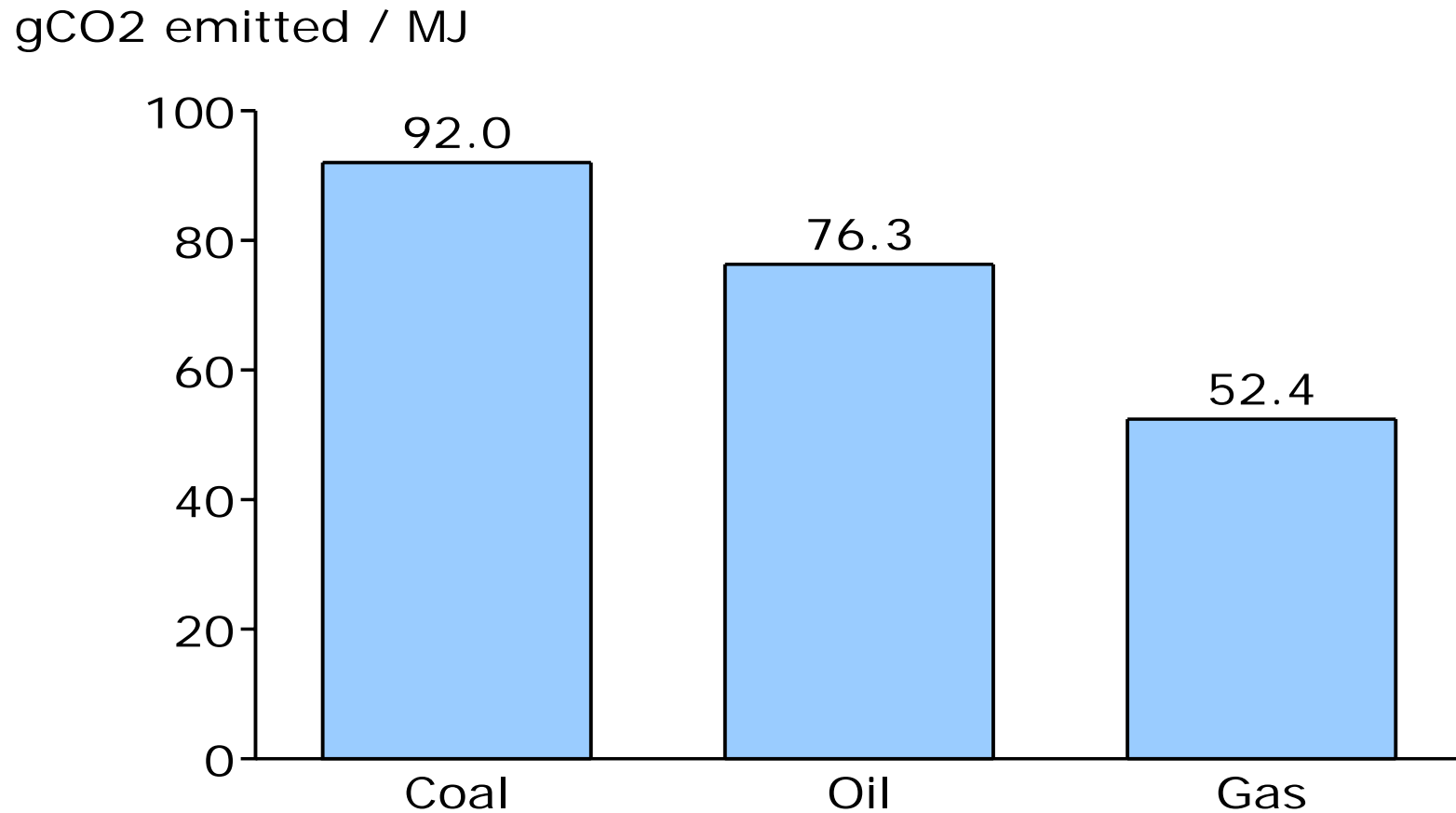
*Others include utilities, interconnection, and BOOT usage
 Source: Egyptian Electric Holding Company Annual Report 2005-2006

Turkey electricity use heavily leaned towards the Industrial sector

Electricity consumption by end use (TWh)



Gas generation releases half the amount of CO₂ per unit of energy as coal



Economic reasons cited to support nuclear power development in the Middle East

Mark Fitzpatrick, a former senior nonproliferation official in the US State Department who is now a fellow at the International Institute for Strategic Studies in London "Egypt can absolutely make a legitimate case for nuclear energy," says Mr. Fitzpatrick. "Its reserves are dwindling, it needs the oil and gas for export, and it needs to diversify its energy resources."

"Forty years from now there will be no oil left, and in 100 years, no more gas," Sarkozy told reporters on the trip, adding that he believes **nuclear power** will be the replacement. "It is the energy of the future."

Toukan said that Jordan was looking to nuclear energy because the country "faces several energy challenges: lack of [energy] resources, lack of water, and the uncertain cost of energy imports."

Khaled Toukan, Minister of Higher Education & Scientific Research of Jordan

Toukan told attendees that Jordan's drive to have **nuclear power** reactors on line in coming years was based on projections for modest population and economic growth, and few viable alternative energy production options. Natural gas, he said, is an expensive short-term option for Jordan. Renewables, he said, are also expensive and cannot be used for baseload power generation. Jordan is interested in developing oil shale resources, but, Toukan said, primarily for liquid fuels, not for **electricity** production

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