Qatar Energy Footprint

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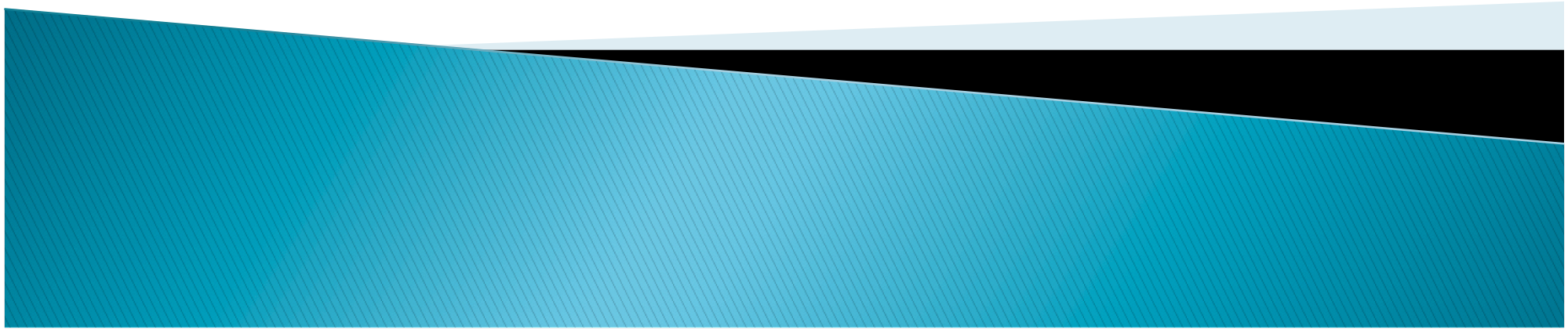


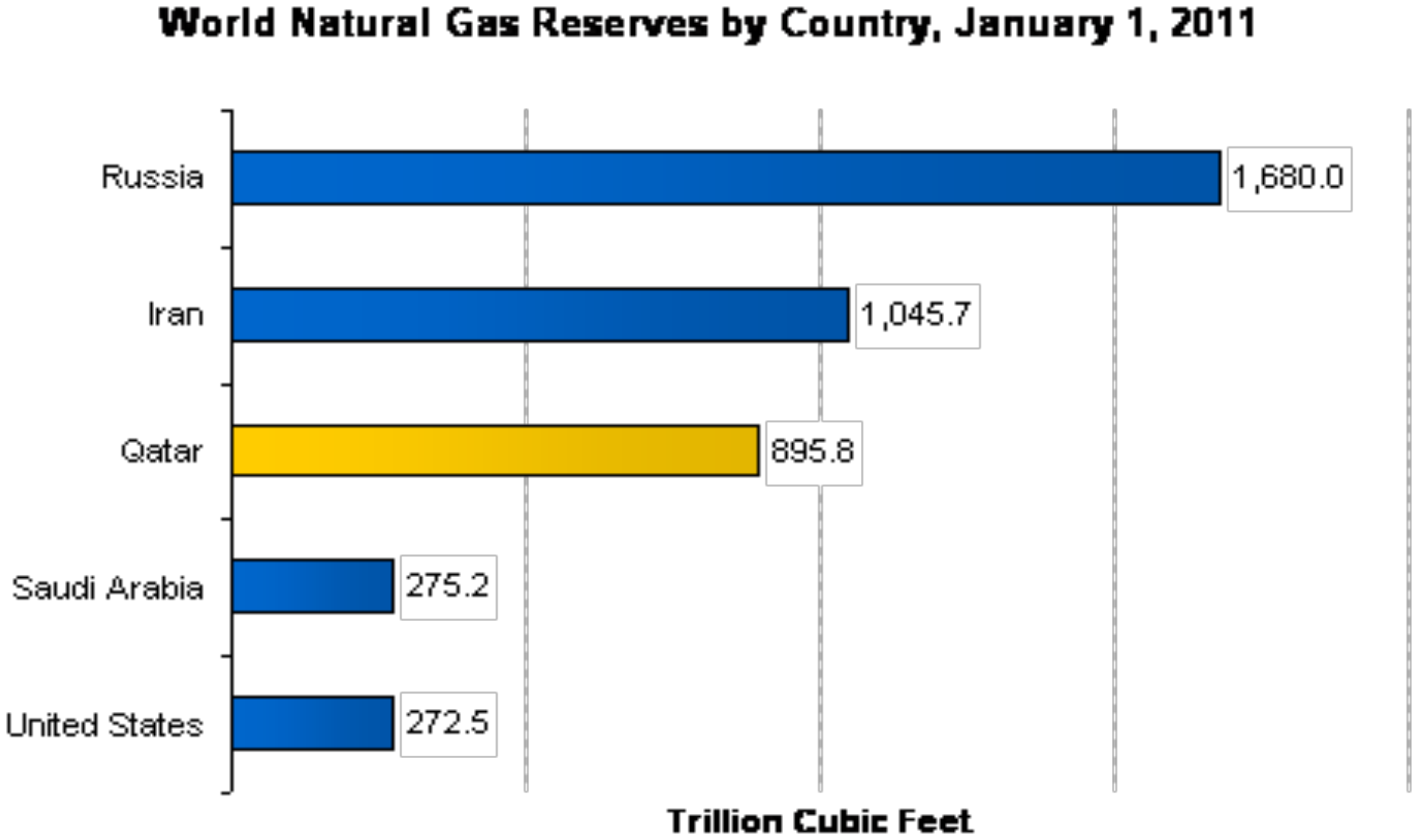
What is Energy Footprints

- **Energy footprint maps the flow of energy supply, demand, and losses in certain sectors.**
- **It is concerned with the prime energy, fossil fuel (FF) or alternative energy; and the electricity supplied (generated onsite, and transported to the local electric utility grid).**
- **It also shows where and how energy is used within a typical plant, and the energy lost due to inefficiencies, both inside and outside the plant boundary.**

- **Different than carbon footprint, GHG emissions caused by organization, event, product or person, expressed in carbon dioxide.**
- **Energy footprint related to energy audit defined by: inspection, survey and analysis of energy flows for energy conservation in building, process or system to reduce amount of energy input into system without negatively affecting the output(s)**
- **To make energy footprints for Qatar as a whole, an energy audit should conducted for each power plant, desalination plant, main buildings, housing, main industries, etc.**

NG Energy Resources and Production

- **Qatar 3rd largest NG resource (world 14%) after Russia and Iran; 46.56% of Arab reserve**
- **Largest supplier of LNG, started prod. in 1997.**
- **Only supplier of LNG in GCCC**
- **It export NG to UAE and Oman (Dolphine).**
- **Confirmed resource 25366 Bm^3, or 896 TCF, (2011), located in offshore North Field**
- **NG is exported in pipelines as gas, or transported in liquid**



Source: Oil & Gas Journal, Jan. 1, 2011 and EIA *Natural Gas Navigator* (U.S. only), Dec. 31, 2009.

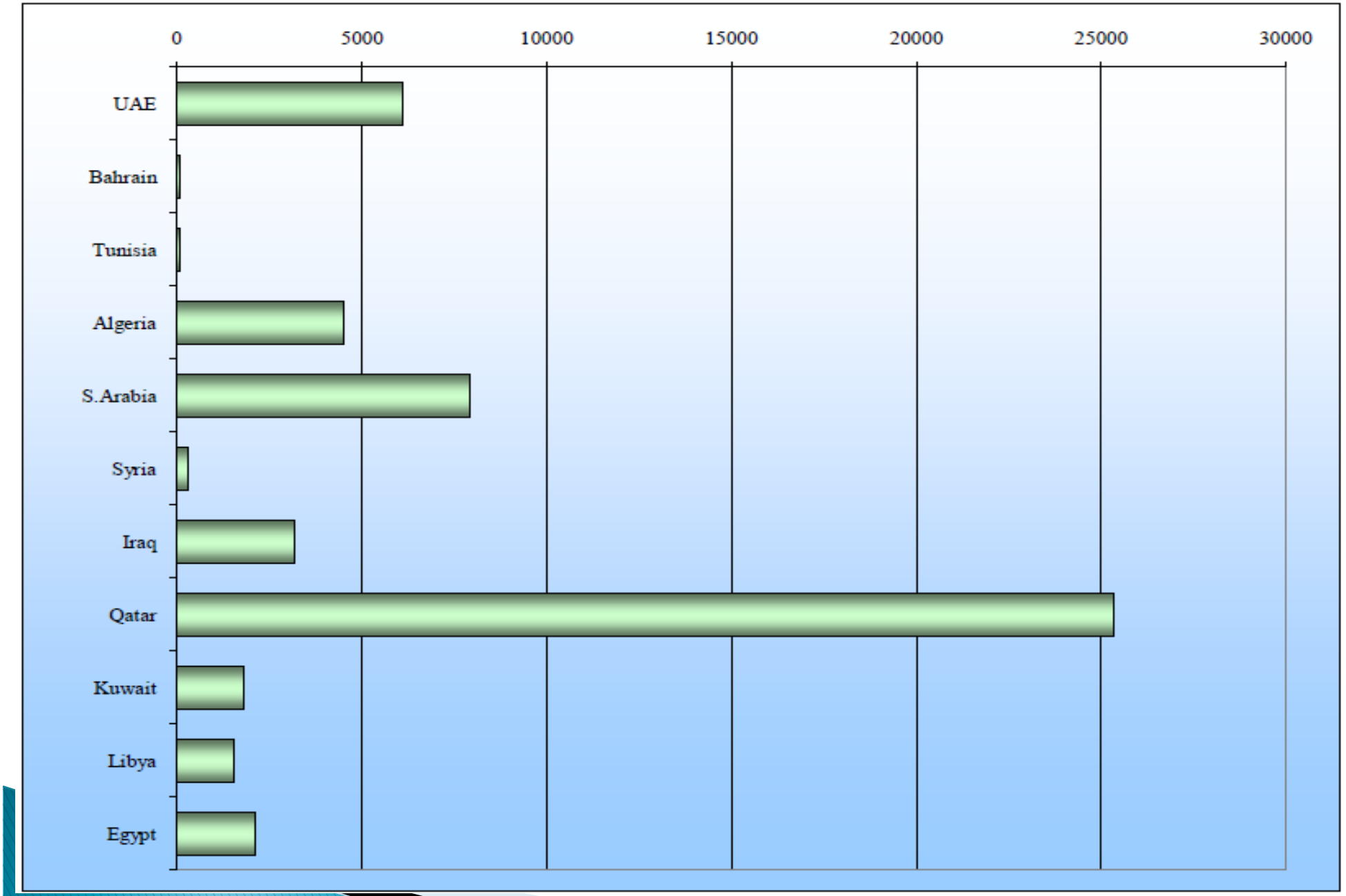
Natural gas NG reserve by country worldwide

Billion cubic meters

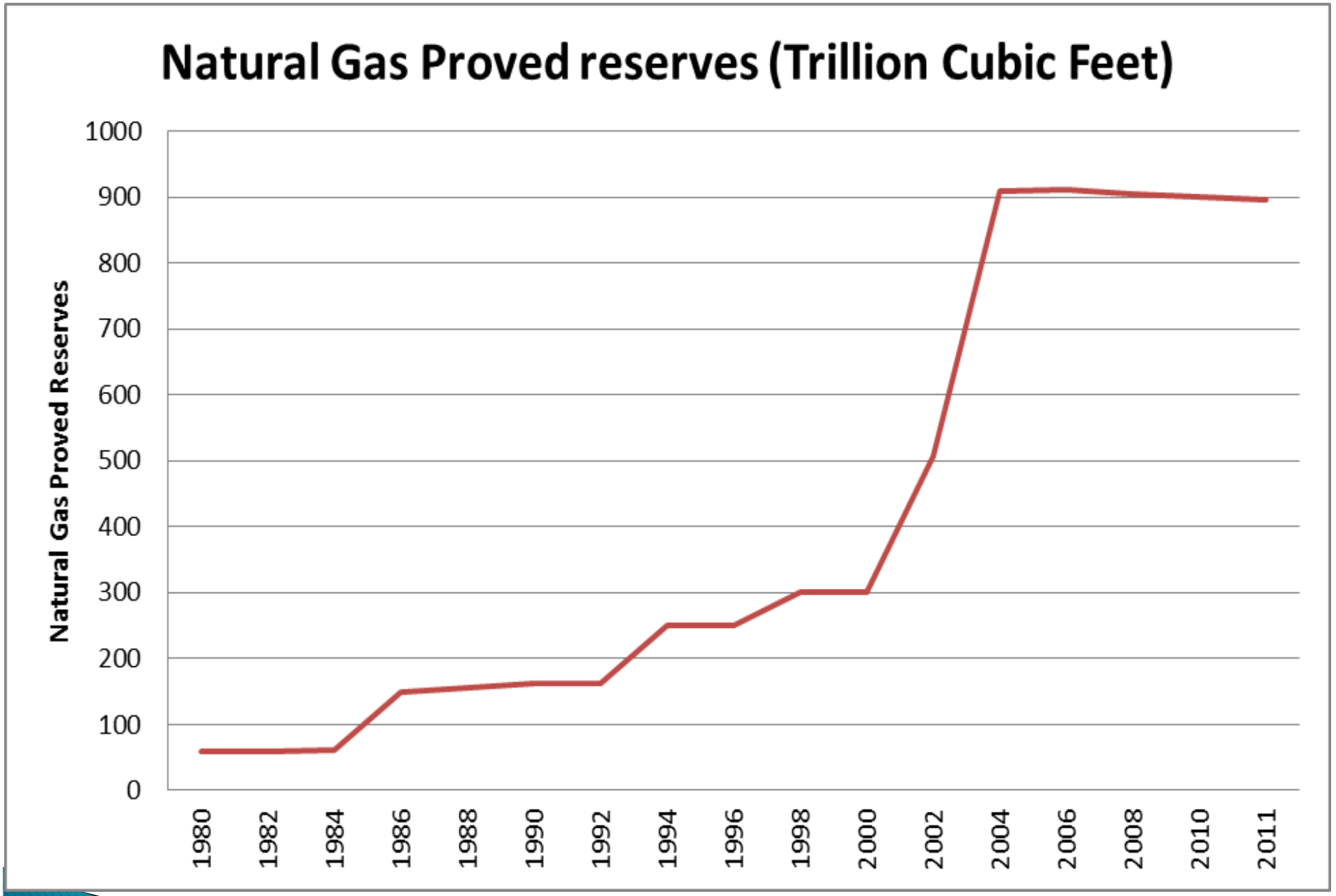
Year 2009

مليار متر مكعب

عام 2009

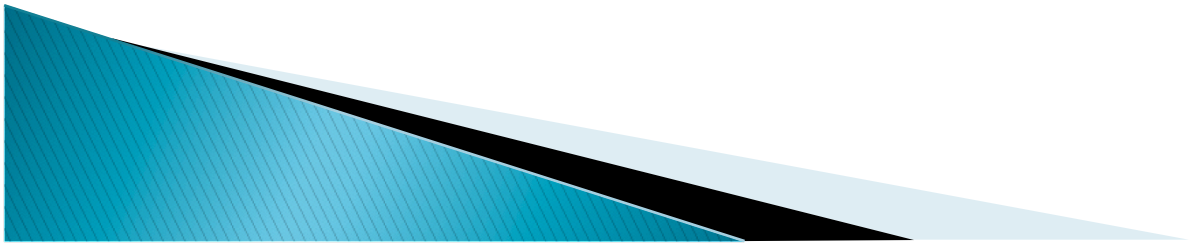


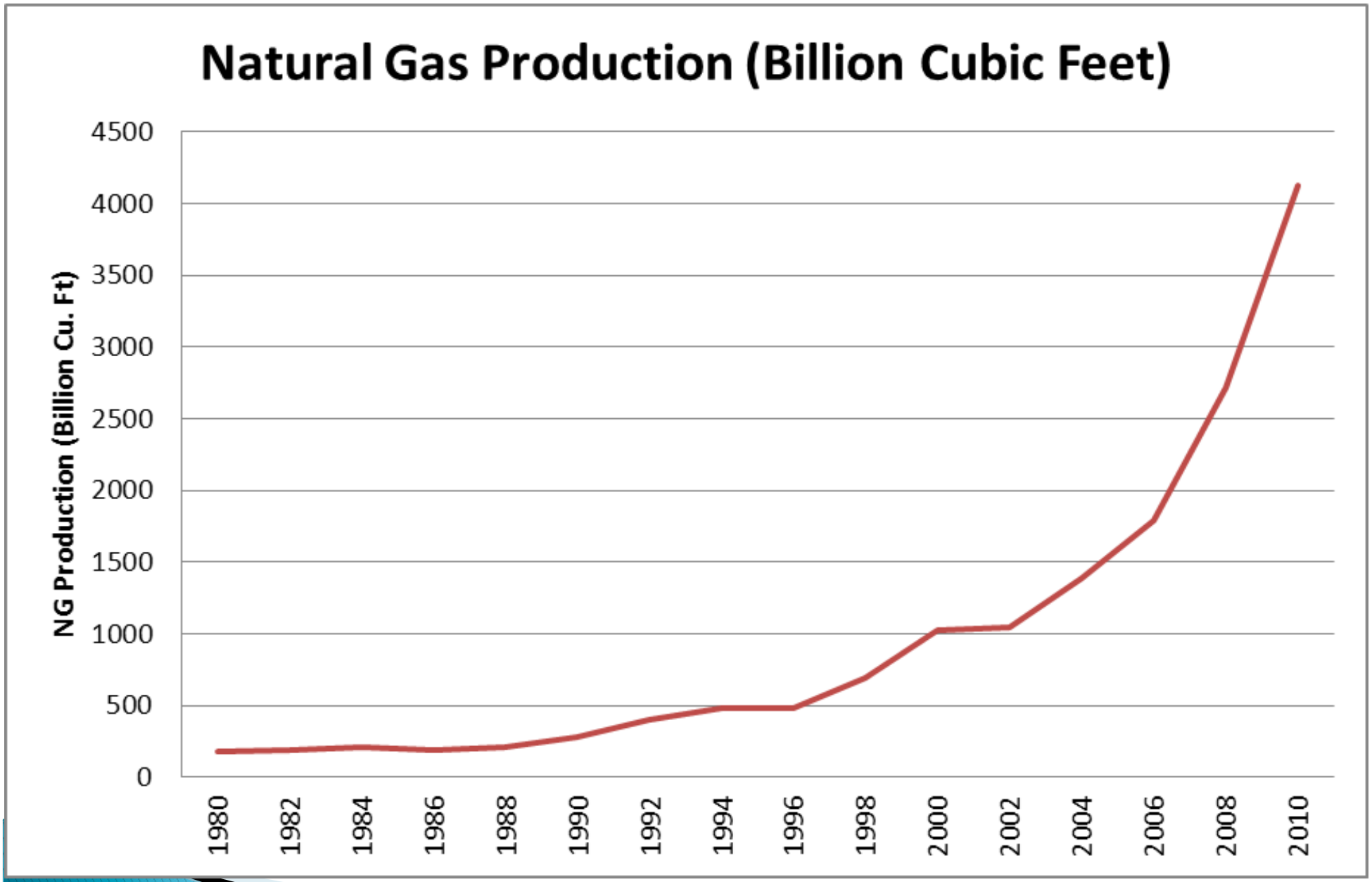
Natural gas NG reserves by country in the Arab world



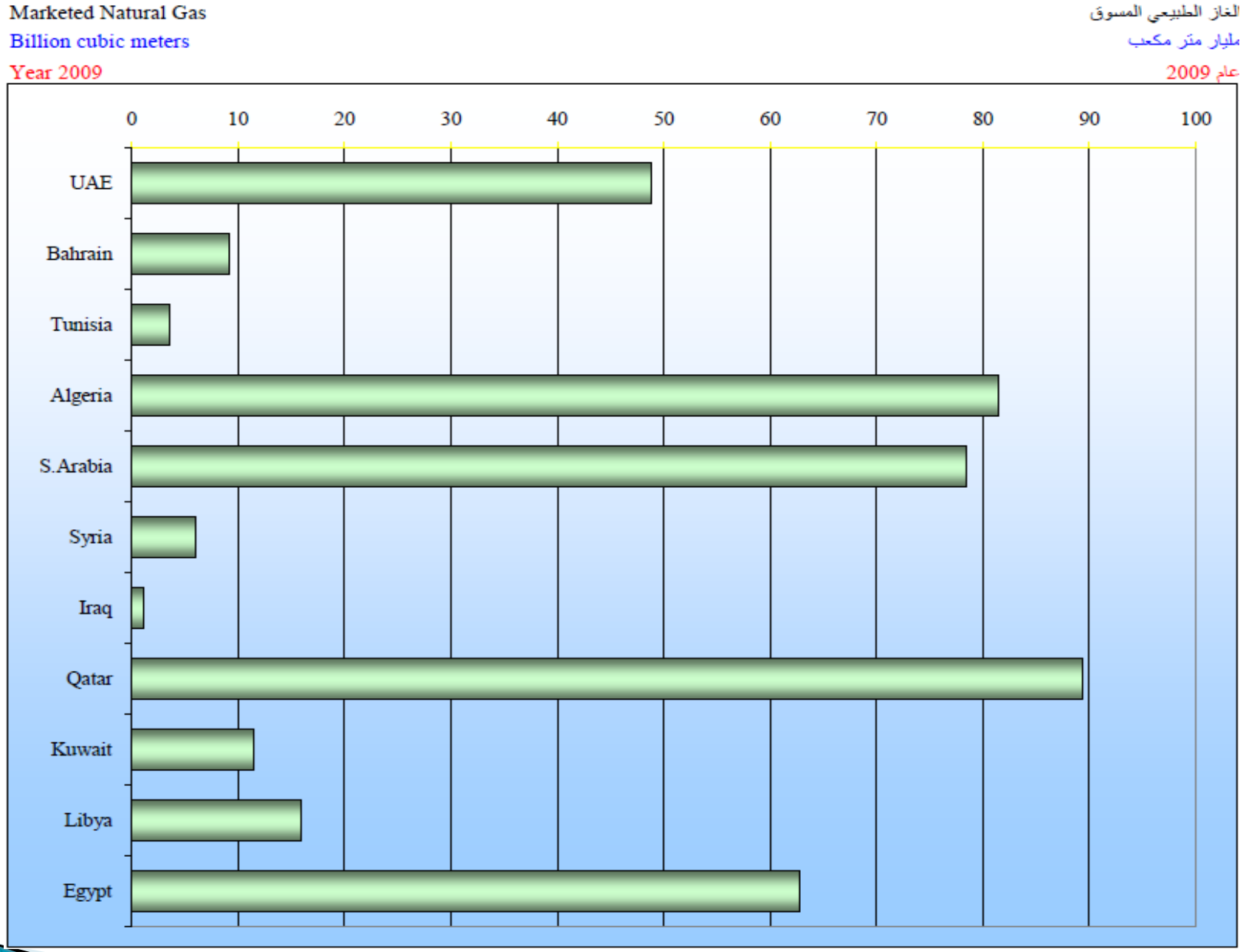
Qatar natural gas NG reserve as confirmed along the years,

- **In 2009, Qatar NG produced 3,154 BCF, 3 times 2000 production**
- **Bulk of increase going towards LNG exports.**
- **Qatar's natural gas consumption in 2009= 745 BCF**

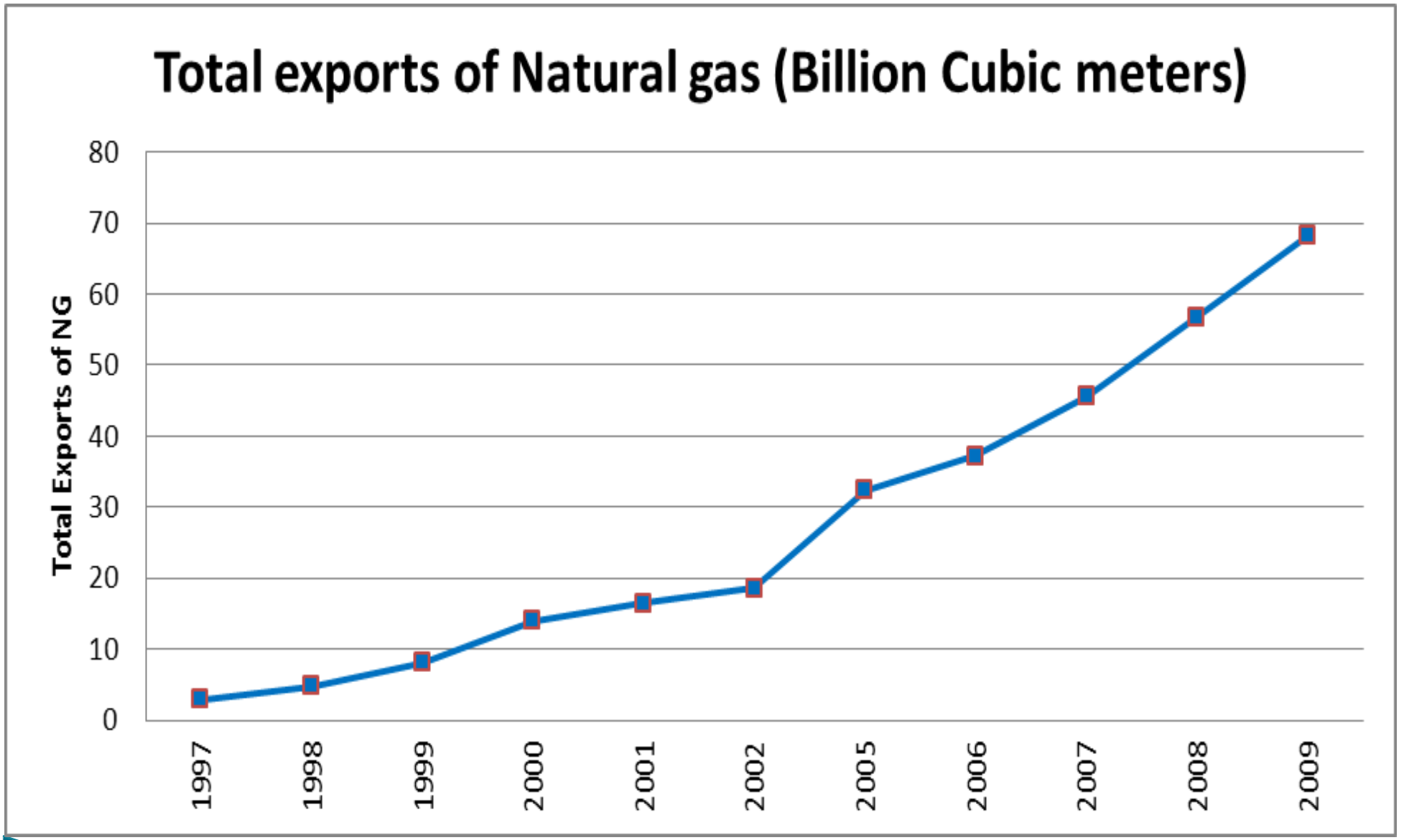




Natural Gas Production in Qatar



2009 LNG Produced, in terms of equivalent, Billion m3 per day in the Arab world



Qatar NG exports along the years, out of almost 90 Bm3/d

LPG Production

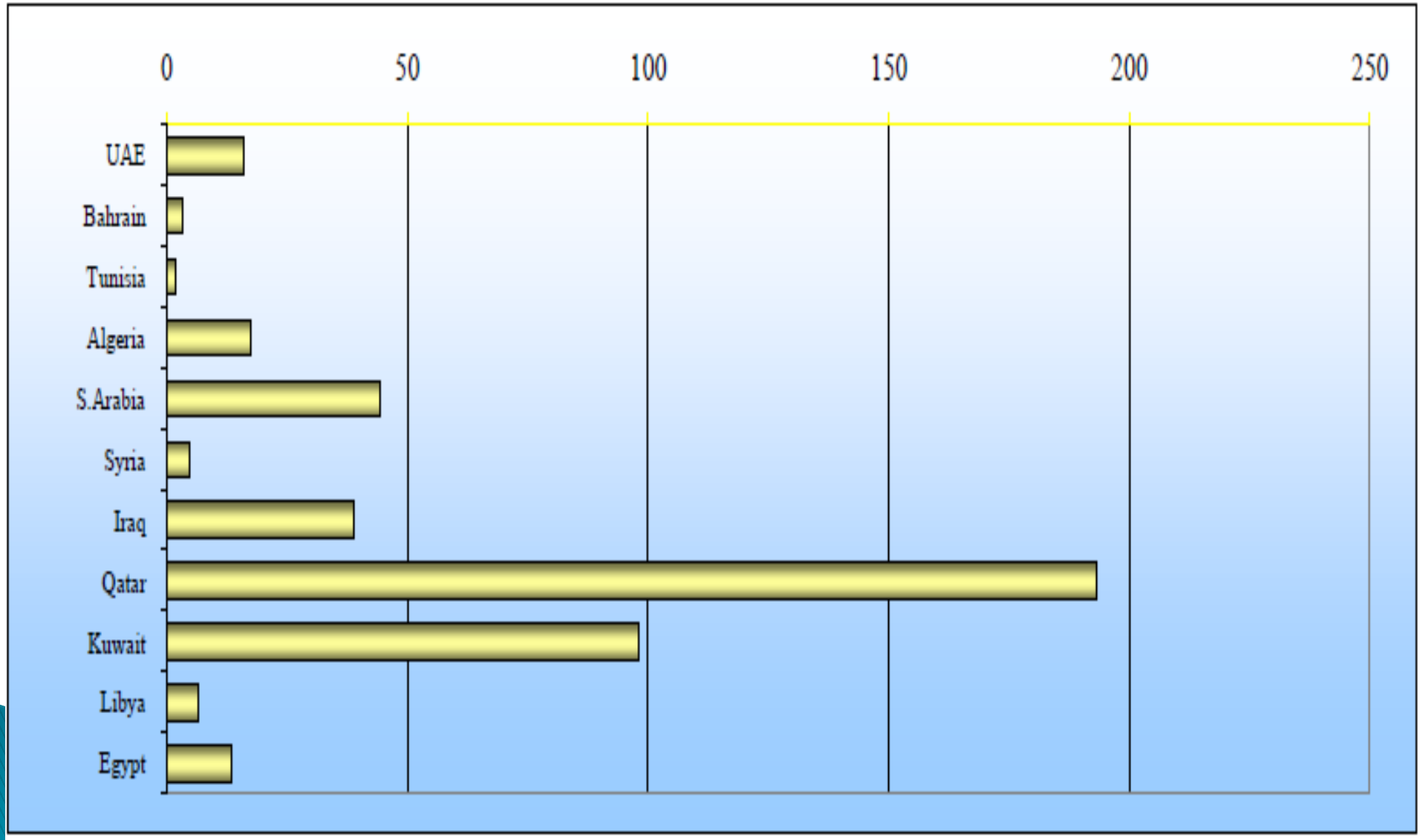
Thousand b/d

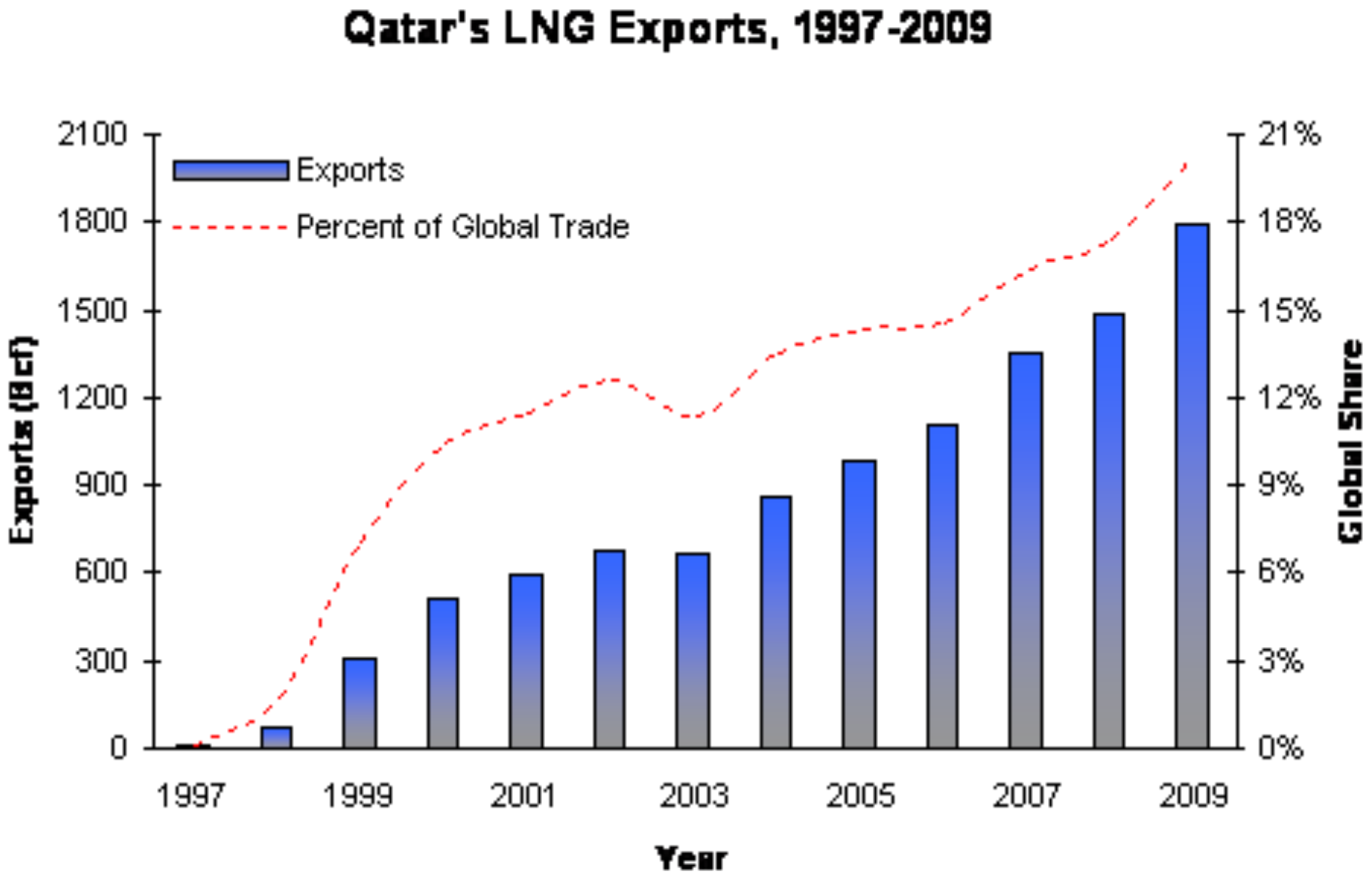
Year 2009

انتاج غاز البترول المسال

ألف برميل / يوم

عام 2009

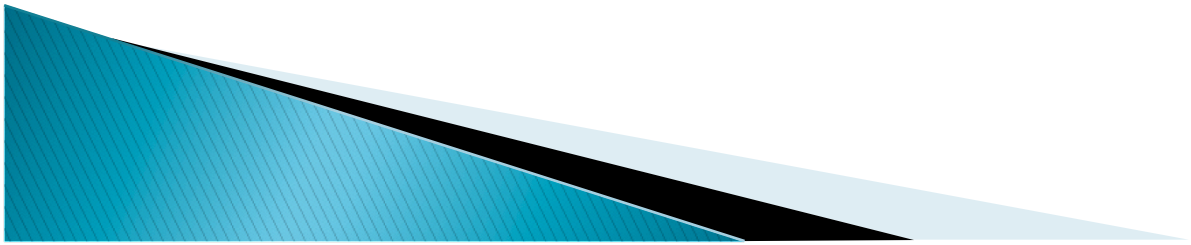




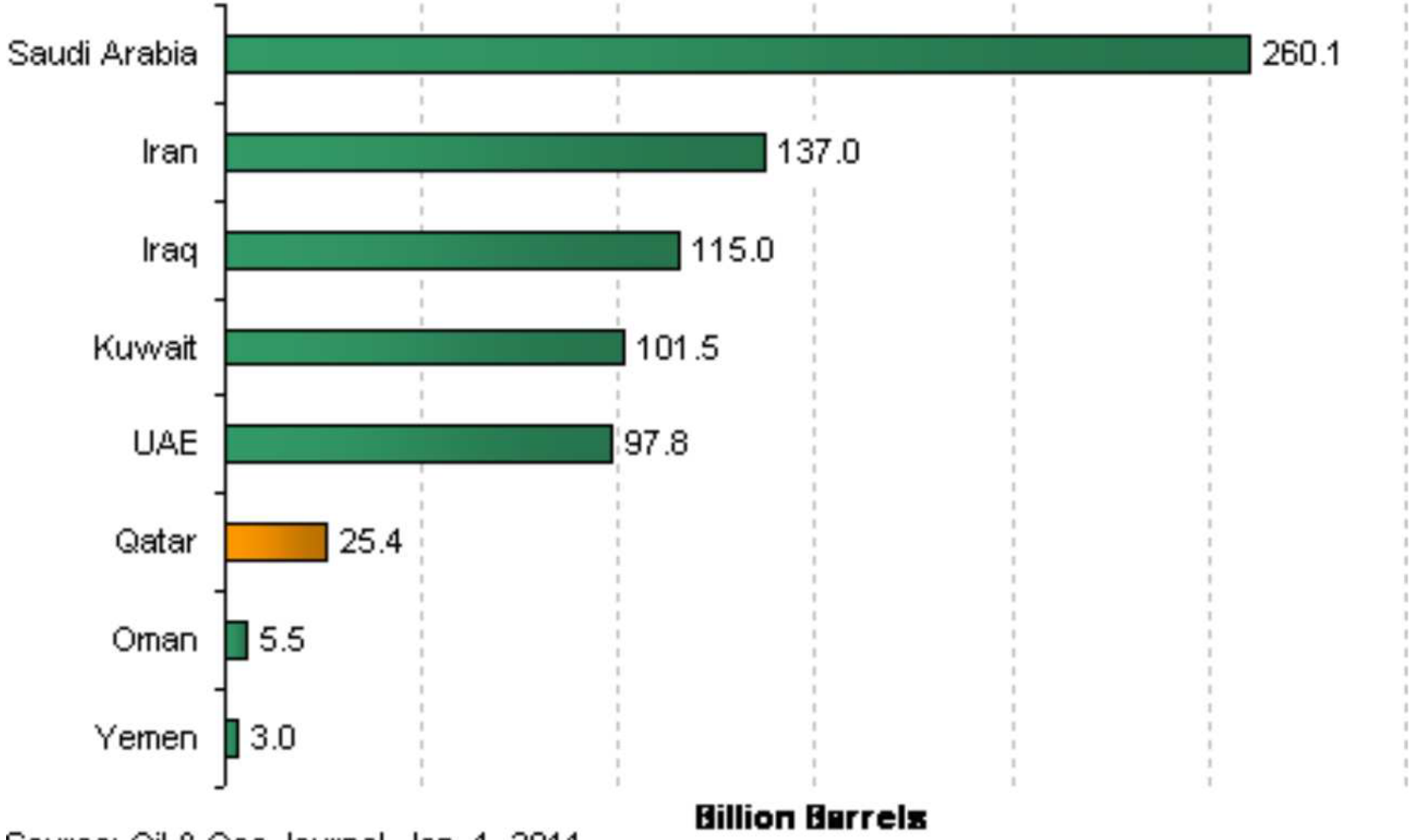
Source:1997-2007 EIA; 2008-9 FACTS Global Energy

Qatar liquefied natural gas (LNG) exports

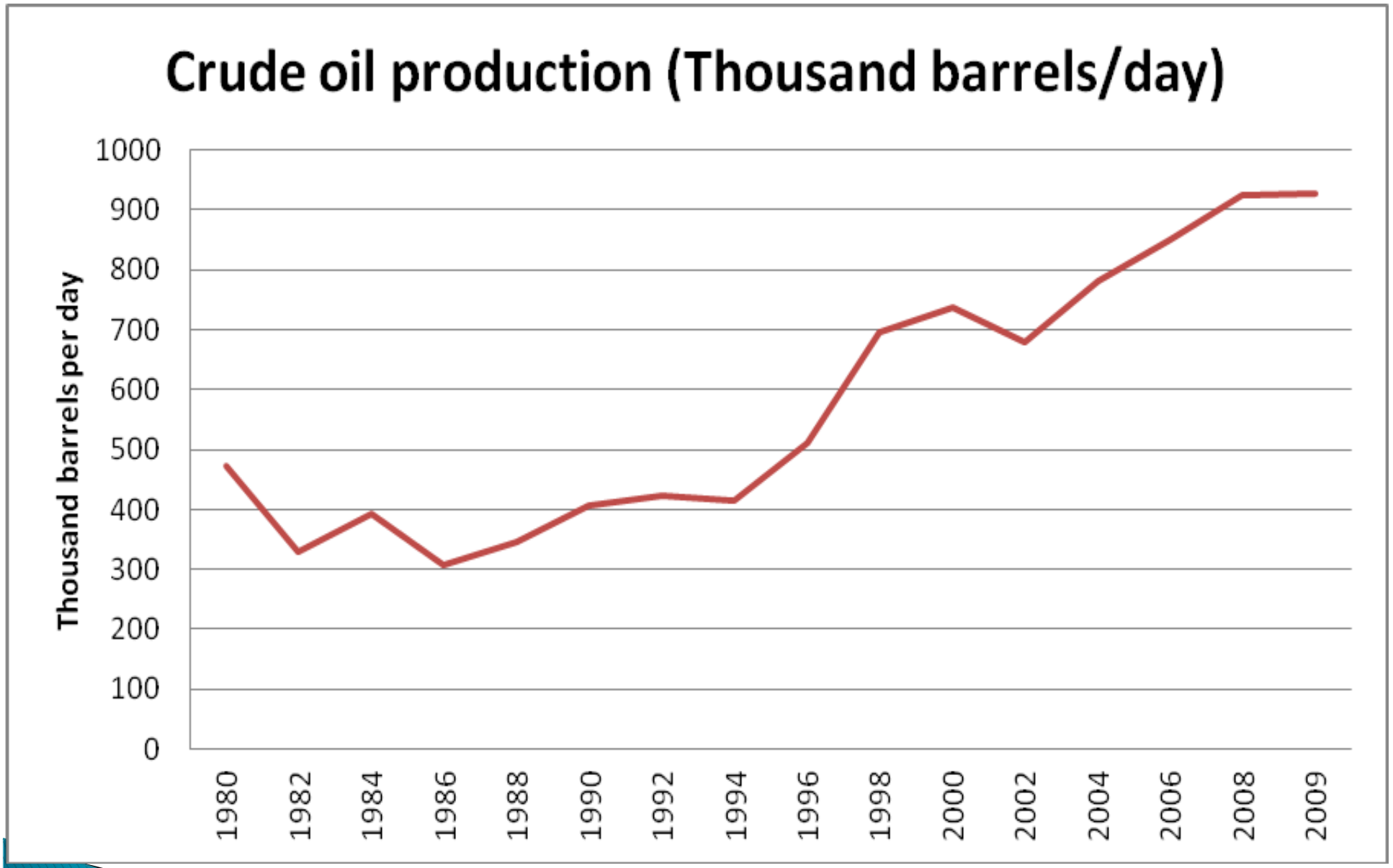
- **Qatar is wholly dependent on oil and natural gas for all of its primary energy consumption.**
- **Although the transportation sector continues to contribute significantly to growth in oil demand, all electricity capacity in Qatar is gas-fired.**



Selected Middle East Proven Oil Reserves, January 1, 2011



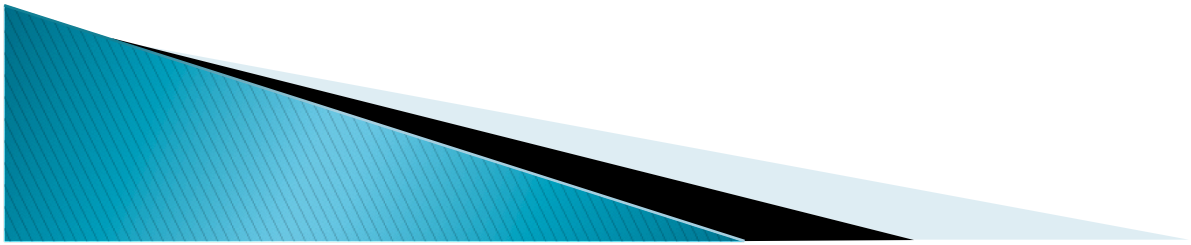
Source: Oil & Gas Journal, Jan. 1, 2011

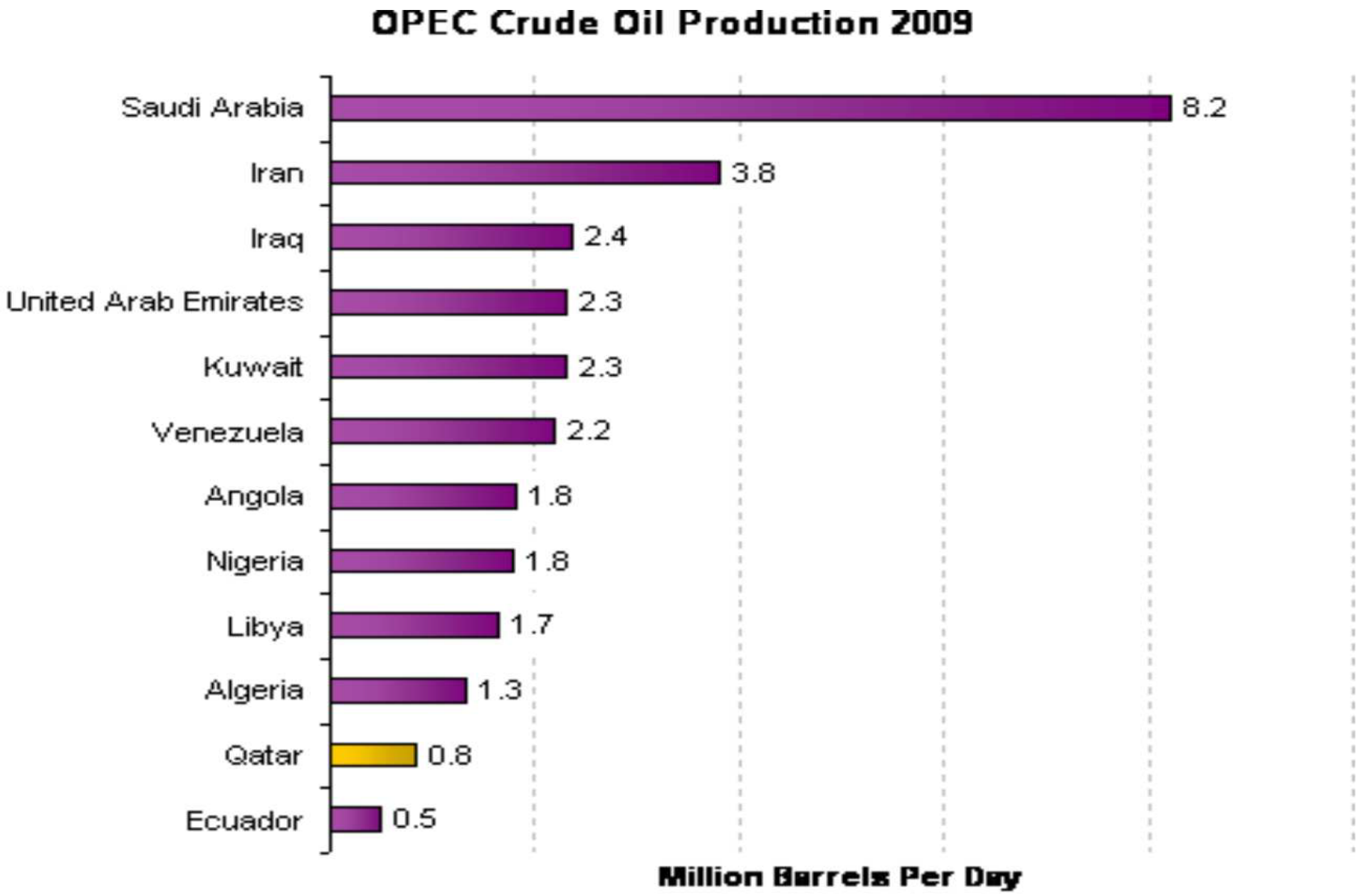

Crude oil production (Thousand barrels/day)
Thousand barrels per day
1000
900
800
700
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2009

Oil Reserve and Production

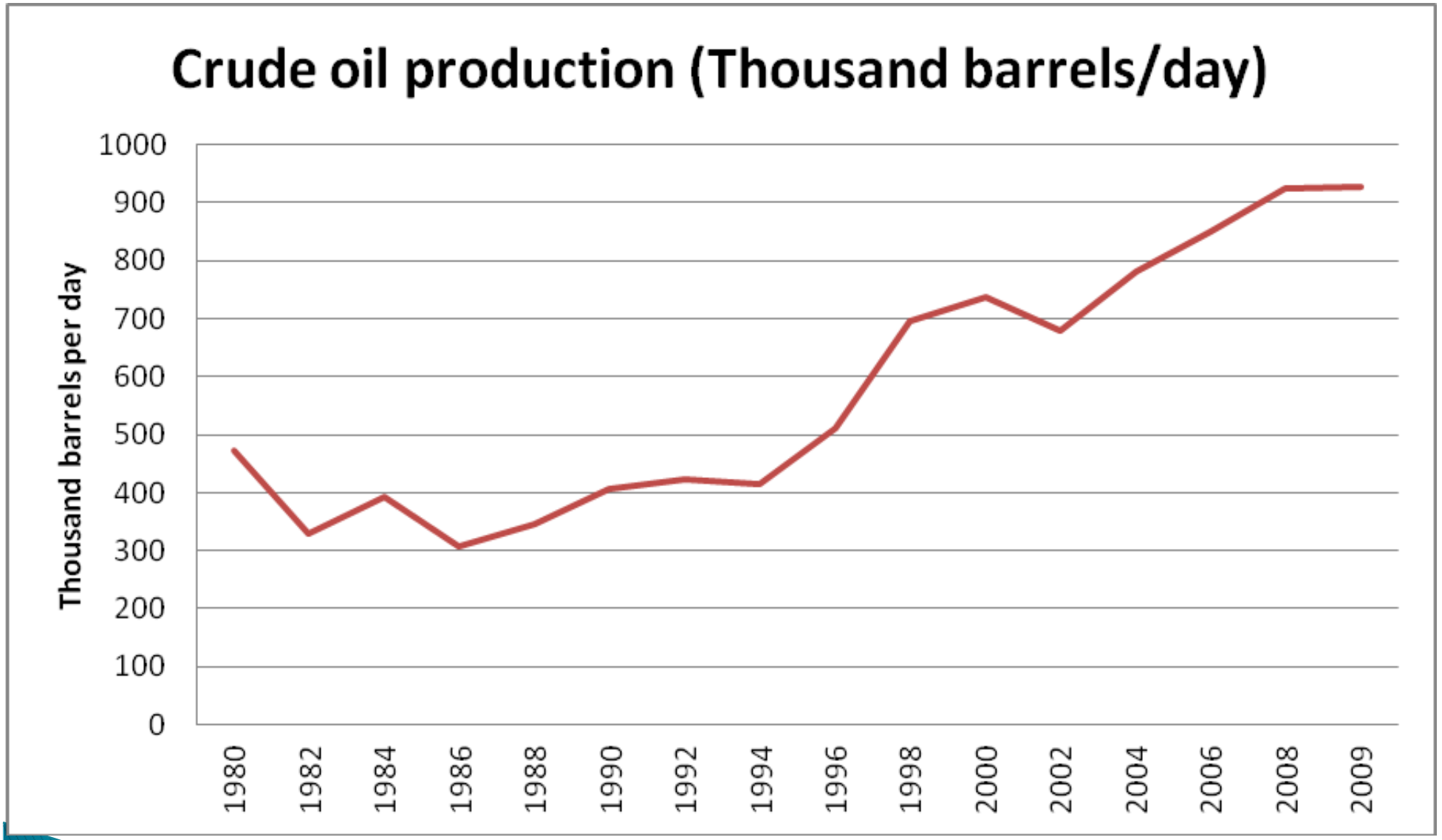
- Qatar has 25.4 billion barrels of proven oil reserves, 16th largest crude oil exporter in 2009,
- Onshore Dukhan field, west of country's oldest oil field
- It was surpassed by Al-Shaheen field production, (300,000 bbl/d in 2009).
- In 2009, Qatar produced ≅ 1.2 mbbl/d total liquids:
- 830,000 bbl/d of crude and
- 380,000 bbl/d of non-crude liquids.
- production in 2010 indicate total liquid 1.4 mbbl/d:
- 850,000 bbl/d of crude and 590 bbl/d of non-crude liquids.

- **EIA estimates that condensate and NGL production almost doubled from 2007 to 2010, from 287,000 bbl/d to 567,000 bbl/d.**





Source: EIA Short Term Energy Outlook, December 2010. Production values do not include lease condensate.


Crude oil production (Thousand barrels/day)
Thousand barrels per day
1000
900
800
700
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2009

Qatar Fuel Energy Consumption

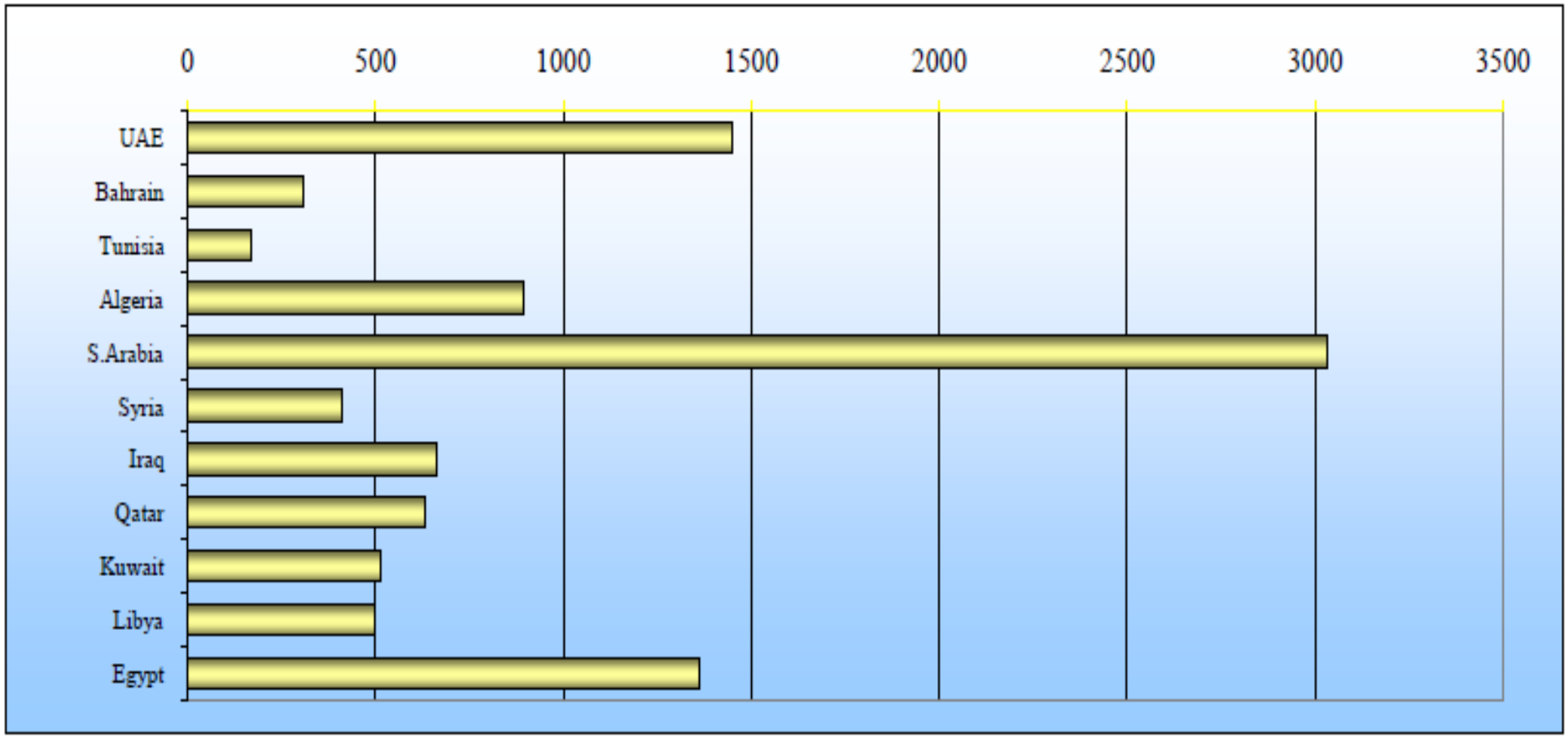
- **Total consumed energy (in equivalent 10^3 bbl/d) increased from 141 in 1995; 393 in 2000, 632.4 in 2009**
- **179% jump between 1995 and 2000 (five years) is significant (annual 12.5%); while the increase of 61% between 2000 and 2009 gives a reasonable 5.5% annual increasing rate of consumed energy.**
- **The total Energy Consumption in 2008 of 1,002 trillion Btu in 2008 includes 74.6% of natural Gas and 25.4% Oil**

Thousand boe/d

Year 2009

ألف برميل مكافىء نفط / يوم

عام 2009



Qatar

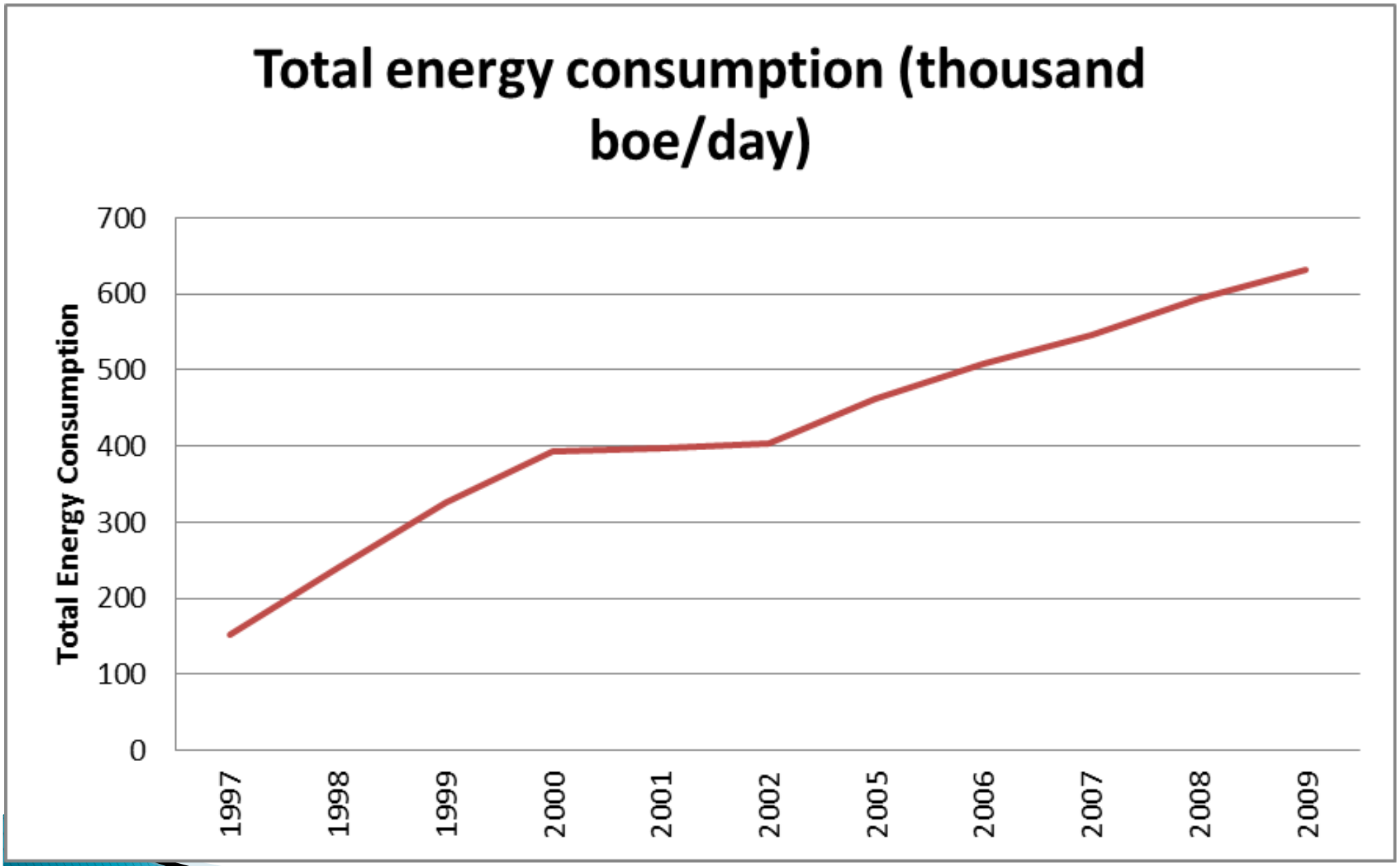
Population 1.639

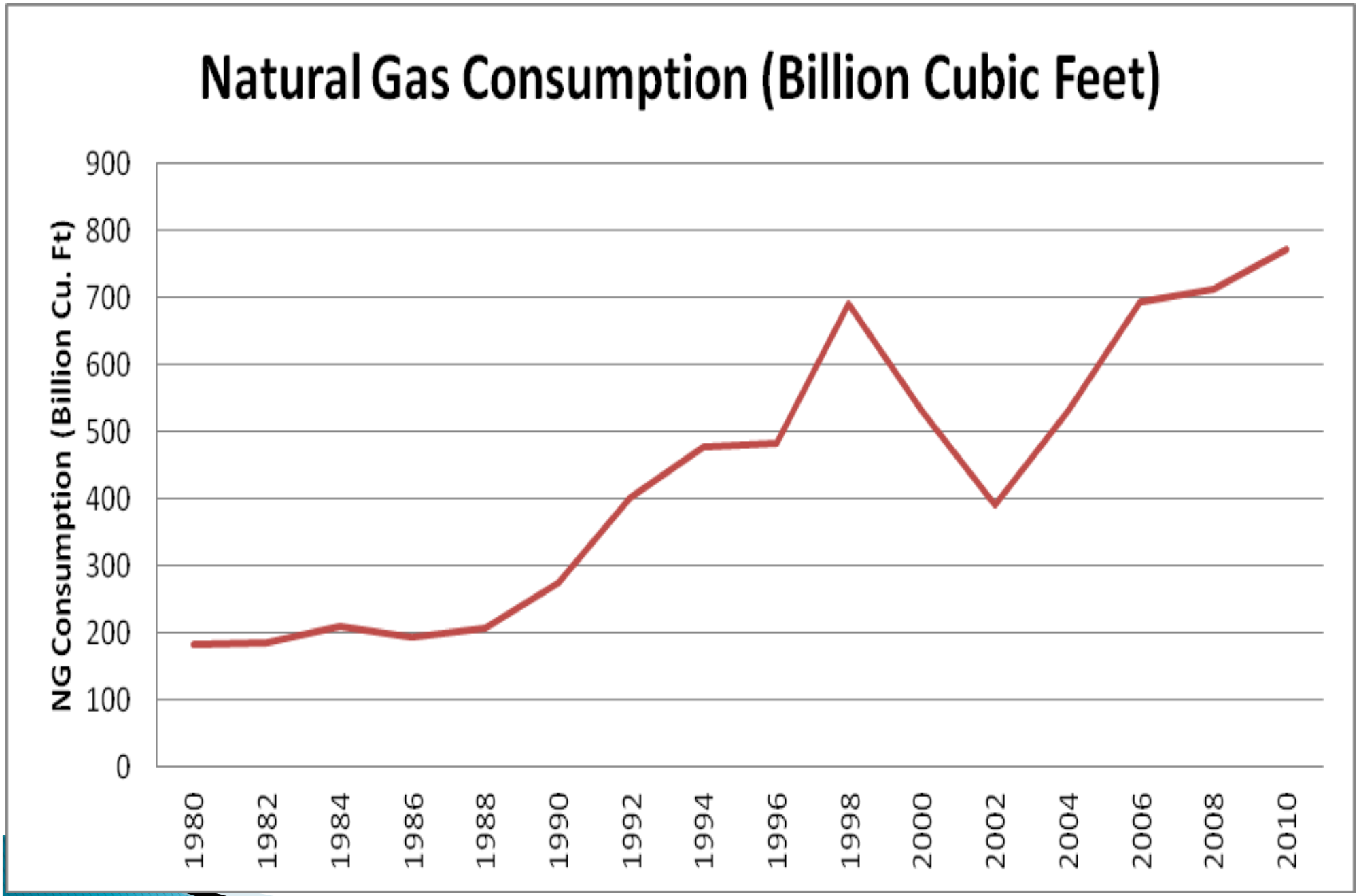
Energy consumption 0.632 Mbbl/d

Kuwait

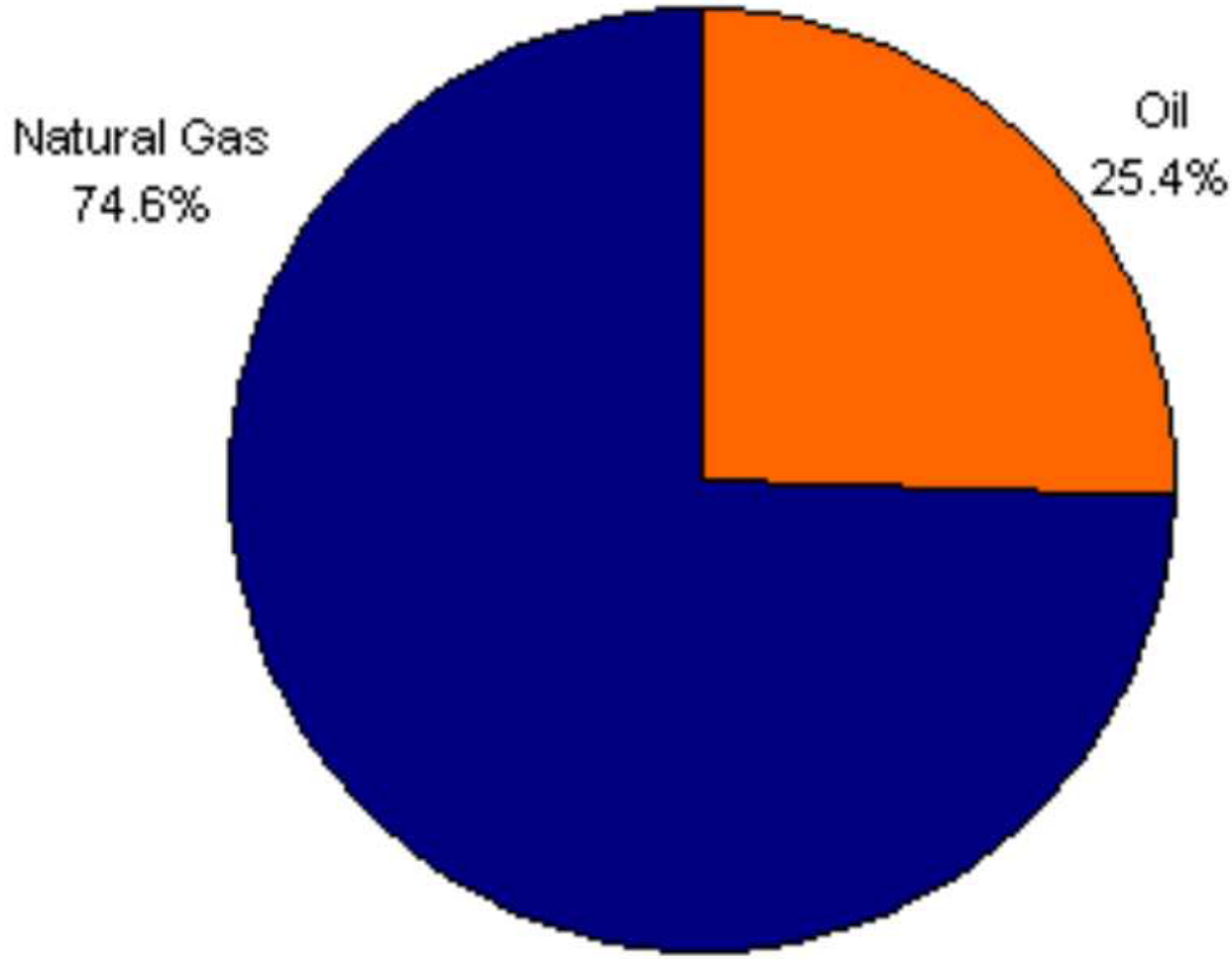
Population 3.657

Energy consumption 0.515 Mbbl/d

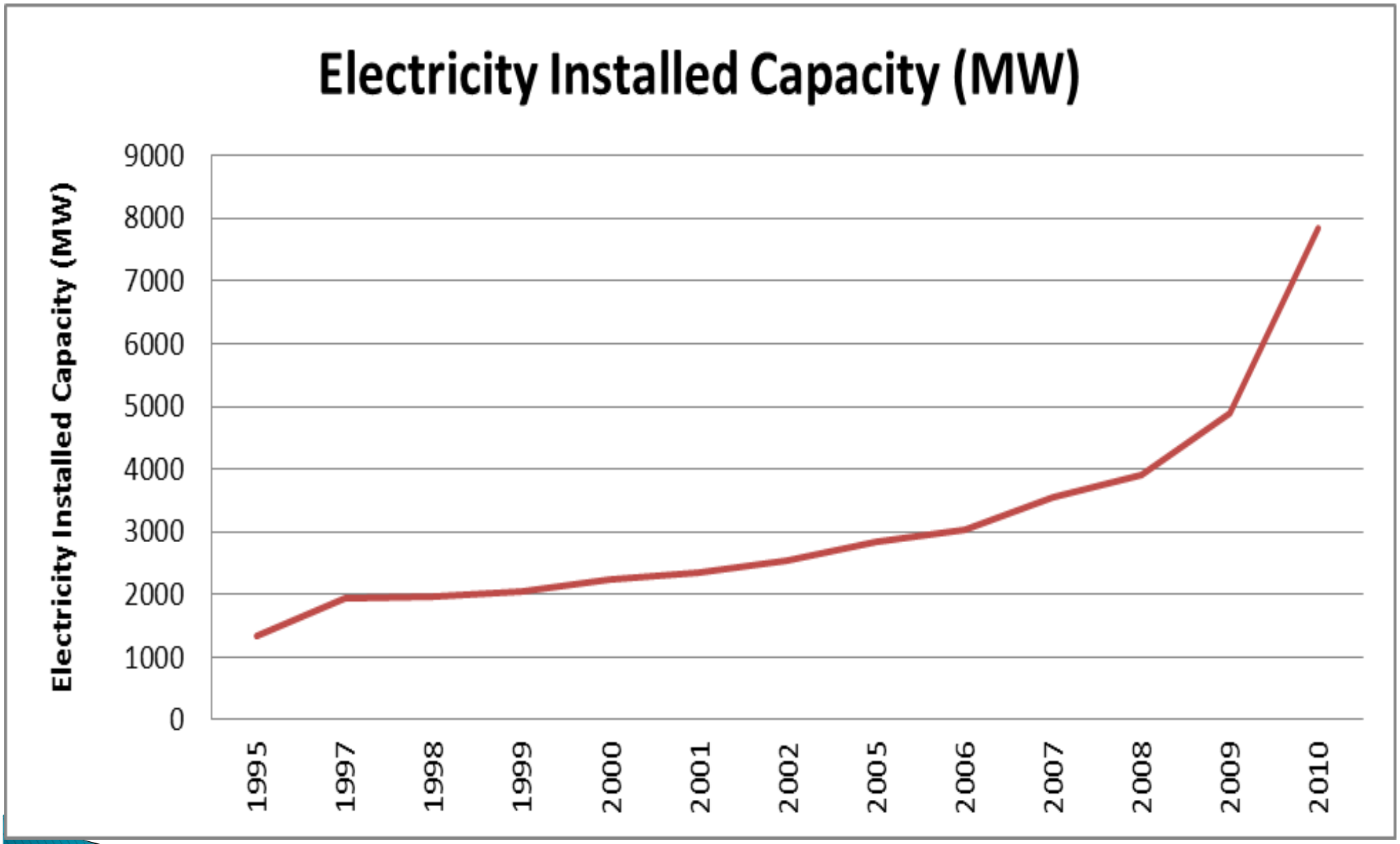

Total energy consumption (thousand boe/day)
Total Energy Consumption
700
600
500
400
300
200
100
0
1997
1998
1999
2000
2001
2002
2005
2006
2007
2008
2009


Natural Gas Consumption (Billion Cubic Feet)
NG Consumption (Billion Cu. Ft)
900
800
700
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

Total Energy Consumption in Qatar, by Type (2008)



Source: EIA, *International Energy Statistics*



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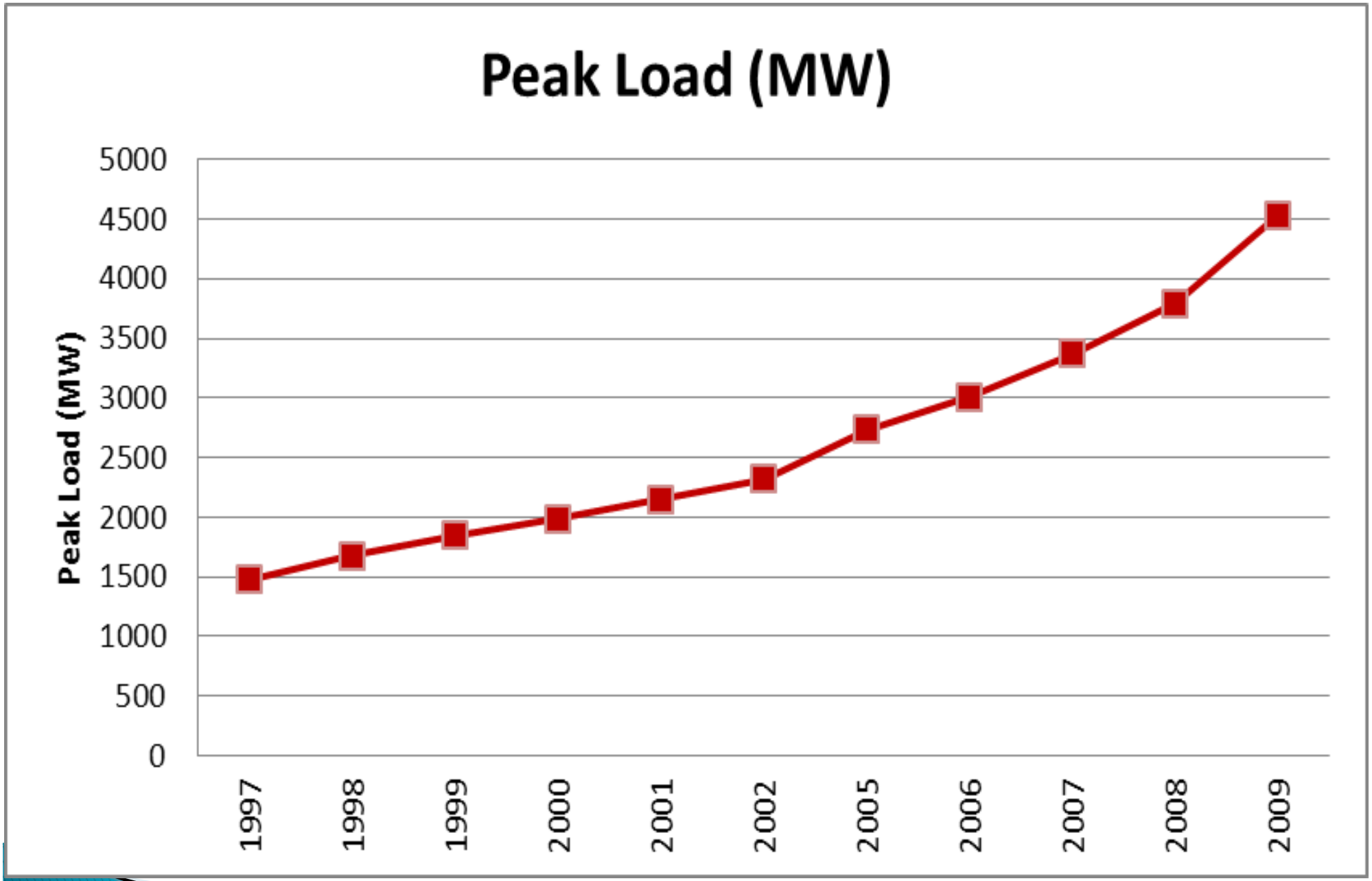
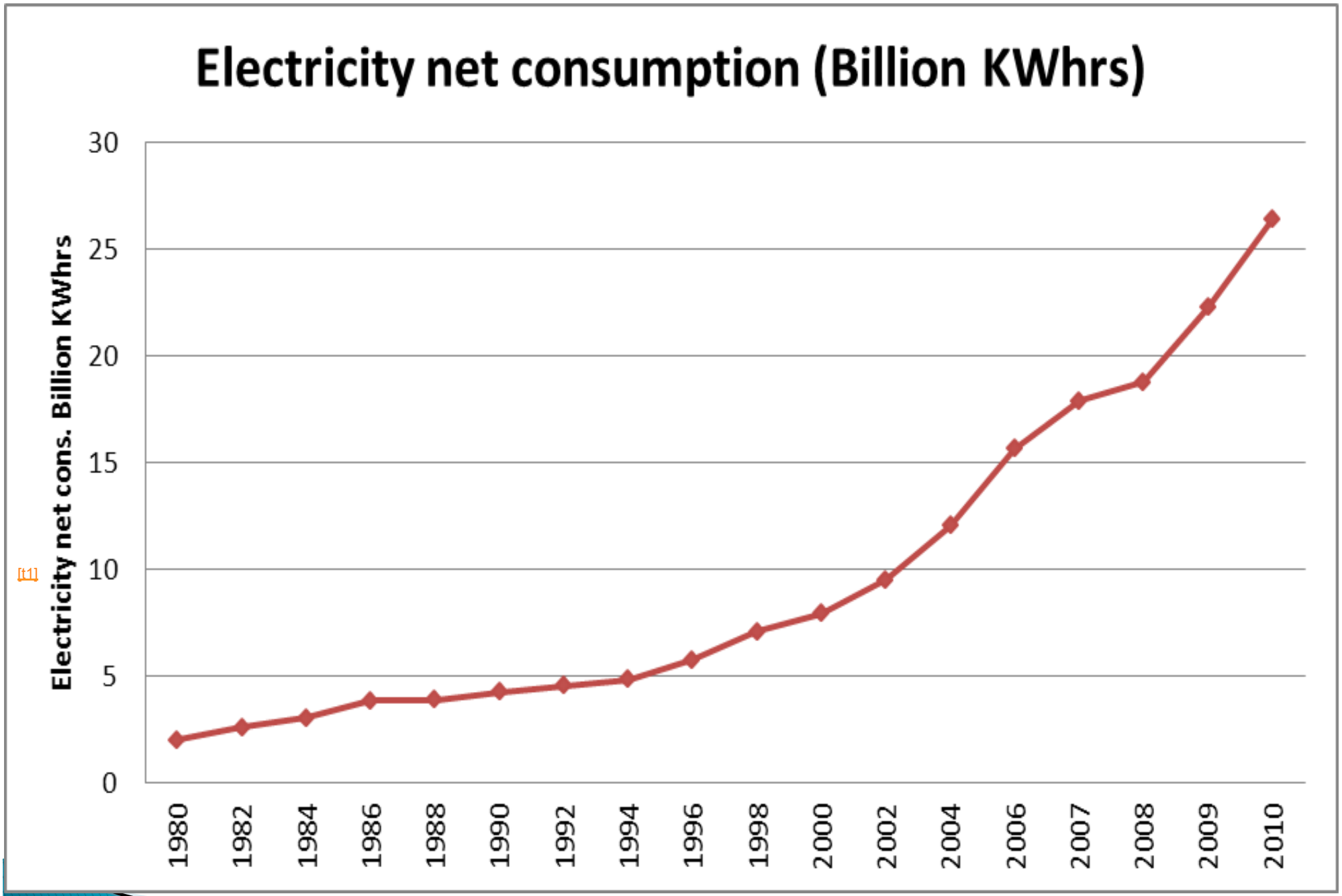
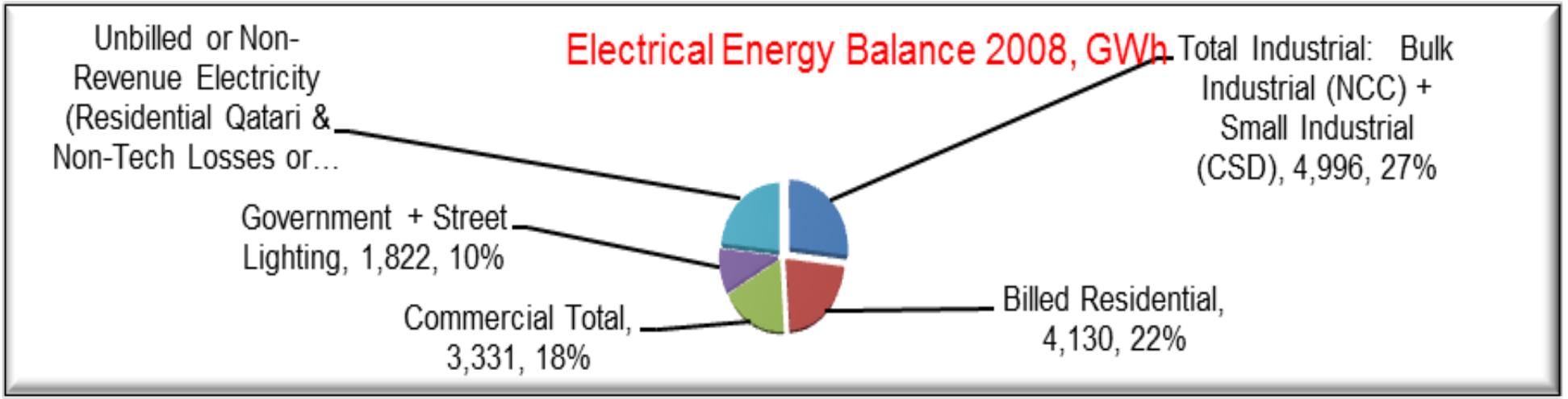
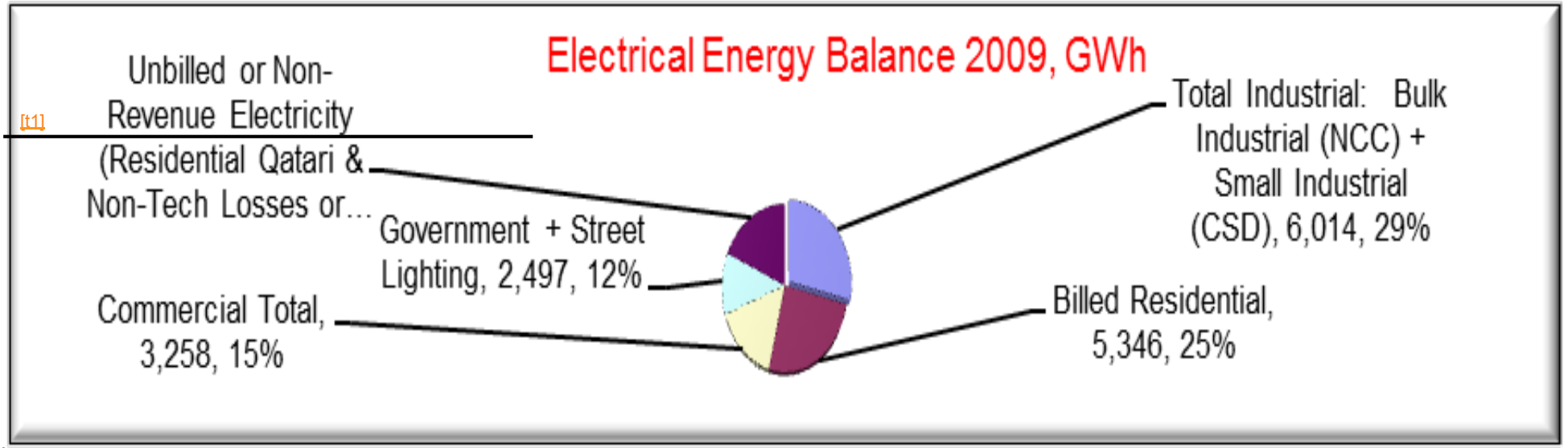
Electiricty Installed Capacity


Peak Load (MW)
Peak Load (MW)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1997
1998
1999
2000
2001
2002
2005
2006
2007
2008
2009


Electricity net consumption (Billion KWhrs)
Electricity net cons. Billion KWhrs
30
25
20
15
10
5
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2007
2008
2009
2010


Electrical Energy Balance 2008, GWh
Unbilled or Non-Revenue Electricity (Residential Qatari & Non-Tech Losses or…
Government + Street Lighting, 1,822, 10%
Commercial Total, 3,331, 18%
Total Industrial: Bulk Industrial (NCC) + Small Industrial (CSD), 4,996, 27%
Billed Residential, 4,130, 22%


Electrical Energy Balance 2009, GWh
Unbilled or Non-Revenue Electricity (Residential Qatari & Non-Tech Losses or…
Government + Street Lighting, 2,497, 12%
Commercial Total, 3,258, 15%
Total Industrial: Bulk Industrial (NCC) + Small Industrial (CSD), 6,014, 29%
Billed Residential, 5,346, 25%

[t1]

Qatar Power Plants

- Ras Abu Fontas A, EP capacity of 497 MW.
- It is 12 GTCC units, 6 of 32 MW each; and 6 of 48 MW each; and 2 simple GT of 9 MW each.
- It has 10x7 MIGD MSF desalting modules.
- Commissioned in 1980. At 2010, DW capacity 55 MIGD.
- Ras Abu Fontas B has 5 GTCC x121.8 MW each, worked in 1995-1996. Total EP capacity is 609 MW.
- Ras Abu Fontas B1 has
- 3 GT open simple x125.5 MW each,
- Desalting capacity 5x6.6 MSF = 33 MIGD
- Ras Abu Fontas B2 has 567 MW, and 29 MIGD desalting capacity.
- Also RAF A1 desalting plant of has 45 MIGD desalting capacity with waste heat from Ras Abou Fontas B1, commissioned in 2010.

More on Qatar Power Plants

- **Saliyah of 2 X 67 MW 9001B gas turbines**
- **Doha Super South has 62 MW EP capacity**
- **So, the total EP capacity belongs to the Qatar Electricity and Water Company is 2273 MW, and its desalting water capacity is 162 MIGD.**

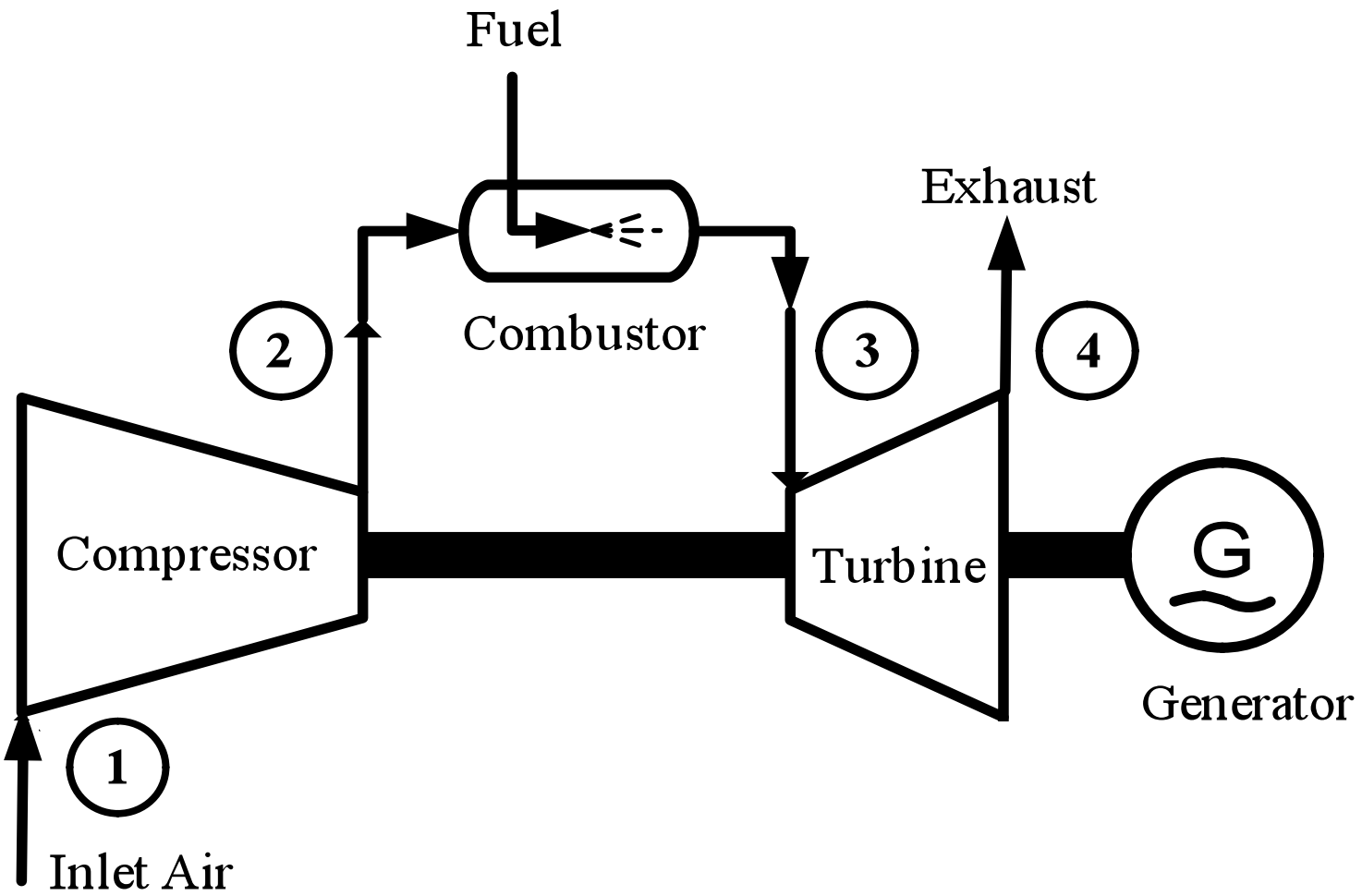
More on Qatar Power Plants

- Ras Laffan-A has 2x GTCC x 378-MW each. Each has 2 GTx100 MW plus ST of 178 W.
- Each GTCC is combined with 2 MSF desalting unit of 10 MIGD each.
- So, Ras Laffan PP has 756 MW total EP and 40 MIGD desalting capacity.
- Ras Laffan B of EP 1025 MW. GTCC; and has 60 MIGD MSF desalting plant, commissioned in 2006
- Ras Laffan C of EP1612 MW. It uses GTCC; planned to have 63 MIGD MSF
- First DW capacity in Nov. 2010.
- EP capacity is planned to be 2730 by 2011.
- Total EP capacity 3550 MW, and its DWcapacity is 163 MIGD.

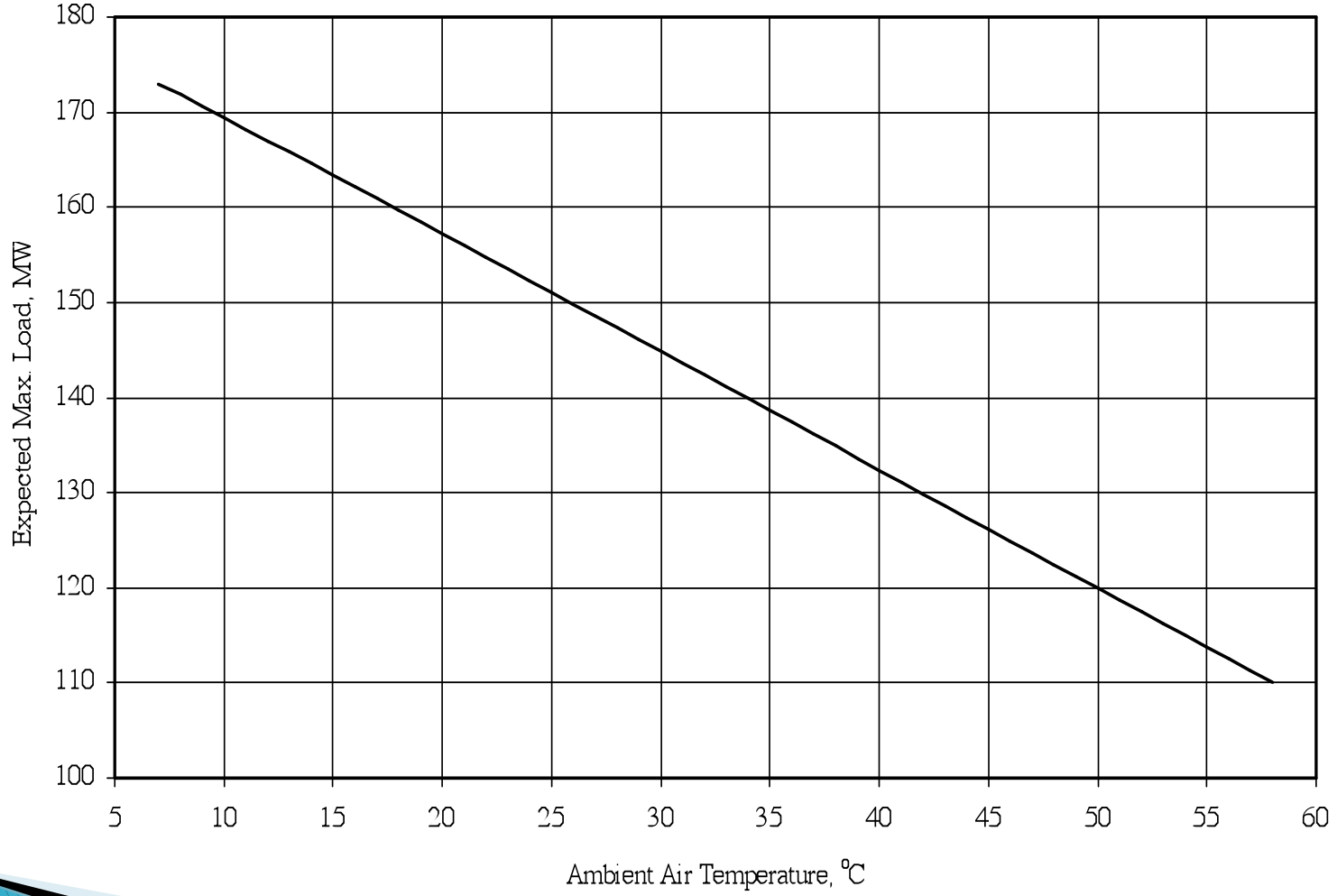
More on Qatar Power Plants

- **Ras Girtas** Power and Water Project 2,730MW (1,0612 completed in 2010, and the balance completed in 2011);
- It has 63 MIGD MSF DW
- Satisfying Qatar with 30% of EP need and 20% potable water need;
- Provide off-peak EP to neighboring GCCC via common grid, commissioned in 2010
- **Mesaieed Power plant**: Its EP capacity is 2000MW power plant. It was commissioned in 2009.

Simple Gas Turbines



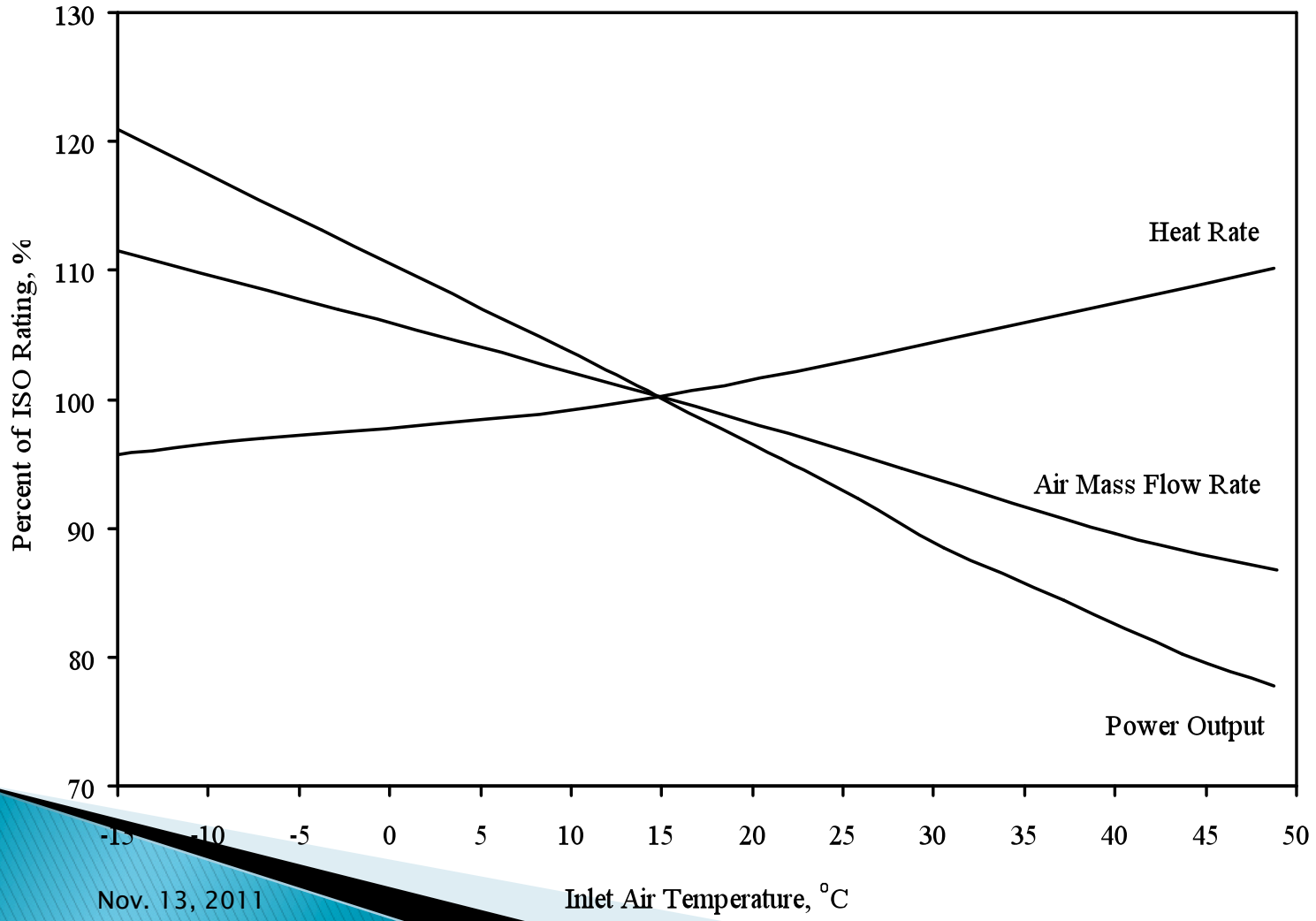
The variation of the GT power with the ambient temperature



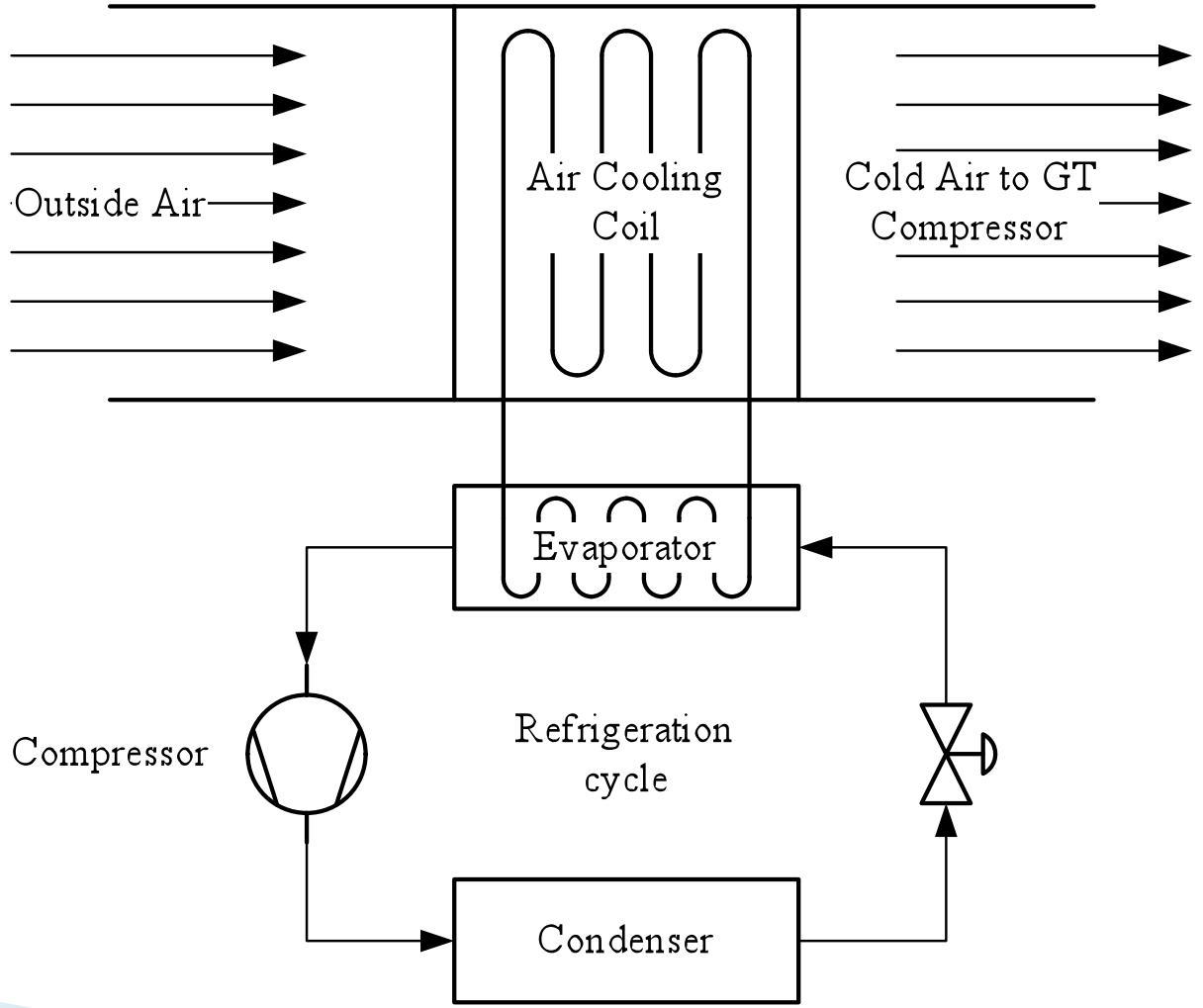
Cooling air intake to the compressor

- **The design outside temperature (OT) of A/C system is 46-48°C.**
- **This gives more than 10% decrease of the air density compared to the ISO conditions of 15°C.**
- **The GT power output and thermal efficiency also decreases by the increase of OT.**

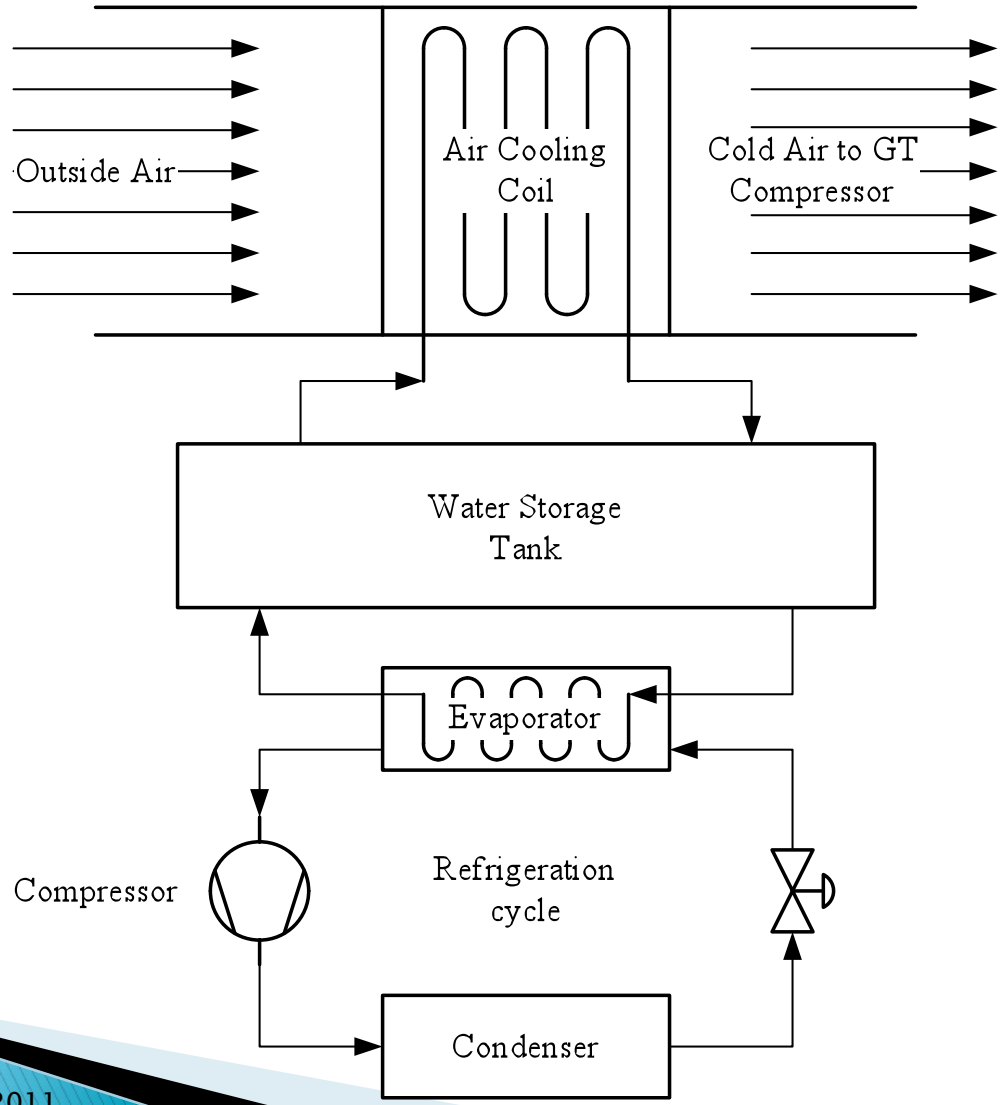
Typical inlet air cooling impacts on GT performance



Water Chiller Using MVC Refrigeration Cycle



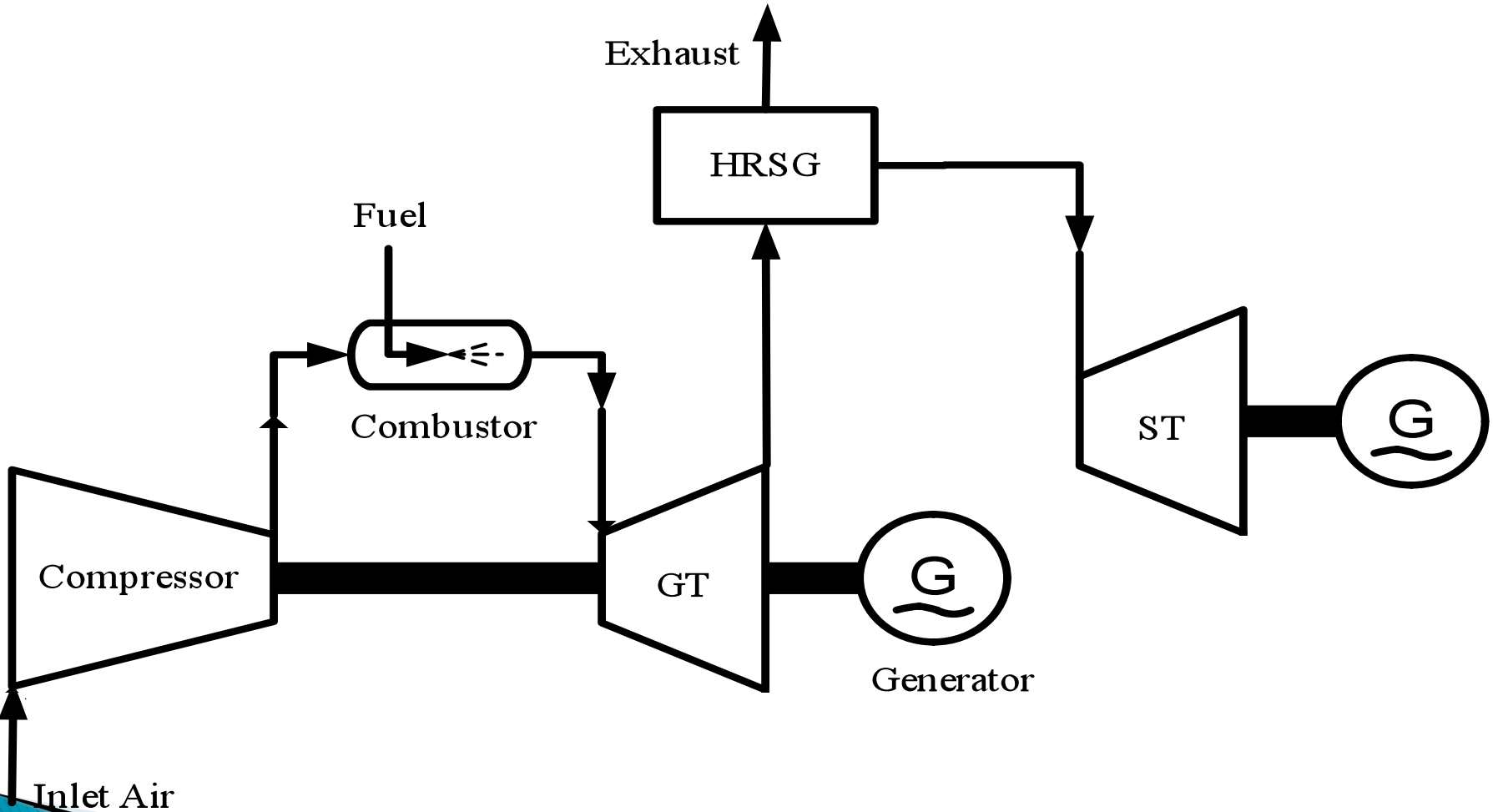
Water Chiller Using MVC Cycle and Water Storage Tank



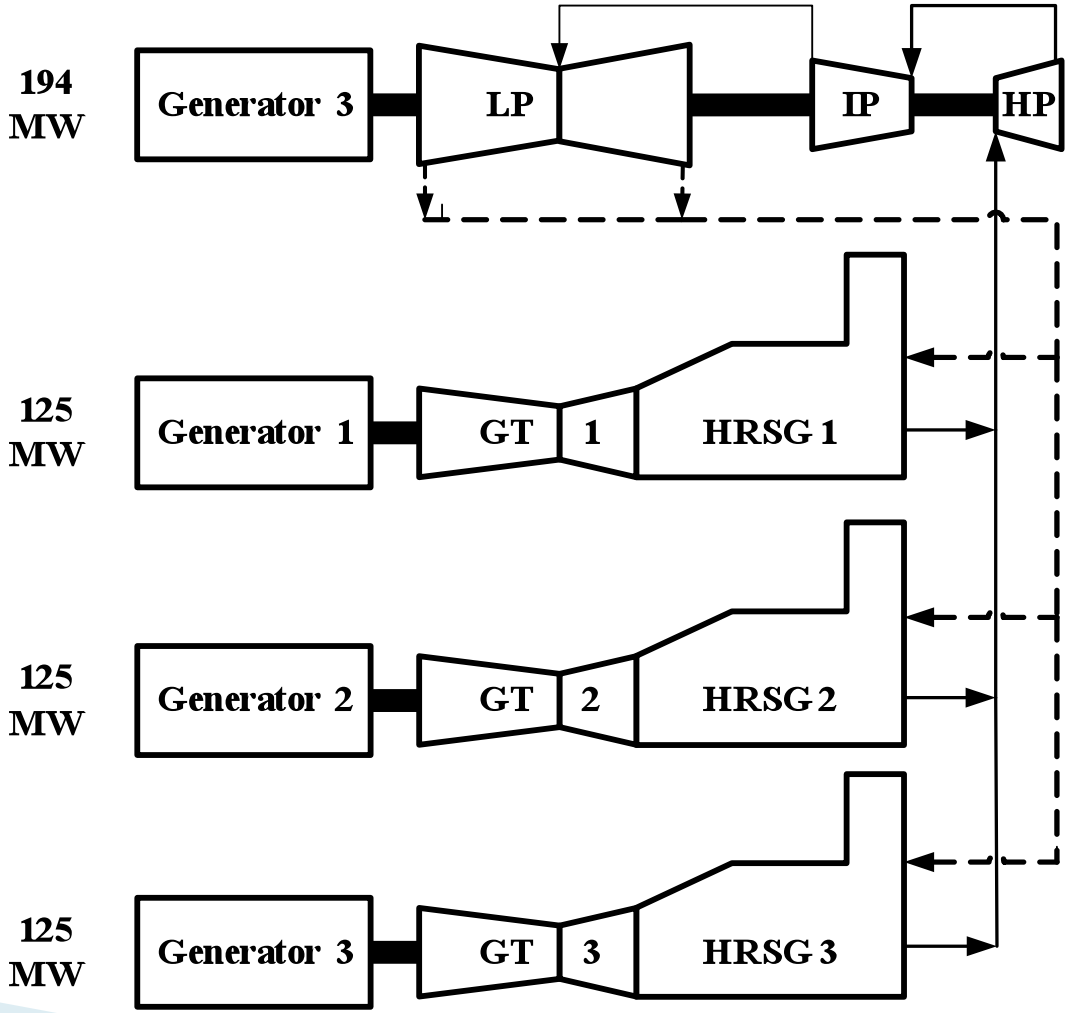
Benefits of Cooling Inlet Air to Compressor

- **Cooling the air intake to the compressor increases the GT net power output from 125 MW to 163.4 MW (24%), by only consuming 7.98 MW for single stage, (or 6.02 MW for three stages) water chiller.**
- **GT cycle efficiency is improved from 31% to 34%**

Gas/Steam turbines Combined Cycle GT/ST CC

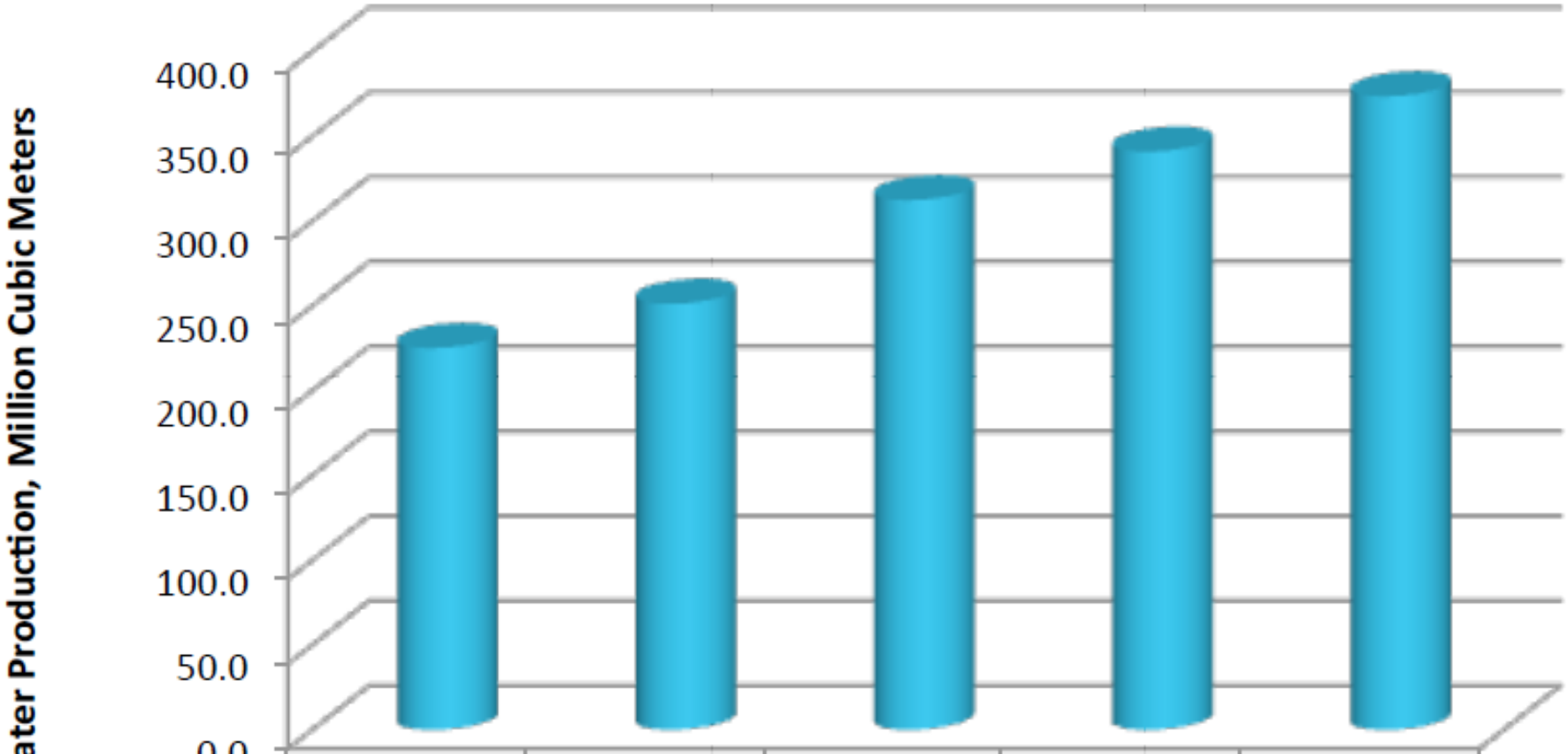


Combined cycle consisting of three GT, three HRSG, and one steam turbine



Growth Indicators	2004	2006	2007	2008	2009	2010	Average % Change
A. ELECTRICITY							
Generated, GWh	13,232	17,071	19,462	21,616	24,158	28,144	14.4%
% Change		18.6%	14.0%	11.1%	11.8%	16.5%	
Sent Out, GWh	12,045	15,667	17,913	19,747	22,258	26,385	15.0%
% Change		19.2%	14.3%	10.2%	12.7%	18.5%	
Maximum Demand, MW	2,520	3,230	3,550	3,990	4,535	5,090	13.3%
% Change		18.1%	9.9%	12.4%	13.7%	12.2%	
No. of customers (billed & non-billed, based on number of meters)	177,041	190,808	193,307	210,057	234,658	255,055	6.1%
% Change		0.4%	1.3%	8.7%	11.7%	8.7%	
B. WATER							
Water production, Mm^3	178	226	251	312	340	373	14.0%
% Change		15.6%	11.2%	24.3%	9.1%	9.7%	
Maximum daily production, MIGD (for 2010 occurred in July)	119.3	146.5	161.7	209.0	222.7	249.3	15.0%
% Change		14.0%	10.4%	29.2%	6.6%	12.0%	
No. of Water customers (billed & non-billed, metered plus served by water tankers)	121,651	137,667	151,485	169,315	185,856	211,211	10.3%
% Change		6.4%	10.0%	11.8%	9.8%	13.6%	

Total Water Production from 2006 to 2010



	2006	2007	2008	2009	2010
Water Production, MM3	225.1	251.2	312.4	341.0	373.6

Desalted seawater plant in Qatar

- **Large desalting plants (DW) combined with PP to satisfy MSF thermal energy needs, ≅260-300 MJ/m3.**
- **DW energy intensive process.**
- **Thermal energy is steam extracted from turbine at 3 bar pressure.**
- **Steam supply to MSF comes either from HRSG by waste heat rejected from GT; or steam extracted from steam turbine GTCC.**
- **MSF consume also pumping energy of about 4-kWh/m3**
- **Meanwhile SWRO consume 4-6 kWh/m3**

Need of power plants energy auditing

- Qatar PP's largest fuel energy consumer.
- Calculation of Consumed fuel energy to produce EP & DW.
- 2010 EP production = 28144 GWh;
- DW production =373.6 Mm^3 (1.0236 Mm3/d).
- Consumed equivalent mech. energy per m^3 = 20 kWh/ m^3,
- Equivalent EP for DW= 20.47 GWh/d, or 7472 GWh/y
- Total EP (for both EP and DW) = 35616 GWh, DW share = 21 %.
- Installed PP Capacity in 2010 = 7830 MW, and CP= 0.519.

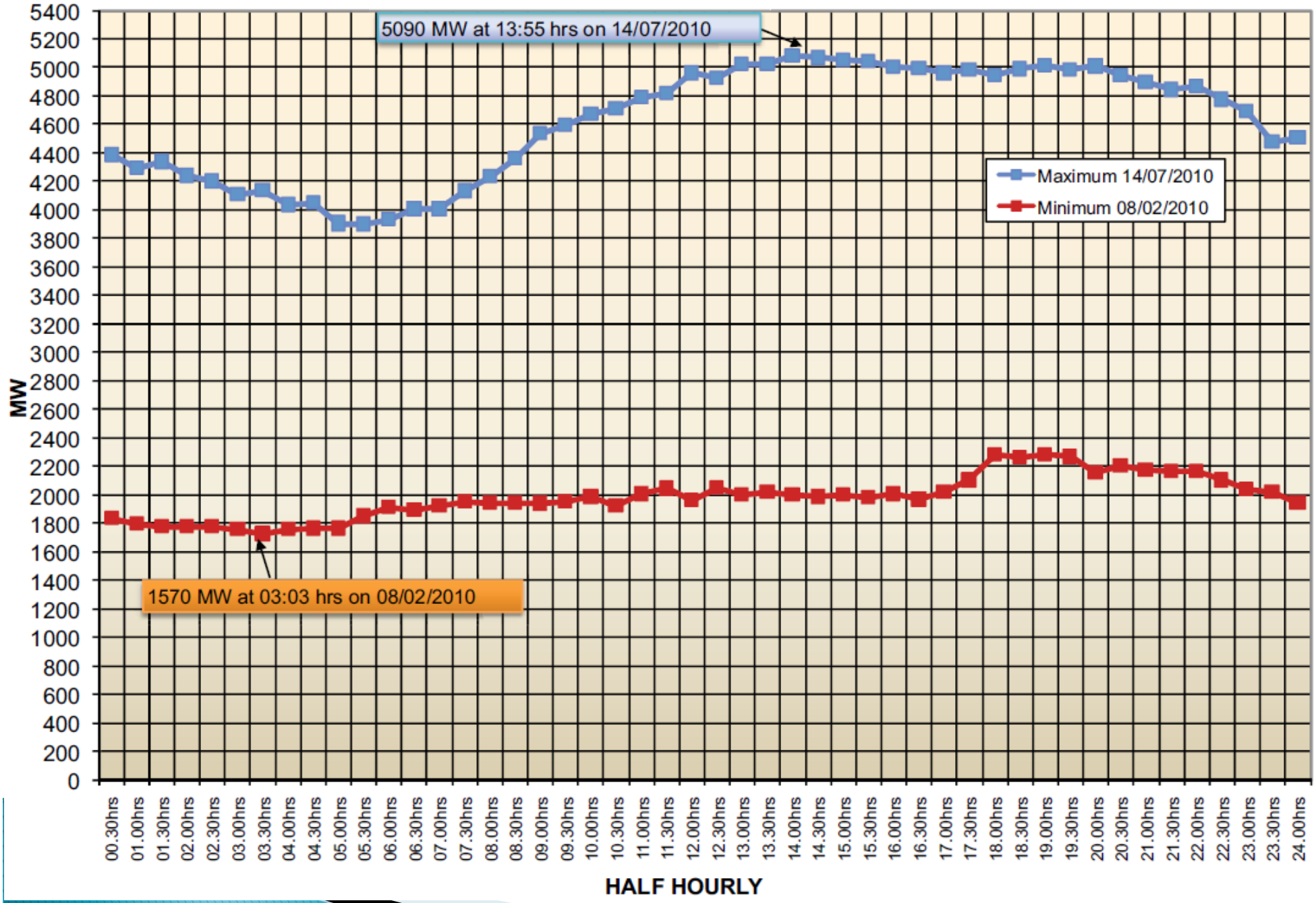
Fuel Energy Consumed by PP

- When efficiency=30%
- Consumed fuel energy in 2010 = 427.4 (343) million GJ, or 406.02 BCF (11.5 Bm3).
- NG produced in 2010 =4121 BCF
- NG consumed= 772 BCF respectively.
- %NG consumed by PP to total consumption= 52%, and 9.82% of total production.
- It was noticed that the NG production in Qatar increased from 3154 BCF in 2009 to 4121 BCF in 2010, amazing 30.6% in one year

MSF vs SWRO

- MSF consumes 260 -300 MJ/m3 plus 4 kWh/m3 pumping energy
- SWRO consumes 5 kWh/m3
- If SWRO was used in place of MSF, 0.75% of fuel used for desalting was saved
- This is equivalent to 121.6 BCF of NG, or 16% of total fuel was saved

HALF HOURLY LOAD CURVE FOR SYSTEM MAX. ON 14/07/2010, MIN. ON 08/02/2010



Use of GT to operate SWRO at off-peak h

- **EP load varies along the day, and differs daily along the year.**
- **It is low in winter and high in summer.**
- **Even at hottest summer day with highest peak load, spare capacity exit, can be utilized during off-peak hours.**
- **In 2010, max. load = 5090 MW in summer, while min. load was 1570 MW in winter.**
- **Even when peak load of 5090 MW, the load below 4400 MW for 10 hours.**

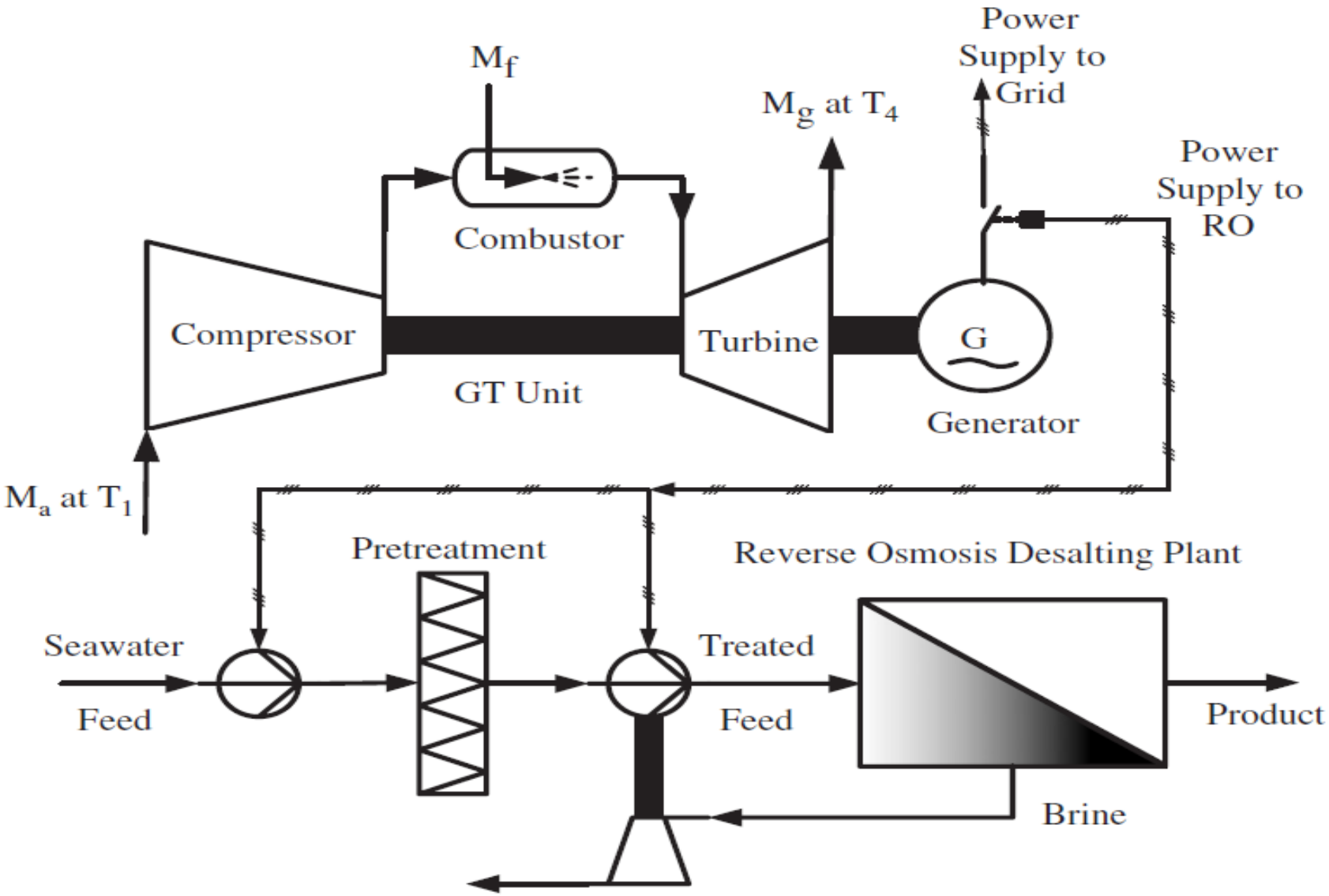
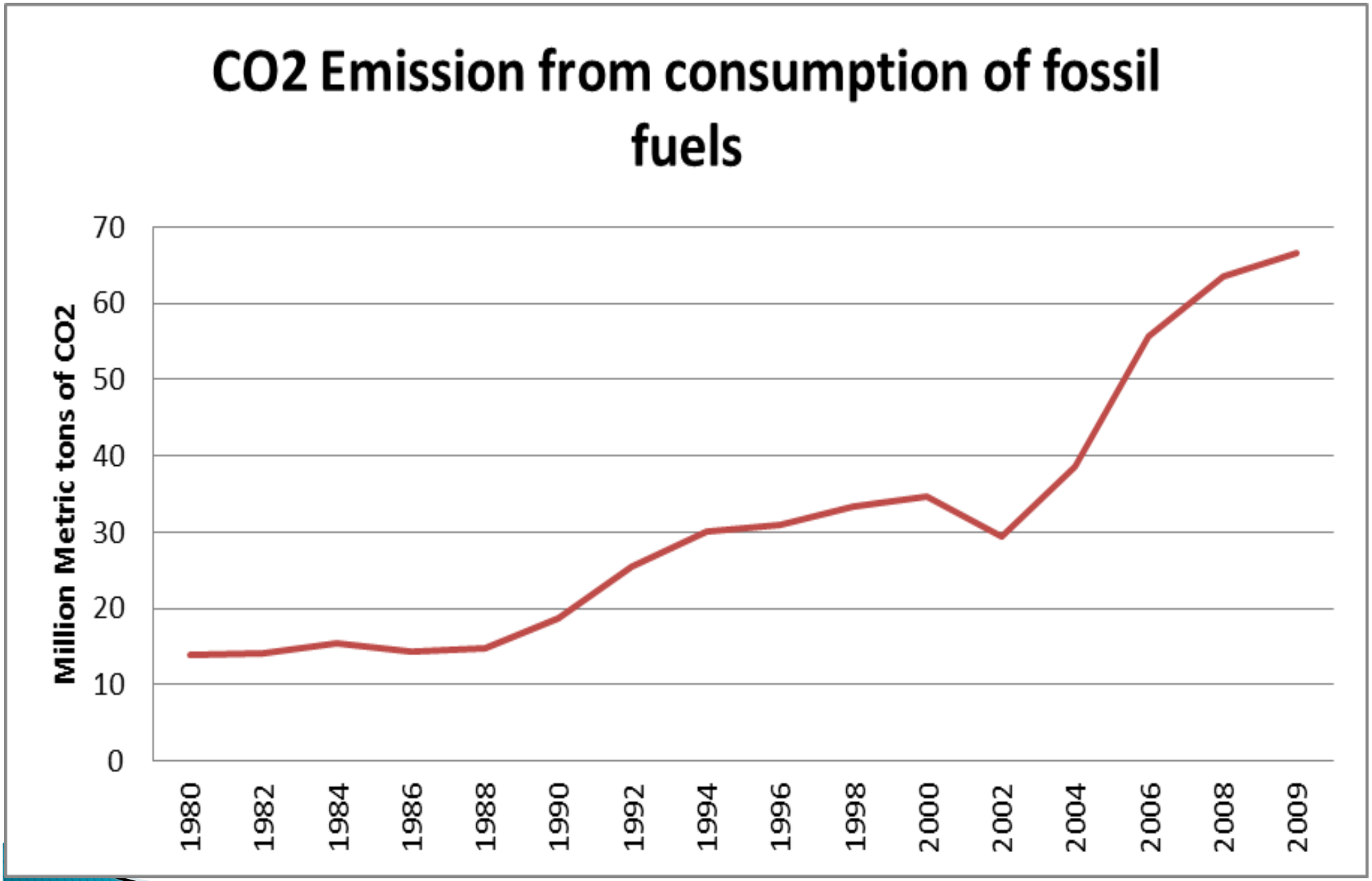
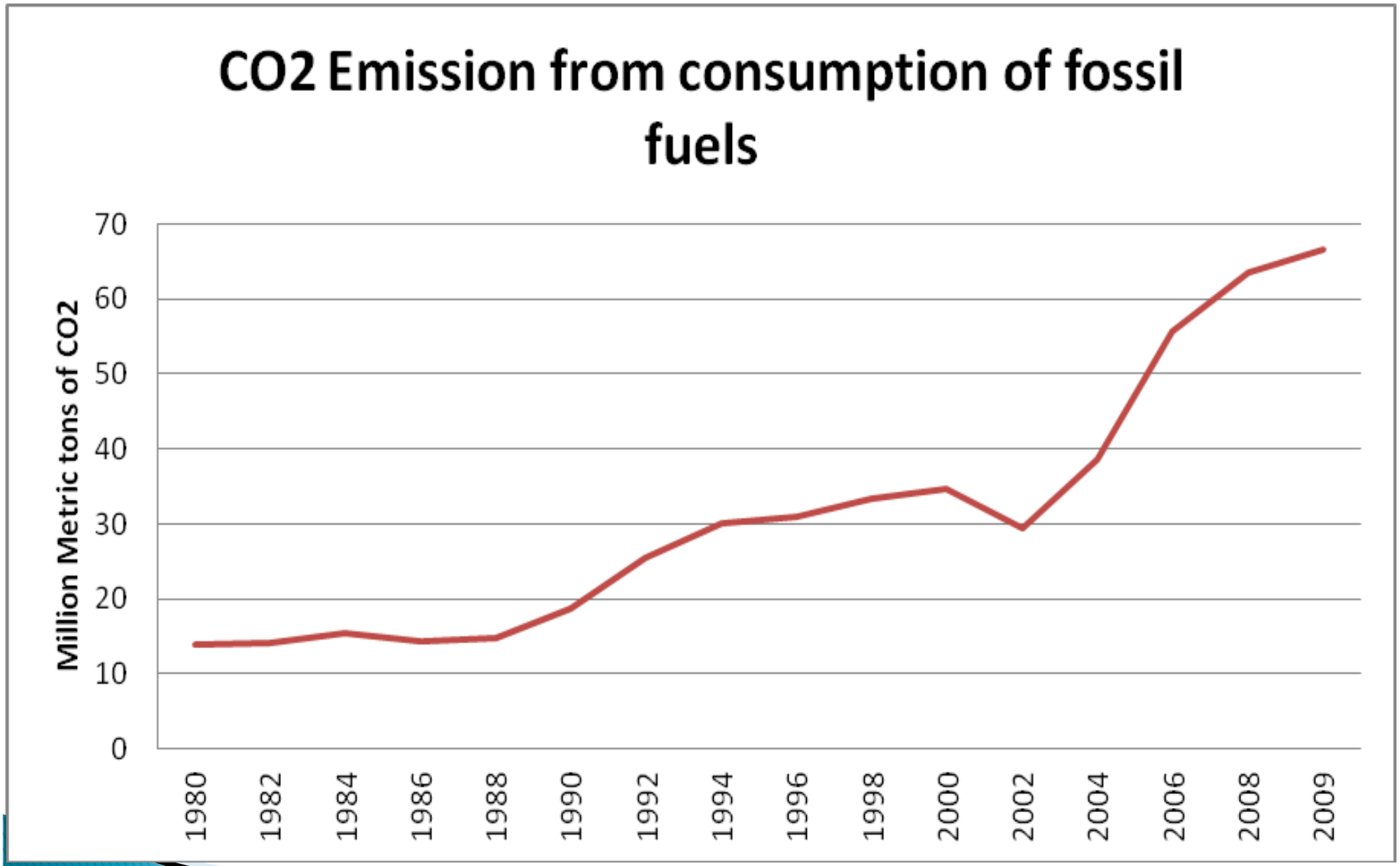


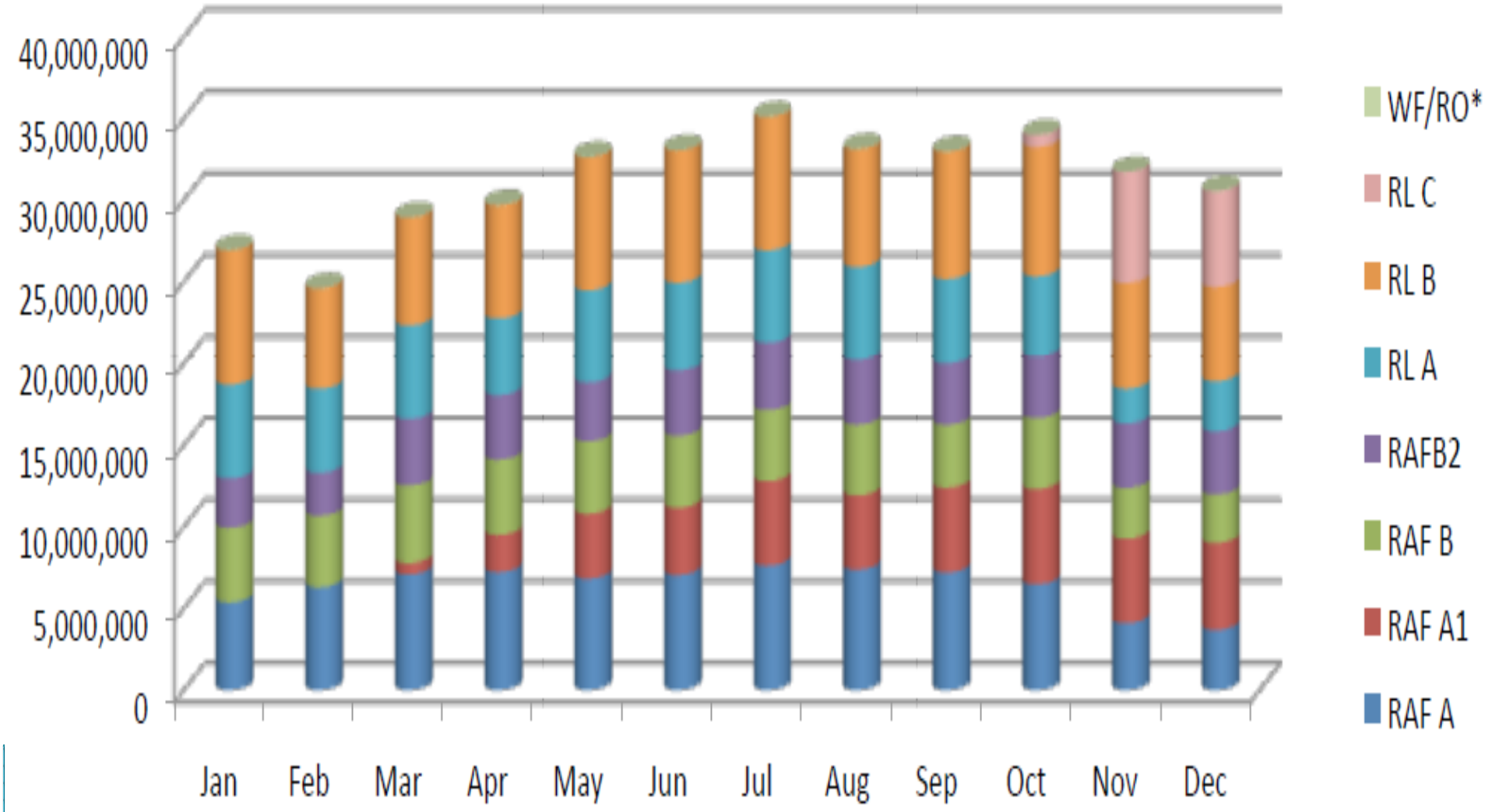
Fig. 6. Arrangement of a simple gas turbine operating seawater RO desalting plant.

- So, PP underutilized in winter with low load factor (LF) ≅ 30%, as well as in summer.
- LF can be raised by let unused capacity operating SWRO desalting plant, mainly in winter, or chilling water for district cooling in summer.
- DW can be used later, stored, or injected in aquifers.
- Every one MW power output produce up to 0.88 MIGD if its specific energy consumption is 6 kWh/m^3.
- Moreover the GT efficiency η_{gt} as well as their power output are higher in winter than in summer.


CO2 Emission from consumption of fossil fuels
Million Metric tons of CO2
70
60
50
40
30
20
10
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2009


CO2 Emission from consumption of fossil fuels
Million Metric tons of CO2
70
60
50
40
30
20
10
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2009

Monthly Water Production in 2010 by IWPP, Cubic Meters



Thanks