What will the global energy landscape look like over the next 50 years? Summary of Lecture 1

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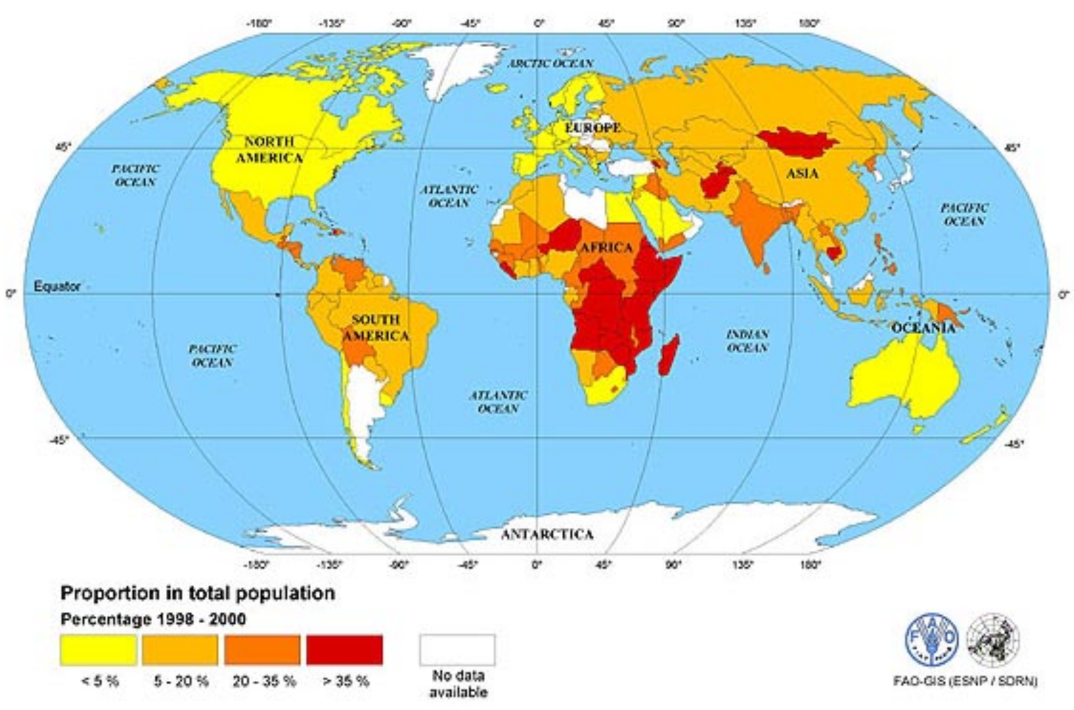

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Energy is a primary driver of development: All energy resources will be utilized as they become economical or are subsidized

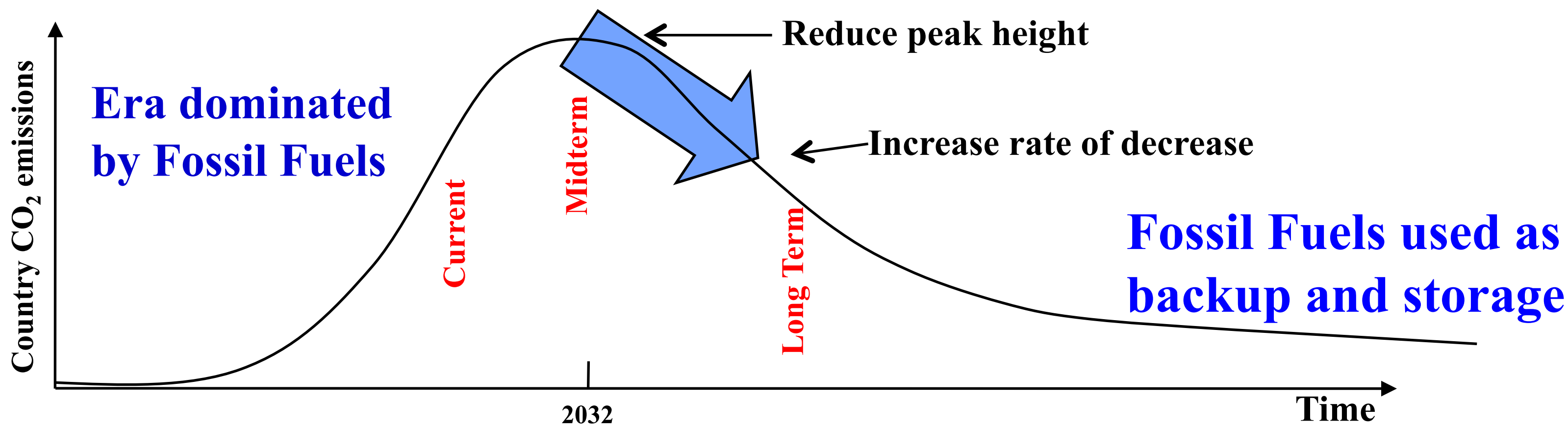
- The goal is to optimize portfolio over
  - Indigenous fuel, water, mineral resources
  - Regional resources (Regional trade)
  - Minimize environmental impact
  - Mitigate climate change (reduce GHG emissions)

The cost of large-scale fuel or energy systems imports will remain high → countries vulnerable to geo-politics

Developing a credible roadmap to GHG-neutral systems

- Focusing on “peak-oil”, declining oil/gas/coal/U resources in one field, one country, etc., is not a compelling strategy. There is plenty of economically accessible fossil fuel for the next 50 years for global need.
- There are compelling forces driving choices countries make
  - Energy security
  - Cost
  - Economic development
  - Easily available fossil fuels
  - Technology
  - Uncertainty of and unfamiliarity with emerging options
  - Social and political pressures
- There is no free lunch. Society must develop a coherent/realistic framework
  - What risk society is willing to accept with respect to impacts of a given energy system
  - What time-evolving adjustments society is willing to make if environmental degradation and climate change is an unacceptable risk

Transition to Carbon-Neutral Systems



- Progressively reducing carbon intensity
- Reducing the peak height
- Reaching the peak early in development
- Developing cost-effective carbon-neutral systems to accelerate the transition

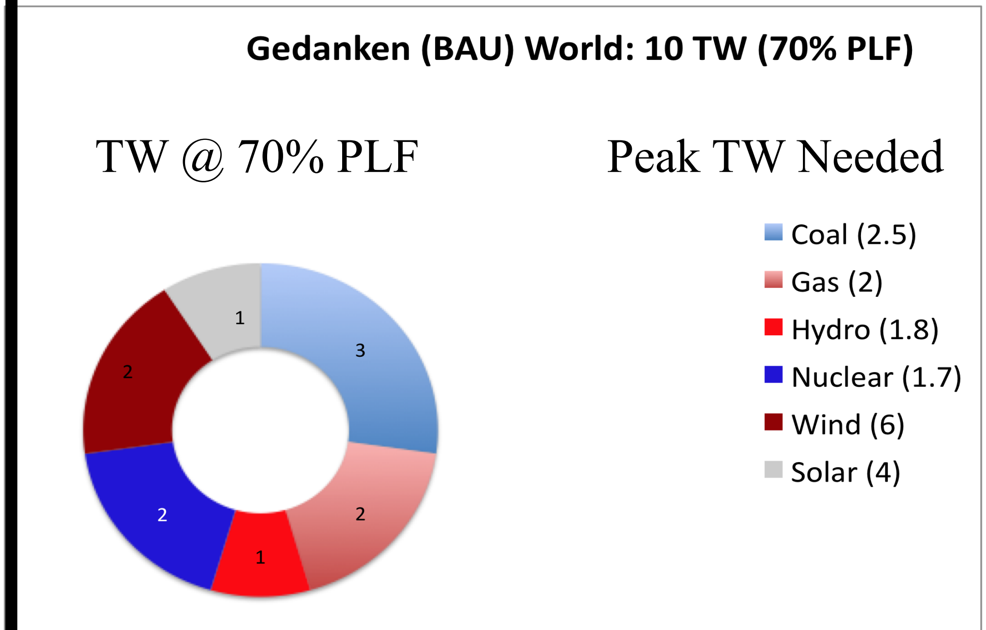
Efficiency

Technology

Fuel Substitution

Constructing Solution Wedges

- Need **10 TW** Electric Power:
  - **1 TW ←→ 6000 TWh**



- Need **85 mbo/day** Liquid Fuel:
  - **10** million barrels oil/day

“Solution Wedge” Likely / Unlikely by 2030

$$ & Risk
- Carbon neutral use of fossil fuels (especially coal)
- Economic Solar & Wind ($1/watt$_p$) + Grid Integration

Need
- Renewable storage of electric energy
- Closed nuclear fuel cycle to enable safe, secure, sustainable nuclear energy

Scale, Impact, R&D
- ***Biofuels ⇐ Pest-resistant, self-fertilizing, low water using, easily degradable biomass***

R&D
- ***H_2 / liquid fuel produced from non-fossil sources***
  - *From Photochemical and/or thermal splitting of H_2O*
- ***Fusion – the ultimate power “source”***

BAU: In the short-term coal use will continue to grow at 2-2.5%/yr

My guess, based on the 20 major consumer countries and resource distribution, is that coal use will peak at about 9 Gigatonnes/yr

9 Gigatonnes of coal → ~18 Gigatonnes of CO_2

GHG Potential of Natural Gas

If all 20,000 TWh of global electricity generation is done by CCGT power plants, the gas consumption is ~4 Gigatonnes/yr

4 Gigatonnes of gas → ~12 Gigatonnes of CO_2

Current global gas consumption is ~2GT

The Emerging Natural Gas Juggernaut (lecture 2)

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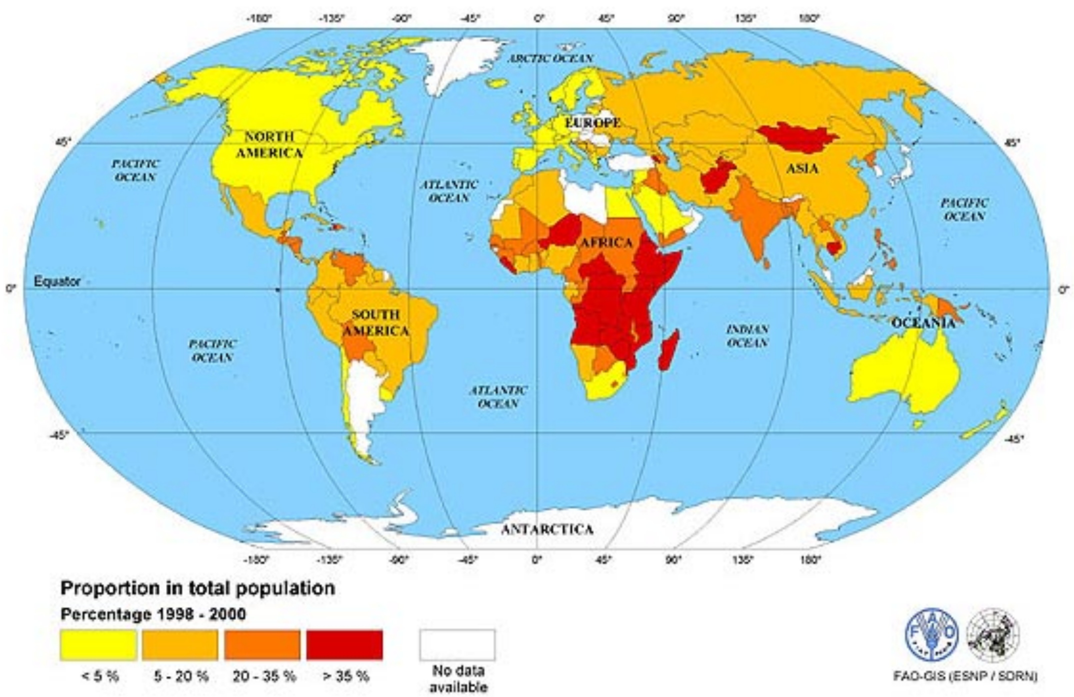

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BAU: Natural gas use will be ubiquitous.

It is a Clean Fuel as consumption is pollution free

As use of natural gas grows, public debate will become more focused:

development/prosperity

versus

climate change

Advantages of Natural Gas as a fuel source

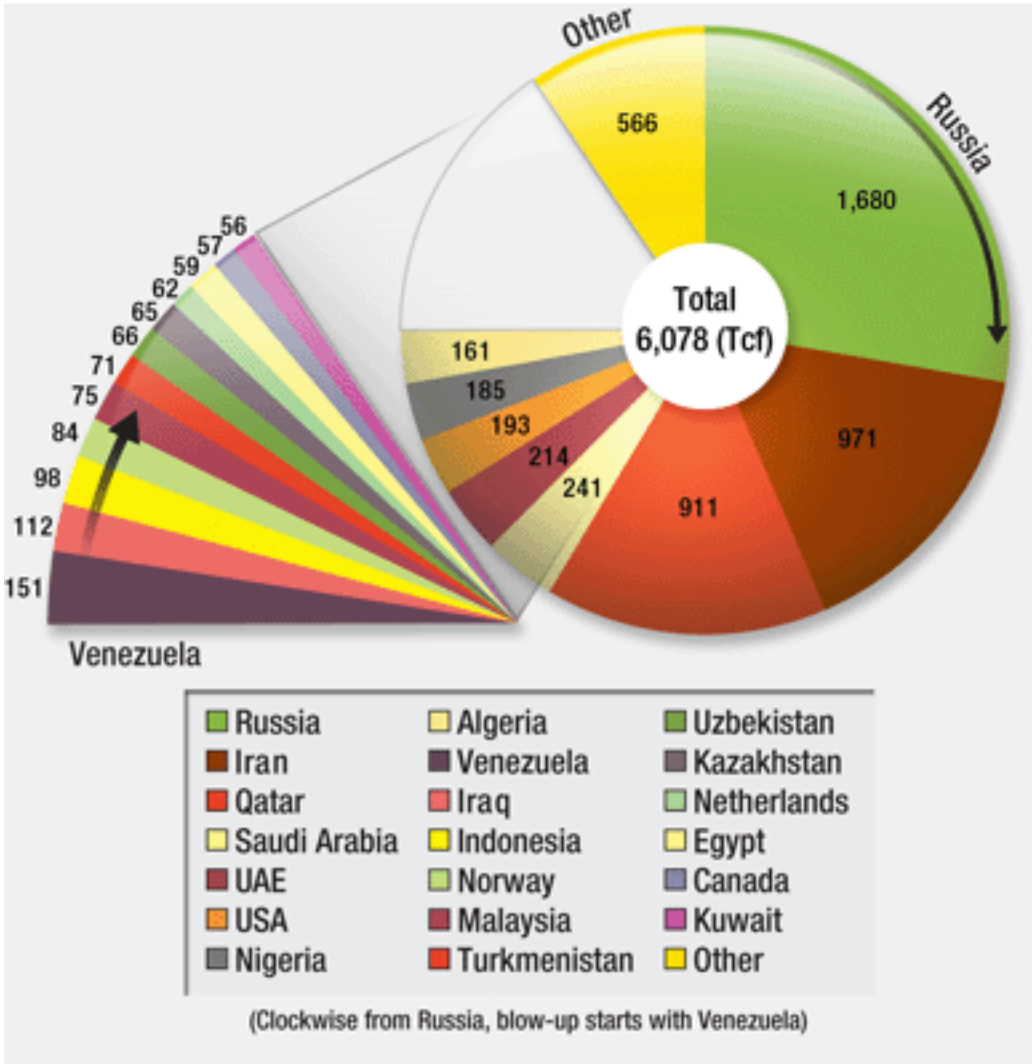
- More globally distributed
- Large reservoirs
  - Conventional Gas
  - Coal bed methane
  - Tight Gas
  - Shale Gas
  - Coal/Shale Gasification
  - Clathrates (methane hydrates)

(Coal bed methane, Tight Gas, Shale Gas: Low permeability formations)

✓ Just as effective as oil for transportation

- Most pollution occurs at source
  - Very little pollution after processing
  - Far less particulates, SOx, heavy metals, … vs coal

Conventional Gas

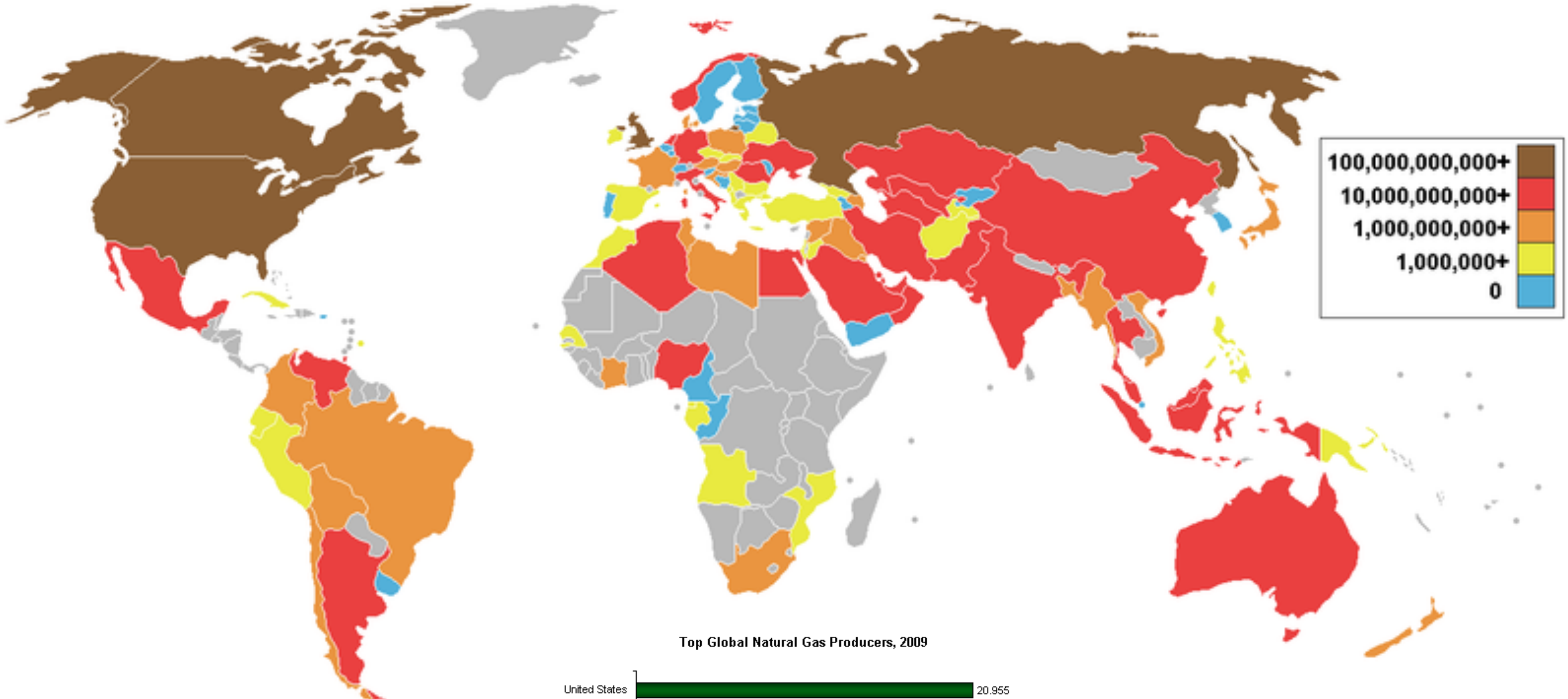


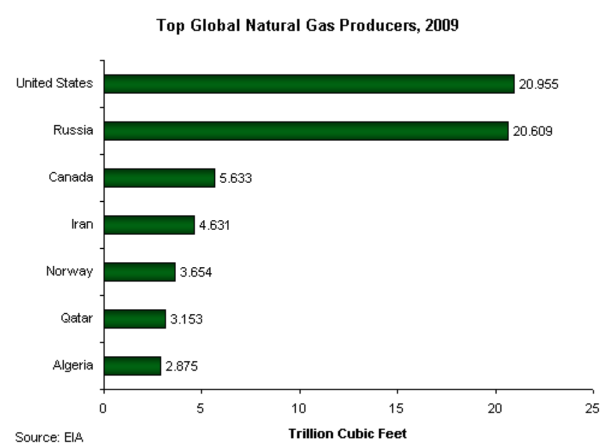
2011 world usage is ~100 Tcf ~2.8T m^2

Most reserves are controlled by national companies = Geo-politics

http://www.energytribune.com/articles.cfm/379/Russia-A-Critical-Evaluation-of-its-Natural-Gas-Resources

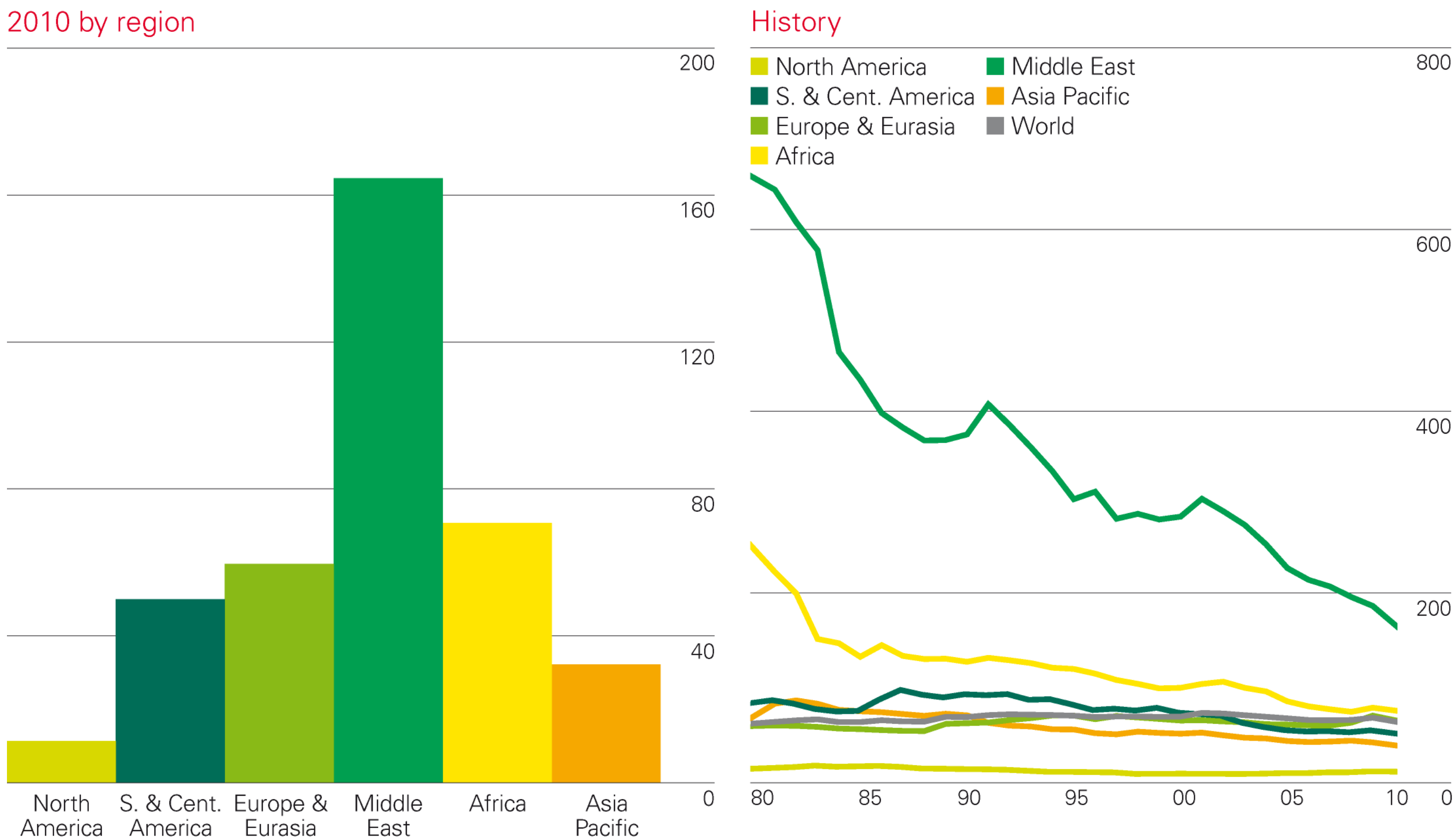
Distribution of Global Production





N. Gas reserves-to-production (R/P) ratios

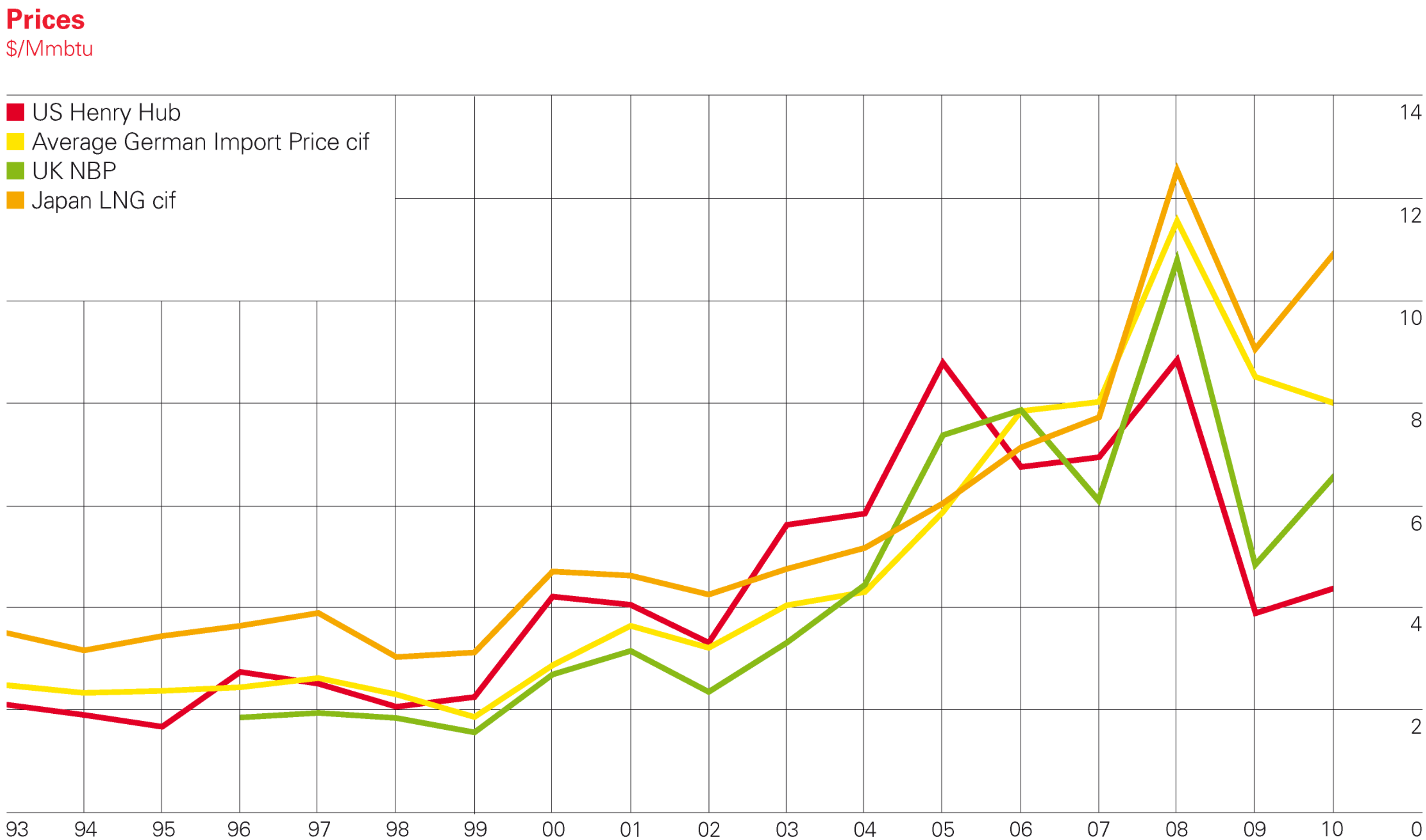
Reserves-to-production (R/P) ratios



World natural gas proved reserves in 2010 were sufficient to meet 58.6 years of global production. R/P ratios declined for each region, driven by rising production. The Middle East once again had the highest regional R/P ratio, while Middle East and Former Soviet Union regions jointly hold 72% of the world's gas reserves.

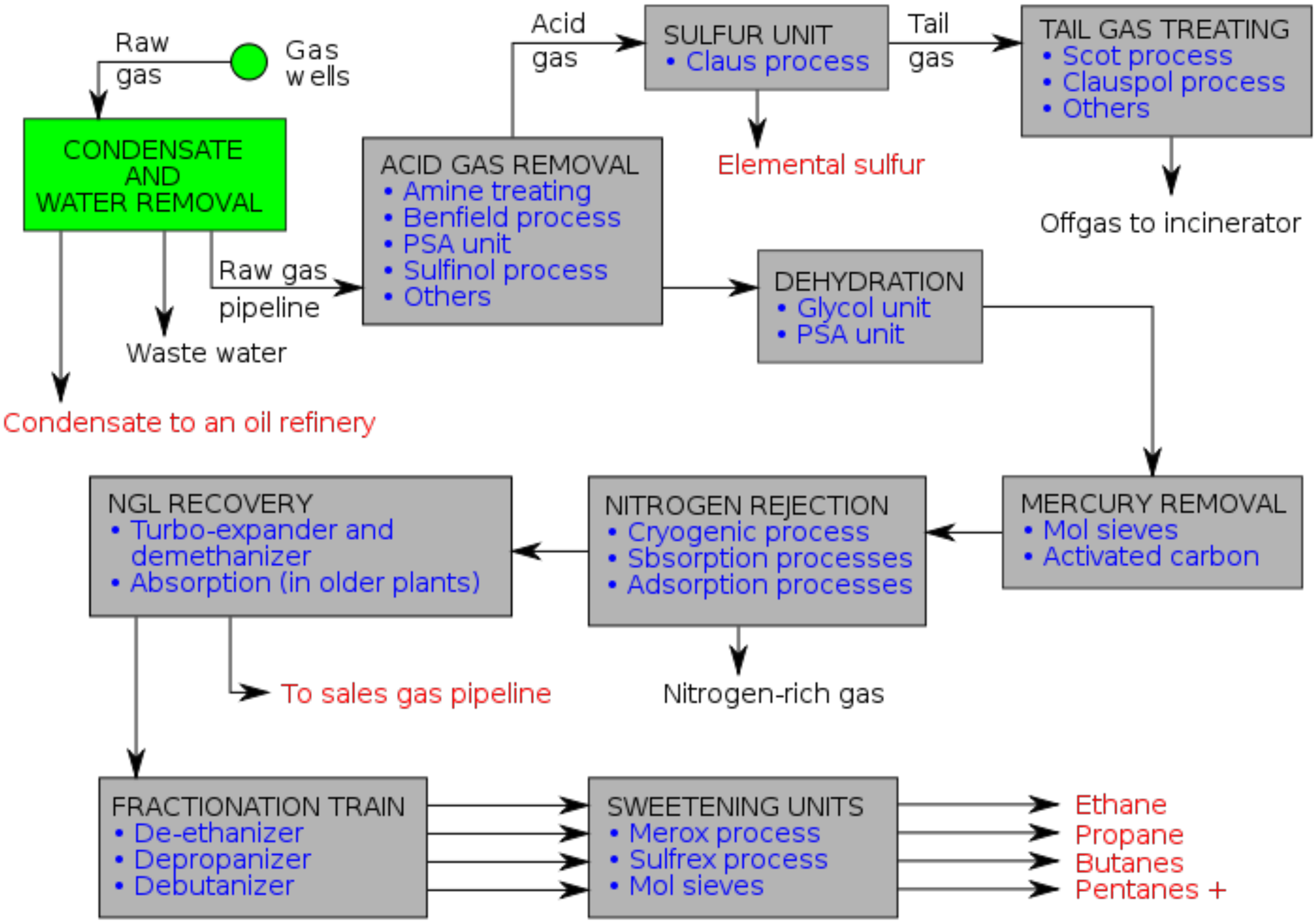
BP Statistical Review 2011

History of gas prices: set regionally



BP Statistical Review 2011

Processing of natural gas



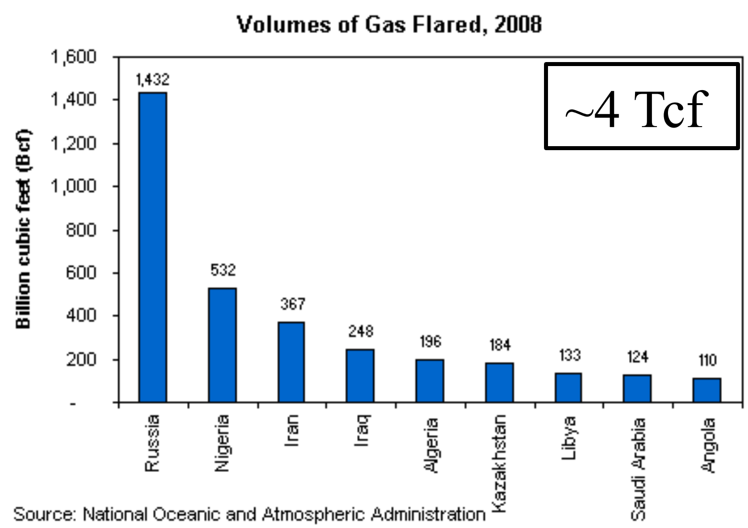
Some Useful Numbers: Natural Gas

- Calorific value of CH_4 (LHV)
  50 MJ/kg = 13.8 kWh/kg
- MMBTU ≈ 28 cum
- 1 cum NG → 4-5 kWh (CCGT)
  CCGT→ 0.2-0.25 Bcum/TWh
- 1 GW CCGT plant (70% plf)
  requires ~1.25 Bcum/year
  ~ 4 Mcum/day

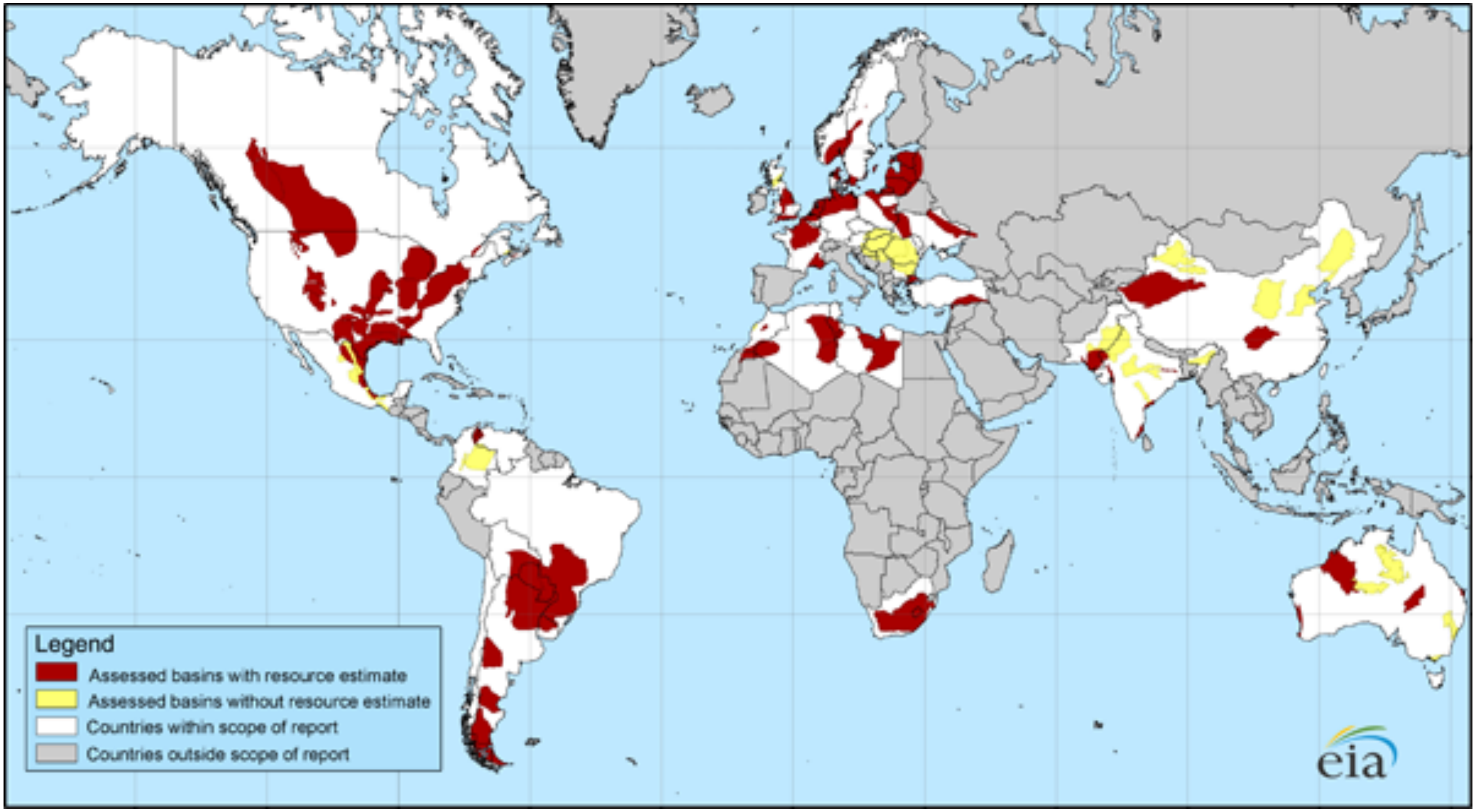
At \$4/MMBTU, fuel cost is ~\$0.035/kWh in CCGT plants

- 1 MJ = 948 BTU
- 1 TWh = 3.412×10^{12} BTU
- Btu/ft^3 = 34.6 MJ/m^3
- 1 tonne LNG = 1458 cum

- m^3 = 35.31 ft^3
- bcm = billion cubic meters



Shale Gas: Map of 48 major basins in 32 countries



Enabling Technology: deep horizontal drilling, hydraulic fracturing

http://www.eia.gov/analysis/studies/worldshalegas/

Important issues not addressed here: Assessing the potential and impacts of shale gas requires far more discussion

- Are the current estimates of recoverable shale-gas reserves realistic and at what cost?
- Will the impacts of production be properly understood, quantified and mitigated before large-scale deployment globally?

Major unaddressed concerns with shale gas extraction is leakage & impacts on water resources due to hydro-fracturing

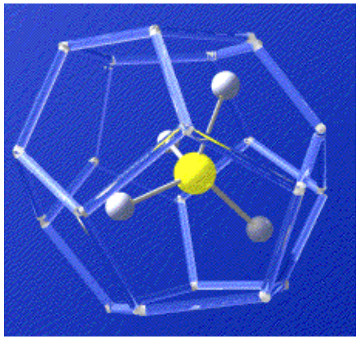
Need R&D for "cleaner & safer" technology

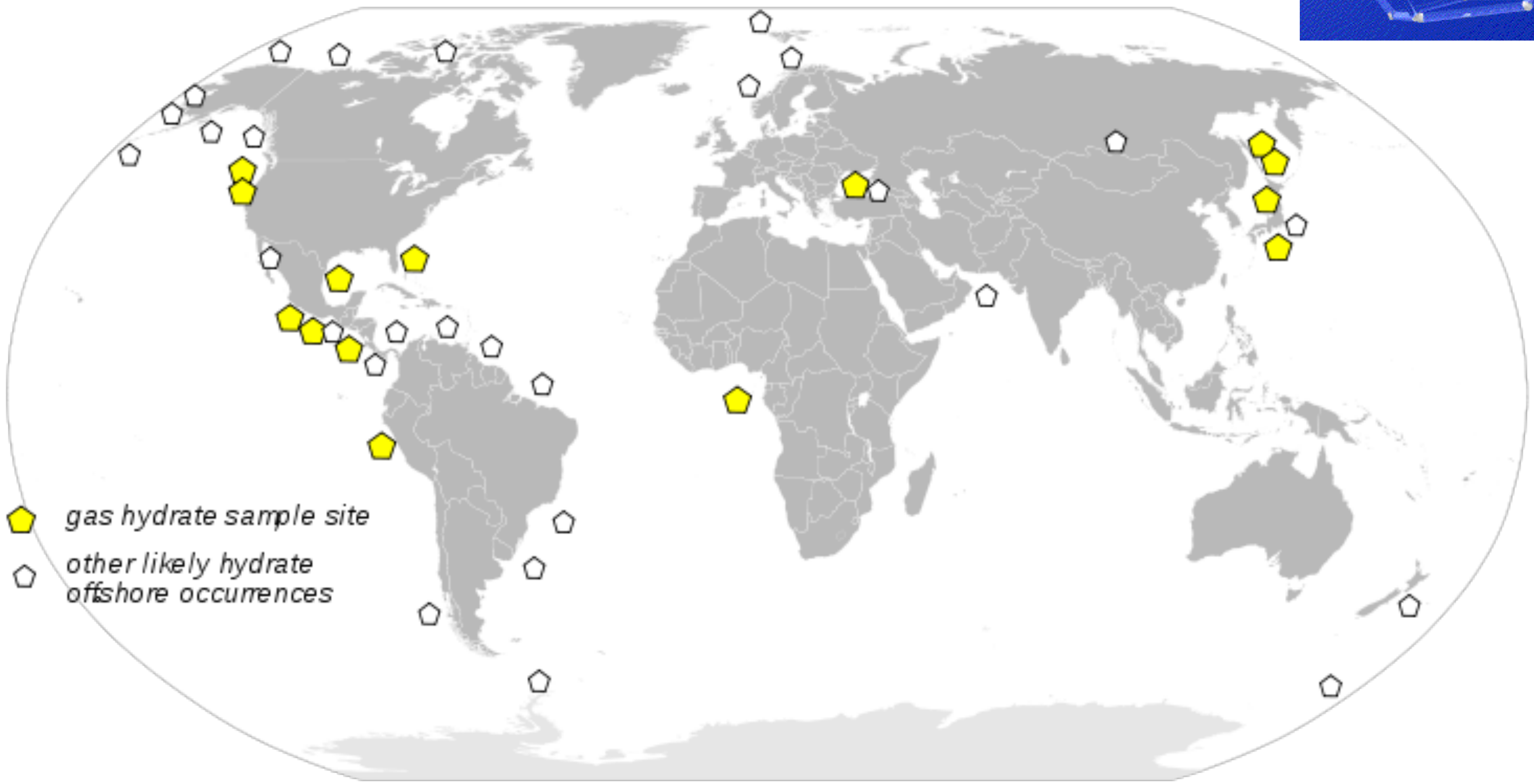
Need to put into place consistent long-term environmental oversight and regulations.

No energy industry has ever been sufficiently responsible to the environment

Winning public confidence will facilitate global business opportunities

Gas Hydrates (Clathrates)





- Large Reservoirs
- Technology in early R&D Stage

http://ethomas.web.wesleyan.edu/ees123/clathrate.htm
http://woodshole.er.usgs.gov/project-pages/hydrates/
http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html

Advantages of Natural Gas: Power Generation

- **Short construction period (~1 year), small footprint, low capital cost (~$0.7-1.0/watt), & less power consumed in operations**
- **Waste heat (~540^{o}C) used for CCGT, Heating, Steam or Desalination**
  - **50–57% of chemical energy used in CCGT plants**
  - **80–85% of chemical energy used in Cogeneration plants**
- **Gas Turbine plants (OCGT or CCGT) require less water than coal**
- **GT Power Plants can be sited in densely populated cities**
- **OCGT a good option as backup to solar and wind (along with hydro)**
- **Least CO_2 emitted per kW-hour (450 gm versus 600 for oil, 1kg for coal)**

The only serious drawback is CO_2 emissions

Natural Gas: Transportation

- Pipelines are the best means of transporting natural gas
  - Need regional cooperation
  - Pipeline integrity, security
  - Compression cost 1-3% (500-2000km)

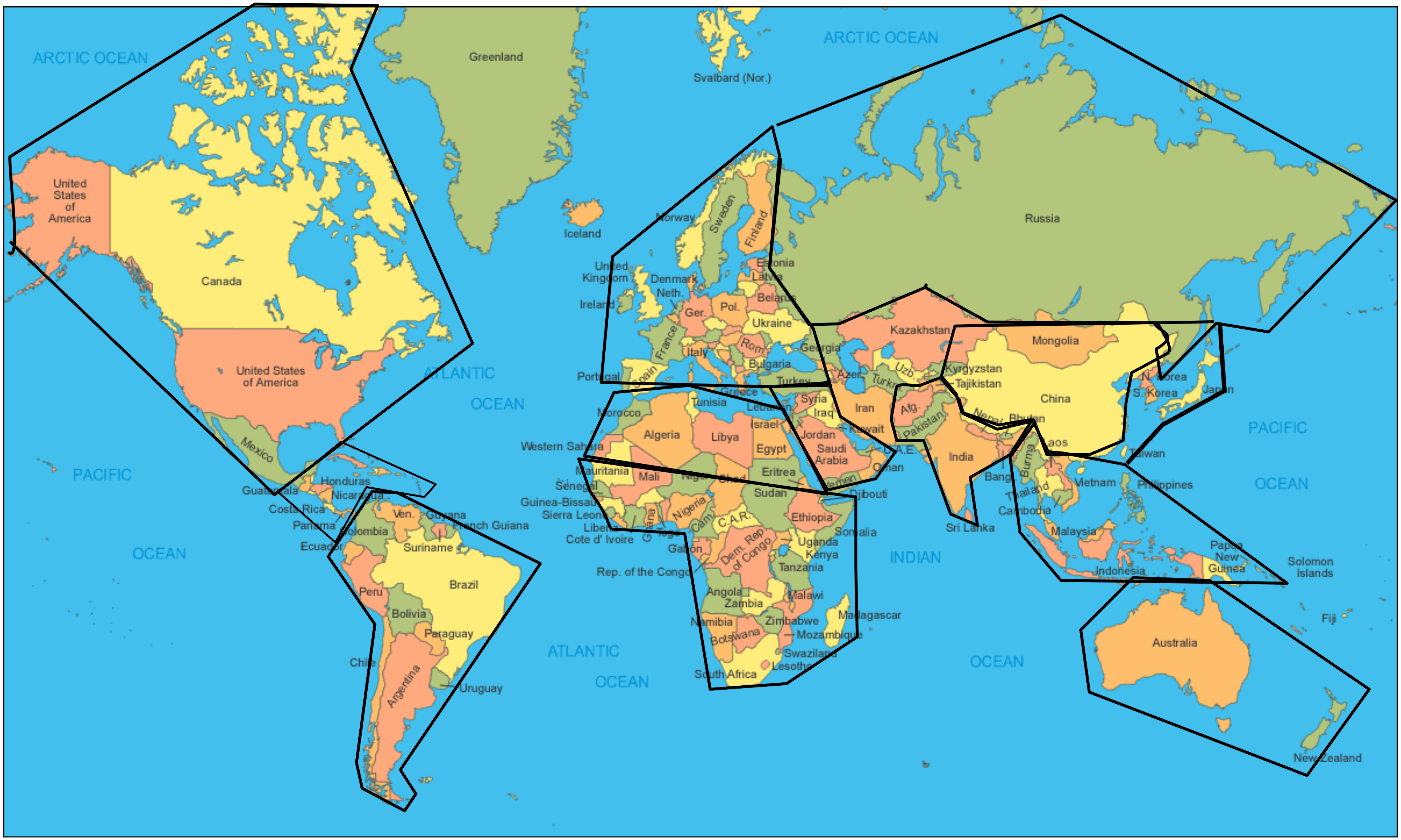
- Not easy to store in large quantities
- Need to liquefy to store or ship (LNG at -162 °C)
  - ~15% lost to liquefy, ship, re-gasify

Pipelines require regional cooperation

CNG–A cleaner and cost-effective fuel for transportation:

Demonstrated technology at scale

Local trade/pipelines can sustain most regions

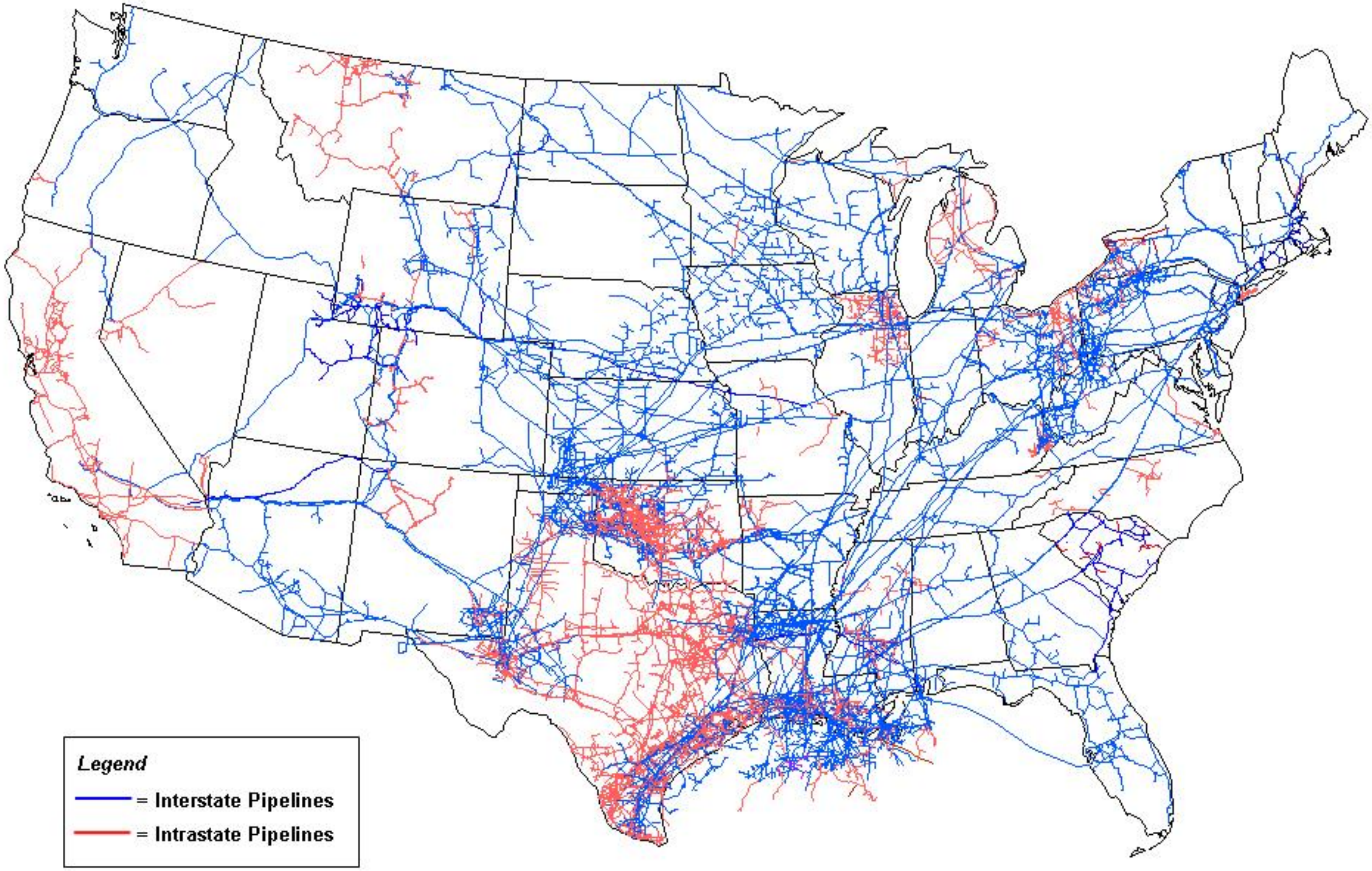


Regions	Major Sources
North America	**Conventional/*Shale gas***
Central America/Caribbean	Trinidad & Tobago
South America	Venezuela, ***Shale gas***
Europe	Russia, Middle East, NA
North Africa (NA)	Algeria, Libya, Egypt
Sub-Saharan Africa	Nigeria, Angola
Arab Middle East	Qatar, Iraq, Saudi Arabia
Russia	Russia
Central Asia & Iran	Iran, Turkmenistan
South Asia	?
South East Asia (SEA)	Indonesia/Malaysia/Australia
China	Russia, Middle East, SEA
Japan, S. Korea, Taiwan	Middle East, Australia, SEA
Oceania	Australia

N. America: Conventional and Shale Gas

North America	Production (Tcf dry)	Consumption (Tcf dry)	Imports (Exports)	Proven NG reserves (Tcf)	Technically Recoverable Shale Gas Resources (Tcf)
United States	20.6	22.8	10%	**272.5**	**862**
Canada	5.63	3.01	(87%)	**62.0**	**388**
Mexico	1.77	2.15	18%	**12.0**	**681**

http://www.eia.gov/analysis/studies/worldshalegas/



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

S. America: Conventional and Shale Gas

South America	Production (Tcf dry)	Consumption (Tcf dry)	Imports (Exports)	Proven NG reserves (Tcf)	Technically Recoverable Shale Gas Resources (Tcf)
Venezuela	0.65	0.71	9%	**178.9**	11
Colombia	0.37	0.31	(21%)	4.0	19
Argentina	1.46	1.52	4%	13.4	**774**
Brazil	0.36	0.66	45%	12.9	**226**
Chile	0.05	0.10	52%	3.5	**64**
Uruguay	-	0.00	100%		21
Paraguay	-	-			62
Bolivia	0.45	0.10	(346%)	26.5	48

http://www.eia.gov/analysis/studies/worldshalegas/

Power: Fuel Mix

Brazil:	Hydro & Gas
Argentina:	Gas & Hydro
Paraguay:	Hydro
Uruguay:	Hydro
Chile:	Mix
Peru/Bolivia:	Gas & Hydro
Venezuela/Colombia:	Hydro & Gas

Brazil and Argentina import small quantities of gas. Imports started only recently

Regional long-term source for oil and gas is Venezuela.
Shale gas: New opportunity

Regional Cooperation can provide energy security to:

[Argentina, Bolivia, Brazil, Chile, Paraguay, Uruguay]

[Venezuela, Colombia]

Use Technology, developed for EOR&CCS + R&D to understand Impacts, Risks

Europe

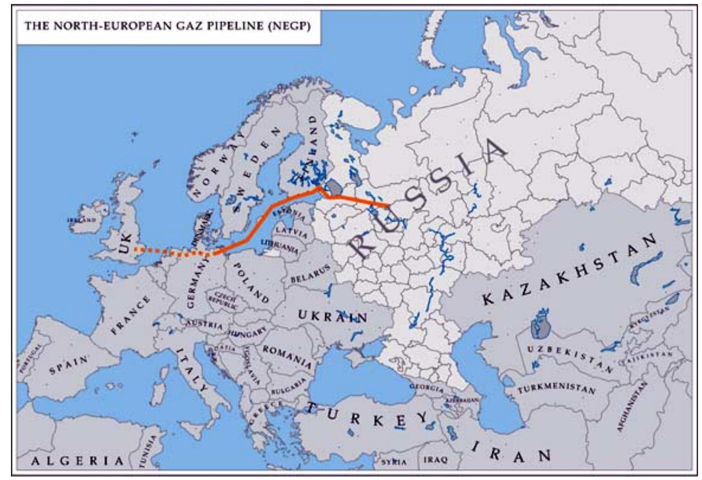
Sources of NG for Europe

- Russia
- North Africa
- Caspian Sea
- Gulf Countries

Existing Gas Pipelines in Europe

Major New Pipelines

http://www.bbc.co.uk/news/world-europe-14803065



Nord Stream Pipeline
(Russia → Germany)
Part 1 inaugurated on 2011-11-08

27.5 → 55 M m^3/day

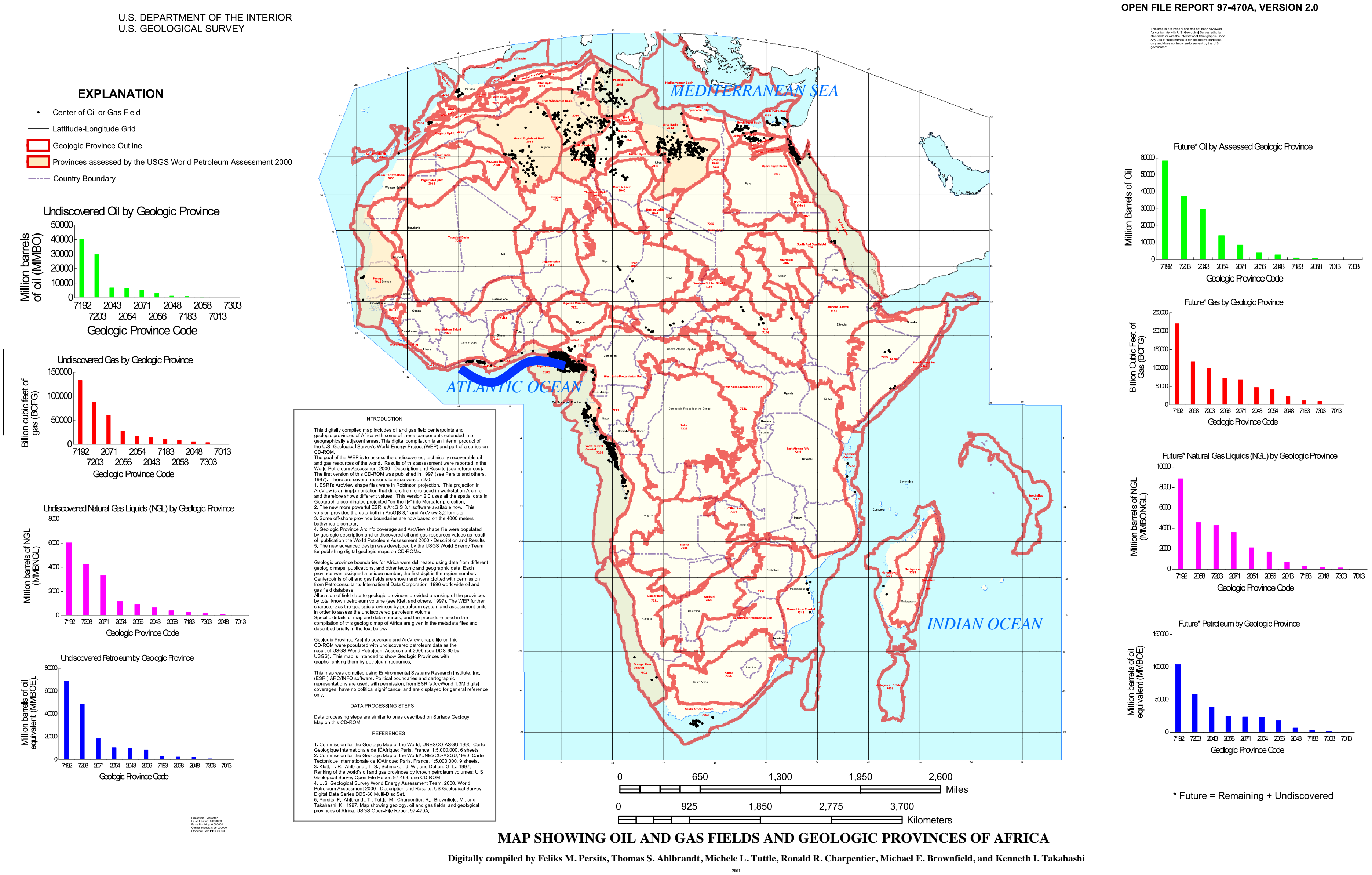
Replaces 13 GW of Nuclear/Coal

Sub-Saharan Africa

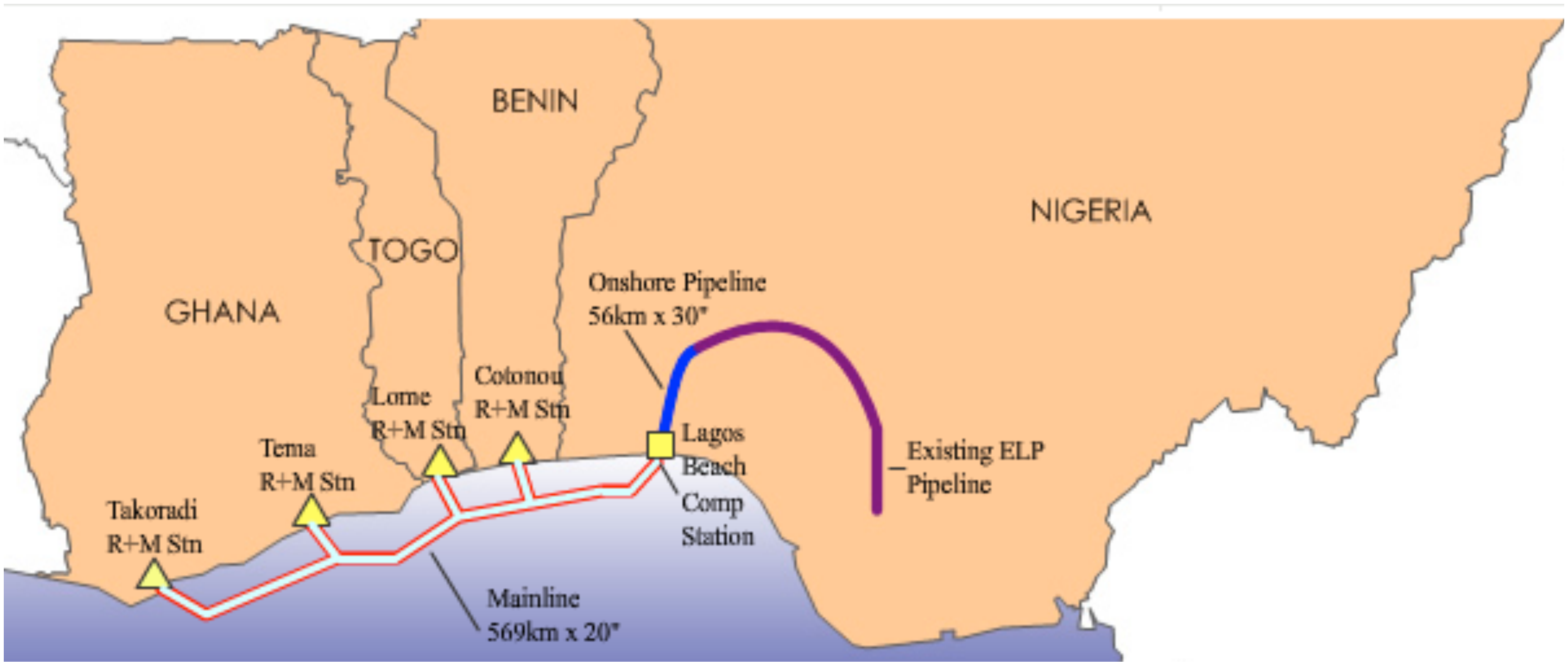
- North Africa: Gas
- West Africa: Gas
- Sub-Saharan Africa: Mostly Hydro
- South Africa: Coal

Africa Oil and Gas:

- North Africa: To Europe pipelines
- Nigeria: West Africa Gas Pipeline
- Angola:



West Africa Gas Pipeline:
Connecting Nigeria, Benin, Togo, Ghana



50.8 cm (20") diameter pipeline with 13 Million cum/day capacity

http://www.wagpco.com/index.php?option=com_content&view=article&id=122&Itemid=85&lang=en

Morocco–Indonesia

Morocco–Indonesia is rich in resources and yet exhausting itself because of poor governance, inadequate cooperation, missing common vision, values, institutions

Consider the 7 Sub-Regions

- North Africa
  - Morocco, Algeria, Tunisia, Libya
- Eastern Mediterranean Arab Nations
  - Egypt, Jordan, Syria, Lebanon, Iraq
- Gulf
  - Kuwait, Saudi Arabia, Bahrain, Qatar, UAE, Oman, Yemen
- Iran
- Central Asia: Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan, Kazakhstan, Afghanistan
- South Asia
  - Pakistan, India, Nepal, Bangladesh, Bhutan, Sri Lanka
- ASEAN
  - Burma, Thailand, Malaysia, Singapore, Indonesia, Vietnam

Turkey is looking westward; Israel is economically developed & a stable democracy

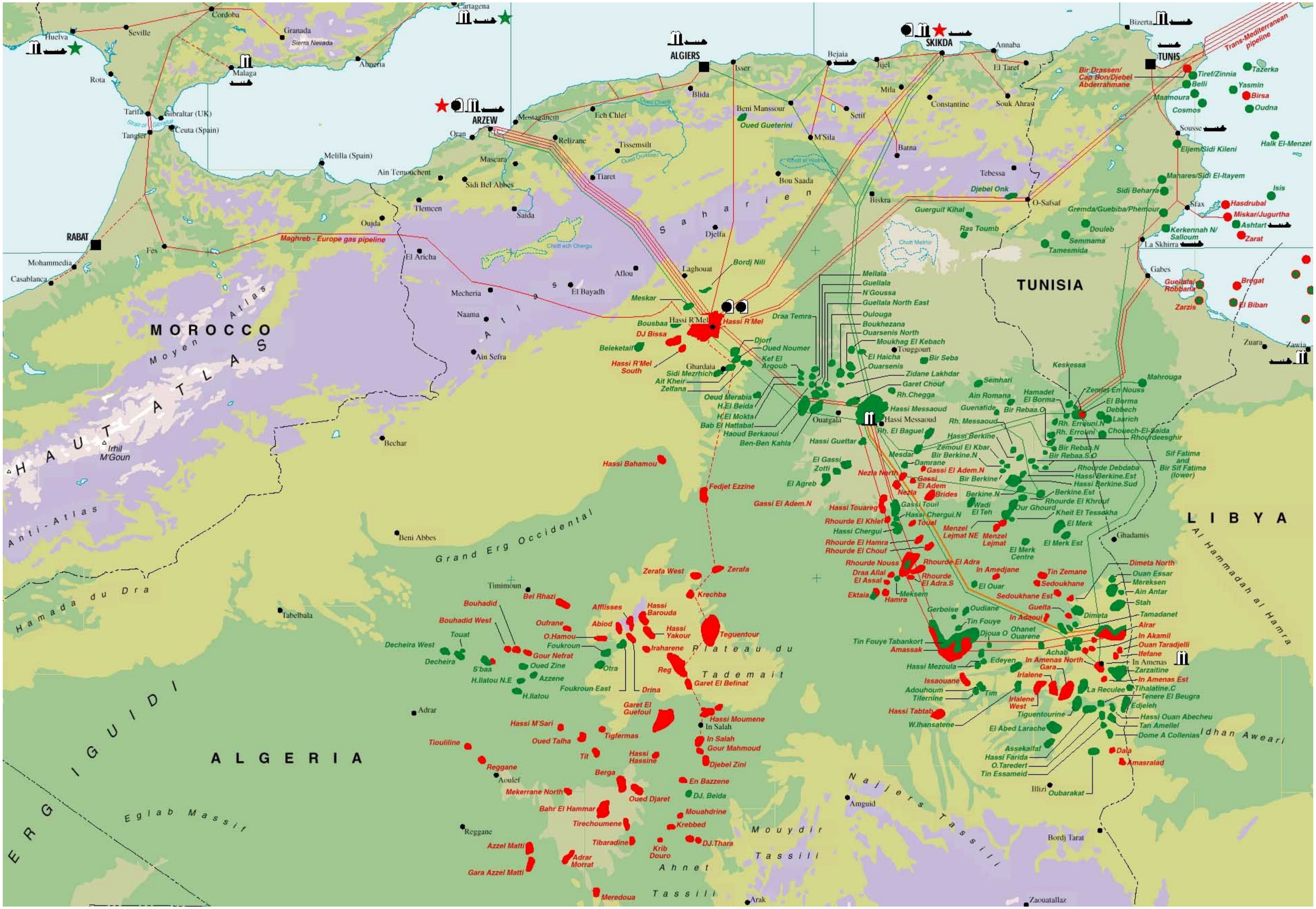
North Africa

	Population (Millions)	Population Growth Rate %	GDP $/Capita	Installed Capacity GW	Watts / Capita	% Gas fueled	Gas Reserves B cum	Gas Production B cum
Morocco	31.9	1.5	4773	6.5	204	30		
Algeria	36	1.8	7103	10.9	300	95	4500	81
Tunisia	10.5	1.2	9488	3.5	333	90	~100	~3
Libya	6.5	1.9	14878	6.2	950	65	1540	15.3
Egypt	80.4	2.1	6367	25	311	40	2190	62.7

Export of NG from N. Africa by Pipelines (bcm/yr)

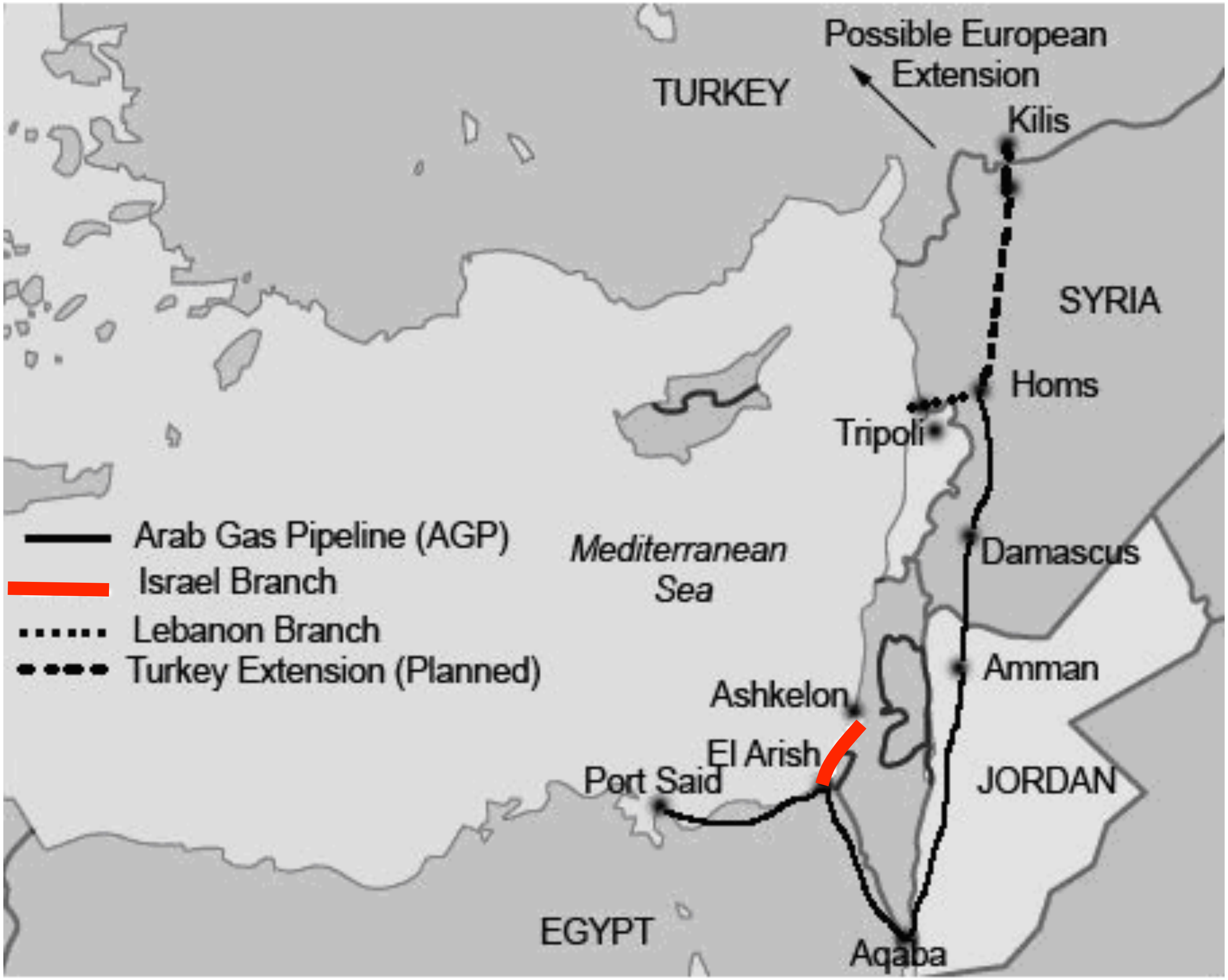
- Maghreb-Europe (12)
- Medgaz (8)
- Galsi (10 in 2014)
- Trans-Mediterranean (30)
- Greenstream (11)

Algerian Gas and Oil Network



Eastern Mediterranean

Pan Arabism And Beyond
The Arab Gas Pipeline Project



Source: BMI

Eastern Mediterranean

- Jordan and Lebanon need to import gas & oil
- Arab Gas Pipeline from Egypt is a start
- A stable Iraq can export through Syria and satisfy the needs of Jordan and Lebanon
- The region can export to Europe by joining in the Nabucco pipeline

Gulf Countries (GCC)

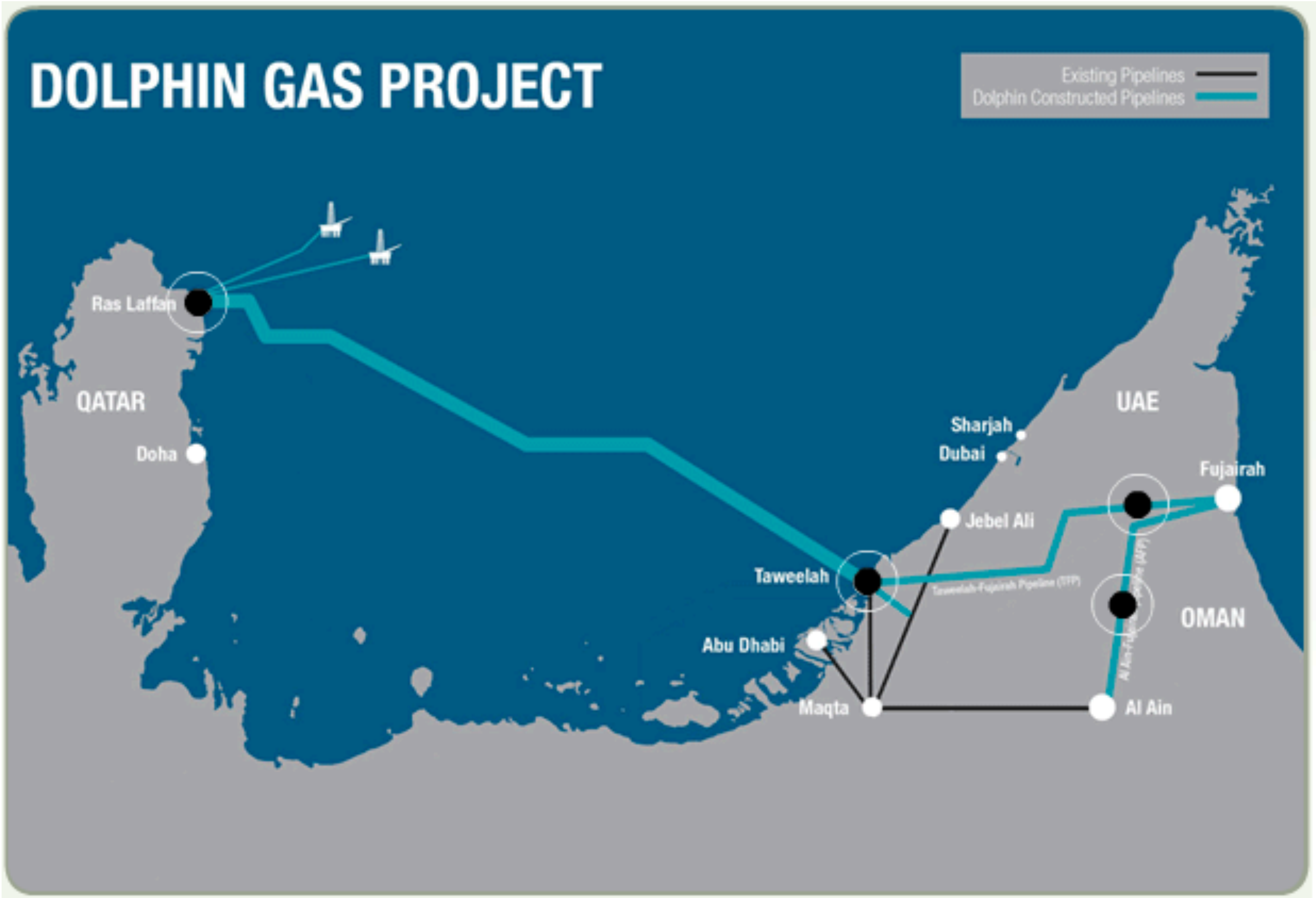
(Kuwait, Saudi Arabia, Bahrain, Qatar, UAE, Oman)

- Rich in Oil and Gas
- Transitioned from Oil → Gas power plants
- Nuclear: South Korea is building a 4x1.4 GW nuclear power plant in the UAE
- Developing regional cooperation
  - Oil and Gas pipelines
  - Interconnected Power Grid and Power Transfer

Gulf Countries

	Population (Millions)	Population Growth Rate %	GDP $/Capita (PPP)	Installed Capacity GW	Watts / Capita	% Gas fueled	Gas Reserves B cum	Gas Production B cum/yr
Kuwait	2.6	1.986	55500	15	5800	**70%**	1798	12.7
Saudi Arabia	26.13	1.536	23800	44	1700	**70%**	7461	77.1
Bahrain	1.21	2.814	24600	3	2500	**95%**	92.03	12.64
Qatar	0.85	0.81	143800	9	10600	**100%**	25470	76.98
UAE	5.15	3.282	38800	18.7	3600	**95%**	6071	50.24
OMAN	3.03	2.023	25300	4.6	1300	**100%**	850	24

Gulf States are increasing cooperation



Ras Laffan (Qatar) to Taweelah (UAE) offshore pipeline:
(design Saipem/Eni, pipes Mitsui, Japan). The 48” pipeline has capacity of 33 bcm/year

GCC: Gulf Cooperation Council

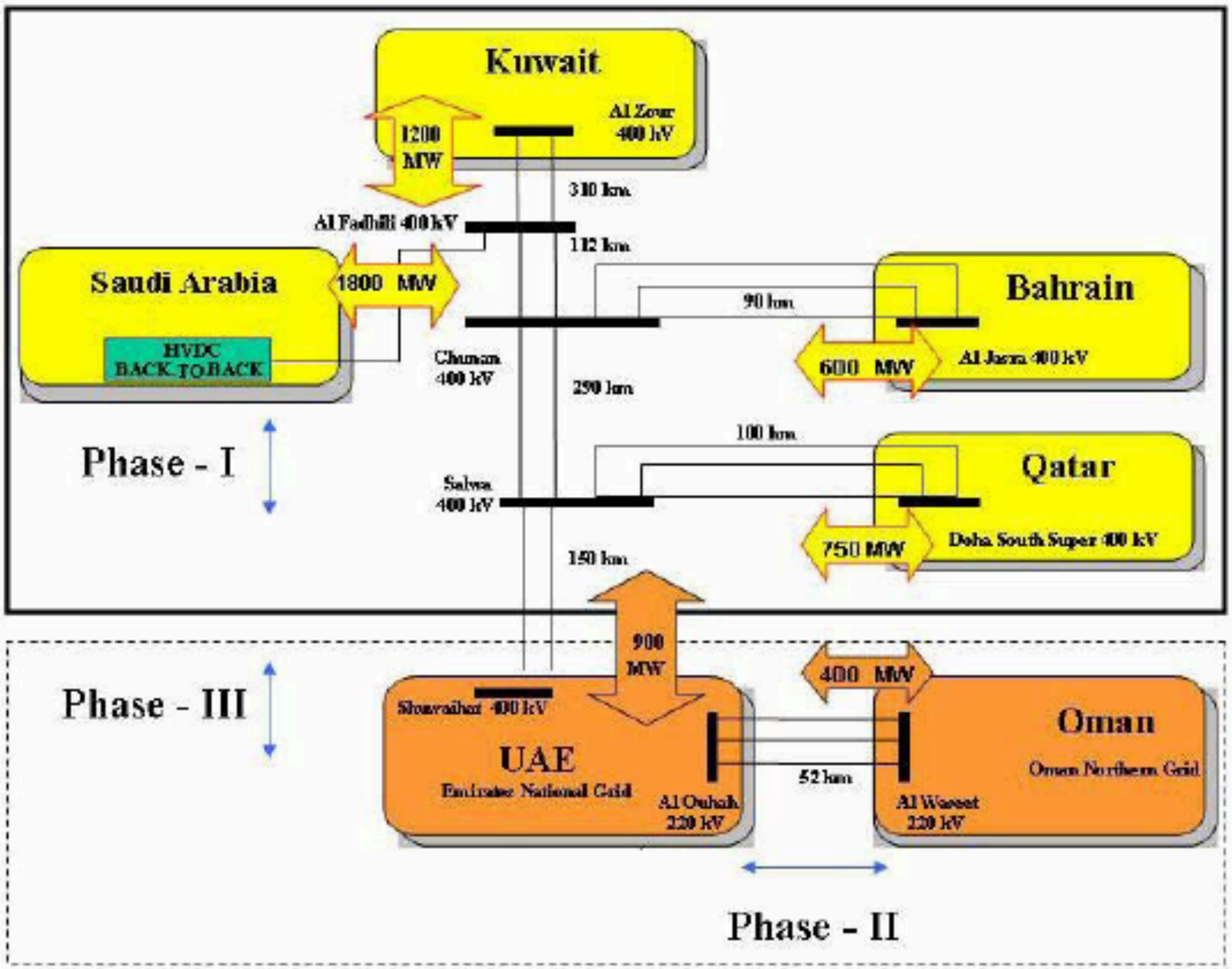


Figure 5.1. Single-Line Block Diagram of GCC Interconnection.

UAE

Bahrain

Saudi Arabia

Oman

Qatar

Kuwait

IRAN

- Second largest reserves of natural gas
  - ~30 trillion m^3 (Russia has ~60)
- Fifth largest reserves of oil
- Strategically located to export to East (India) and West (EU)
- Siemens/Ansaldo V94.2 based CCGT plants of 480 MW (2x160 GT+160 ST) are being built by MAPNA (TUGA) are the standard power block (about 30 blocks installed) (http://en.wikipedia.org/wiki/MAPNA)

Iran: The (160+160+160) MW CCGT power plants by Siemens/TUGA

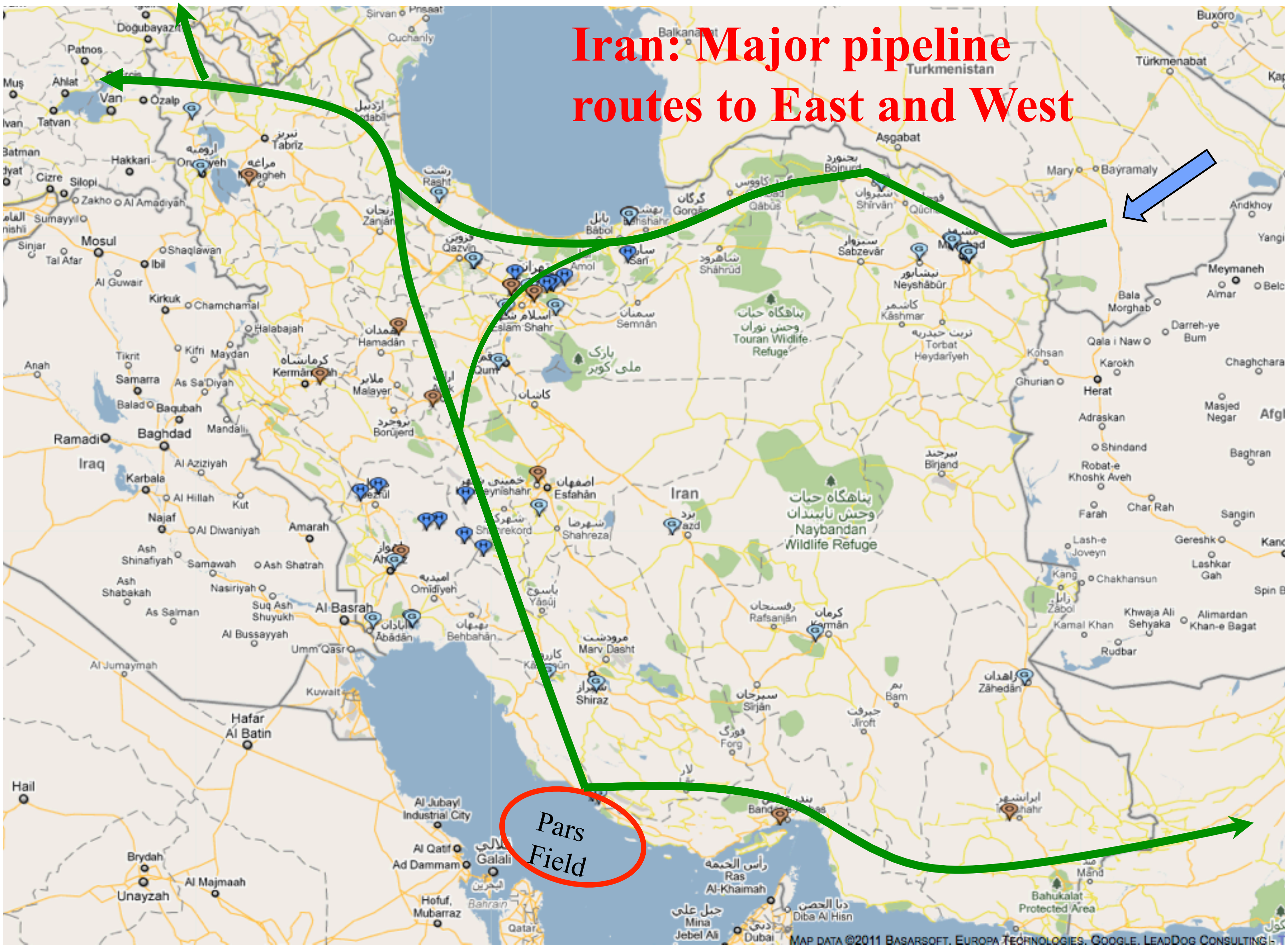
Table 15-1: Time Schedule for Completion of Various New Thermal and Hydro Power Plants

No.	Status	Number of Power Plant	Type of Power Plant Regional Electric	Dispatching Region	2009	2010	2011	2012	2013	2014
1		Ardabil		Azerbaijan			324			320
2		Jahrom		Fars				480		
3		Zanjan		Zanjan		648				
4		Sanandaj		West		160	160			
5		Abadan		Khoozestan			320			
6		Damavand		Tehran	480	480				
7		Shirvan		Khorasan				480		
8		Kerman		Kerman						
9		Yazd Solar		Yazd	159	160				
10		Ghaien		Khorasan	477					
11	MOE	Oroumieh	C.C	Azerbaijan		324		480		
12		Iranshahr		Sistan&Baloochestan		162	162			
13		New Chabahar		Sistan&Baloochestan	159					
14		Sarband-Mahshahr		Khoozestan			648			
15		Semnan		Semnan		648				320
16		Kermanshah		West		648			320	
17		Hormozgan		Hormozgan			648			
18		Parand		Tehran					480	
19		Khalij-Fars		Hormozgan					160	320
20		Rey small gas		Tehran	150					
21		Noshahr small gas	Gas	Mazandaran	50					
22		Chabahar barej		Sistan&Baloochestan	50					
23		Roodbar lorestan		Bakhtar						450
24		Khoda Afarin		Azerbaijan	100					
25		Ghiz ghale si		Azerbaijan		40				
26		Siahbisheh pomp storage		Mazandaran			250	750		
27		Seimareh		West				480		
28		Karoon4		Isfahan	250	750				
29		Gotvand	Hydro	Khoozestan			1000			
30		Tang mashooreh		Bakhtar						167
31		Menj		Khoozestan	6					
32		Darian		West					191	
33		Sardasht		West					120	
34		Small hydro		-	61	9	3			
35		Azad Pump Storage		West						250
36		Booshehr	Nuclear	Fars	500	500				
37		Steam power plant Extension	Steam	-					975	1950
38		Bistoon power plant Extension		West				315	315	
39		Tabas		Yazd					650	
40		Fars		Fars			954			
41	B.O.T	Paresar		Gilan			938			
42		Heris	C.C	Azerbaijan					1132	
43		South Isfahan		Isfahan				320	160	
44		Zanjan2		Zanjan					324	160
45		South Fars		Fars				484	484	
46		North Fars		Fars			324	484	160	
47	B.O.O	Asalooieh	C.C	Fars				320		
48		Isfahan 1 (Harand)		Isfahan				484	484	
49		Isfahan 2 (Zavareh)		Isfahan			324	160		

Table 15-2: Time Schedule for Completion of Various New Thermal and Hydro Power Plants

No.	Status	Number of Power Plant	Type of Power Plant	Dispatching Region	2009	2010	2011	2012	2013	2014
50		Ilam		West				324	160	
51		Bakhtar 1 (Saveh)		Bakhtar				548	250	
52		Bakhtar 2 (Khomein)		Bakhtar			324	160		
53		Torbat Heidarieh		Khorasan				324		
54		Tehran 1		Tehran			324	160		
55		Tose-e-Zargan		Khuozestan			324	486	160	
56		Khoram Abad		Bakhtar			324	972		
57		Khoramshahr		Khuozestan	810	320	160			
58		Roodeshoor 2		Tehran			550	250		
59		Zanjan 1		Zanjan				324	160	
60		Zanjan		Zanjan				484	484	
61		Zanjan4		Zanjan			324	160		
62		Sabzevar		Khorasan				324	160	
63		Sarakhs		Khorasan			324	160		
64	B.O.O	Sirjan	C.C	Kerman			324	160		
65		Shahrood		Semnan		162	162		160	
66		Asalooye 1		Fars				162	162	160
67		Aliabad		Mazandaran	162	970	320			
68		Gheshm		Hormozgan			324	160		
69		Kashan		Isfahan	324					
70		Kermanshah		West			324	486	160	
71		Kahnooj		Kerman			648	320		
72		Ghom 1		Tehran				324	160	
73		Ganaveh		Fars			324	160		
74		Malayer (Bakhtar 3)		East				324	160	
75		Noshahr		Mazandaran			324	160		
76		Hormozgan 1		Hormozgan			324	160		
77		Hormozgan 2		Hormozgan				648	320	
78		Yazd 1		Yazd			324	160	0	
79		Yazd 2		Yazd					324	160
80		Torbat Heidarieh		Khorasan					100	
81		Hormozgan 3		Hormozgan				484	484	
82		Saveh 2		East				324	160	
83		Zanjan		Zanjan					484	484
84		Kerman		Kerman					484	
85		Sistan&Baluochestan		Sistan&Baloochestan				324	160	
86				-					484	
87			Gas Diesel	CHP & DG	80	220	400	400	400	480
88			Wind, Biomath, Geotenmal & Solar	Renewable Energy	50	262	312	330	345	660
Total Increase of Nominal Capacity of MOE and non-MOE Power Plants (Confirm & Unconfirm)					2442	4529	3515	2985	3211	3777
Total Increase of Annual Nominal Capacity of MOE and non-MOE Power Plants (Confirm & Unconfirm)					1426	1934	9304	12014	8665	2104
Total Increase Gathering of Nominal Capacity of MOE and non-MOE Power Plants (Confirm & Unconfirm)					3868	6463	12819	14999	11876	5881
Total Increase Gathering of Nominal Capacity of MOE and non-MOE Power Plants					3868	10331	23150	38149	50025	55906
Total Gathering Nominal Capacity of Country with 52944 MW in the end of 2008					56812	63275	76094	91093	102969	108850
Max Demand Consumption of Country (MW)					40161	44604	48071	51510	54850	58460

Iran: Major pipeline routes to East and West



Central Asian Countries

Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan, Kazakhstan, Afghanistan

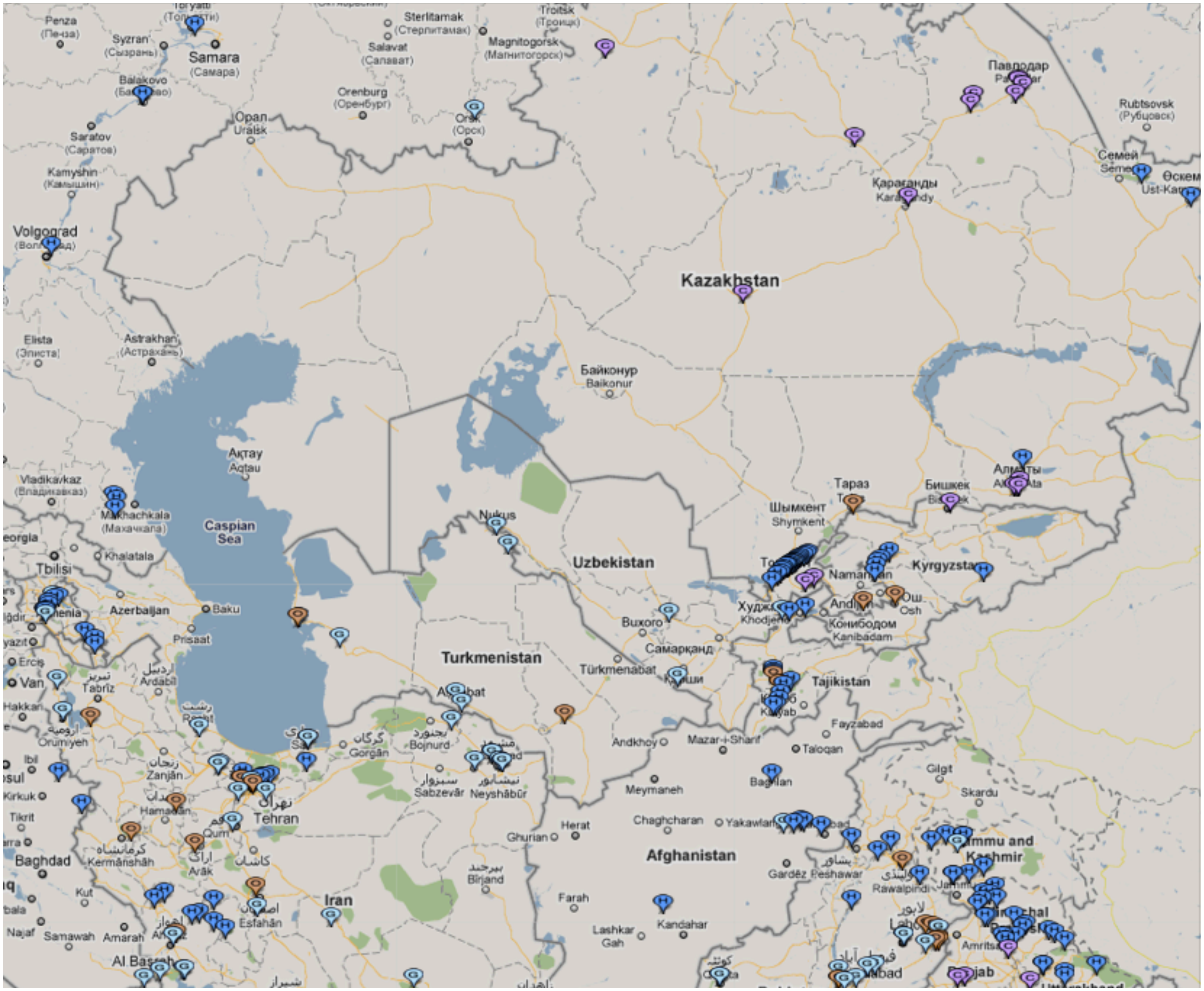
- Rich in Gas, Oil, and Minerals
- Most energy systems are from the Soviet era (1960s-1980s) and need modernization
- Trend towards Combined Cycle Gas Turbines
- Need to develop regional cooperation
  - Oil and Gas pipelines
  - Modernize the Soviet era Interconnected Power grid
  - Sharing water resources
- China is an emerging power wanting resources. Contention between Russia, China and the US

Central Asian Countries

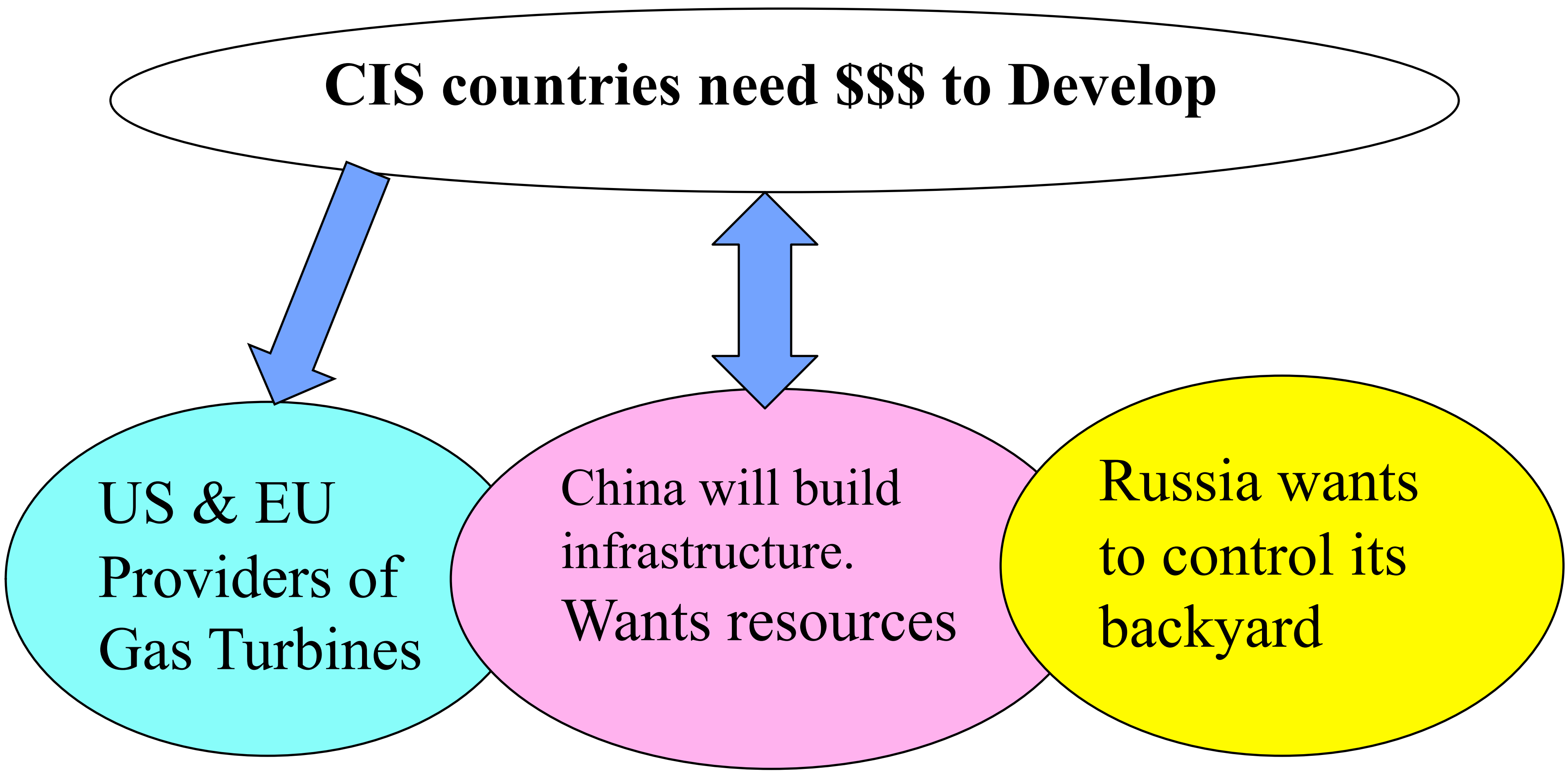
	Population (Millions)	Population Growth Rate %	GDP $/Capita (PPP)	Installed Capacity GW	Watts / Capita	Hydro GW/%	Gas fueled GW/%	Gas Reserves B cum	Gas Prod/Cons B cum
Turkmenistan	5.2	1.4	5000	3.6	692	0/0	3.6*/ 100%	7504	44/22
Uzbekistan	28.1	1.8	3000	12.36	440	1.71/ 14%	8/ 70%	1841	60/45
Tajikistan	7.6	2.4	1900	5.1	671	4.7/ 92%	0.4*/ 8%		
Kyrgyzstan	5.3	1.6	2240	3.7	698	2.95/ 80%	0.76*/ 20%		
Kazakhstan	16.3	1.4	12000	18.73	1150	2.217/ 12%	Coal	2407	34/25

WB/EIA/BP2011

Mapping the global energy infrastructure: GlobalEnergyObservatory.org



Will co-operation prevail in CIS?



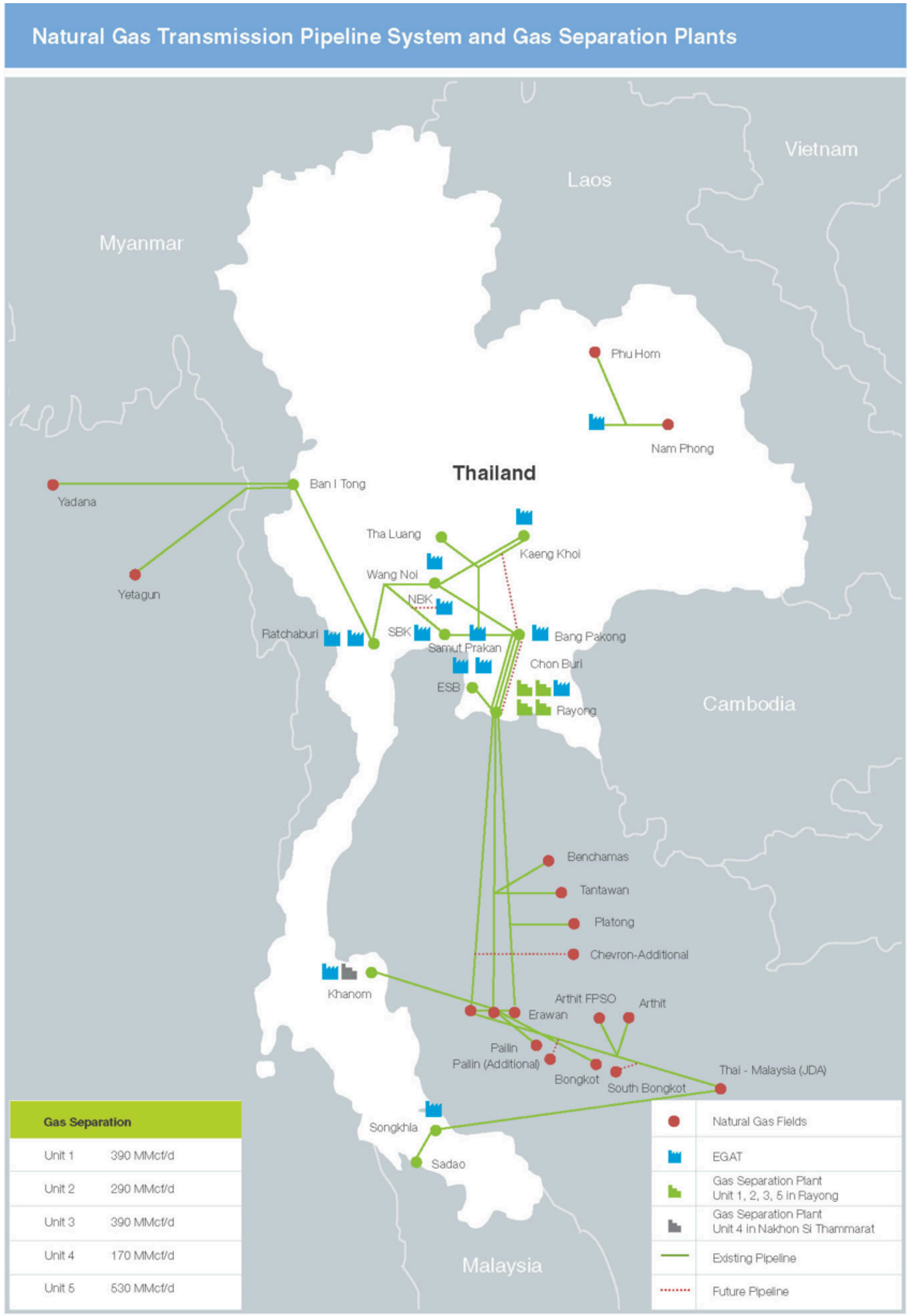
Export from CIS

Uzbekistan→Europe

Bukhara–Tashkent–Bishkek–Almaty pipeline (22 bcm)

Central Asia-China gas pipeline (40 bcm) built (2007 – 2009) by Stroytransgaz, Uzbekneftegas, KazMunayGas and CNPC

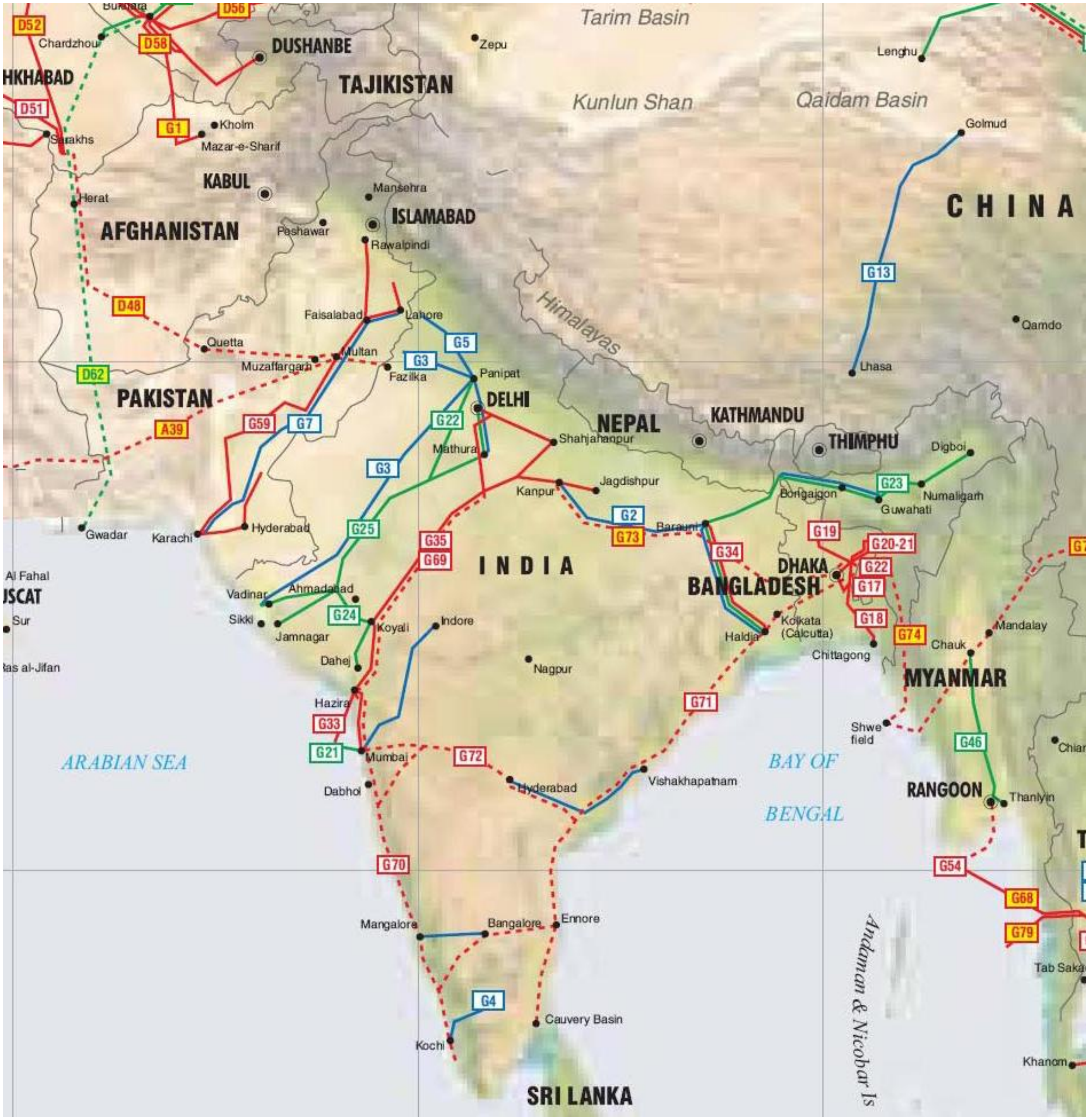
ASEAN (Association of South East Nations)



ASEAN:

Growing regional trade & cooperation

Growing fear of China's power



South Asia:

No significant inter-country trade

India:

Islanded due to unfriendly relations with Pakistan, China, Burma

Countries in South Asia that can develop using hydropower

	Potential Giga Watts	Exploited Giga Watts	Population (Million)
Pakistan	53	6.7	181
Nepal	43	0.6	27.5
Bhutan	23	1.5	0.7
Burma	39	2.5	50

That leaves India, Bangladesh, Sri Lanka

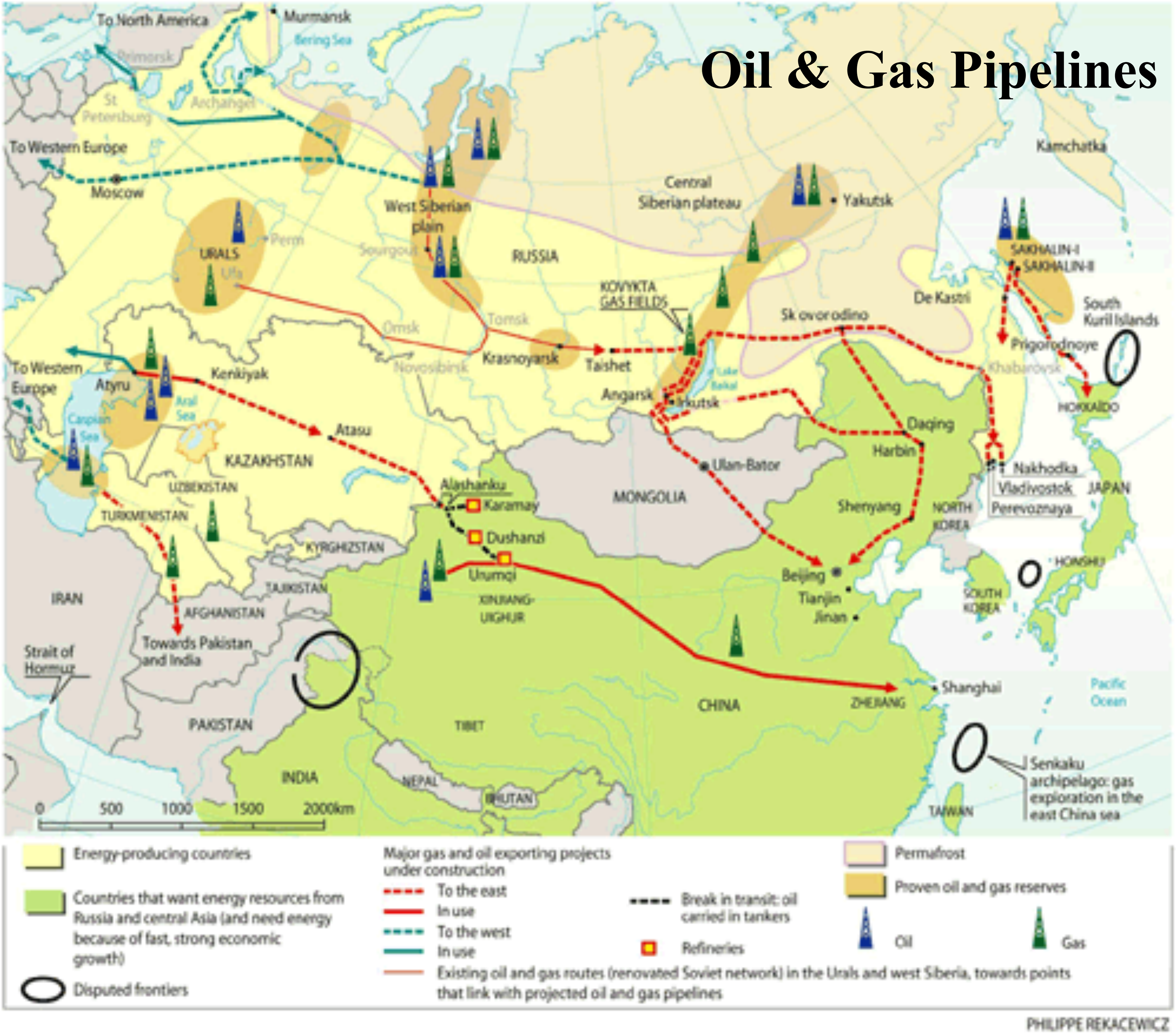
China and India

- China is in much better position
  - Surrounded by regions that are rich in resources
    - + China has the single largest reserves of shale-gas
  - Has [is building] good relations with all countries
    - For Resources
    - For Markets

- India is isolated
  - All its imports and exports will be by sea
  - Needs to develop manufacturing/services to pay for imports (in particular energy)

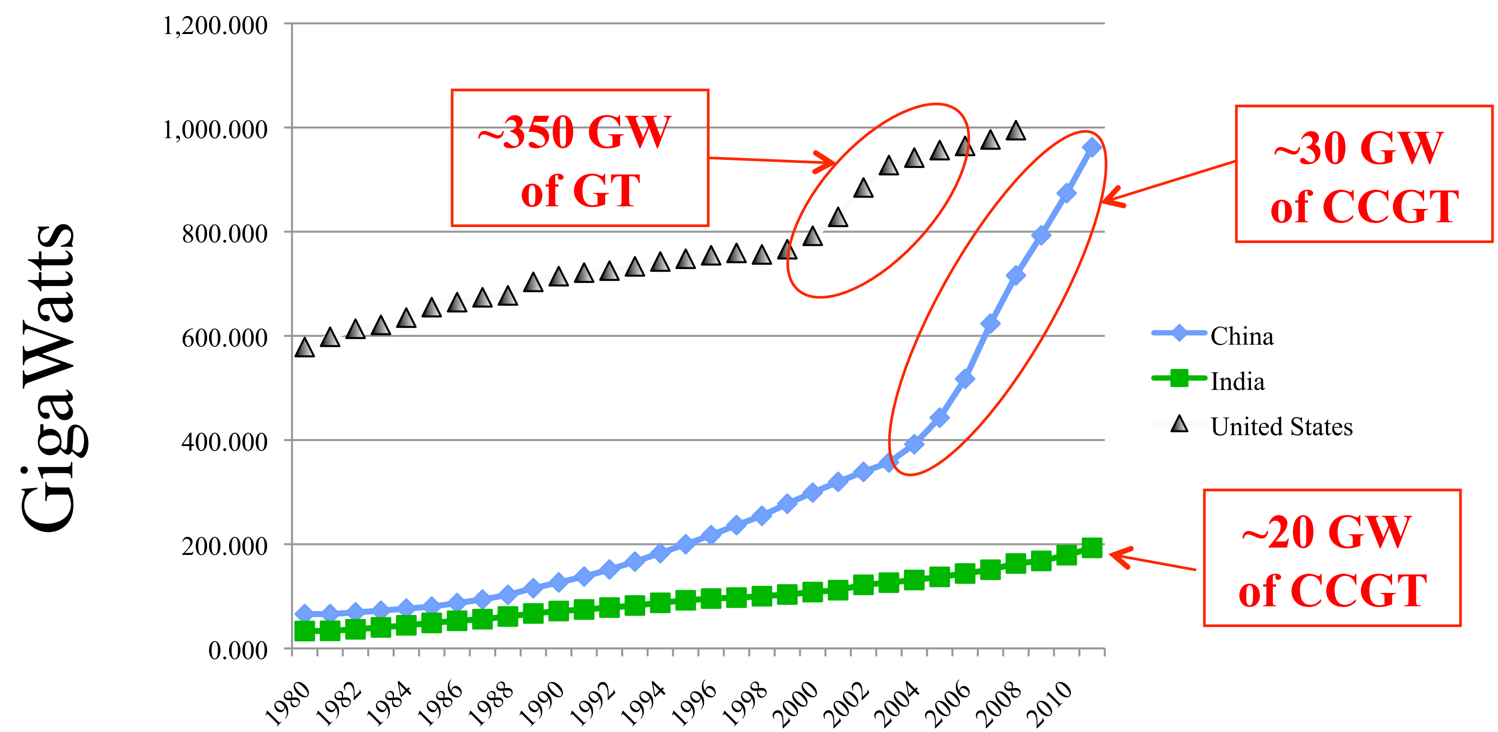
China's neighbors are rich in resources

Oil & Gas Pipelines



Land routes & barriers to resources and markets

Installed Capacity: China, India, USA



- US does not have significant extra gas capacity to replace coal
- China is developing pipelines, LNG ports, CCGT power plants
- India's development of gas infrastructure is slow. Needs $$+Gas

Source: EIA, http://www.world-nuclear.org/info/inf63.html

Manufacturers of Gas Turbines & Systems

Major Technology Innovators & Manufacturers

- GE
- Siemens
- Mitsubishi (MHI)

Major Manufacturers

- Alstom, Ansaldo, Asea Brown Boveri (ABB)

Regional Manufacturers

- Iran: MAPNA / TUGA (Siemens V94.2)
- India: BHEL (GE, Siemens), Larson & Toubro (MHI)
- China: GE-Harbin Power (9351FA);
  Siemens-Shanghai (SGT5-4000F);
  MHI-Dongfang (M701F)

Natural Gas-fueled power generation

Dominant in

- South America (after Hydro)
- North Africa
- Middle East
- Iran
- Central Asia
- Russia

Major fuel in

- North America
- Europe
- South-east Asia

Countries that will drive the future of shale-gas R&D and production

	2011 Consumption (T cum)	Reserves Conventional (T cum)	Reserves Shale-Gas (T cum)
China	0.11 ↑	3	36
USA	0.65	7.7	24
France	0.05	0.006	5.1
Poland	0.015	0.16	5.3
Argentina	0.04	0.38	22
Brazil	0.01	0.36	6.4
South Africa	0.005	-	13.7

Driven by Need

Natural Gas is the cleaner fossil-fuel of the 21st century

~10 million CNG cars on the road in 2010 versus a billion cars + small trucks

- Pakistan (2.0 million)
- Argentina (1.7 million)
- Brazil (1.6 million)
- Iran (1.0 million)
- India (0.65 million)

Regional collaboration can foster development by cost-effective transportation of natural gas through pipelines & reduce GHG emissions

By promoting natural gas we will increase our CO_2 footprint in the short-term as the world develops, but much less so than under BAU scenarios using coal

How long before renewable energy (carbon-neutral) systems and nuclear power become TW scale?

↓

Lecture 3