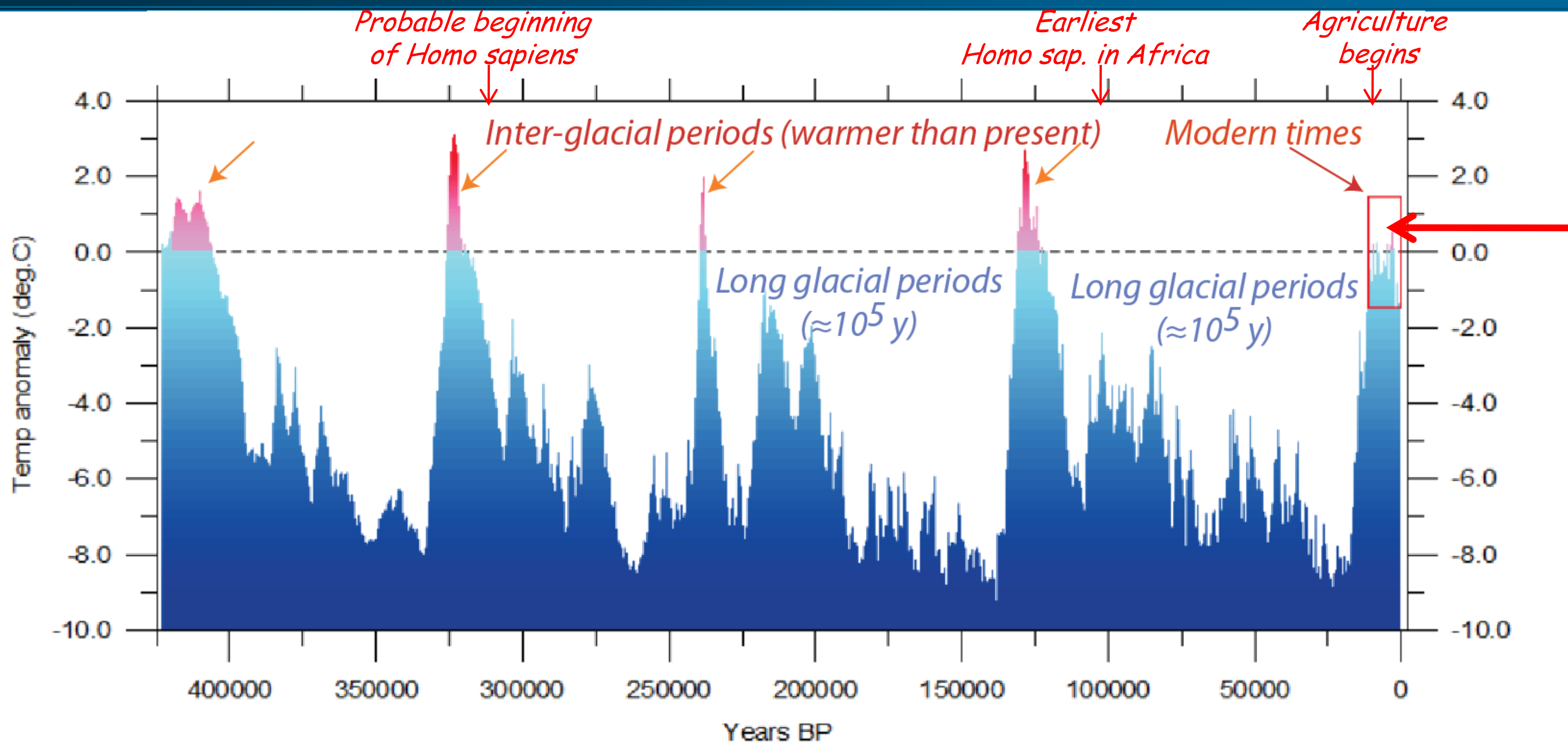
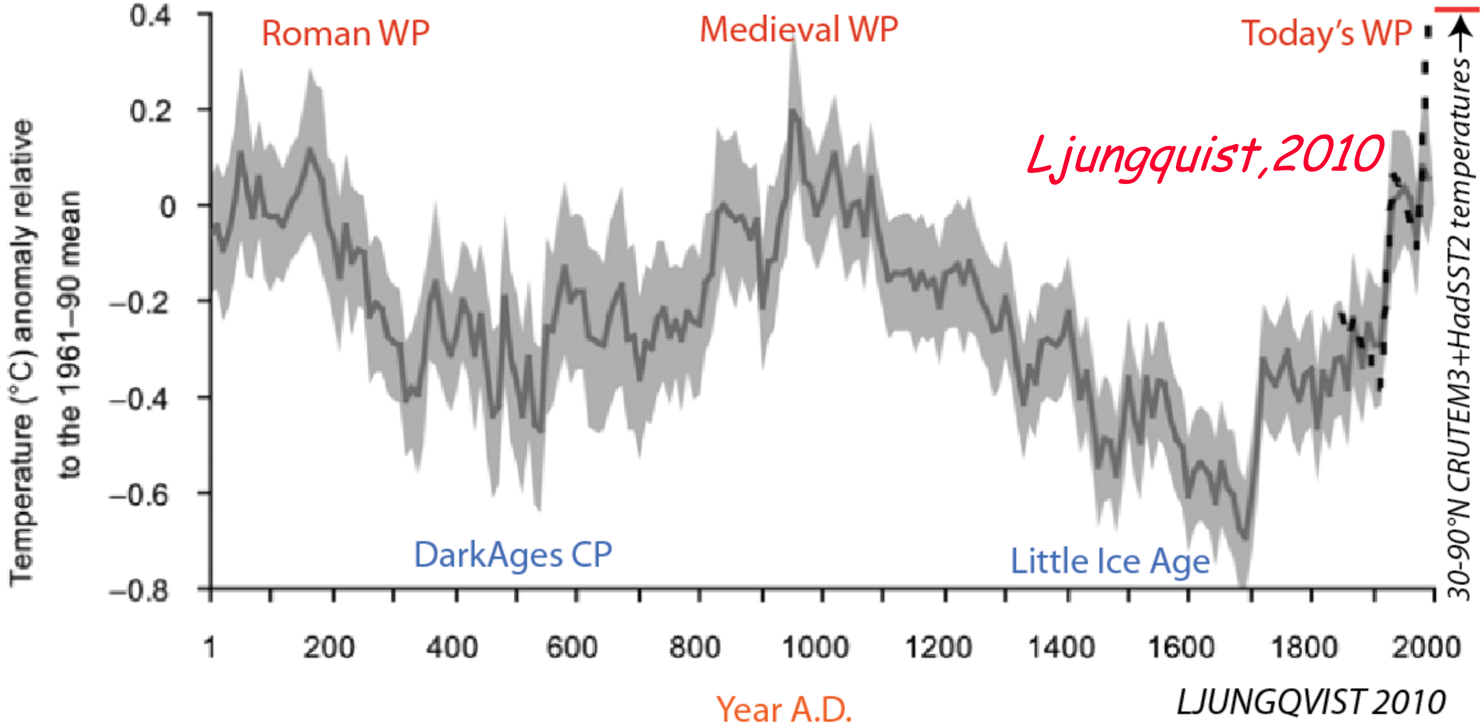


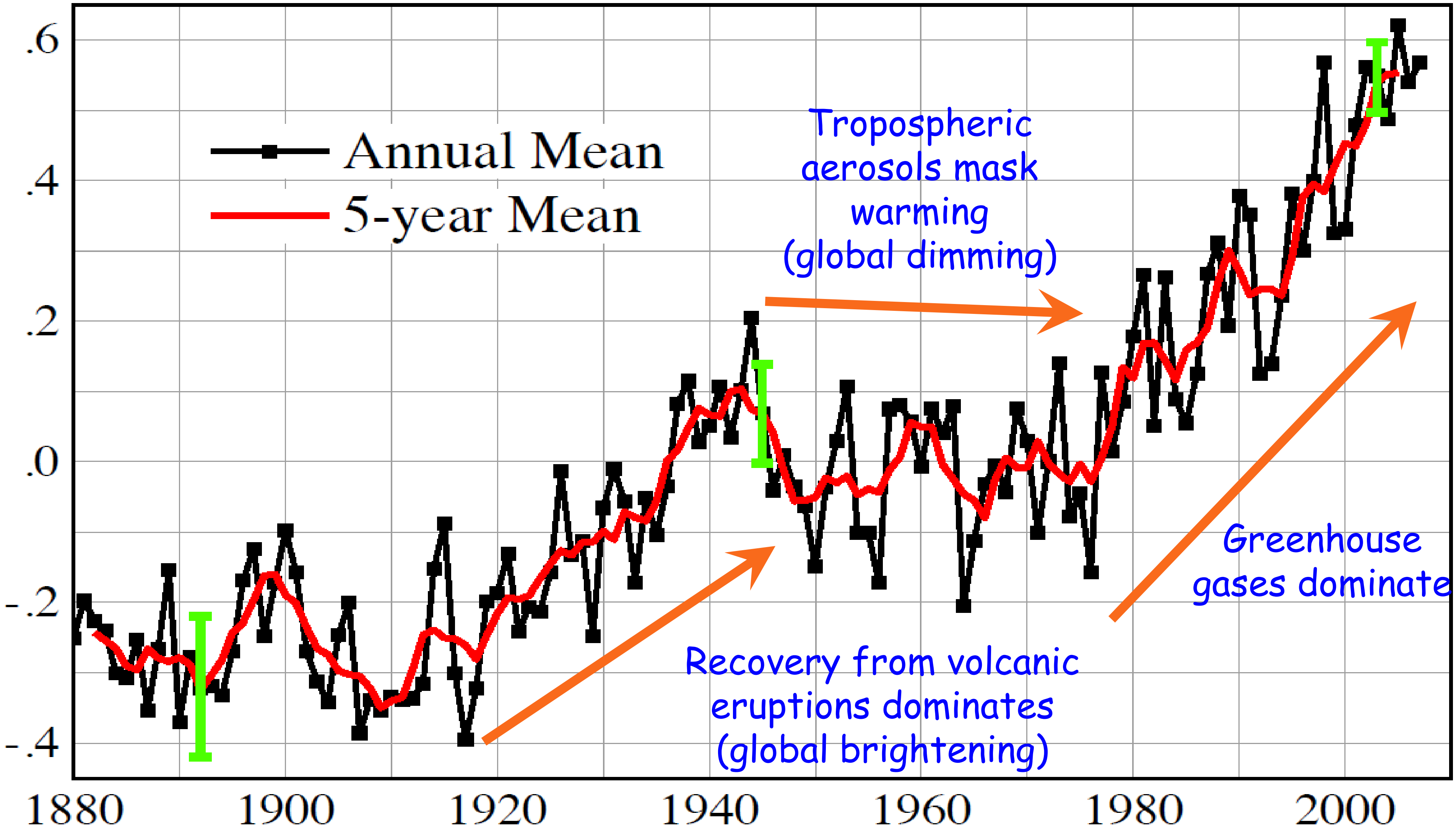
- Reconstructed global temperature over the last 420'000 years based on the Vostok ice core from the Antartica (Petit et al. 2001)
- It has been the last inter-glacial period during the last 10'000 years which has permitted to sustain the development of the human civilization.

2000 years of temperatures in the 30-90° North hemisphere

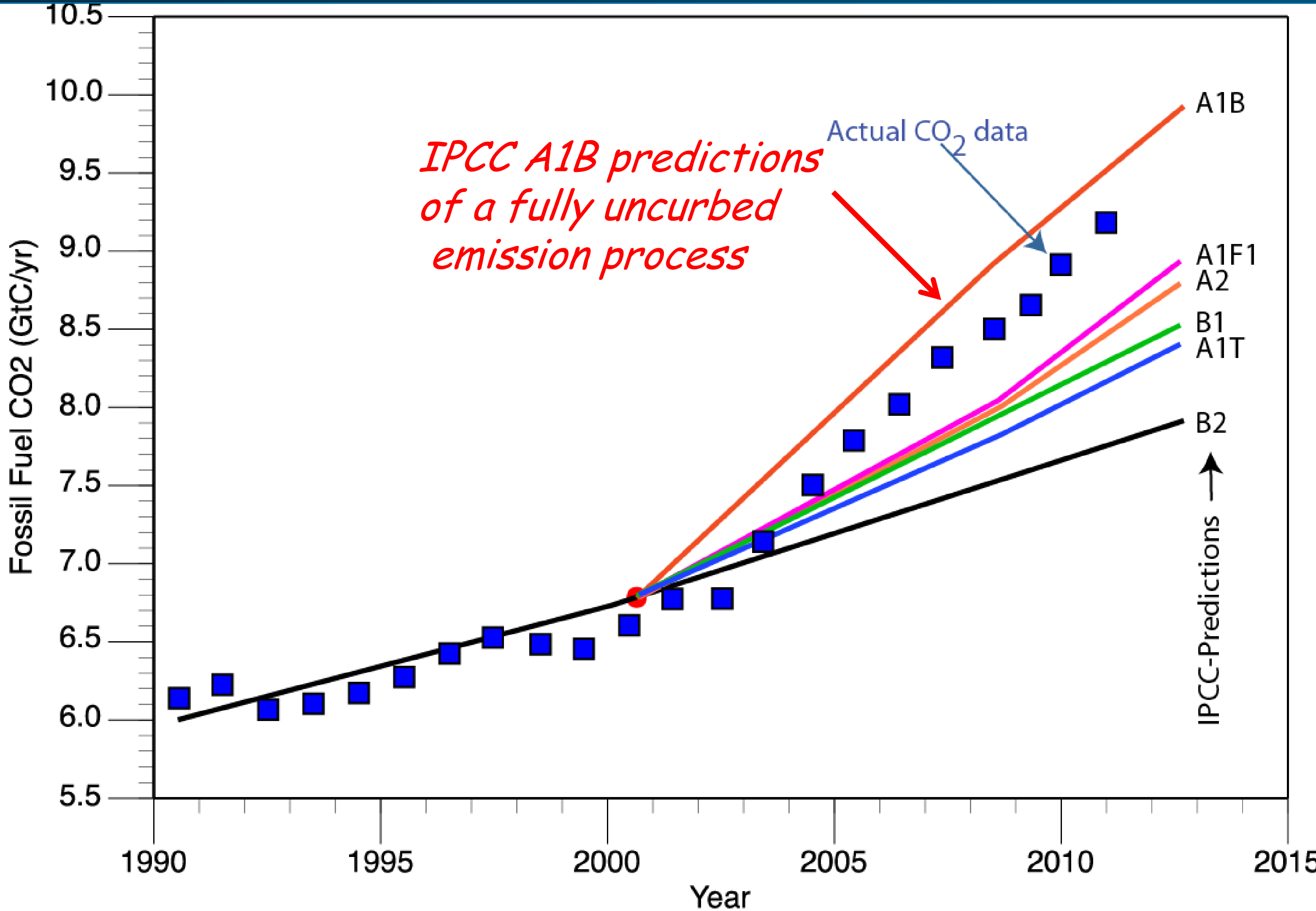


- Earth's climate has changed *naturally* between cooler and warmer conditions on a millennial timescale.
- Extra-tropical Northern Hemisphere (90–30° N) decadal mean temperature variations (dark grey line) relative to the 1961–1990 mean temperature with 2 standard deviations bars

An “associated” global temperature pattern (C°)?

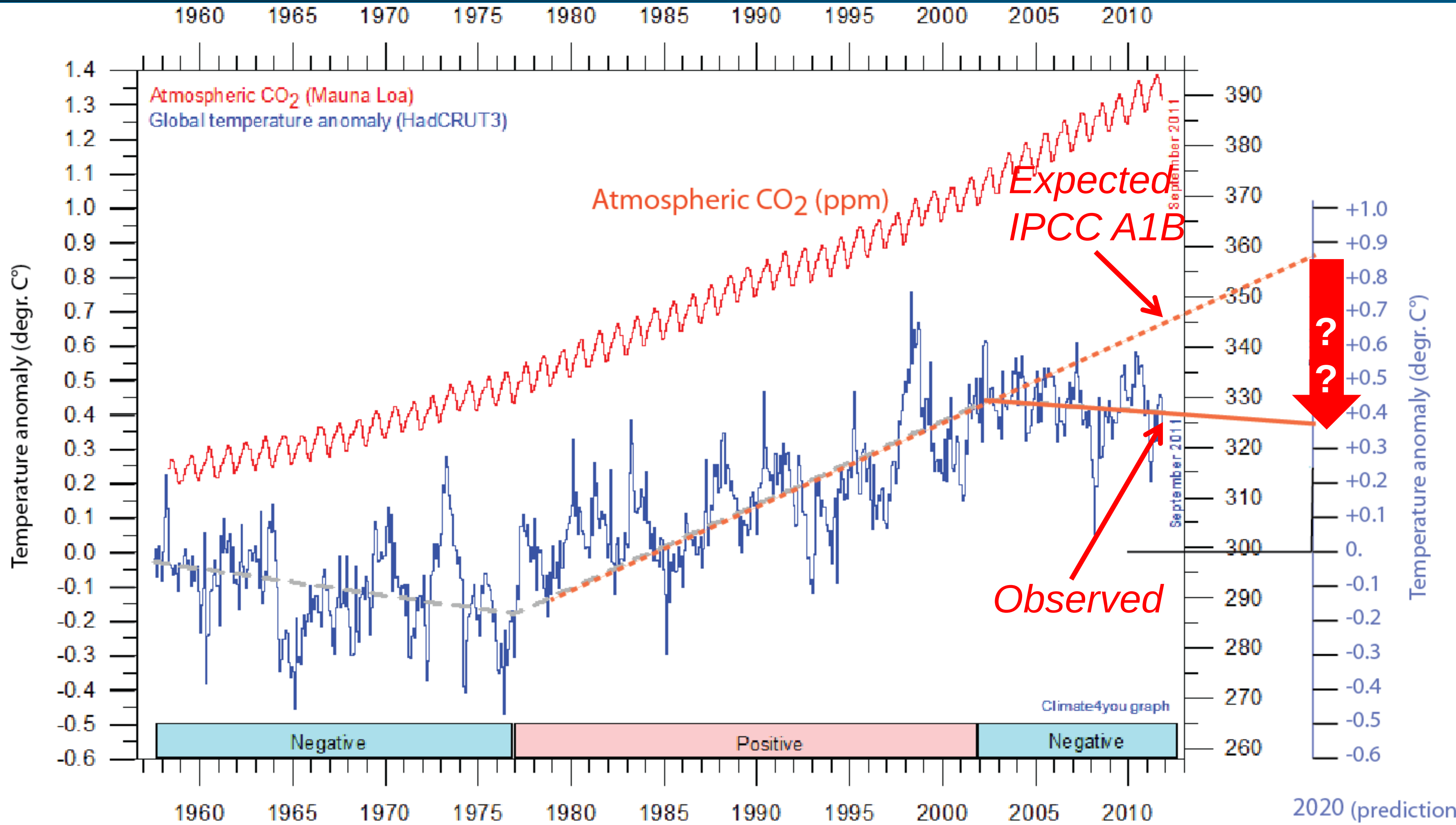


Man made fossil CO_2 emissions are rising at a rapid pace

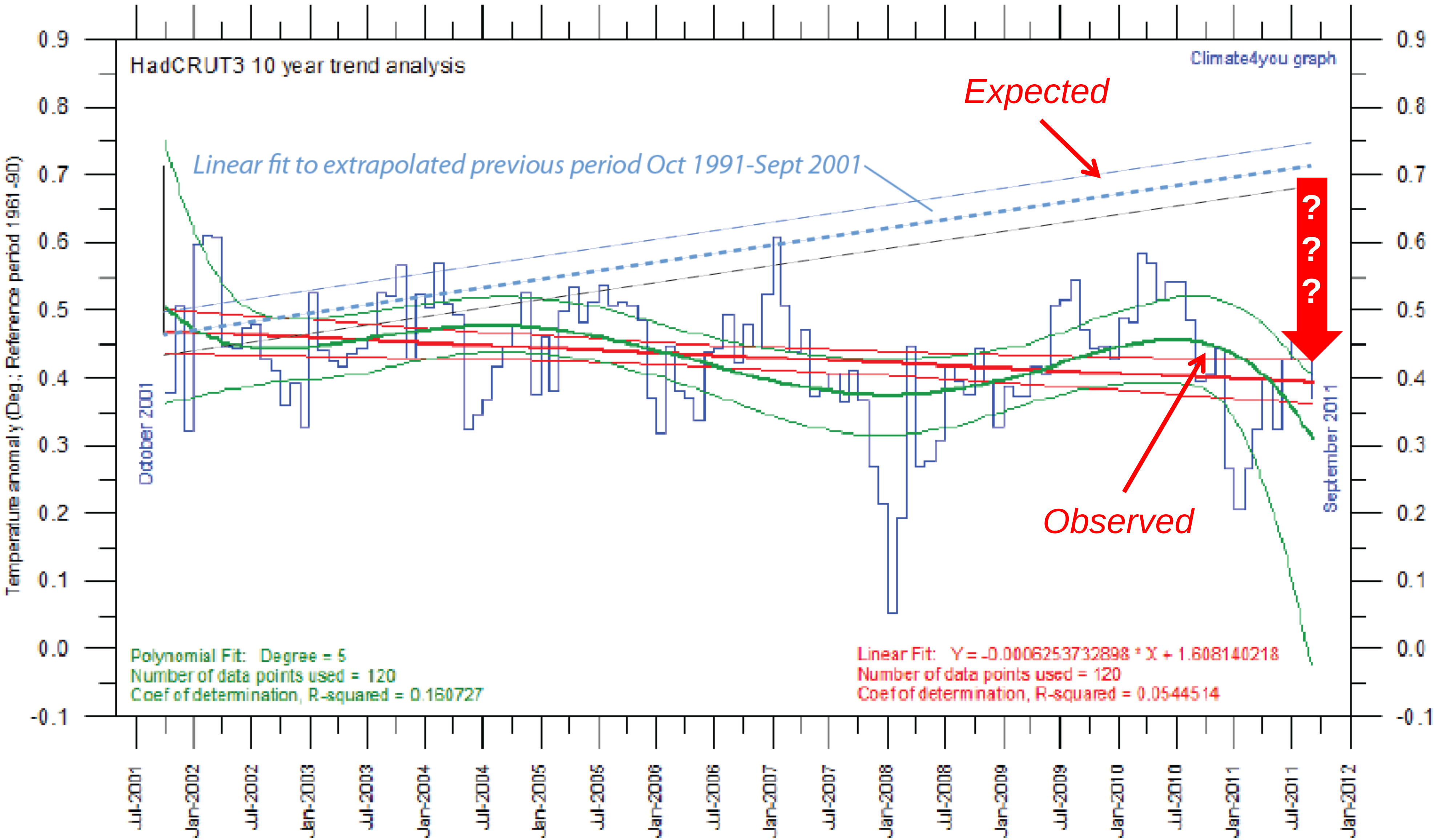


- From about 6 GtC/y in 1995, we are now at 9.5 GtC/y. By 2020 and at the present rate CO_2 will reach ≈ 12 GtC/y.

BUT, has the Anthropogenic warming slowed down ?

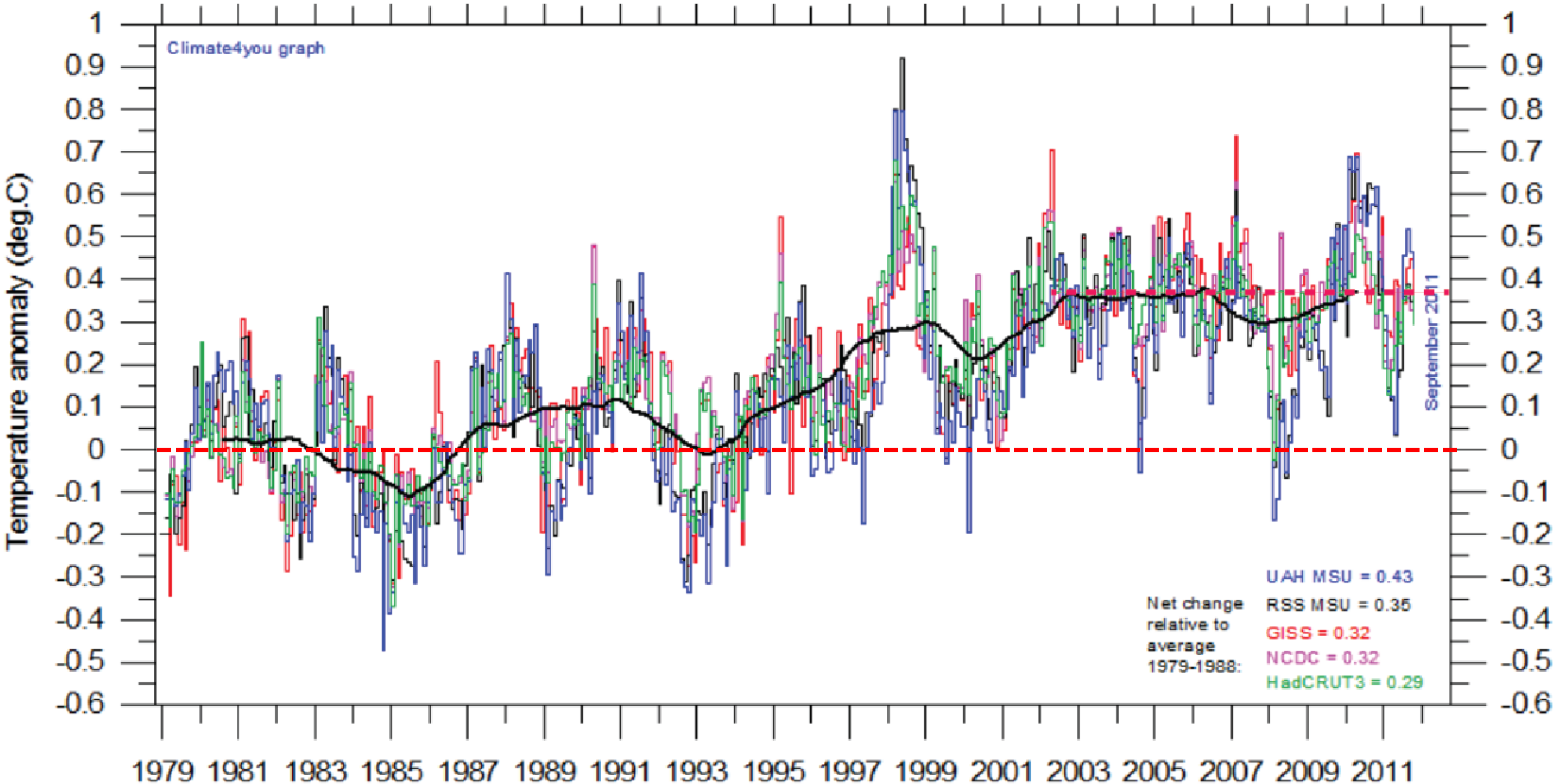


- Average temperature and CO_2 emissions over the last 17 years *show a small temperature drop rather than a significant rise, in contrast with more naive previous extrapolations.*



HadCRUT3 10 year trend analysis
Climate4you graph
Expected
Linear fit to extrapolated previous period Oct 1991-Sept 2001
Observed
October 2001
September 2011
Temperature anomaly (Deg.; Reference period 1961-90)
Polynomial Fit: Degree = 5
Number of data points used = 120
Coef of determination, R-squared = 0.160727
Linear Fit: Y = -0.0006253732898 * X + 1.608140218
Number of data points used = 120
Coef of determination, R-squared = 0.0544514

Five independent global estimates

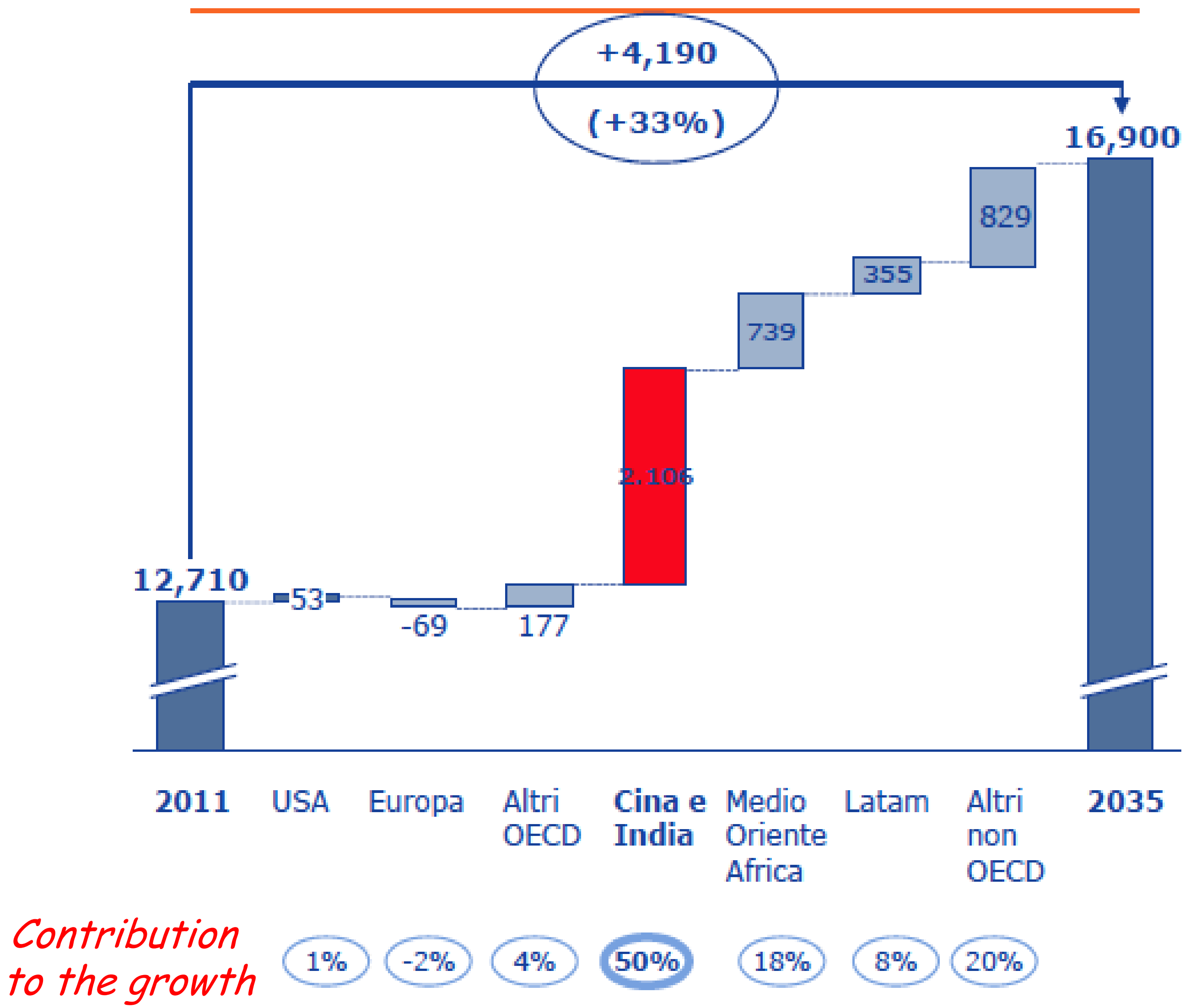


Superimposed plot of all five global monthly temperature estimates shown above. As the base period differs for the different temperature estimates, they have all been normalised by comparing to the average value of their initial 120 months (10 years) from January 1979 to December 1988. The heavy

Hadcrut3 data

http://theclimatescepticsparty.blogspot.de/2014/02/england-passes-wind-and-discovers-heat.html

Primary energy growth during the next 25 years (IEA)

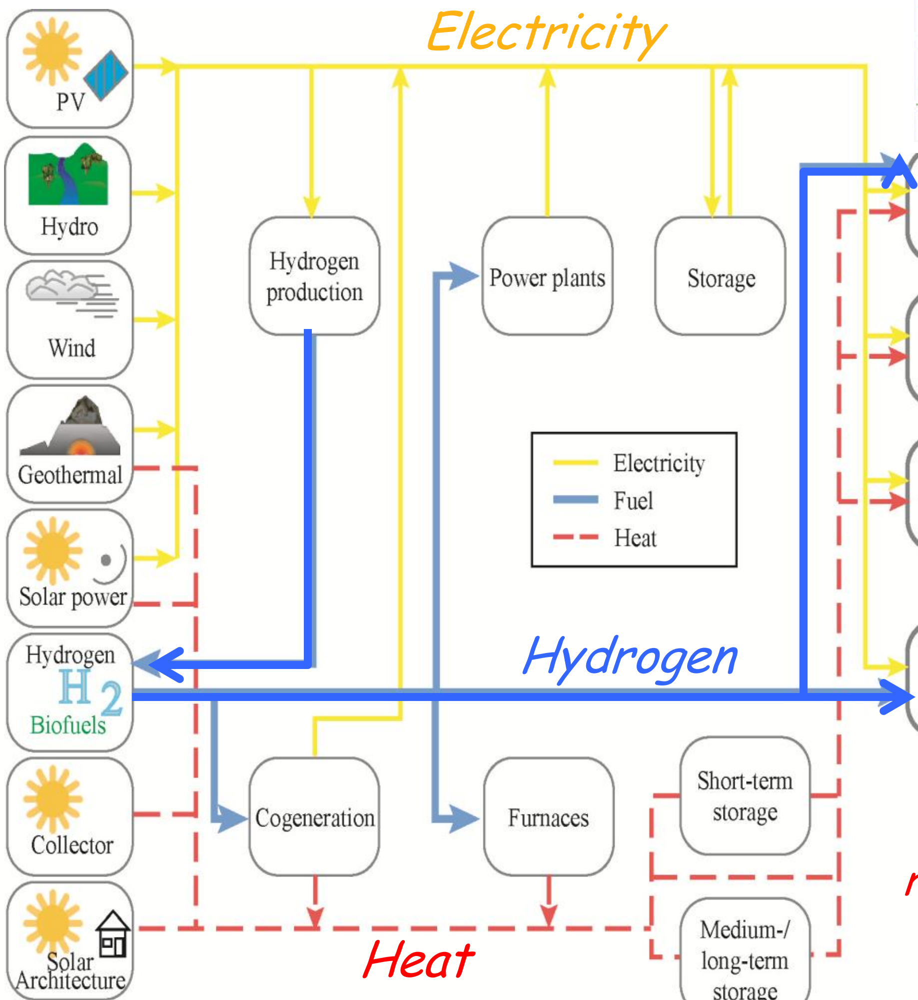


The main pillars of the European energy policy

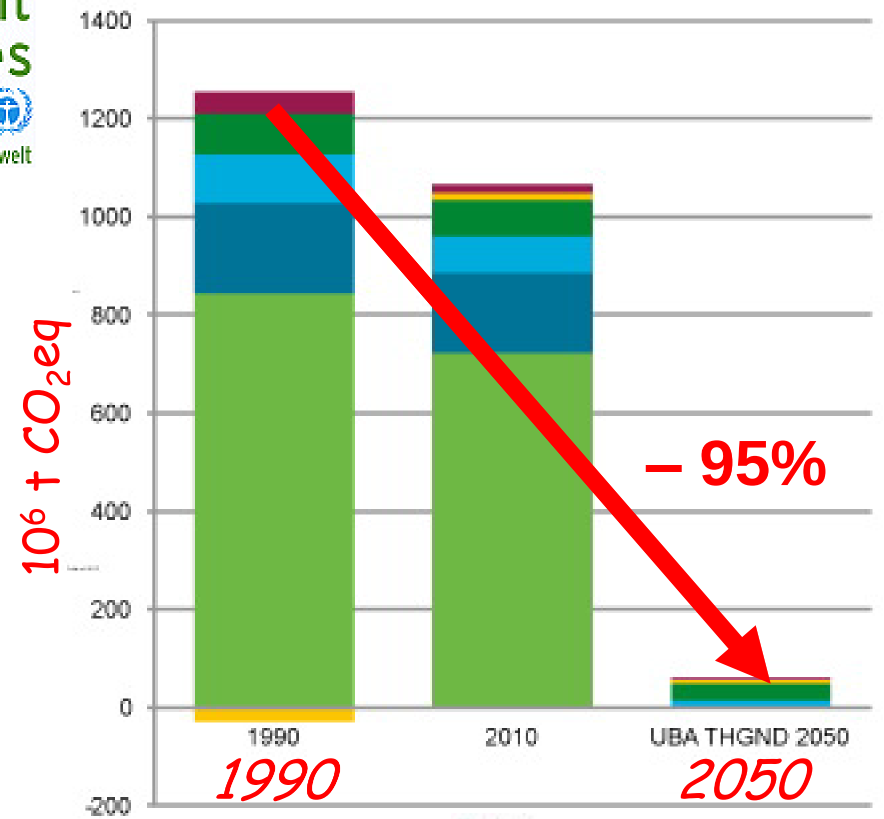
- During as many as twenty years, the energy policy has been determined by *two main priorities*:
  - The first strategic priority for the European Union has been the one to prevent dangerous climatic changes
  - The second consideration is based on the assumption that the energy prices will rise inexorably as global energy demand rises and the resources become scarce and this *will necessarily make renewable energies competitively the winners*
- The resulting energy policy by 2020 is based on the so-called **EU "20-20-20" climate and energy package**, namely:
  - 20% reduction of CO_2 emissions from 1990
  - 20% of EU energy produced from renewables
  - 20% improvement in EU energy efficiency.
- By circa 2040 about 80% of the EU primary energy should eventually come from renewables

European Energy System based on renewable Sources

Greenhouse Gas Neutral Germany

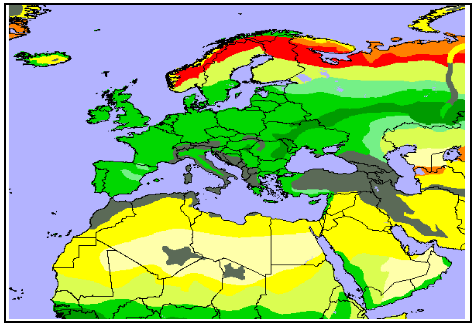
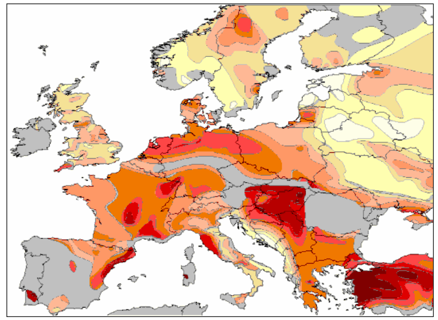
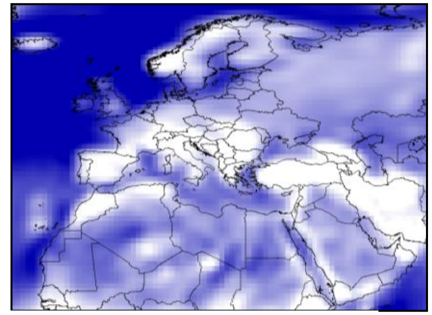
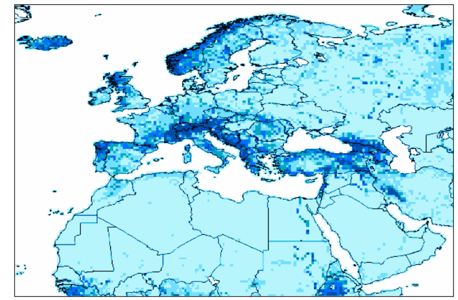


Umwelt Bundes Amt
Für Mensch und Umwelt



Hydrogen electrically produced by PV, Hydro, Wind, Geoth. and Solar are the main energy sources of Industry and Transport

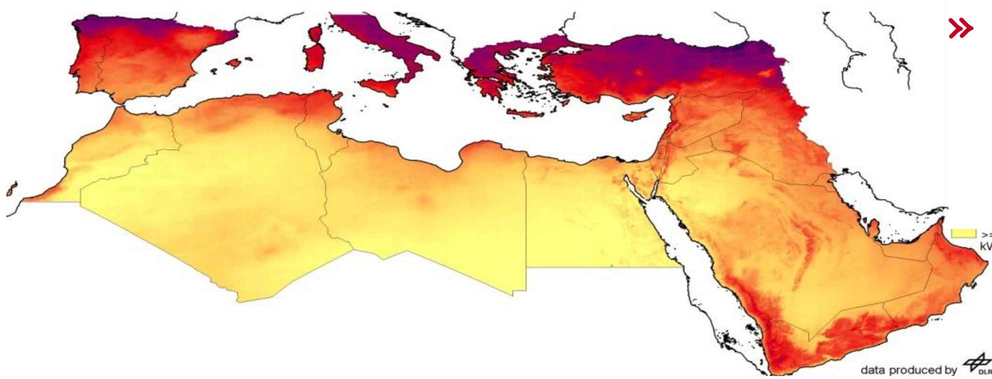
Greenhouse gas emission reductions is a top priority. The goal of German energy policy is to reduce such emissions by at least 40 percent by 2020 and by 80 to 95 percent by 2050, relative to 1990 levels.

Biomass	Geothermal	Wind	Hydropower
≈1 $GWh_{el}/km^2/y$	≈1 $GWh_{el}/km^2/y$	≈ 30 $GWh_{el}/km^2/y$	≈ 30 $GWh_{el}/km^2/y$
			
890 TWh_{el}/y	750 TWh_{el}/y	1700 TWh_{el}/y	1090 TWh_{el}/y

Typical Yield

Economic potentials

Typical yield CSP, PV≈250 $GWh_{el}/km^2/y$



Economic potentials > 600 000 TWh_{el}/y

Demand of electric power:

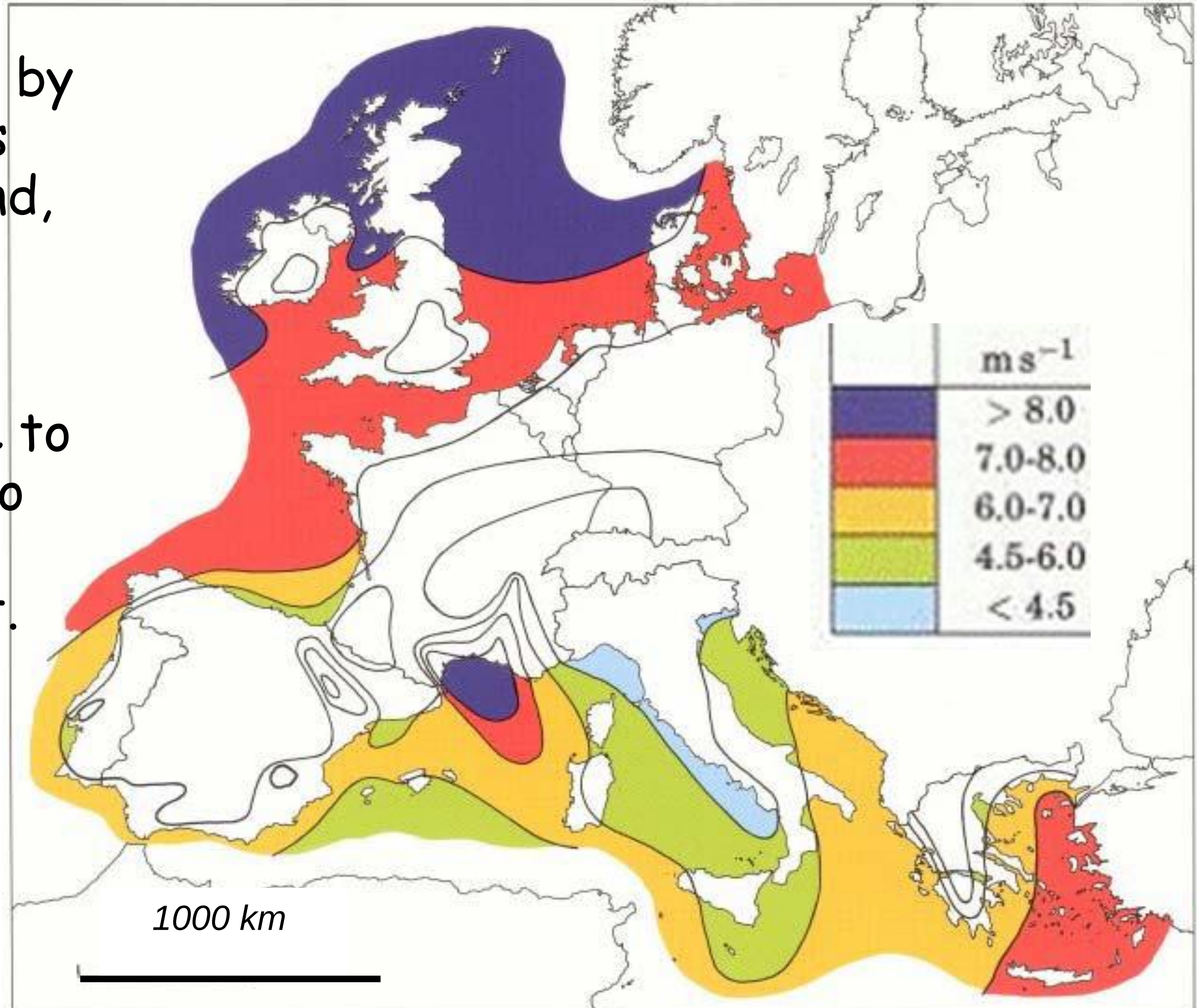
» 7 500 TWh/y Europe + Desert 2050

» 35 000 TWh/y world-wide 2050

Nasser lake area

A new role of renewable energies in Europe: wind

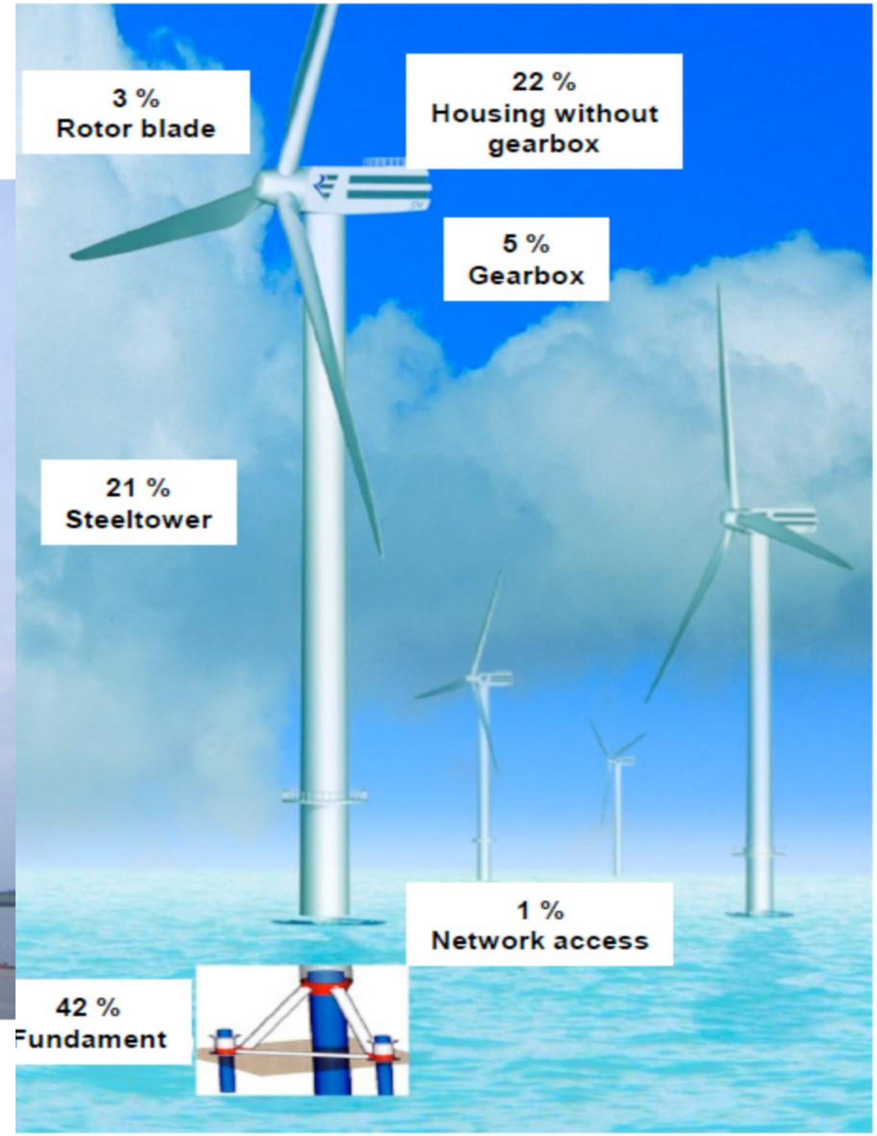
- In line with the commitments taken by the Member States for 2020 and beyond, wind energy should indeed become the most prominent renewable resource to be used in Europe to contribute to GHG emission abatement.



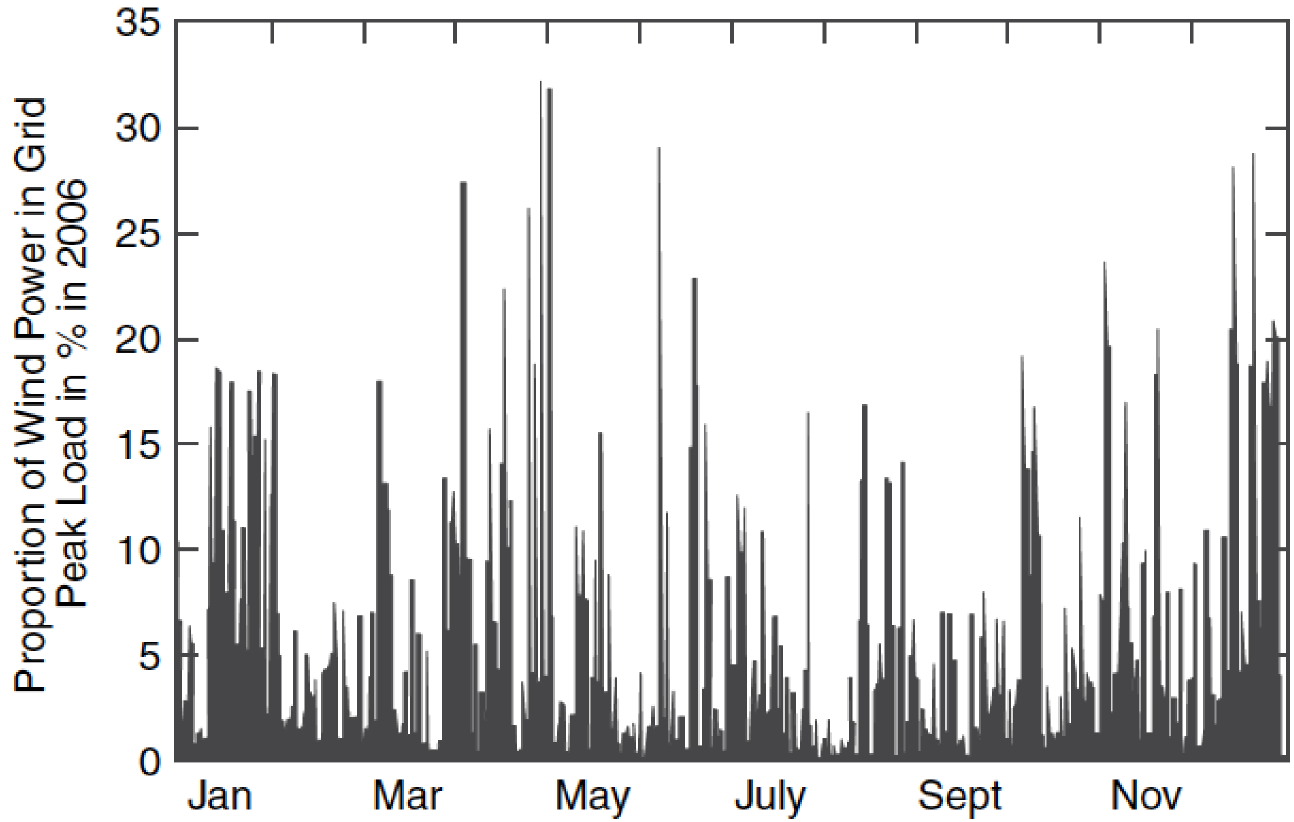
Wind off-shore: average power 6 MW/unit

Up to 700 m deep

Foto: Große Boeckmann, August 2008

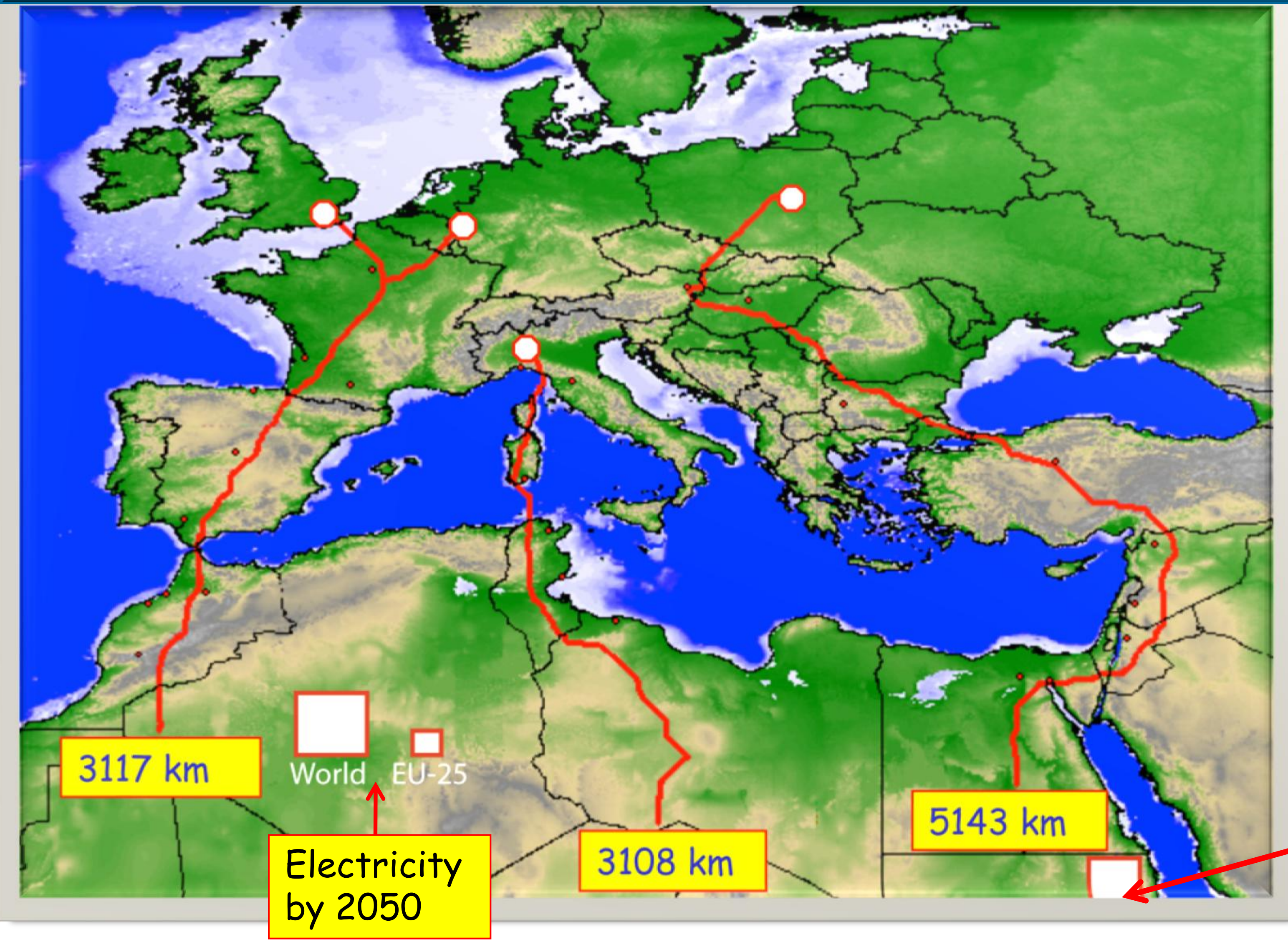


Wind



- Wind variability in Germany. Percentage of electrical demand delivered by all the wind turbines of E.ON Energie during the year 2007. Averaged over the year, wind power delivered 18% of installed capacity. (Courtesy of E.ON Energie)

The EU-MENA Solar project in Europe



By 2050

Area: 2500 km^2
HV Lines 4000 km^2
Capacity: 100 GWatt
Transfer:700TWh/y
EU needs:7500TWh/y

Costs:
Turnover: 35 G€/y
Solar 350 G€
HV lines: 50 G€

Nasser Lake area = Oil + Gas from Saudi Arabia

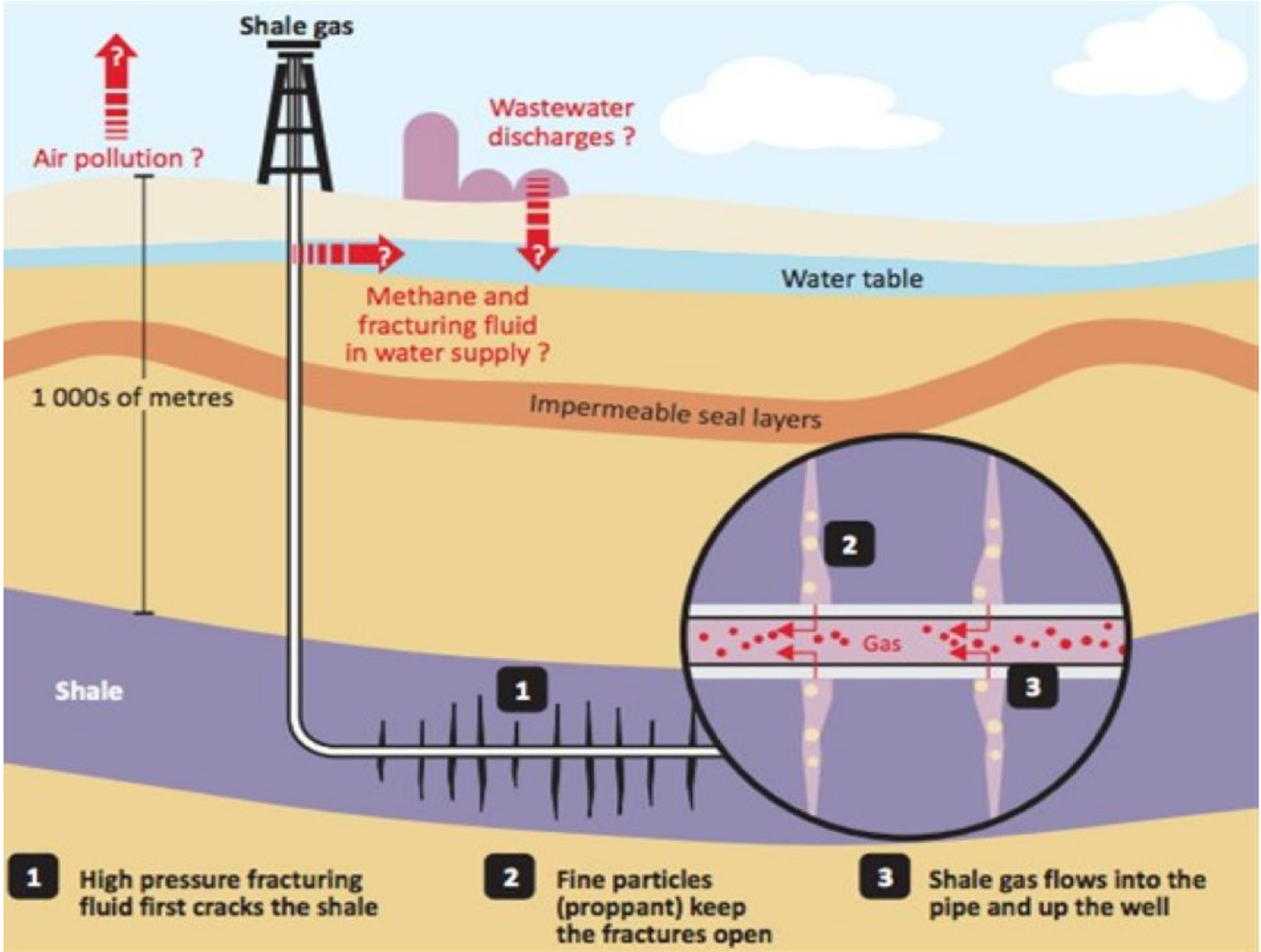
The planned EURO-MED electricity interconnection permits to produce from the Sahara large amounts of wind/solar electricity toward the Pan- European network.

The shale revolution in the US

- In 1967, Herman Kahn and Anthony J. Wiener published *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years.*
- It predicted that by the year 2000, there would be "commercial extraction of oil from shale."
- " *We conclude that the proven reserves of these five major fossil fuels (oil, natural gas, coal, **shale oil and tar sands**) alone could provide the world's total energy requirements for about 100 years, and only one-fifth of the estimated potential resources could provide more than 200 years of the projected energy needs." --*

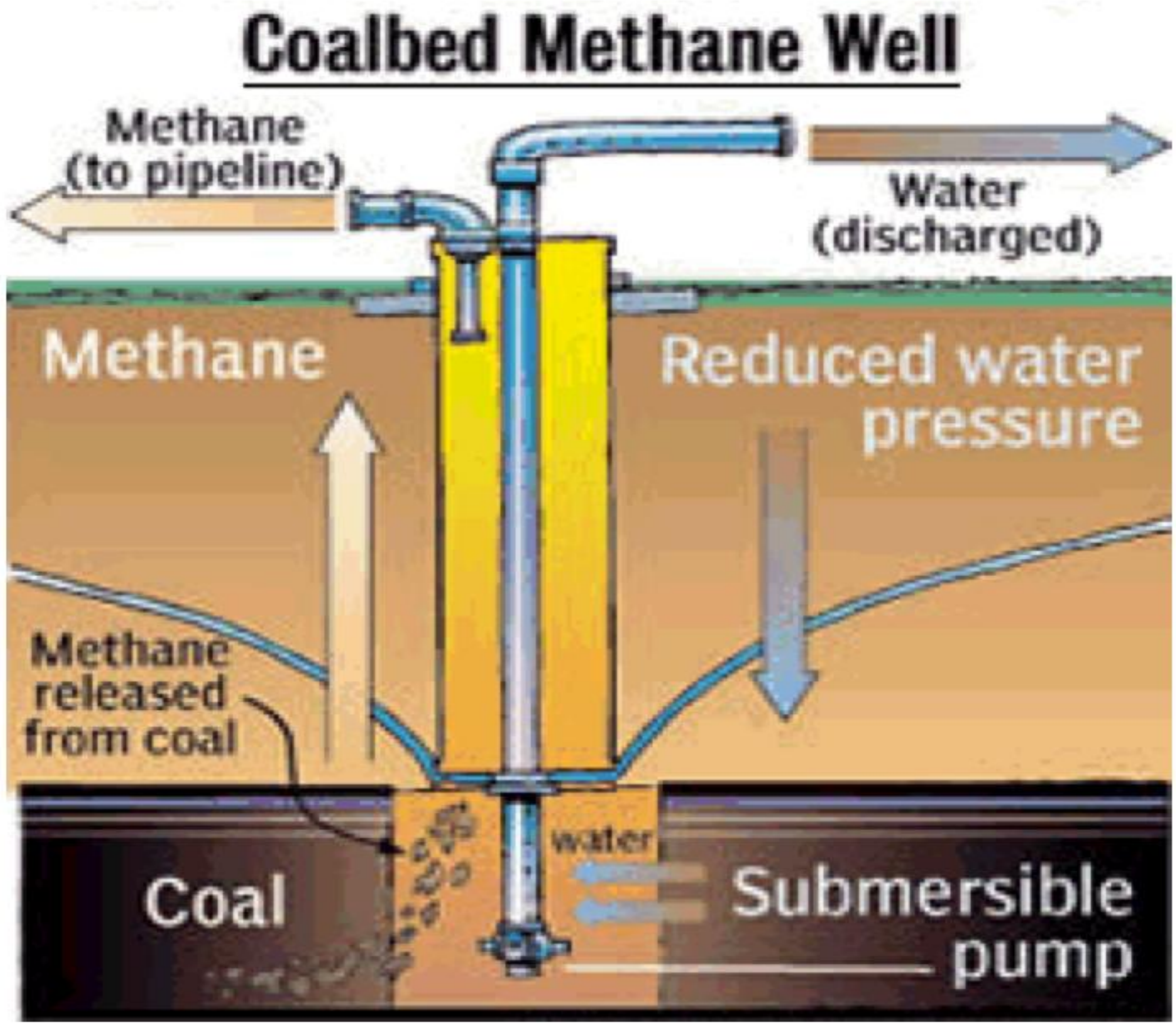
1.-Gas Naturale da scisti

- **Shales** are sedimentary rocks formed from deposits of mud, silt, clay and organic matter.
- Hydraulic fracturing involves pumping of water mixed with chemicals at high pressure into a well that has been drilled. The fluid creates fractures in the rock, in order to get the gas out.



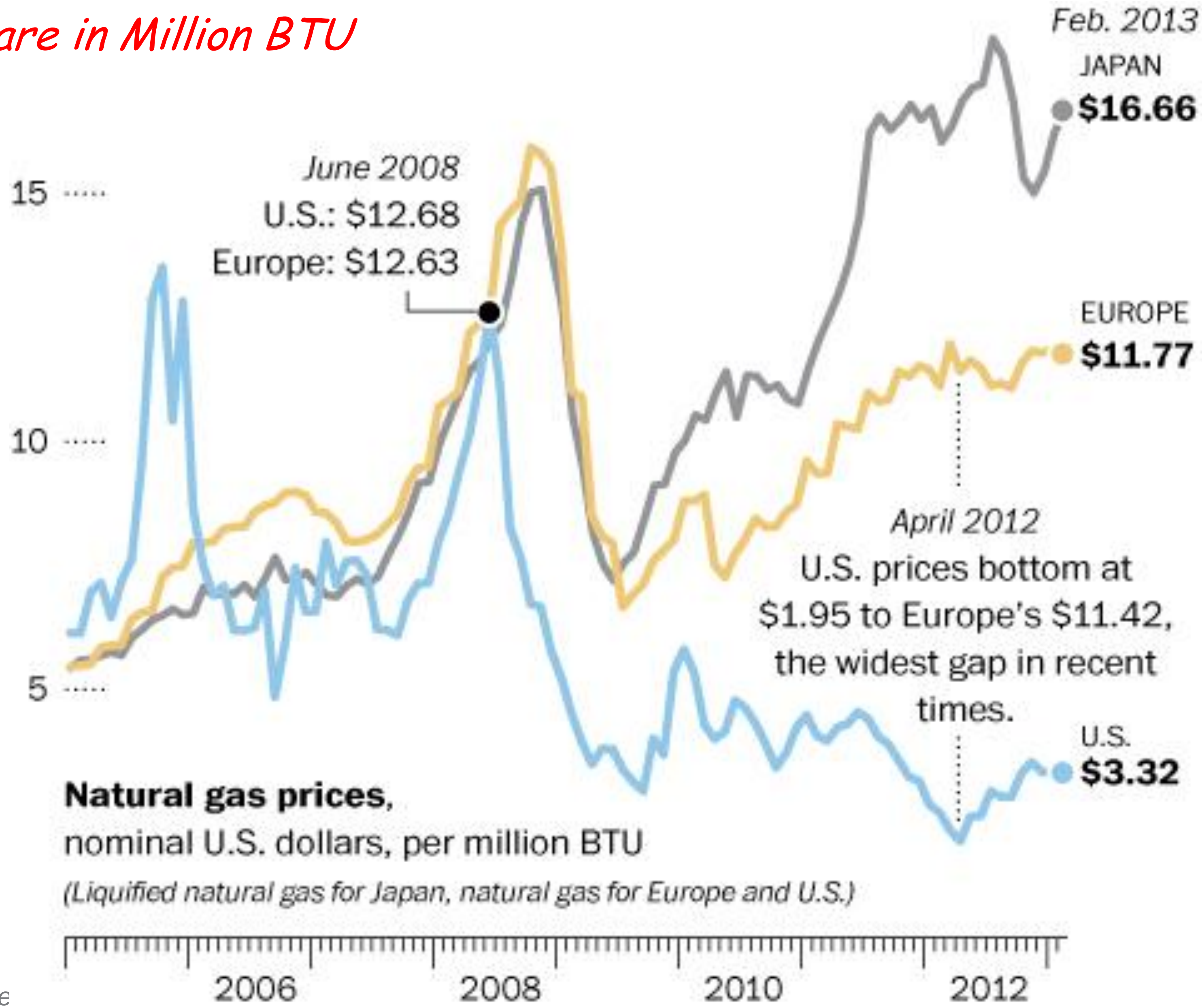
2.-Metano da sedimento carbonifero

- CBM is **Coalbed Methane** adsorbed into a solid coal matrix (macerals) released if the coal seam is depressurised.
- Methane is extracted by drilling wells into the coal seam. The water pressure is decreased by pumping water from the well. The decrease in pressure allows methane to desorb from the coal and flow as a gas up the well to the surface

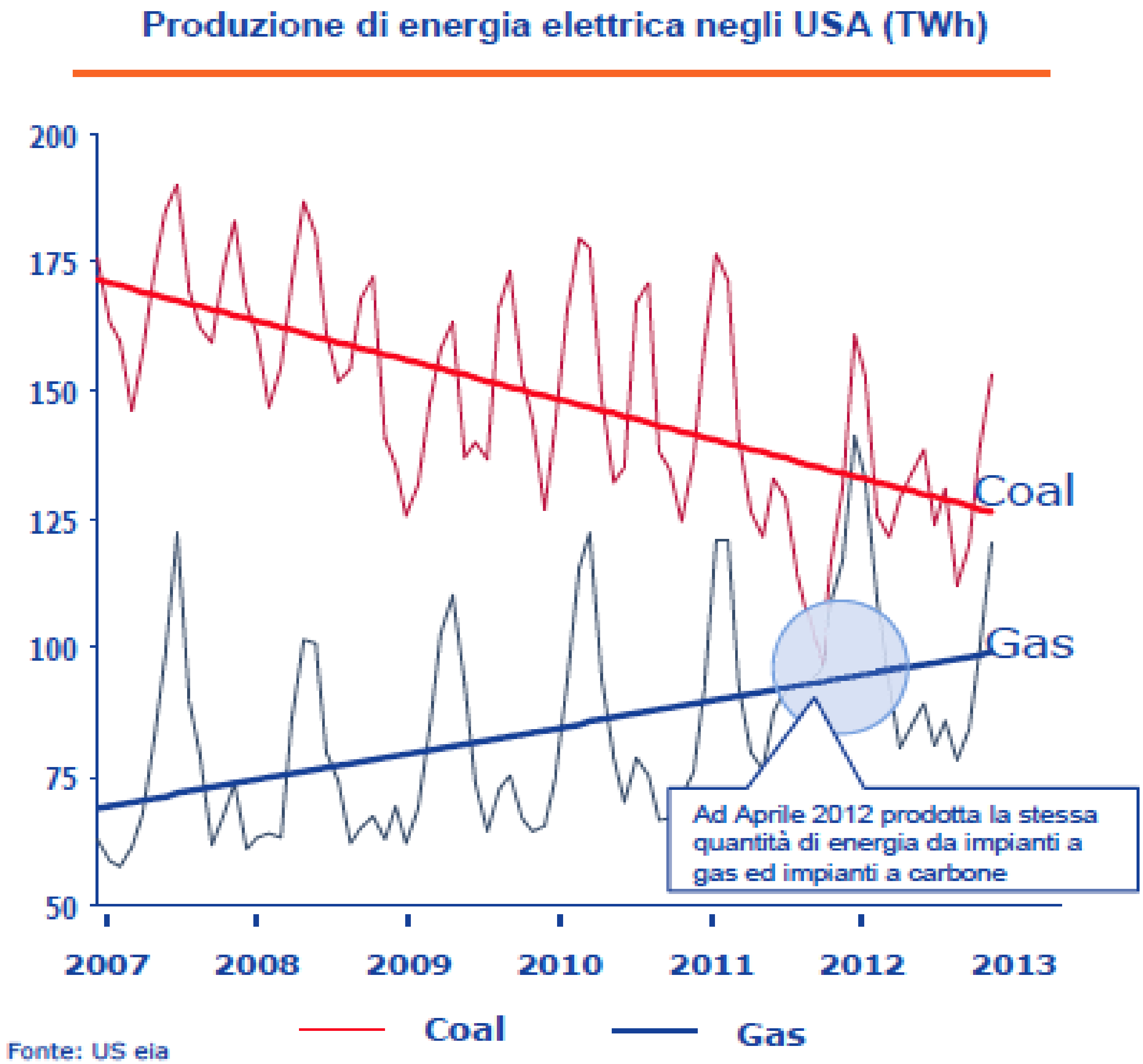


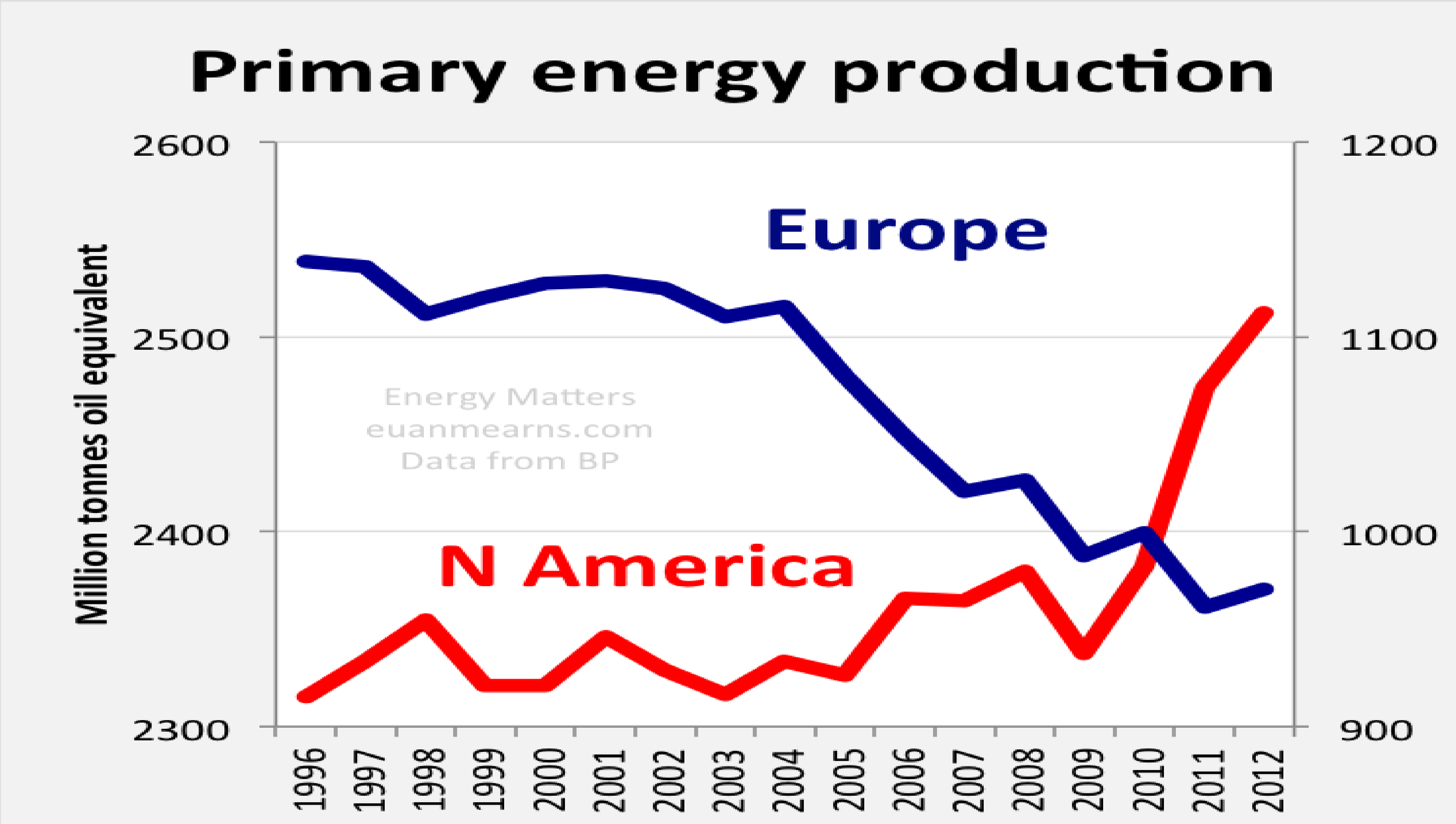
Consumi di gas naturale

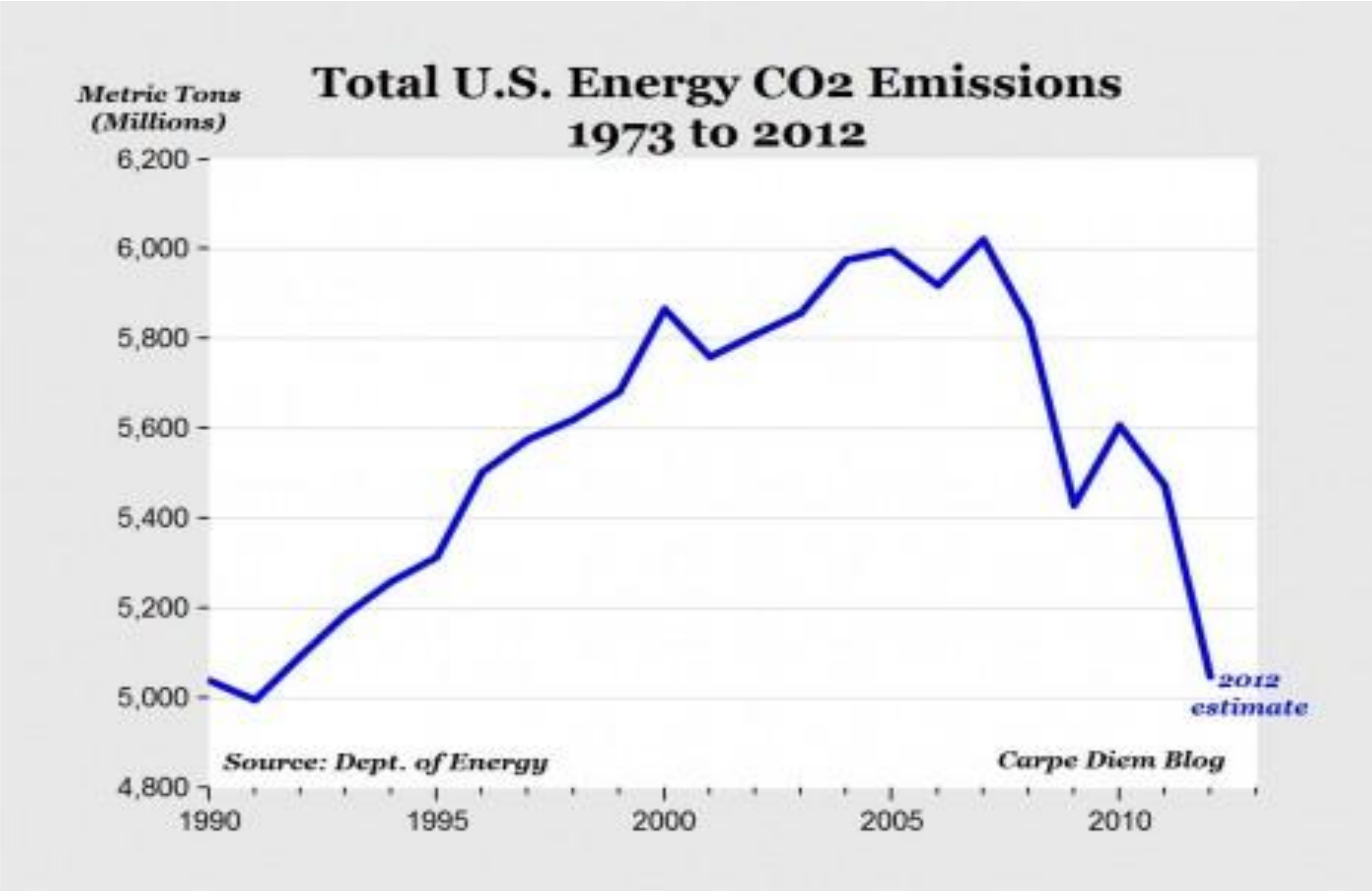
Units are in Million BTU

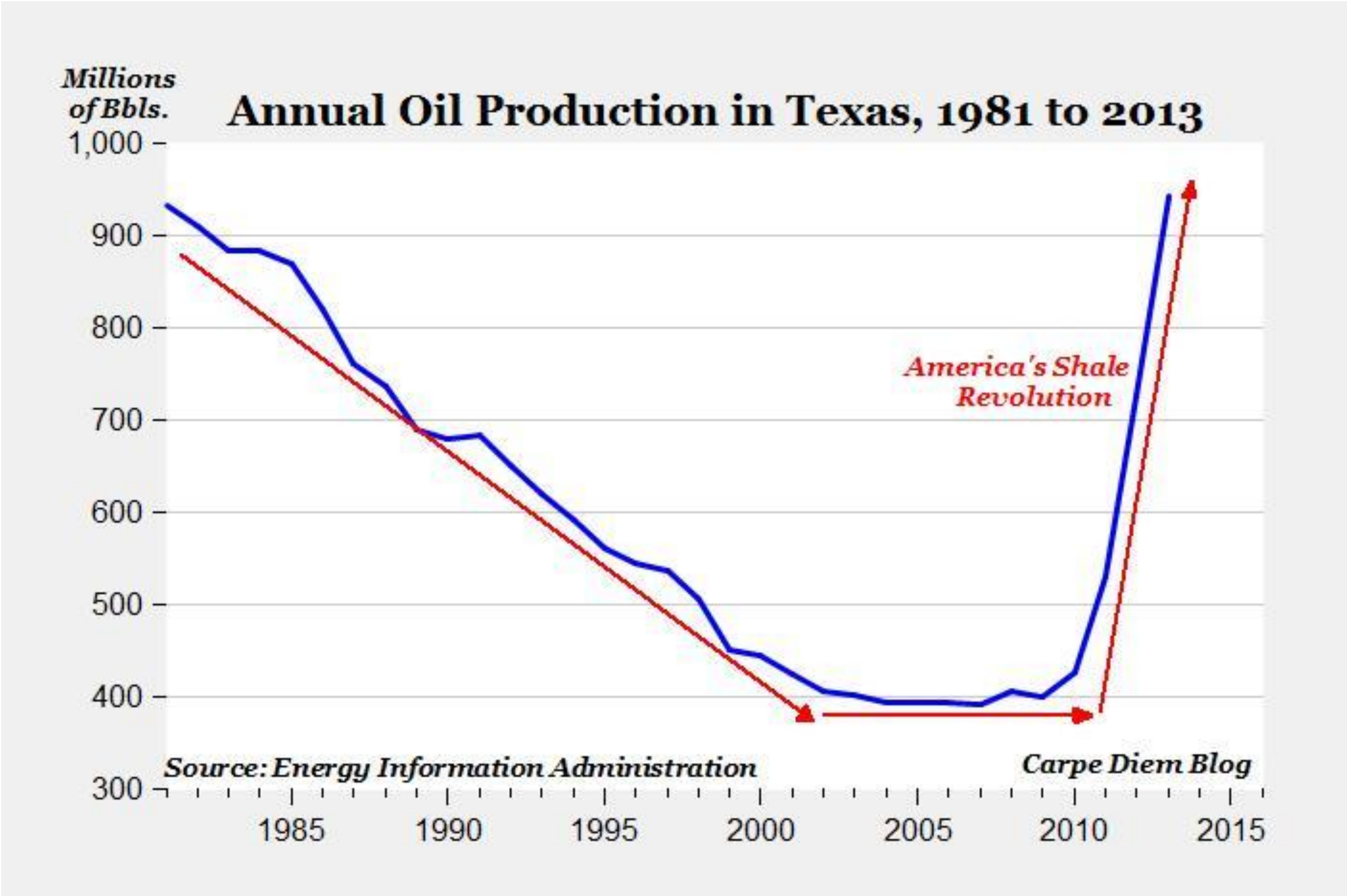


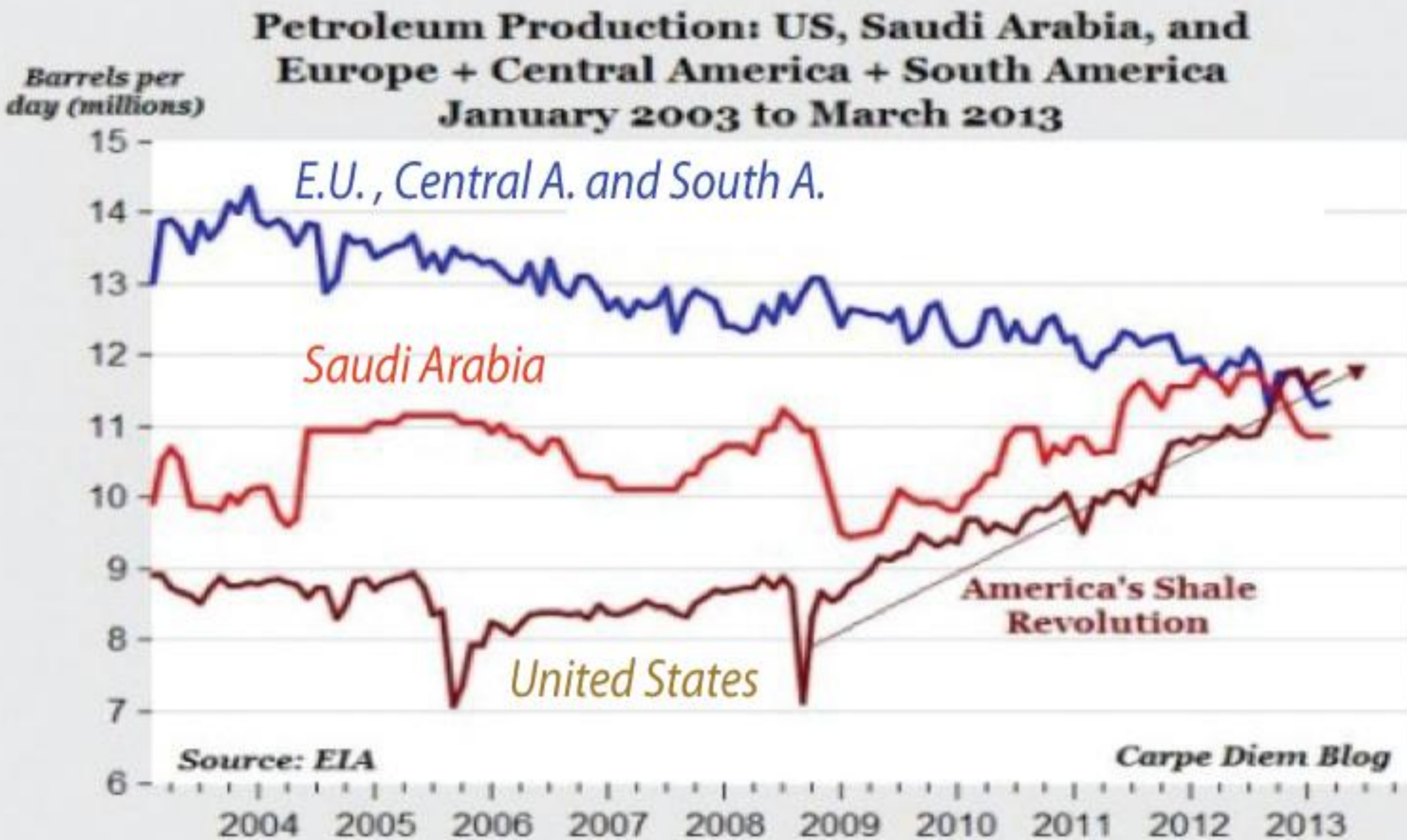
Gas naturale vs. Carbone

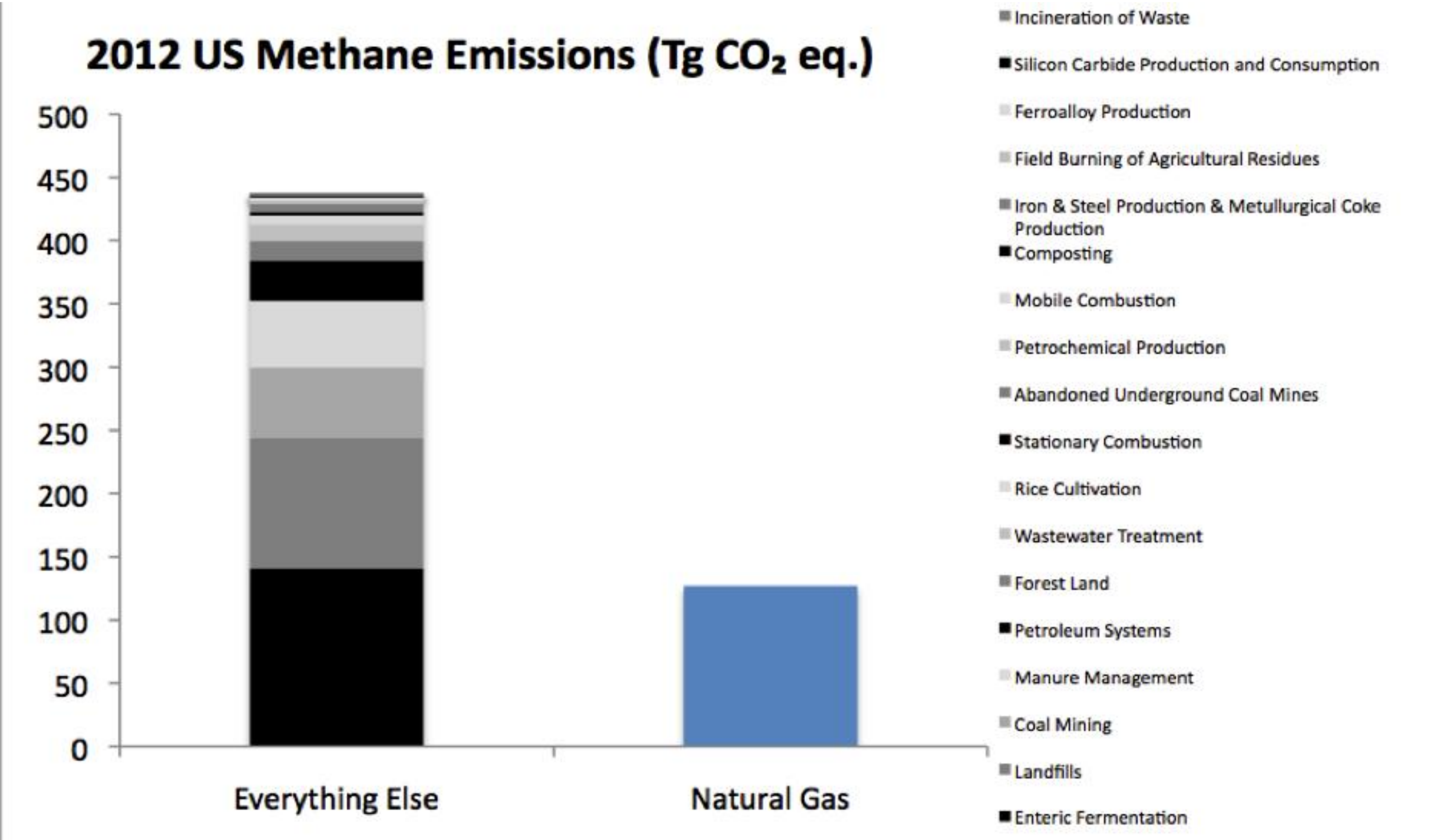



Primary energy production
Million tonnes oil equivalent
2600
2500
2400
2300
1200
1100
1000
900
Europe
N America
Energy Matters
euanmearns.com
Data from BP
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

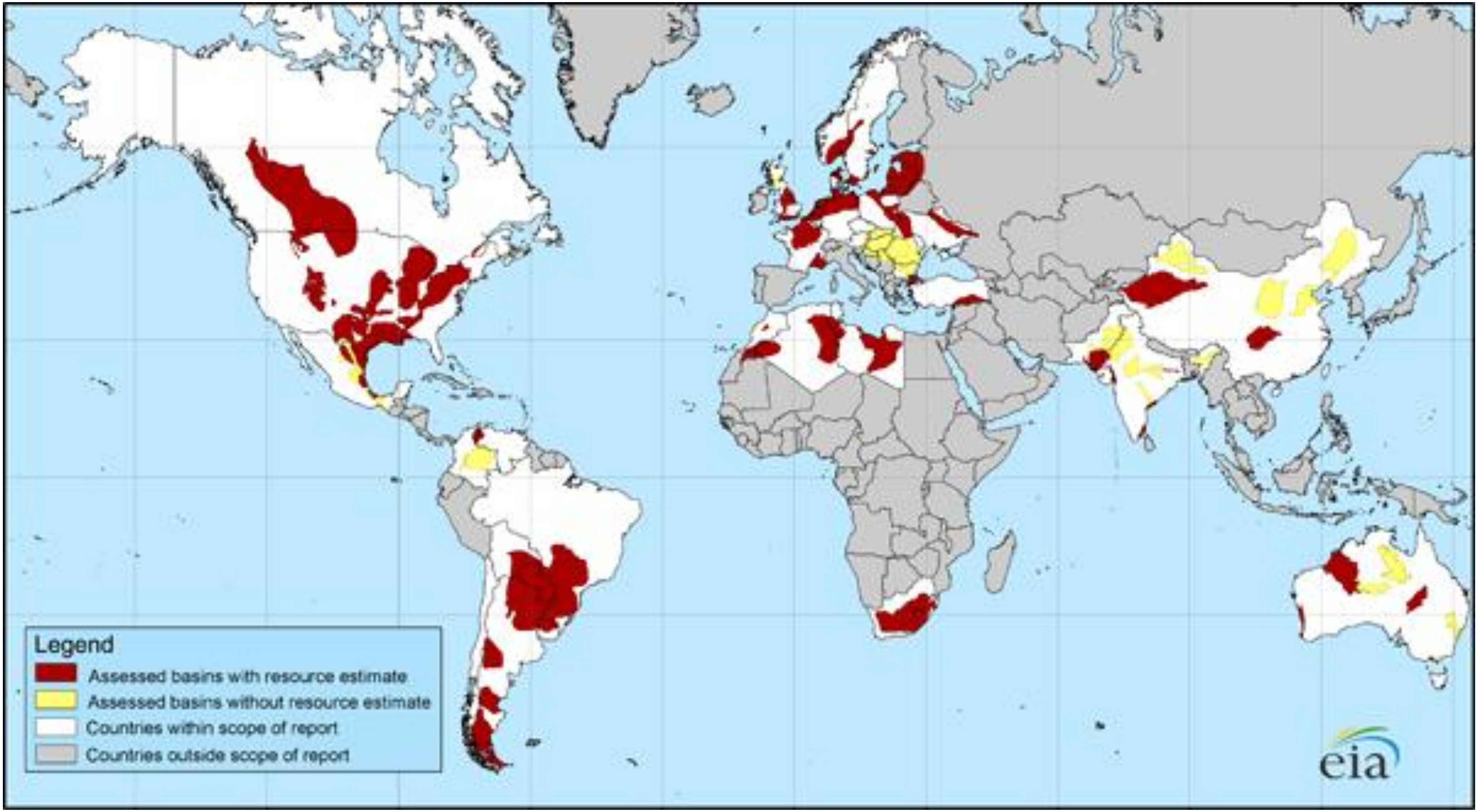

Total U.S. Energy CO2 Emissions
1973 to 2012
Metric Tons
(Millions)
6,200
6,000
5,800
5,600
5,400
5,200
5,000
4,800
1990
1995
2000
2005
2010
2012
estimate
Source: Dept. of Energy
Carpe Diem Blog


Millions of Bbls.
Annual Oil Production in Texas, 1981 to 2013
1,000
900
800
700
600
500
400
300
America's Shale Revolution
Source: Energy Information Administration
Carpe Diem Blog
1985
1990
1995
2000
2005
2010
2015


Petroleum Production: US, Saudi Arabia, and
Europe + Central America + South America
January 2003 to March 2013
Barrels per day (millions)
15
14
13
12
11
10
9
8
7
6
E.U., Central A. and South A.
Saudi Arabia
United States
America's Shale Revolution
Source: EIA
Carpe Diem Blog
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


2012 US Methane Emissions (Tg CO_2 eq.)
500
450
400
350
300
250
200
150
100
50
0
Everything Else
Natural Gas
Incineration of Waste
Silicon Carbide Production and Consumption
Ferroalloy Production
Field Burning of Agricultural Residues
Iron & Steel Production & Metullurgical Coke Production
Composting
Mobile Combustion
Petrochemical Production
Abandoned Underground Coal Mines
Stationary Combustion
Rice Cultivation
Wastewater Treatment
Forest Land
Petroleum Systems
Manure Management
Coal Mining
Landfills
Enteric Fermentation

World-wide Shale resources are global & massive



CBM reserves

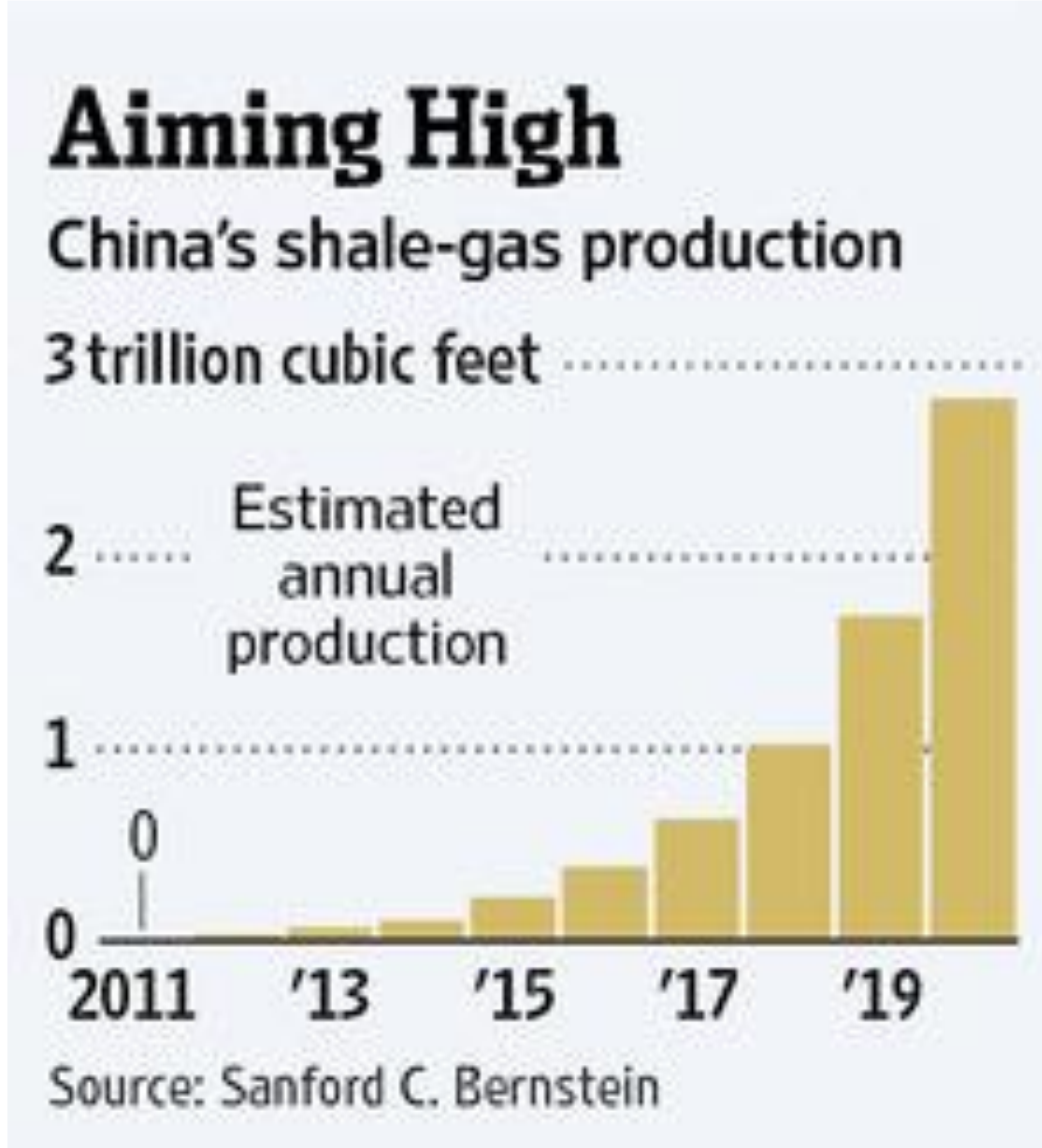
CBM Reserves (Johnston, et al., 2009)

Units are in Trillion ft³

China

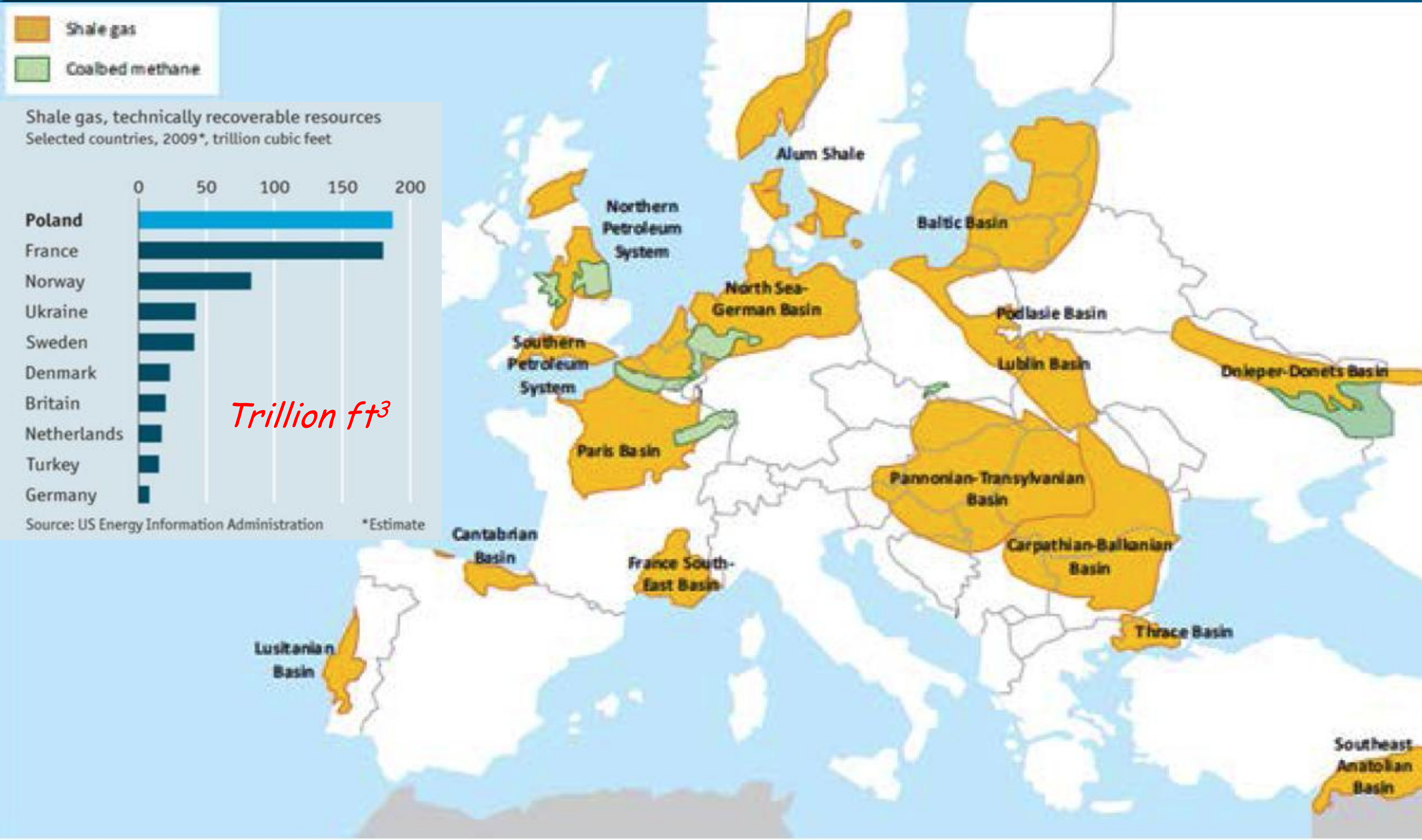
- China has 900 trillion ft^3 of potentially recoverable shale gas – enough to supply the country's needs for nearly 200 years at current levels.
- The goal is to produce 0.25 trillion ft^3 of shale gas annually by 2015 and 2.5 trillion ft^3 annually by 2020, a huge leap from today.

Conversion: $1m^3 = 35.315ft^3$

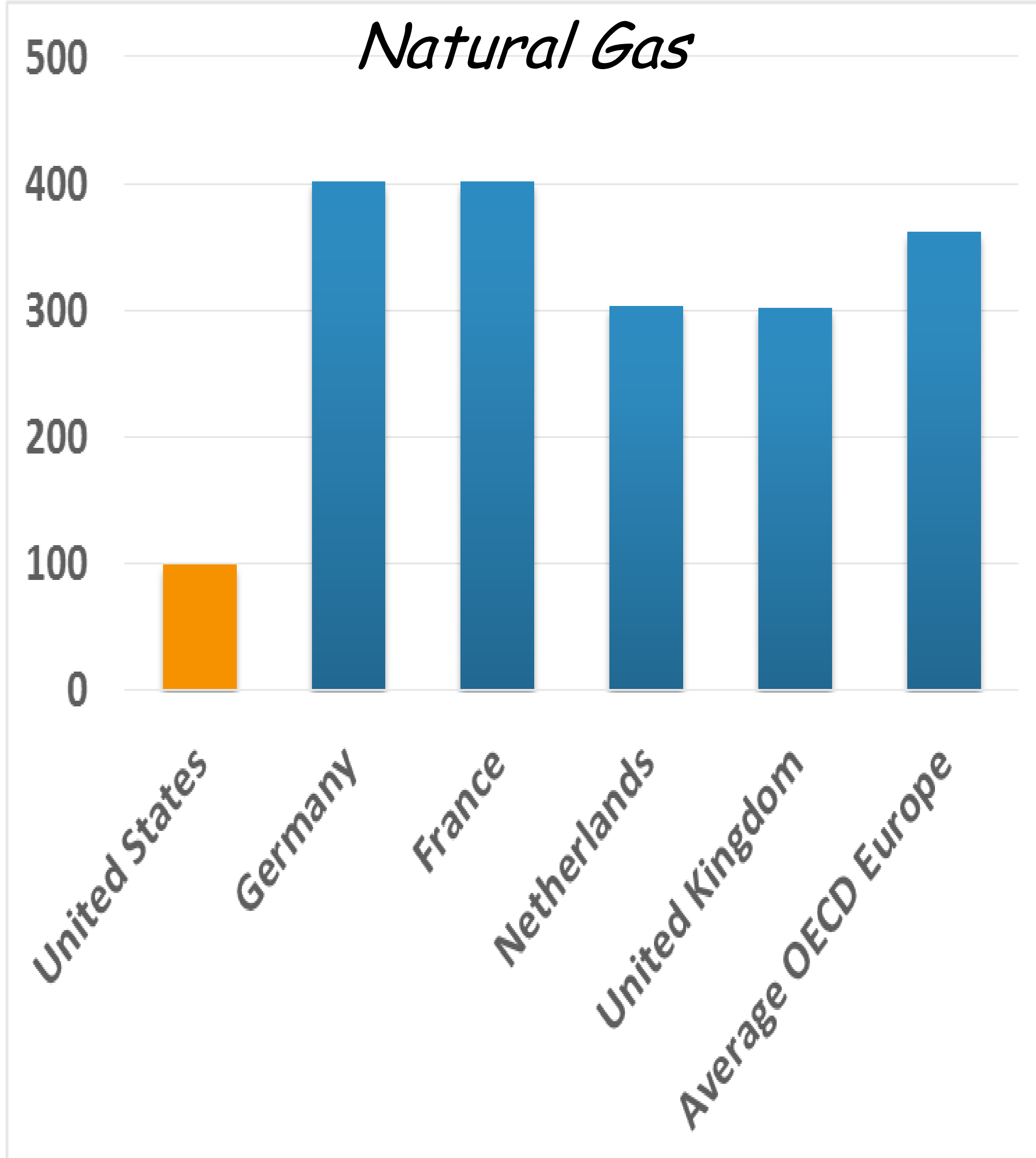



500 km
Companies exploring for shale gas
1 Sinopec
2 PetroChina
3 Shell
4 Chevron
5 Cnooc
6 Henan Coal Seam
Songliao
Junggar
KYRGYZSTAN
XINJIANG
Tu-Ha
MONGOLIA
INNER MONGOLIA
Tarim
Beijing
N. KOREA
S. KOREA
Ordos
Bohai Bay
CHINA
Yellow Sea
Jiangsu
INDIA
TIBET
Anhui
Shanghai
Yangtze
Sichuan
Hubei
Key shale gas basin/region
NEPAL
INDIA
Hunan
Other shale gas basin/region
Guizhou
BANGLADESH
Ganzhou
Yunnan
BURMA
Sources: Wood Mackenzie's China Gas Service; FT research

European resources

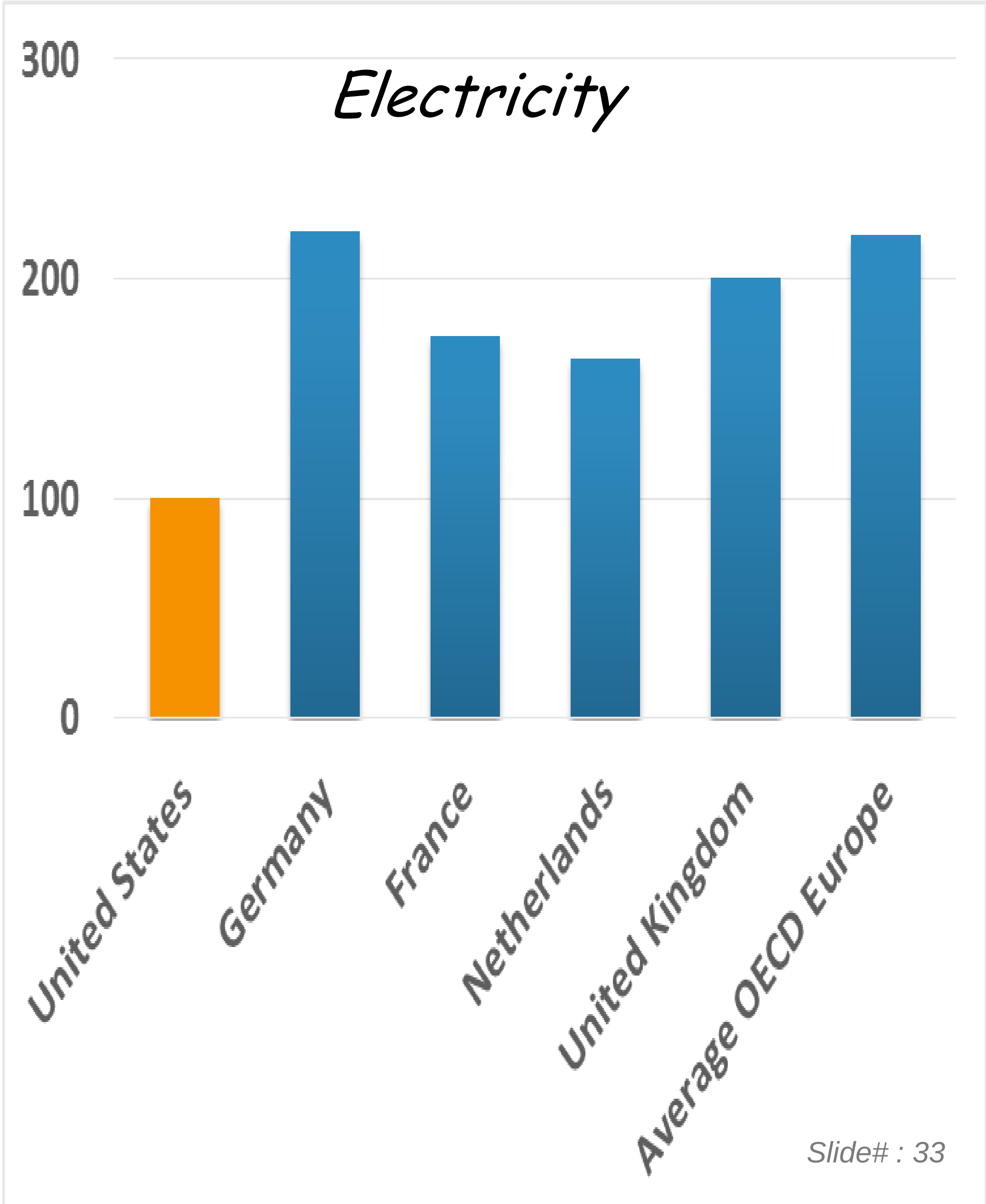


NG for EU industry are more than 3x higher than in the US

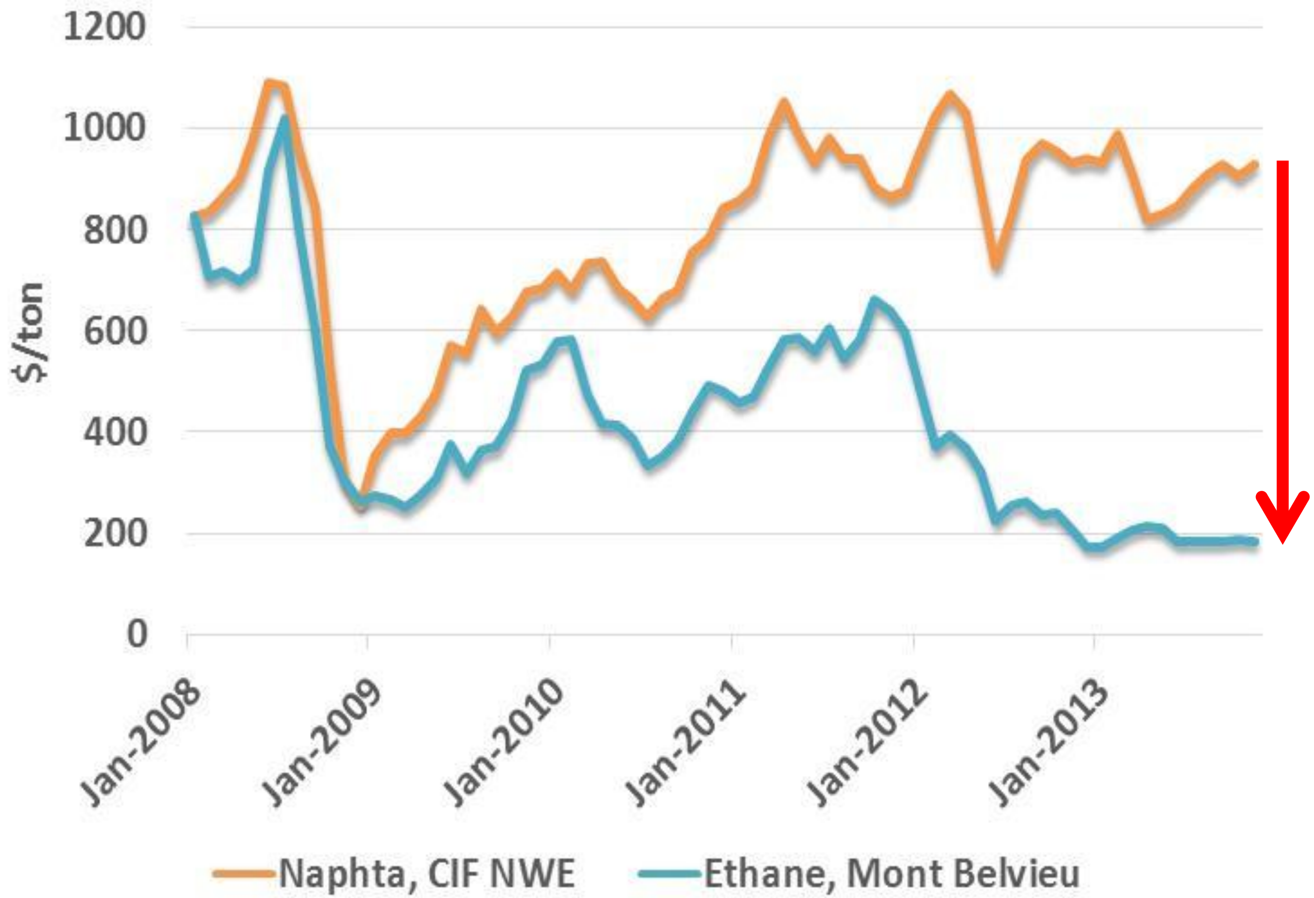


Teatro_Trieste_Popular

EU industry pays twice as much for its electricity



Chemicals

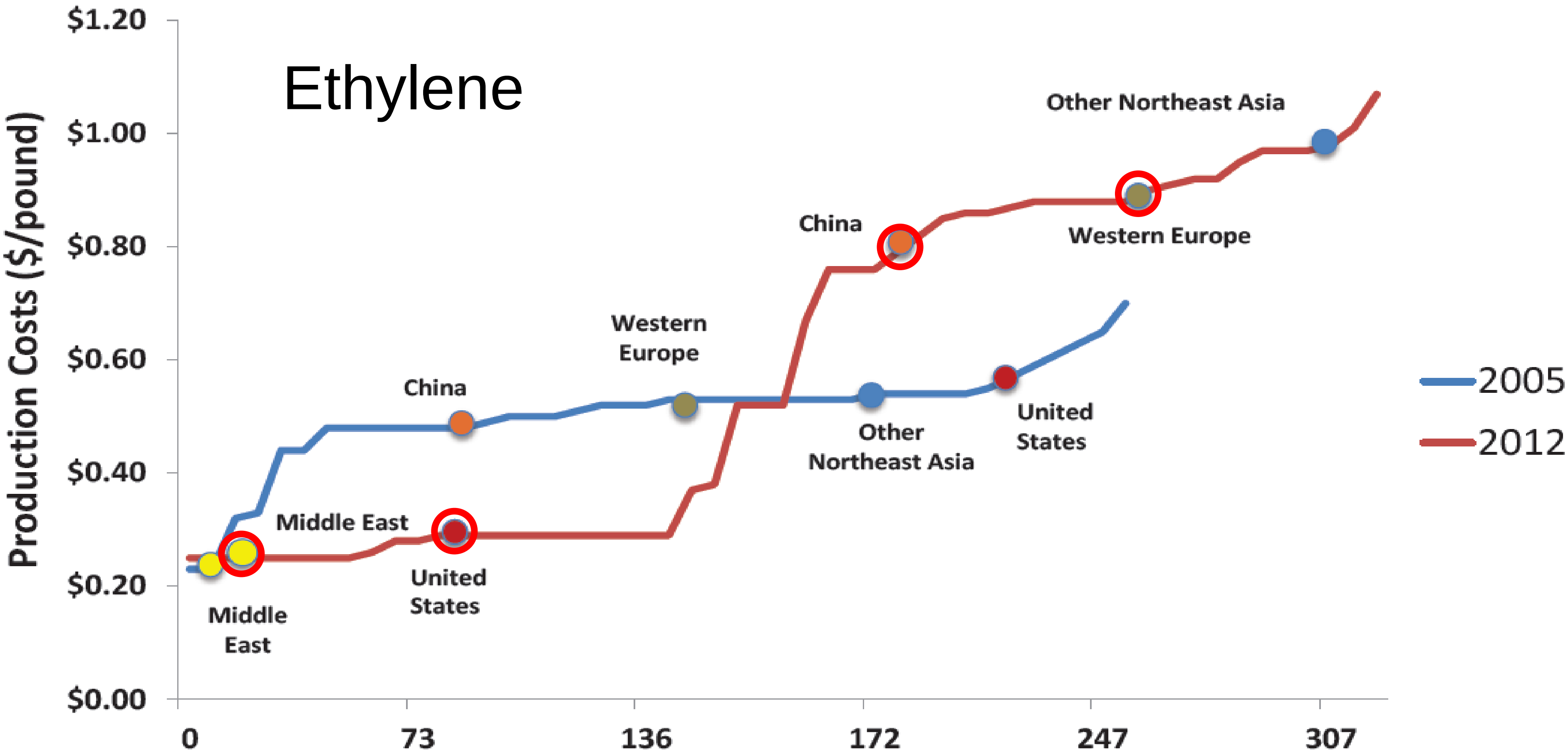


EU prices are four times higher than US ethane

US chemical trade surplus could rise fast :

800 m in 2012
2.7 bn in 2013
46 bn by 2020

Chemical industry boom

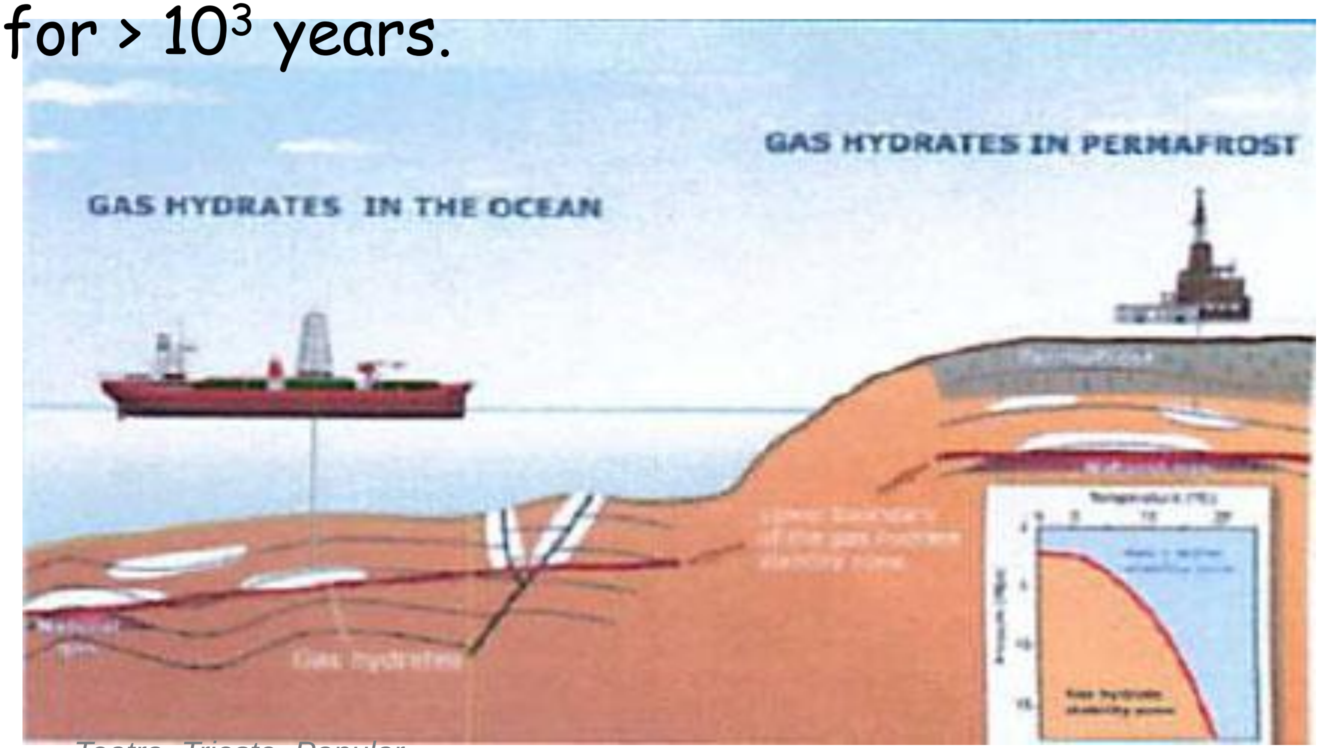


- Renewed US competitiveness: the United States is now a low-cost producer, thanks to shale gas. For instance US ethylene production costs are a third of those in Europe

Clathrates: the largest reserves of hydrocarbons on the crust

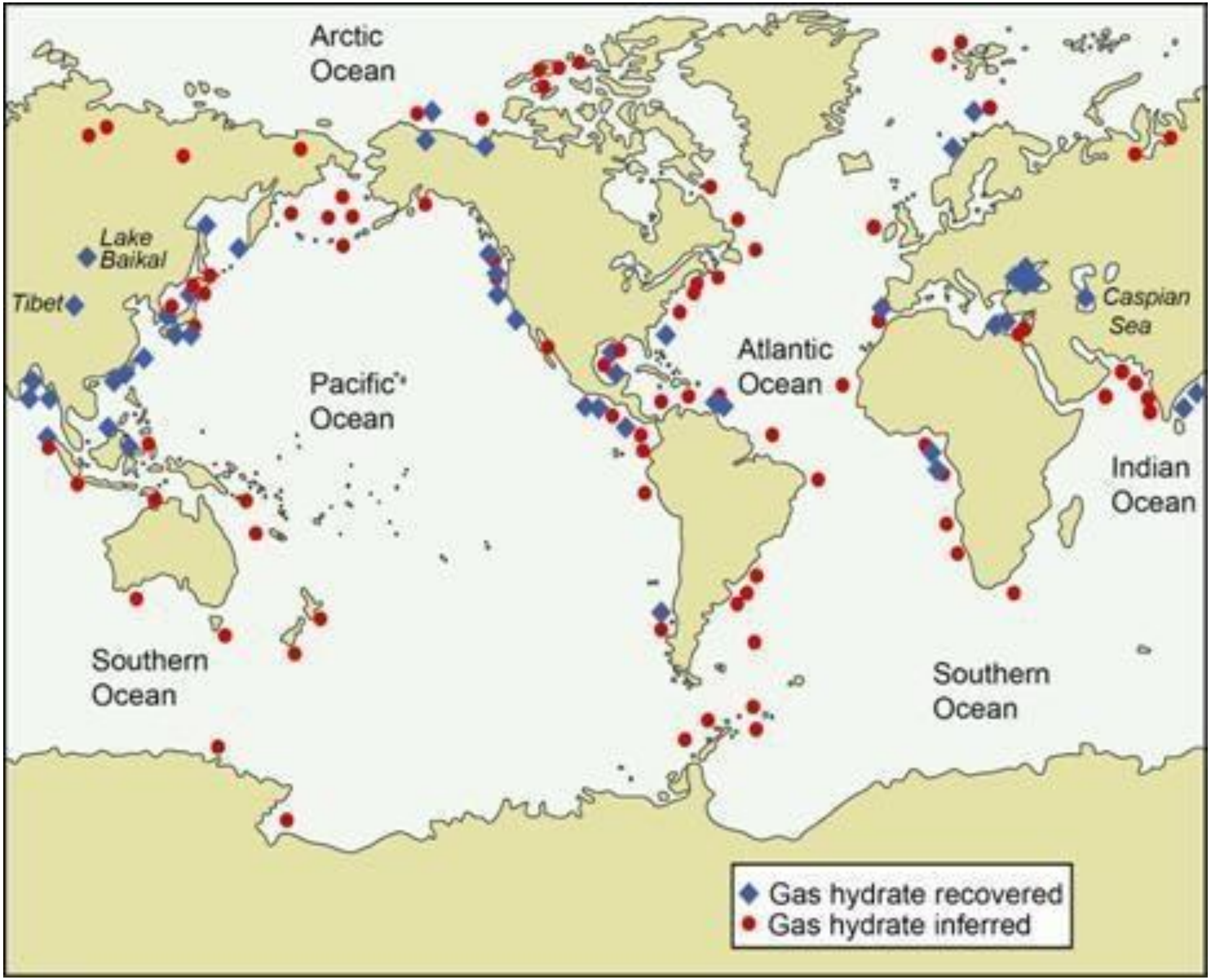
- Methane hydrate is a natural form of clathrate, a chemical substance in which molecules of water form an open solid lattice that encloses, without chemical bonding, appropriately-sized molecules of methane.
- At high pressure methane clathrates remain stable up to 18 ° C. One litre of methane clathrate contains as much as 168 litres of methane gas.

- The US Energy Information Administration estimates that methane hydrates contain more carbon than all other fossil fuels available on Earth combined.
- Methane hydrates are the largest reserve of hydrocarbons in the planetary crust. The methane hydrates in sediment considered part of U.S. territory alone could supply U.S. natural gas needs for > 10^3 years.



Oil ≈ 200 GtC
Coal ≈ 5000 GtC
Clathrates >12000 GtC

The very vast experimental evidence of clathrates



Can we reconcile NG production with global warming ?

- .In order to economically harvest this immense energy wealth it is essential that the effects of a progressive global warming are kept under control, curbing both the emissions of NG (CH_4) and of CO_2.
  - Leaks of NG should be kept under strict control.
  - However the ordinary combustion of NG is inevitably emitting CO_2, although roughly at one half of what compared to Coal.
- The CO_2 production could however be avoided with a alternative decomposition – at sufficiently high temperatures

CH_4 -> $2H_2$+C (hydrogen gas + solid black carbon)

- This promising process is under active investigation.

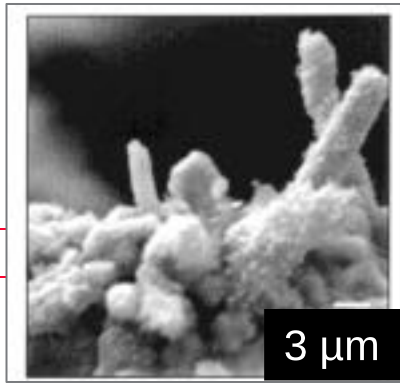
Comparing reforming and pyrolysis of NG for H_2 production

Reforming and CO2 *sequestration*

Spontaneous pyrolisis without CO2 emissions

Item	SRM–Reforming	TDM–Pyrolysis
Reaction chemistry	$CH_4 + 2H_2O = CO_2 + 4H_2$	$CH_4 = C + 2H_2$
Mols H_2 per mol CH_4	4	2
Endothermic Ht of reaction Kcal/mol CH_4	60	18
At 80% Thermal Eff. process heat in Kcal/mol H_2	18.8	11.3
Process Thermal Efficiency for H_2 Production–%	75	58
CO_2 Emission Mols CO_2/mol H_2	0.43	0.0
Lbs CO_2 Gas/MMBTU	155	
Lbs C Solid/MMBTU	0	49
Process Unit Operations	1. Reformer 2. Shift 3. CO_2 separation	1. Pyrolyzer 2. CH_4 Separation if needed
Sequestration % net energy reduction	Liquid CO_2, in ocean, gas wells, aquifers = ∼15%	Solid C, in land fill, mines o market = ∼0%
Net Energy Efficiency %	75–15 = 60% Energy Lost = 40%	58% Energy Stored = 42%
By-product value	Low	High materials potential
Uncertainties	Possible Hazardous Environmental Effects	Minimal
Process development	Well developed	Needs development

Carbon structure



Conclusion: a new age of Abundance

- One of the best available solutions to meet the rising demand in energy lies in the ability to economically develop unconventional gas resources, initially
- (1) *coalbed methane and shale gas* and later the future
- (2) *methane hydrates*.
- North America, India, China, Africa and Latin America will all have access to cheap and abundant shale gas and oil.
- With both environmental sensitivities and gas consumption on the rise, the question is how to recover these huge resources and to economically harvest this immense energy wealth in the most efficient and cost effective matter and with a minimal environmental foot print.

The European Union has to decide between CHEAP and EXPENSIVE energy

"I'm starting to get concerned about global warming."