Are we running out of fossil fuels?

Sustainable Energy

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May 14, 2018

ULg - Applied Sciences

Introduction

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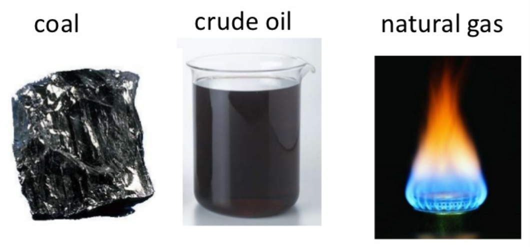
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{heat}$$

Conventional Fossil Fuels



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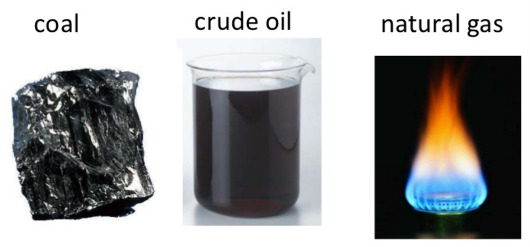

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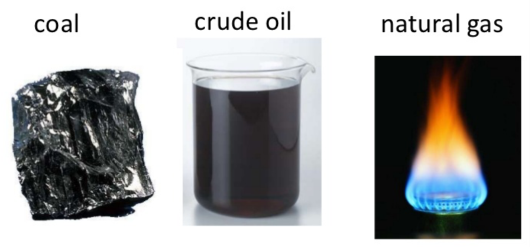

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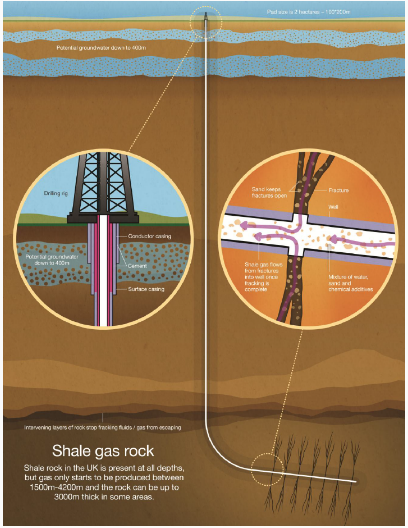
Natural Gas : Found in underground reservoirs of porous rocks (sometimes mixed with petroleum), it consists primarily of methane (CH_4).

Non-Conventional Fossil Fuels



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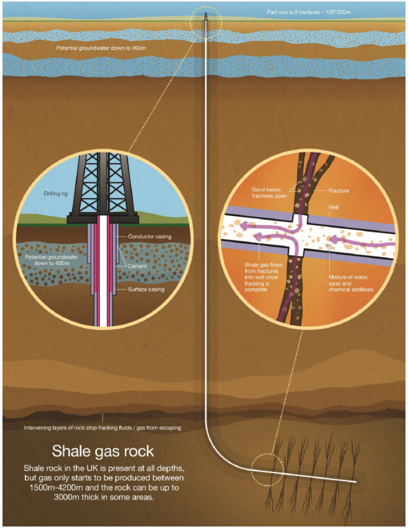

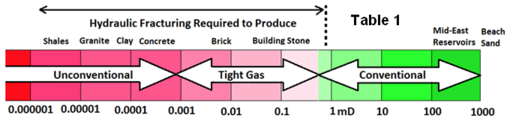

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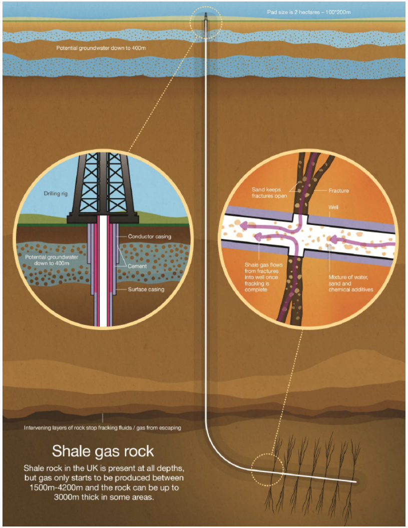

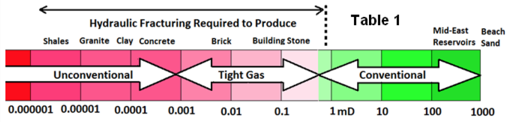

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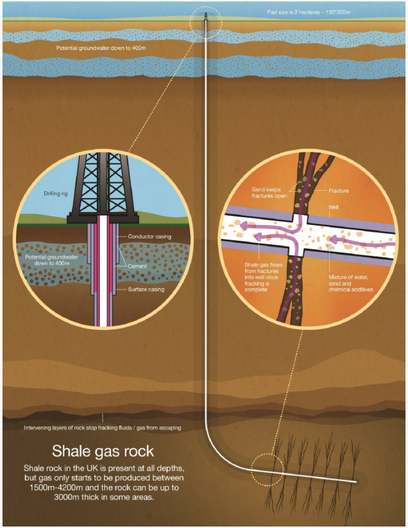

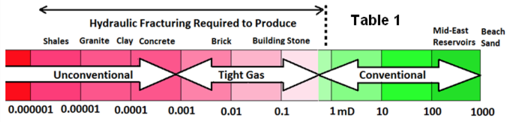

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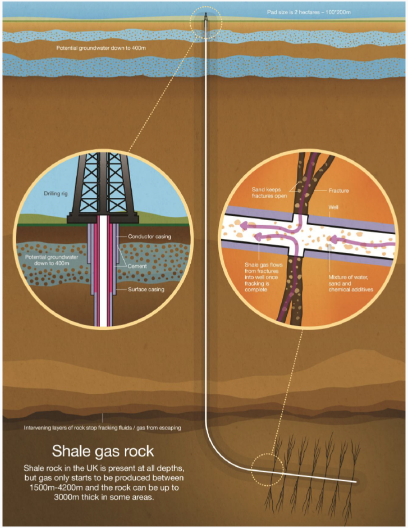

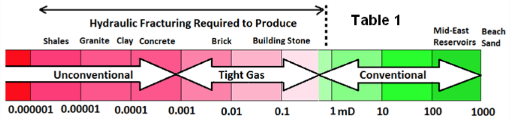

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Tar Sands : a sand impregnated of a viscous hydrocarbon substance (up to 18%) known as *bitumen*.

Why fossil fuels are so attractive ?

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- Designing, testing and validation of new concepts requires 2 to 10 years and permitting, constructing and commissioning a new commercial facility needs 10 years.

While changing the energy sector from fossil fuel to something else is possible, the time needed to make the change makes it difficult to switch rapidly.

Fossil fuels : the resource

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$$dt = -\frac{dQ}{490 \times 10^3} \rightarrow \int_{2010}^{\Delta t + 2010} dt = \int_{Q}^{0} -\frac{dQ}{490 \times 10^3}$$
$$\rightarrow \Delta t = \frac{Q}{490 \times 10^3} = \frac{290 \times 10^6}{490 \times 10^3} = 592 years$$

at actual consumption.

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- After some algebraic steps, we obtain $\Delta t = \frac{\ln\left[m\frac{Q_\infty - Q_{2010}}{\left.\frac{dQ}{dt}\right|_{t=2010}} + 1\right]}{m}$. Taking $m = 2\%$ leads to $\Delta t = 192\,\text{years}$.

Conventional approach to fossil fuel depletion

One possible approach is to consider that, as fossil fuels are exhaustible, they exist in the Earth in a fixed stock.

- → When this stock is used up, it becomes harder to recover whatever fuel from the resource.
- → the recovery cost and the resulting price to consumers will increase.

The conclusions of that reasoning is that the time of *cheap oil* is finished as oil production has already peaked or will be very soon peaked.
Conventional depletion arguments express the temporal history of mineral-fuel production in terms of Hubbert curves.

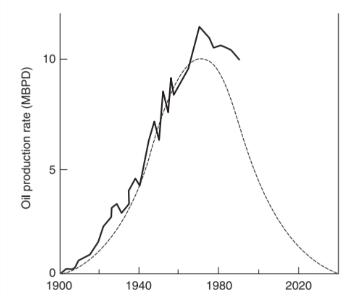


Figure 1 – The Hubbert curve for US crude oil production. The actual production is well above the one predicted by the Hubbert curve.

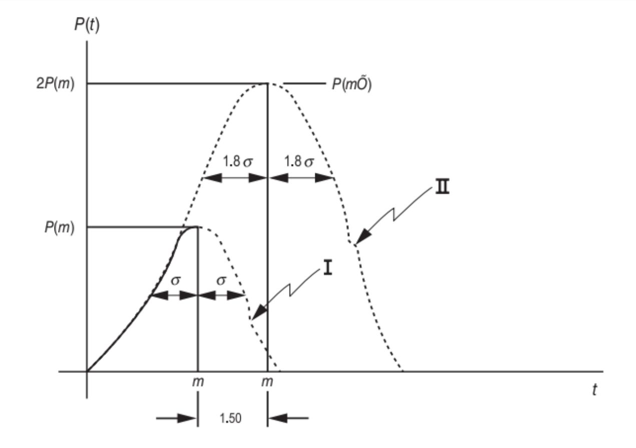


Figure 2 – Two production curves estimated from production data.

Non-conventional approach to fossil fuel depletion

However, **nobody knows when the world will run out of oil or any other fossil fuel**.

Indeed, for a single reservoir, geologists can assess the amount of petroleum available but the petroleum reserves exist in many dispersed regions differing widely in size, quality and production costs.

The classical view of depletion theory does not account for advances in technology that will enable the profitable exploitation of stocks of fuels that previously were unknown or judged unattractive to develop. The history of our knowledge of fossil resources to date favors the latter thinking.

- the last 75 years, the recorded world's petroleum reserves are growing, not declining and the prices (corrected for inflation and taxes) are stable or declining.
- Energy price fluctuation are better explained by political and economic crises than available resources.

How long will fossil fuels last ?

If the incremental cost of production from a given source exceeds the cost of other wells or mines producing fossil fuels the production of that source is suspended.

So far, the technology has won the battle for fossil fuel production...

	1944	1945–1960	1961–1970	1971–1980	1981–1993	Total 1944–1993	Year 2010[b]
OPEC							
Cumulative production	–	26	55	103	100	284	34.3
Gross reserve additions	–	219	251	128	434	1,032	0
Reserves at end	22	215	412	436	770	770	1,068
Non-OPEC							
Cumulative production	–	51	64	102	190	407	34.3
Gross reserve additions	–	98	187	114	207	607	6.1
Reserves at end	29	76	200	212	229	229	188.7
Total World							
Cumulative production	–	77	119	205	289	690	82.1
Gross reserve additions	–	318	439	242	640	1,639	77
Reserves at end	51	291	611	648	999	999	1,382[c]

Figure 3 – World production and cumulative reserves of fossil fuels in bbl (1944-2010).

Oil resource per category

	Conventional resources		Unconventional resources			Total	
	Crude oil	NGLs	EHOB	Kerogen oil	Tight oil	Resources	Proven reserves
OECD	**316**	**99**	**810**	**1 016**	**114**	**2 355**	**250**
Americas	247	54	807	1 000	80	2 187	230
Europe	63	34	3	4	17	121	15
Asia Oceania	6	11	-	12	18	47	4
Non-OECD	**1 923**	**377**	**1 068**	**57**	**230**	**3 655**	**1 449**
E.Europe/Eurasia	342	83	552	20	78	1 074	136
Asia	110	29	3	4	56	202	45
Middle East	968	179	14	30	0	1 190	814
Africa	284	55	2	-	38	379	131
Latin America	219	32	497	3	57	809	323
World	**2 239**	**476**	**1 879**	**1 073**	**344**	**6 010**	**1 699**

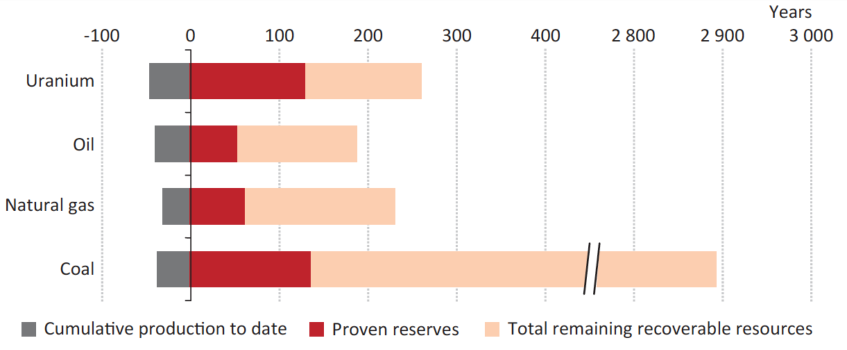
Figure 4 – Oil resources an reserve in 2013 (source IEA) expressed in bbl.

Gas resource per category

	Conventional	Unconventional				Total	
		Tight gas	Shale gas	Coalbed methane	Sub-total	Resources	Proven reserves
E. Europe/Eurasia	143	11	15	20	46	189	73
Middle East	124	9	4	-	13	137	81
Asia-Pacific	43	21	53	21	95	138	19
OECD Americas	46	11	48	7	65	111	13
Africa	52	10	39	0	49	101	17
Latin America	31	15	40	-	55	86	8
OECD Europe	25	4	13	2	19	45	5
World	**465**	**81**	**211**	**50**	**342**	**806**	**216**

Figure 5 – Gas resources an reserve in 2013 (source IEA) expressed in tcm (1 tcm $\simeq$ 6 bbl).

Available resource duration



Sustainibility aspects

Primary energy prices

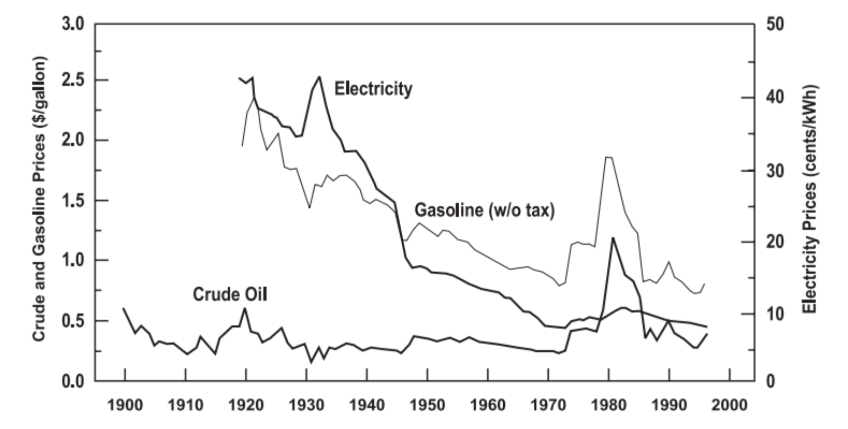


Figure 6 – Energy prices evolution from 1900 to 1996 (without taxes).

The role of non-conventional fossil fuels

Importance of non-conventional fossil fuels

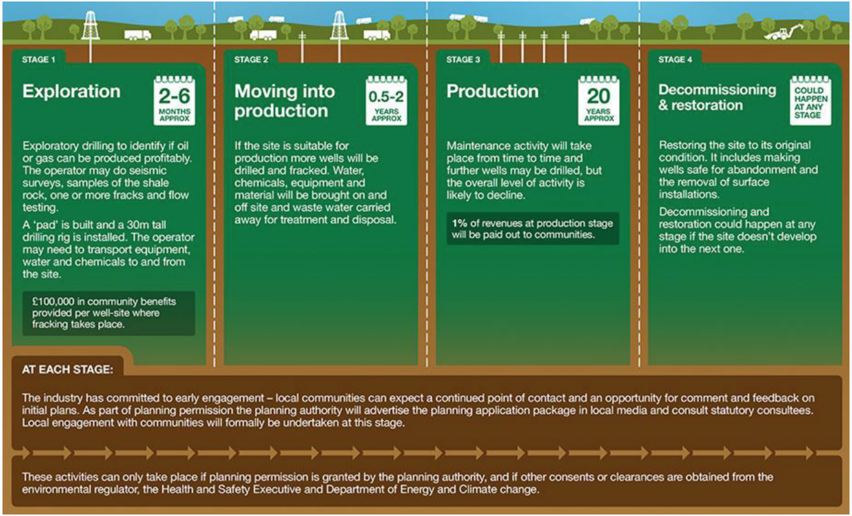
Gas is a relatively clean (high hydrogen content) and flexible fuel (used in gas turbines) that make it an ideal complement to renewable energies BUT :

- Half of the gas consumed in Europe comes from Russia and is still sold on prices indexed on oil price (makes gas more expensive).
- The gas is losing shares with respect to coal (cheaper).
- In countries with high renewable share, the average utilization of gas-fired plant has dropped significantly.

In order for the EU to develop policies some questions need to be addressed :

1. Will fracking be environmentally unsafe and environmentally disruptive ?
2. Will shale gas be as cheap as in the US ?

Shale gas well operation stages

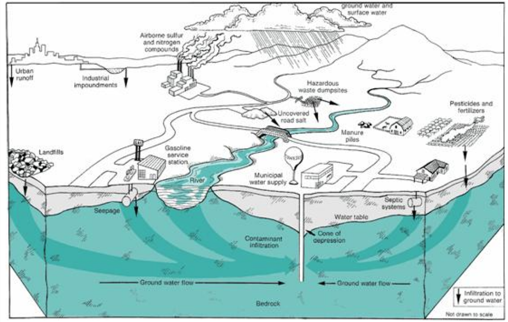


Methane contamination in fresh water wells

Natural source of methane are

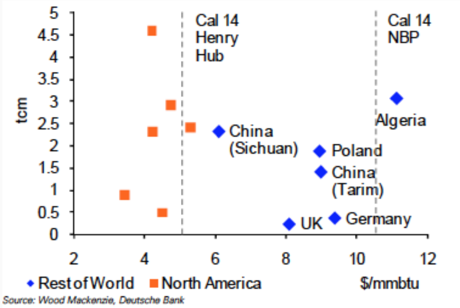
- decaying or digesting vegetation that can come in contact with groundwater and
- methane gas adsorbed onto the organic shallow coal surface that can access ground water.

If water is withdrawn from the well at a rate above the recharge rate, the methane will be absorbed by the well.



The later cause of contamination could be a default in the cement isolation or channel leakage (as for the frac fluid).

Resource of shale gas



Country	Technically Recoverable Shale Gas Resources
China	$36.1 \times 10^{12}\ m^3$
United States	$24.4 \times 10^{12}\ m^3$
Argentina	$21.9 \times 10^{12}\ m^3$
Mexico	$19.3 \times 10^{12}\ m^3$
South Africa	$13.7 \times 10^{12}\ m^3$
Australia	$11.2 \times 10^{12}\ m^3$
Canada	$11.0 \times 10^{12}\ m^3$
Libya	$8.2 \times 10^{12}\ m^3$
Algeria	$6.5 \times 10^{12}\ m^3$
Brazil	$6.4 \times 10^{12}\ m^3$
Poland	$5.3 \times 10^{12}\ m^3$
France	$5.1 \times 10^{12}\ m^3$
Total	$158 \times 10^{12}\ m^3$

Oil and natural gas major net importers

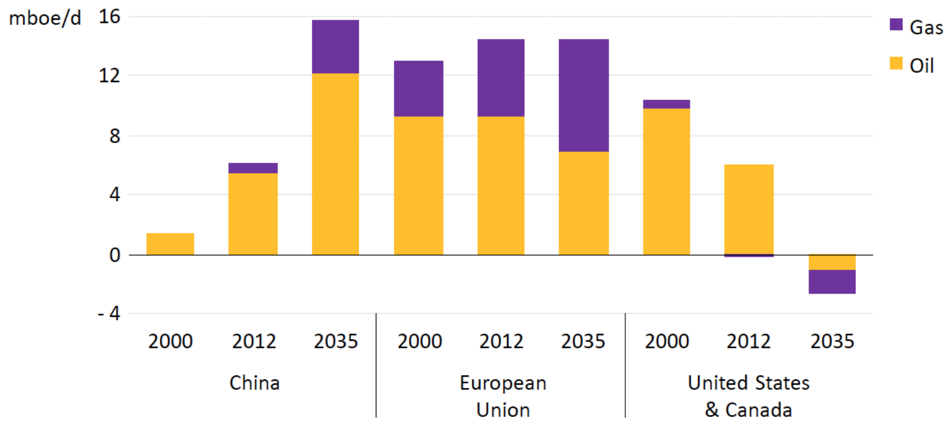


Figure 7 – The new geography of demand and supply means a re-ordering of global energy trade towards Asia

Influence of shale gas on energy prices

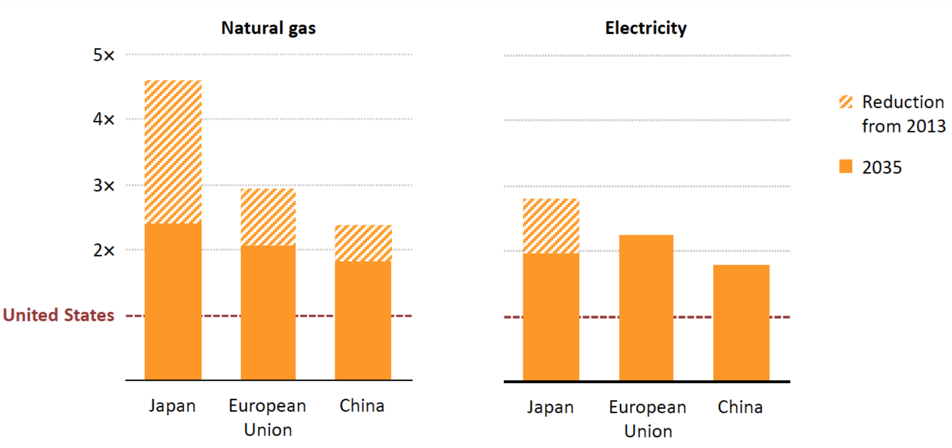


Figure 8 – Ratio of industrial energy prices relative to the United States

Could Europe simply import the cost advantage of cheeper US gas ?

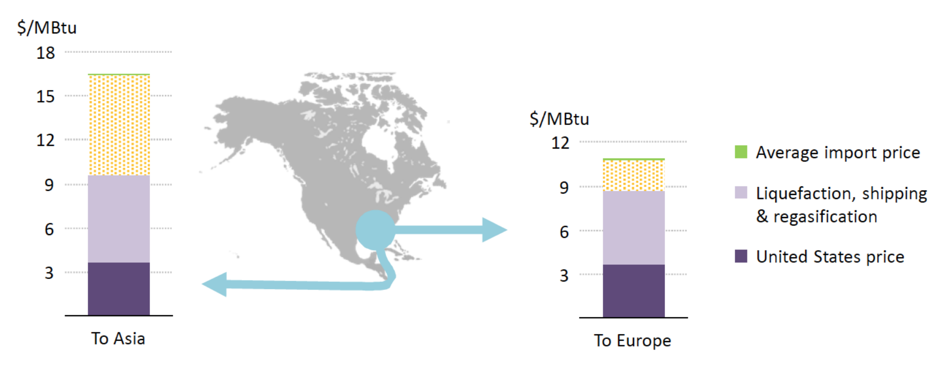


Figure 9 – Indicative economics of LNG export from the US Gulf Coast (at current prices). High costs of transport between regions mean no single global gas price.

Energy prices in the industry

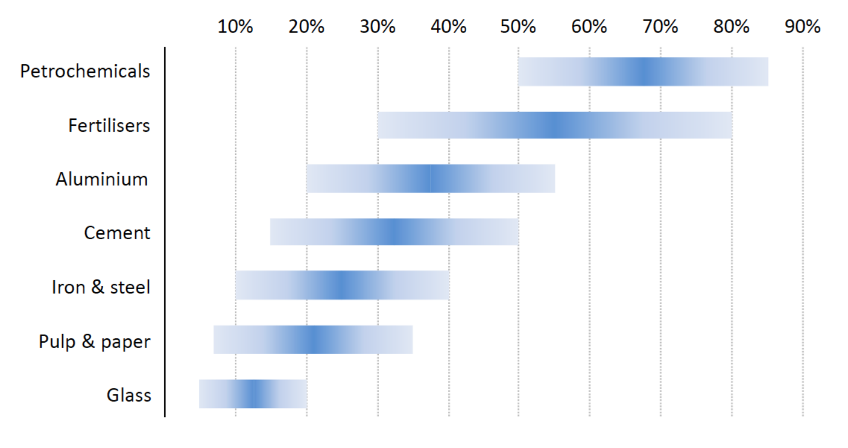


Figure 10 – Share of energy in total production costs for selected industries.

Energy prices and economic growth

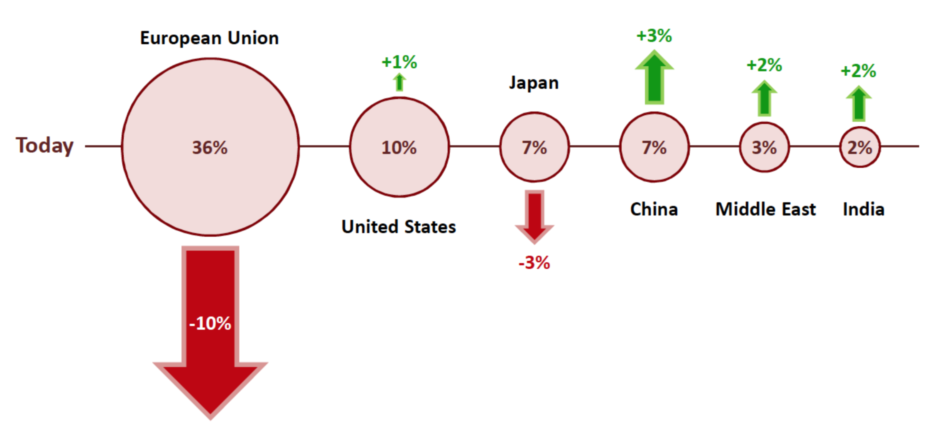


Figure 11 – Share of global export market for energy-intensive goods.

Energy policies critical for Europe's future !

- Stronger action to improve energy efficiency must be central to reconciling energy security, competitiveness and climate goals
- Supporting indigenous sources of energy supply, including renewables, nuclear power and unconventional gas can also help
- Renegotiation of long-term gas import contracts involving a shift away from oil indexation to hub-based pricing could also cut costs

Fossil resource and sustainability

As it is mentioned above, the driving force for sustainability is not that the world is running out of fossil fuels and needs to seek for alternative energy sources. The energy supply from fossil fuels seems guaranteed for the several decades to come.

However, alternatives energy sources do need to be developed for any of the following reasons :

- In case higher levels of global warming predicted from a doubling of current atmospheric concentrations of CO_2 prove to be correct.
- As a way to diversify our energy sources and avoid over reliance on any one source (would it become unavailable for political, environmental, regulatory or technological factors).

In this frame, fossil fuels are able to supply energy as a transition to non fossil alternatives at a pace that will prevent economic disaster.