Fundación Universidad Rey Juan Carlos

Curso de verano

"Tecnologías de captura, almacenamiento y usos del CO_2: Soluciones para afrontar el cambio climático"

Madrid 1 de Julio de 2019

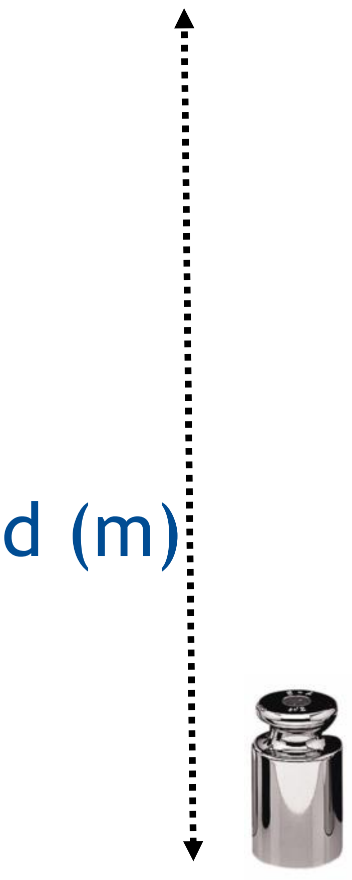
¿Porque las necesitamos?

Samuel Furfari

Trabajo ≡ energia

$W = \vec{F} \times \vec{d}$ $\quad$ $W = \int \vec{F} \cdot \overrightarrow{du}$

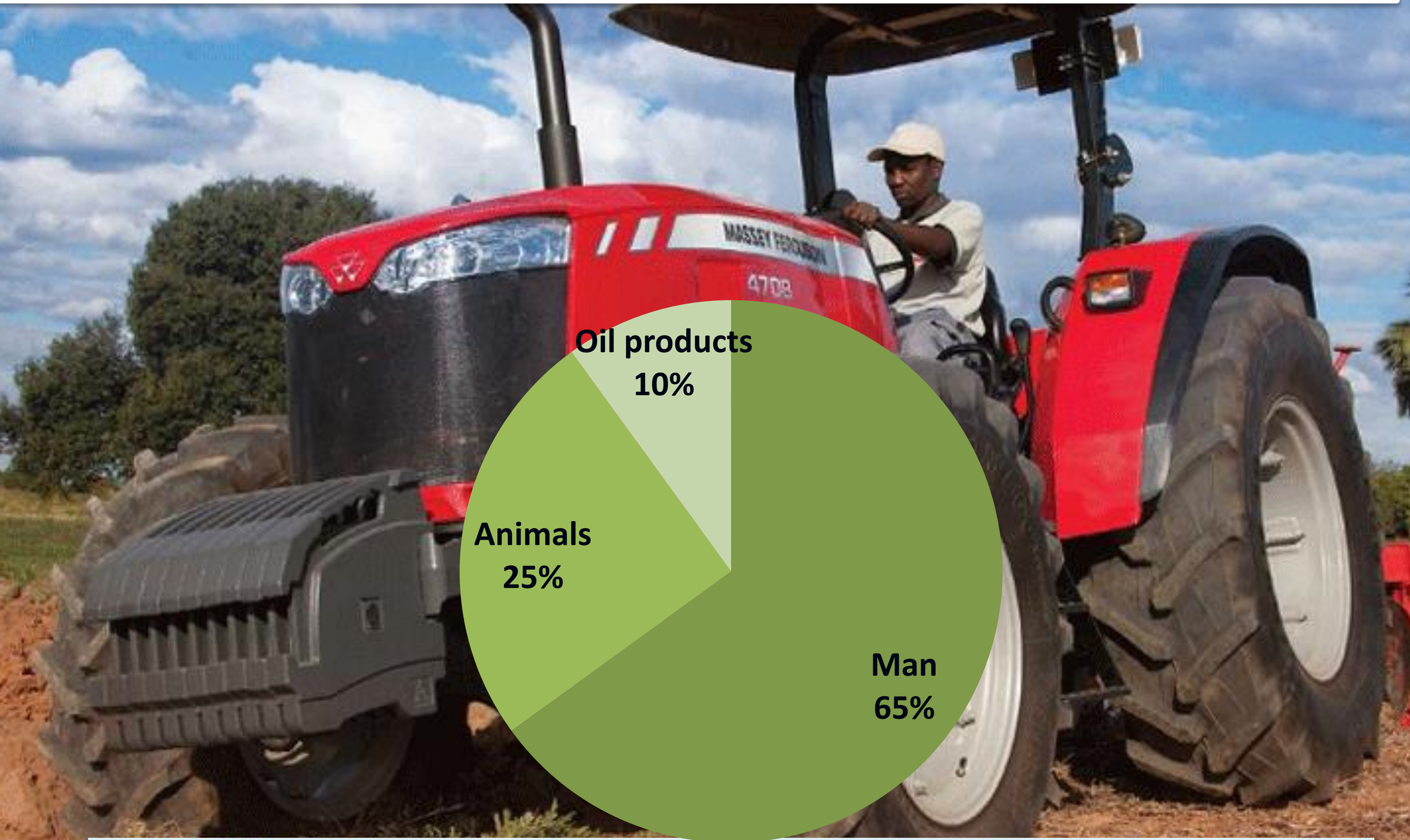
[1 Joule = 1 Newton x 1 metro]



Trabajo en termodinámica

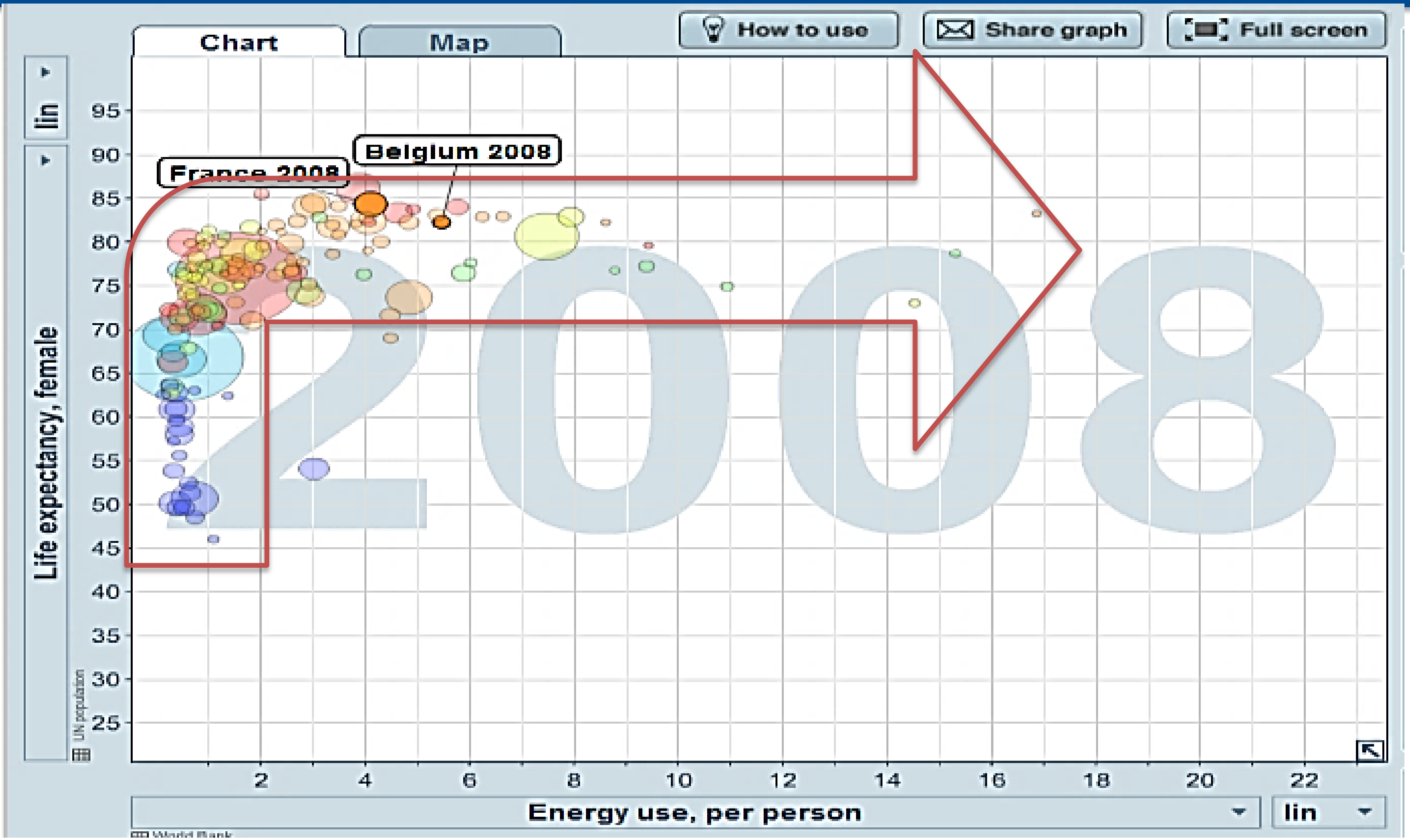
$$W_{12} = \int_{V_1}^{V_2} p \, \mathrm{d}V$$

30 millones x 100 x 7,36 - 22 mil millones



Claude Stéphane SIDE et Michel HAVARD, DEVELOPPER DURABLEMENT LA MECANISATION POUR AMELIORER LA PRODUCTIVITE DE L'AGRICULTURE FAMILIALE EN AFRIQUE SUBSAHARIENNE, INTERNATIONAL JOURNAL OF ADVANCED STUDIES AND RESEARCH IN AFRICA, https://agritrop.cirad.fr/577133/1/Side%20Havard%20int%20J.%20Advance%20Studies%202015%20mecanisation%20agricole.pdf

Energía para una vida mejor y larga



40% de la población mundial (2,7 mil millones) depende de la biomasa tradicional

Photo: O. Furfari

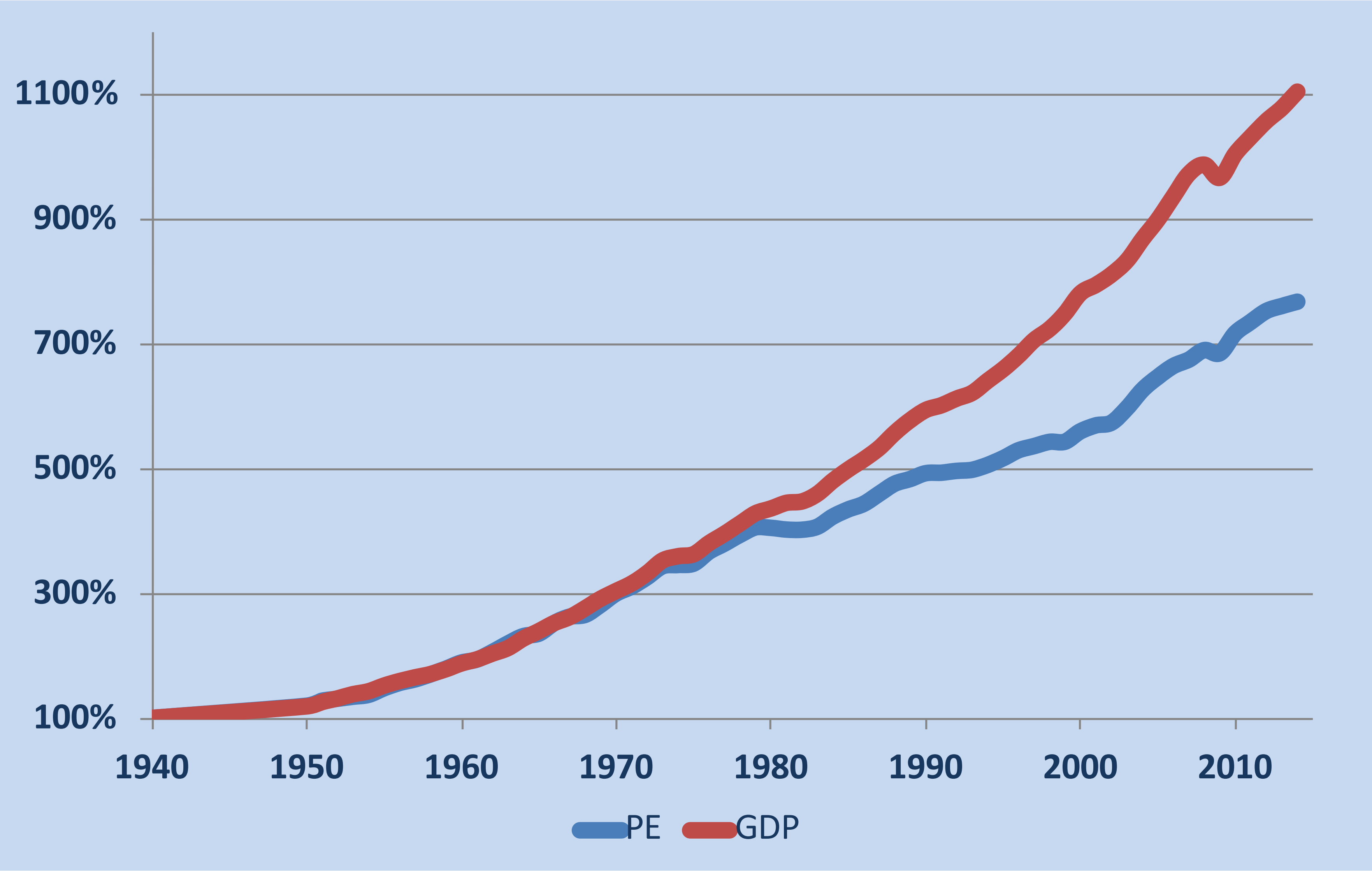
1,2 mil millones no tienen acceso a la electricidad

Photo: O. Furfari

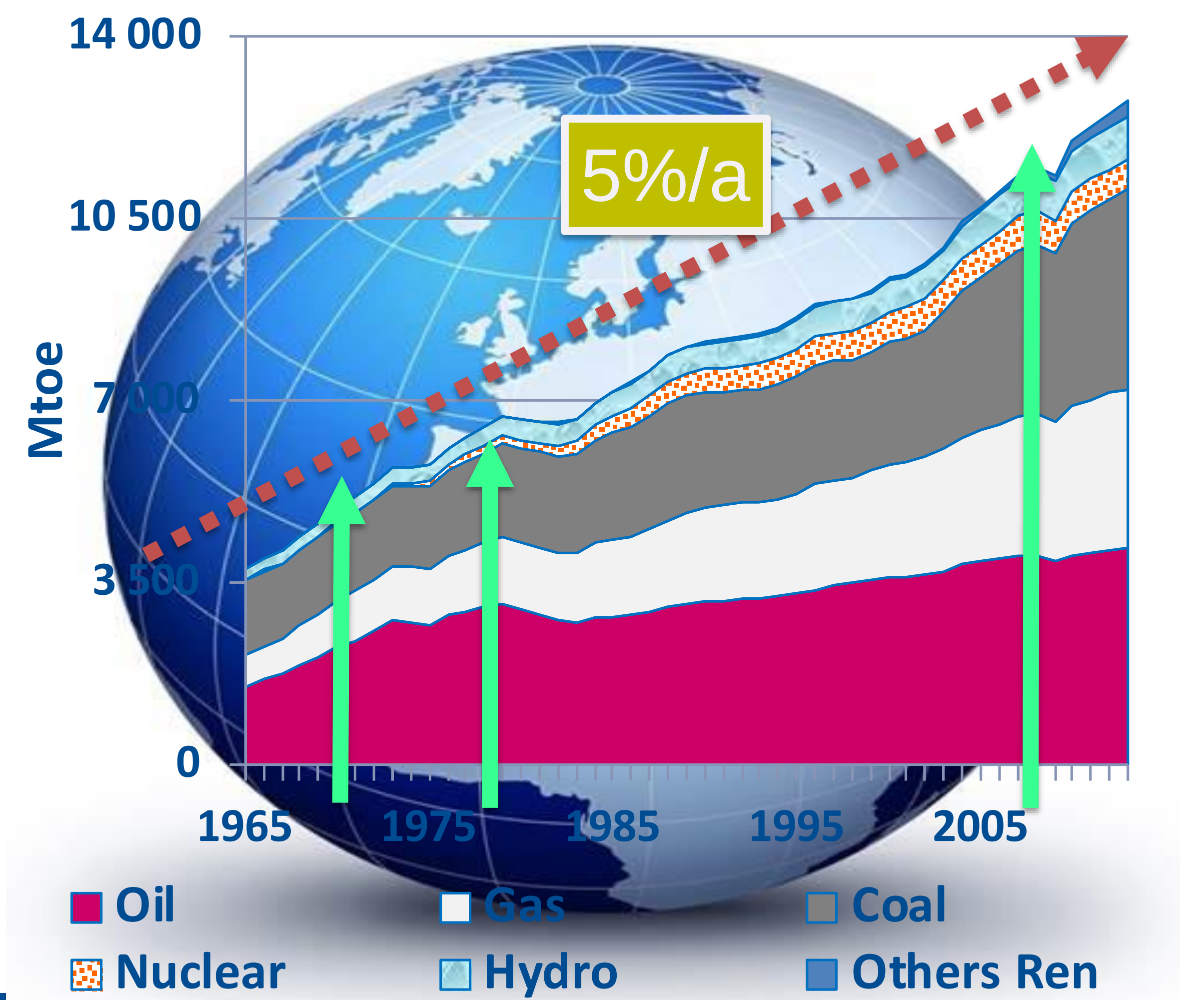
ULB ECOLE POLYTECHNIQUE D

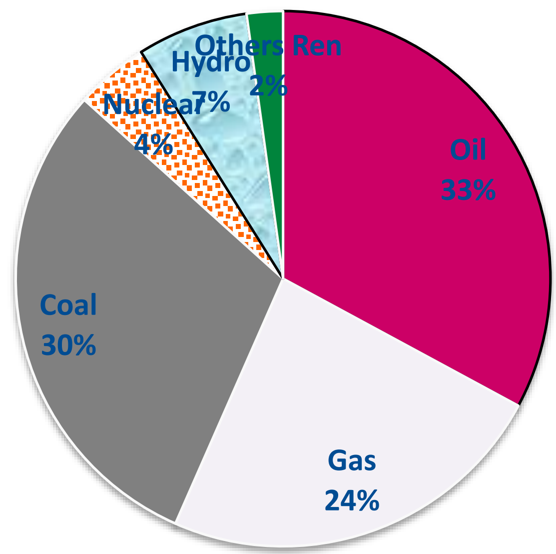
1,0 + 0,4 billion ⬆
+ 8%/a GDP
⇧ energy +3,9% 2007-2017
⇧ Electricity +7,2% 2007-2017

Demanda de energia y pil

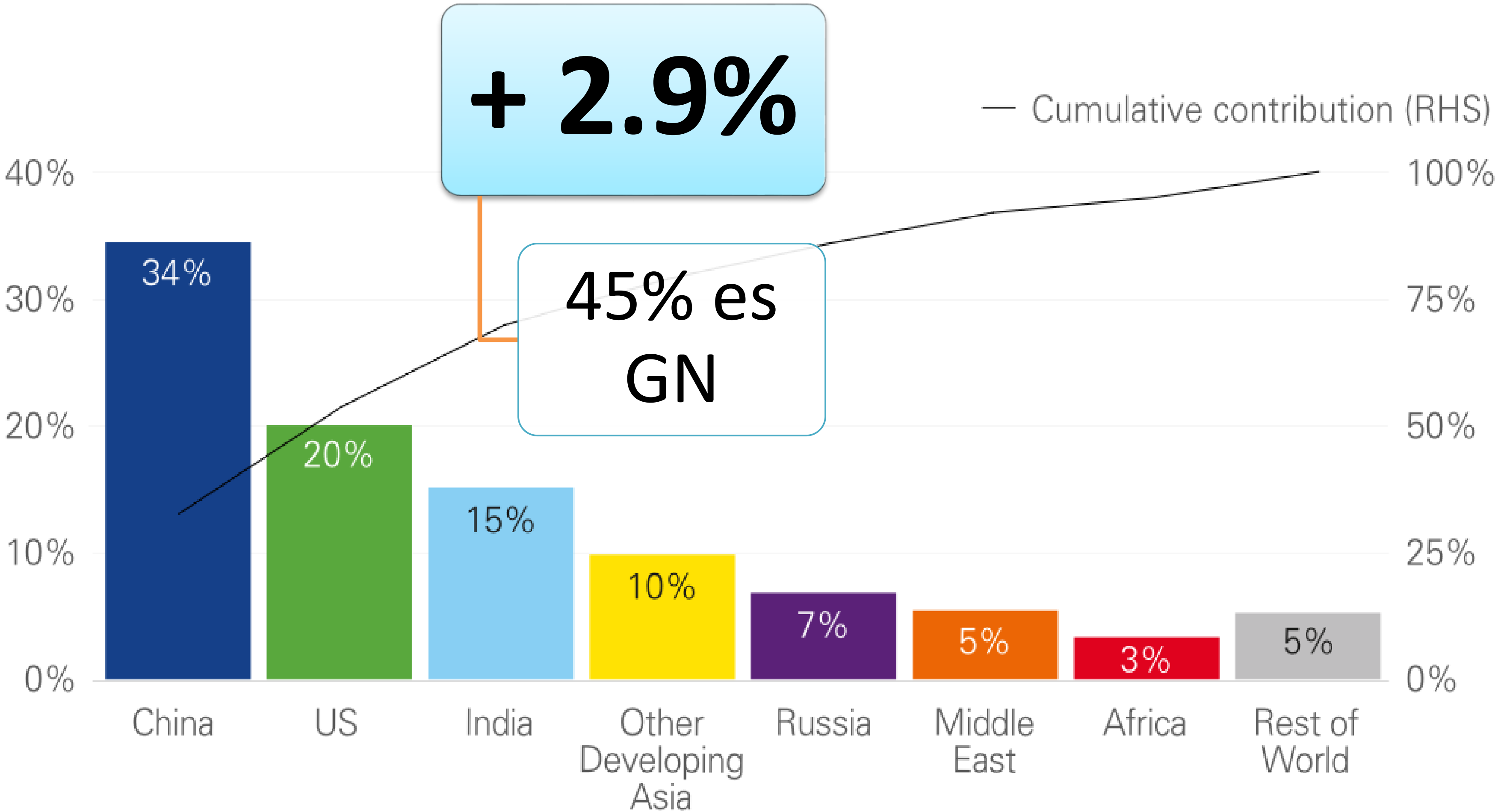


World energy consumption is growing linearly

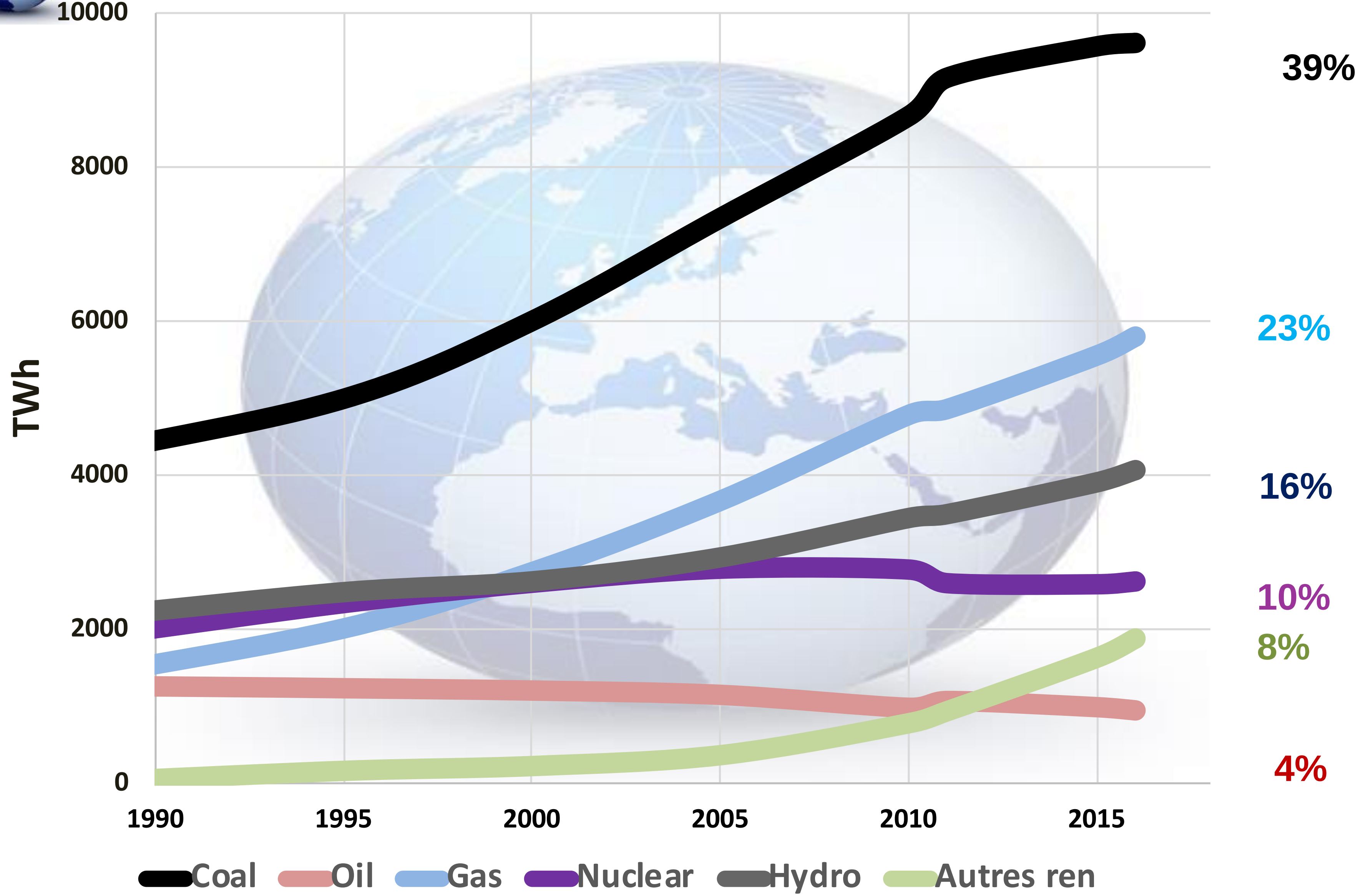




Contribución al crecimiento de la energía primaria en 2018

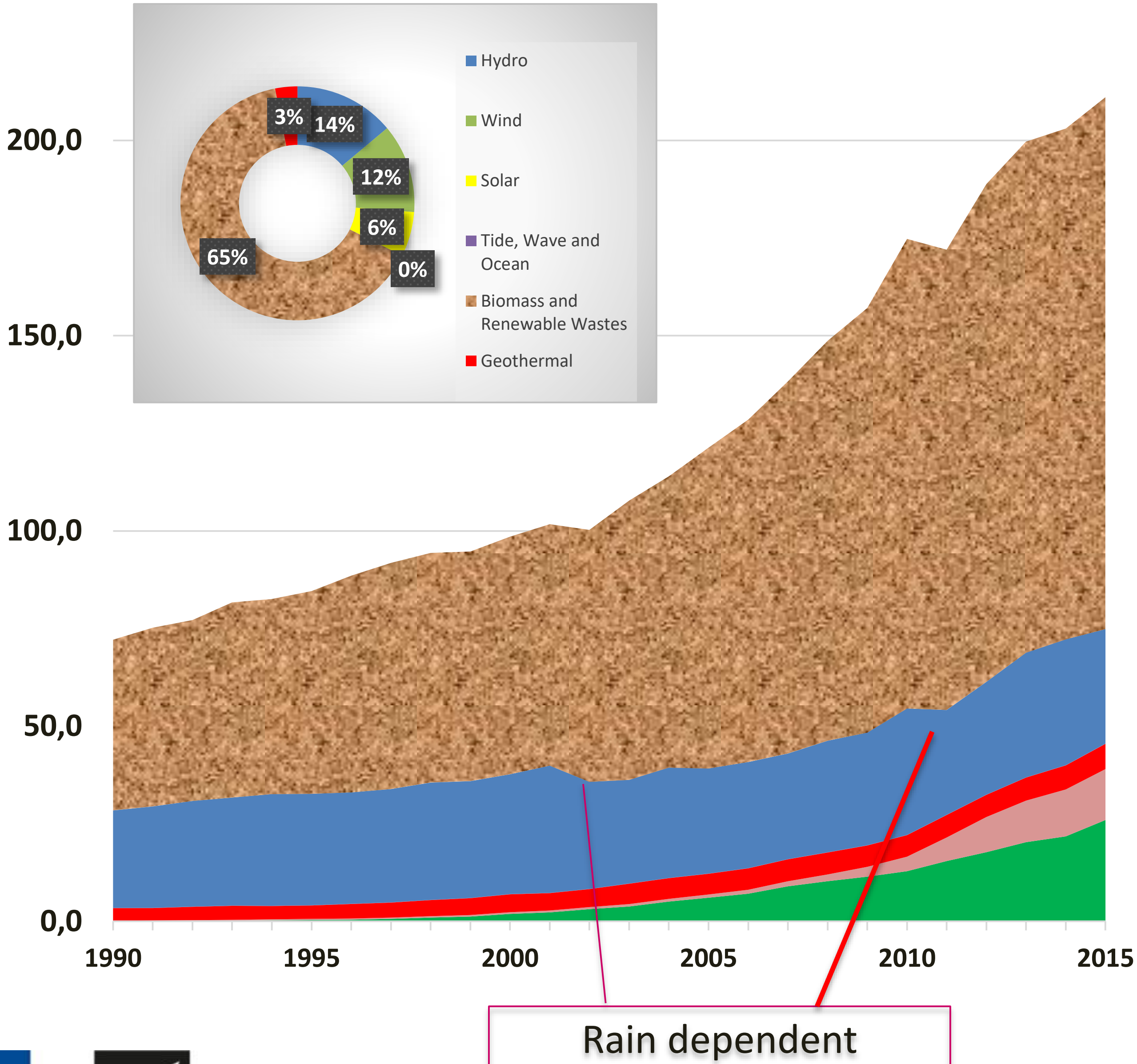


Generación eléctrica mundial por tipo de combustible



Data : Energy Pocket Book (EC, 2018)

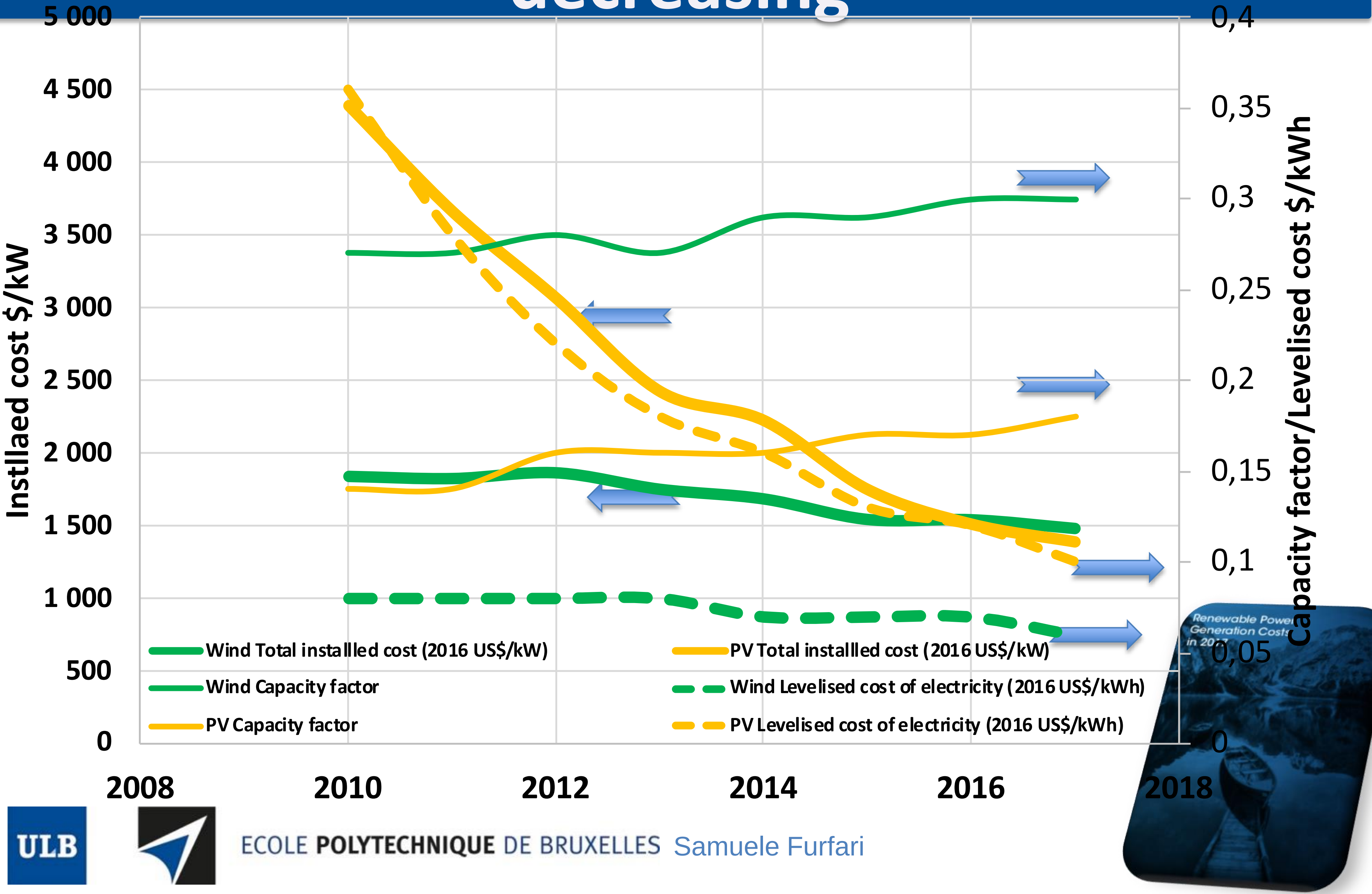
Development of REN in the EU



13 % Primary energy	
Biomass and Renewable Wastes	8.4%
Hydro	1.8%
Tide, Wave and Ocean	0.0%
Geothermal	0.4%
Solar	0.8%
Wind	1.6%

V1 Fig 11-2

Investments and production costs are decreasing



The challenge of the European Union load factor

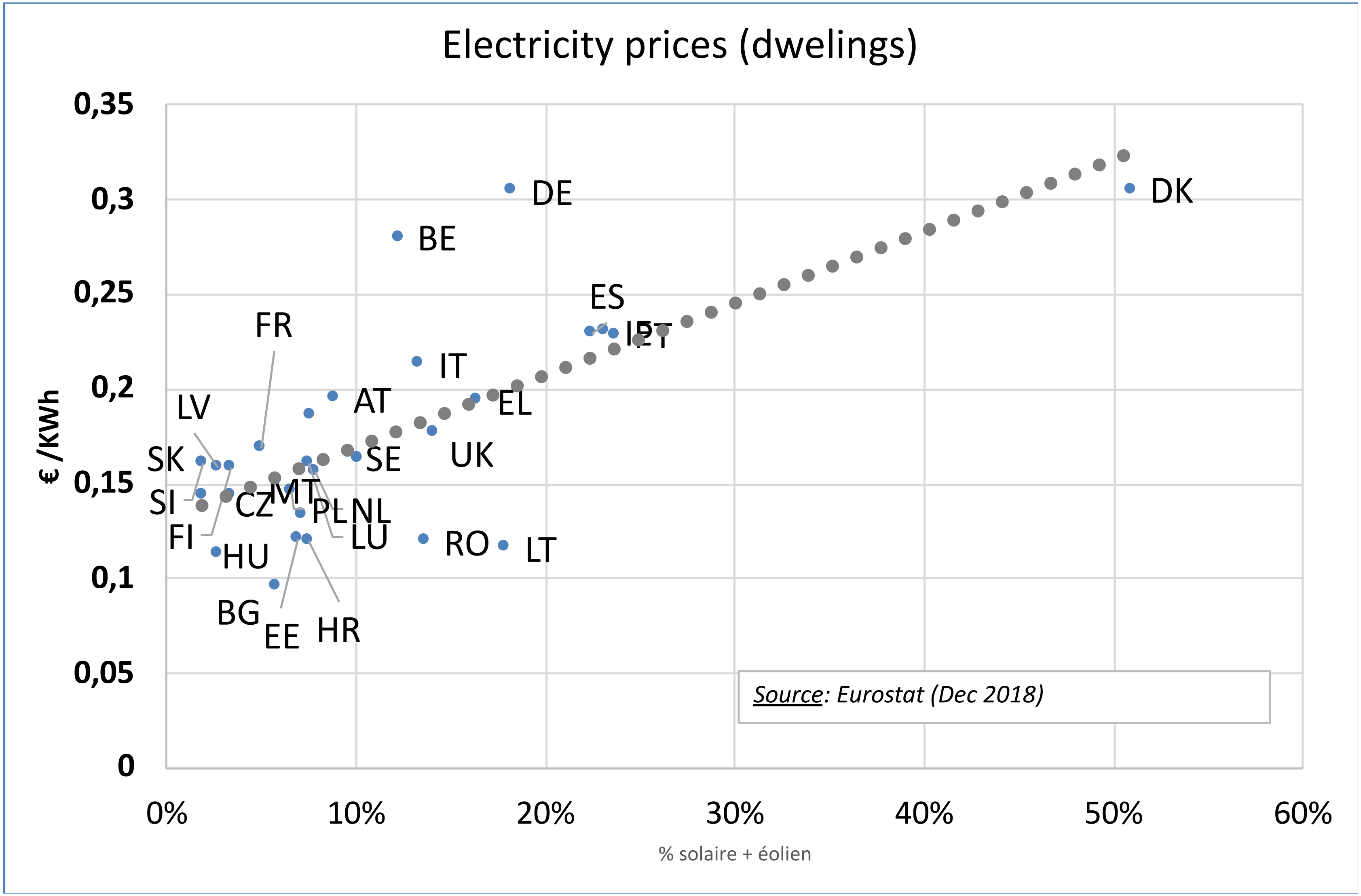
	Wind	Solar PV
Production (TWh)	302,9	110,8
Installed capacity (MW)	154 325	100 812
Operating hours (TWh/MW)	1 963	1 099
Load factor (% hours in a year)	23%	11%

Data for European Union, Eurostat August 2018 for 2017

"renewables are intermittent and if they are to become a major contributor to the more efficient energy mix we need to have a cost-effective remedy to their intermittency. This means that the problem of electricity storage on a massive scale must be solved. Otherwise, wind and solar will require alongside deployment of auxiliary power generation, e.g., natural gas or diesel. Unfortunately, the majority of battery research is focused on variations to existing lithium-ion technology which is far too costly for stationary storage applications. We need to think about this problem differently if we are to succeed. That means a complete break with the past and invention of something much more radical than what we know today. That defeats the sustainability of the operation. A breakthrough is not the integral of an infinity of incremental improvements. A breakthrough is a departure from the present routine. Axiomatically a breakthrough is high-risk and unpredictable."

Source: Personnal communication (Smart Cities, Barcelona), Nov 2014

… but more expensive electricity

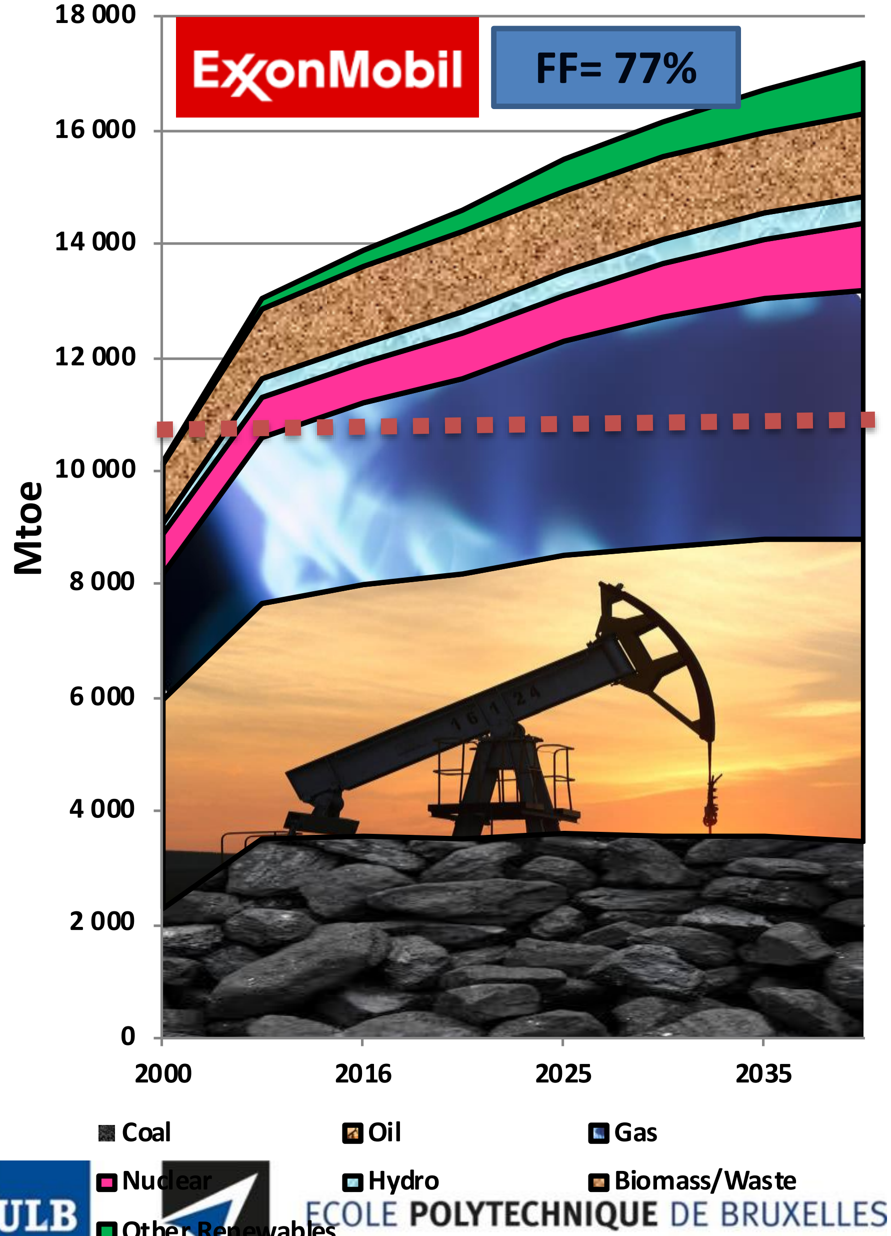


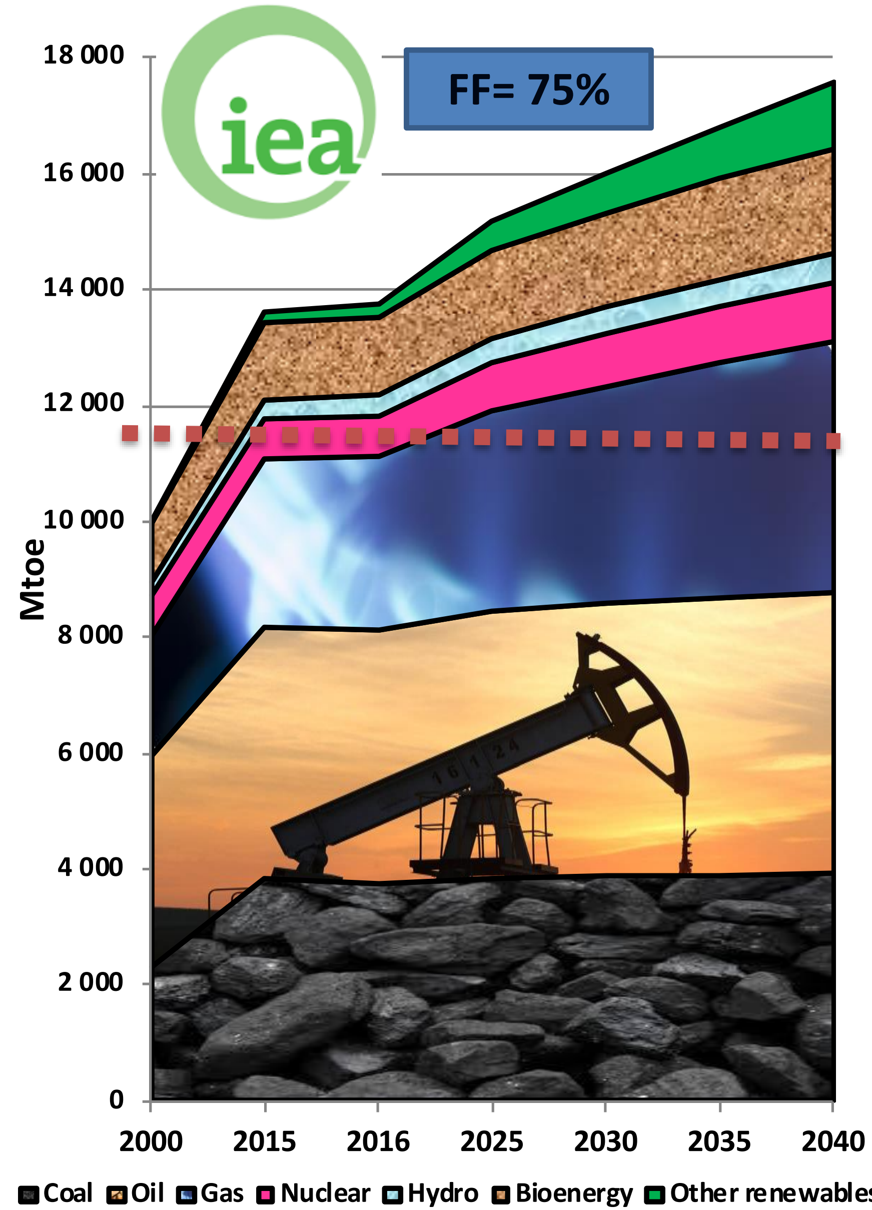
First Lesson of Energy Geopolitics

100	100	100	100
-16	-20	-32	-25
84	80	68	75

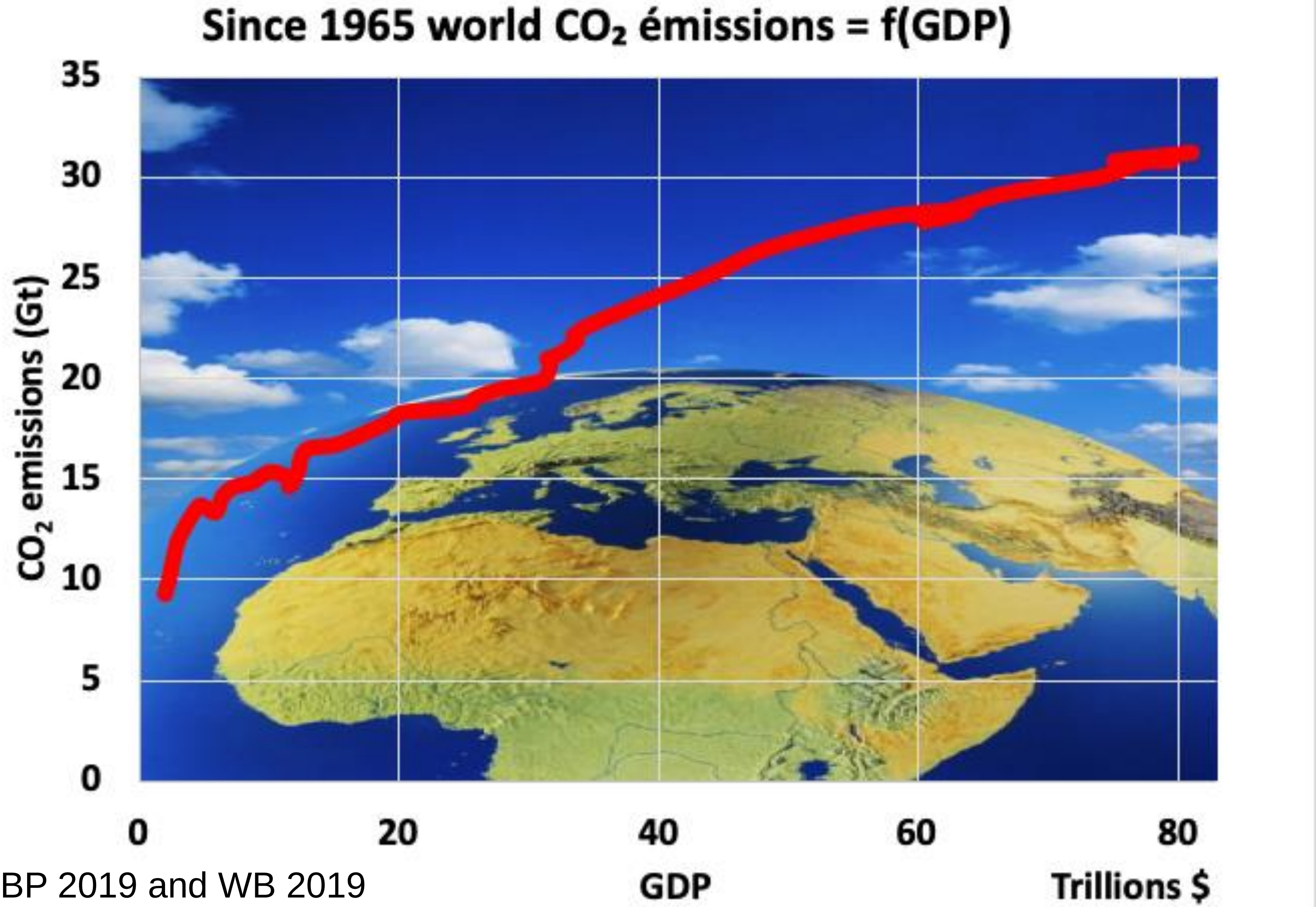
Samuele Furfari

Total energy demand forecasts



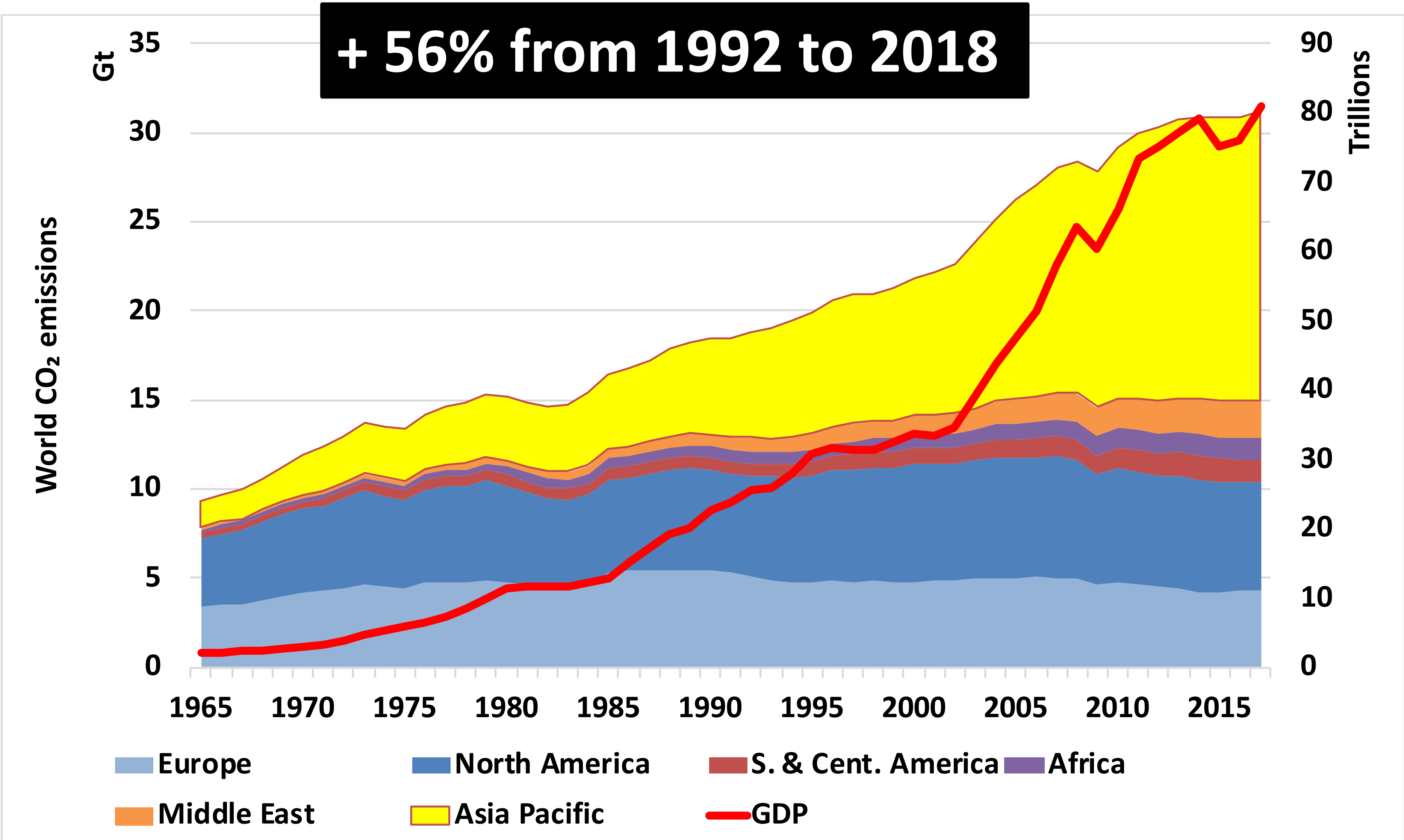


Since 1965 world CO_2 émissions = f(GDP)



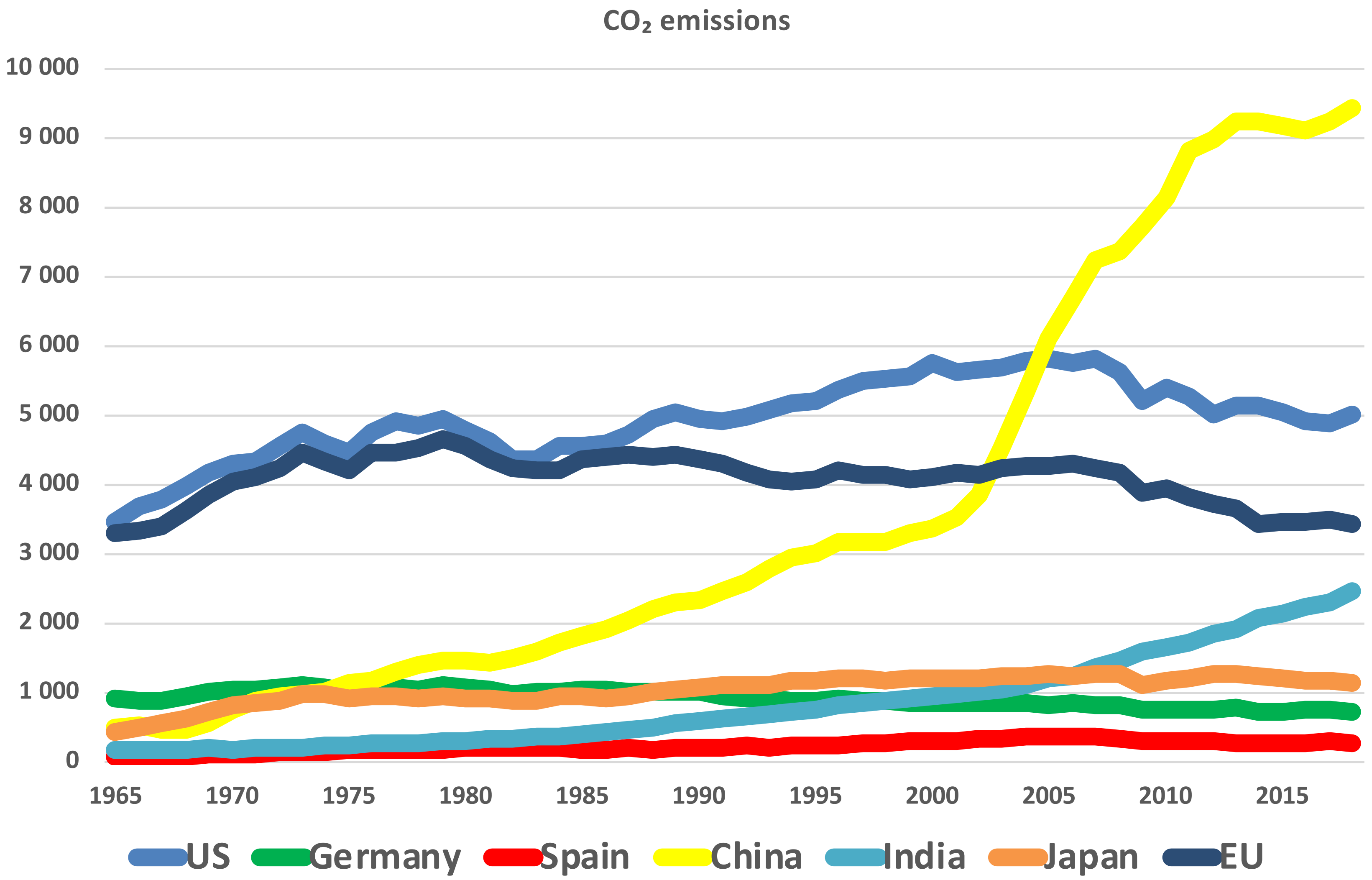
Data: BP 2019 and WB 2019

CO_2 emissions since 1965

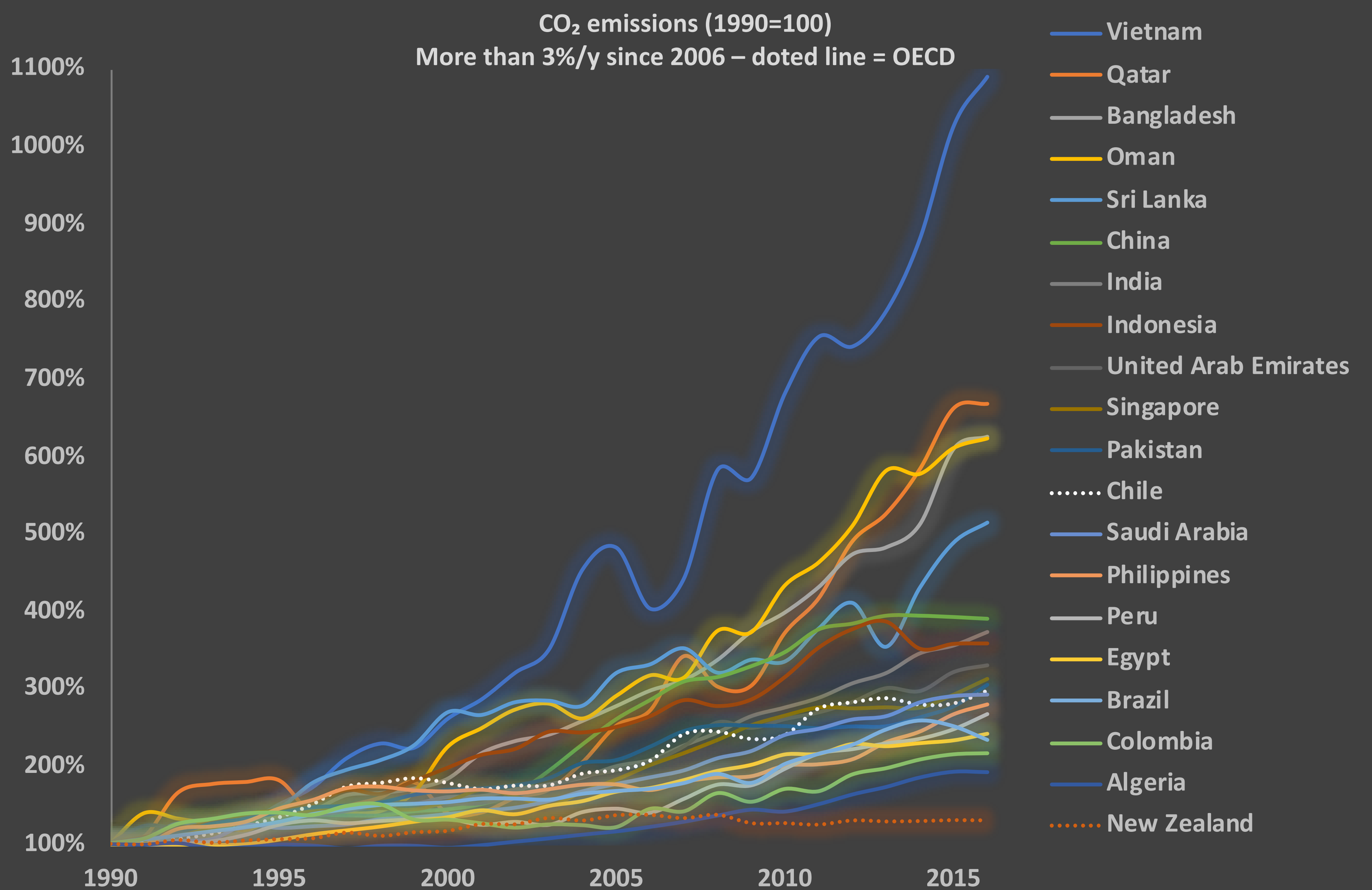


Data: BP 2019 and WB 2019

Evolution of CO_2 emissions of main emitters

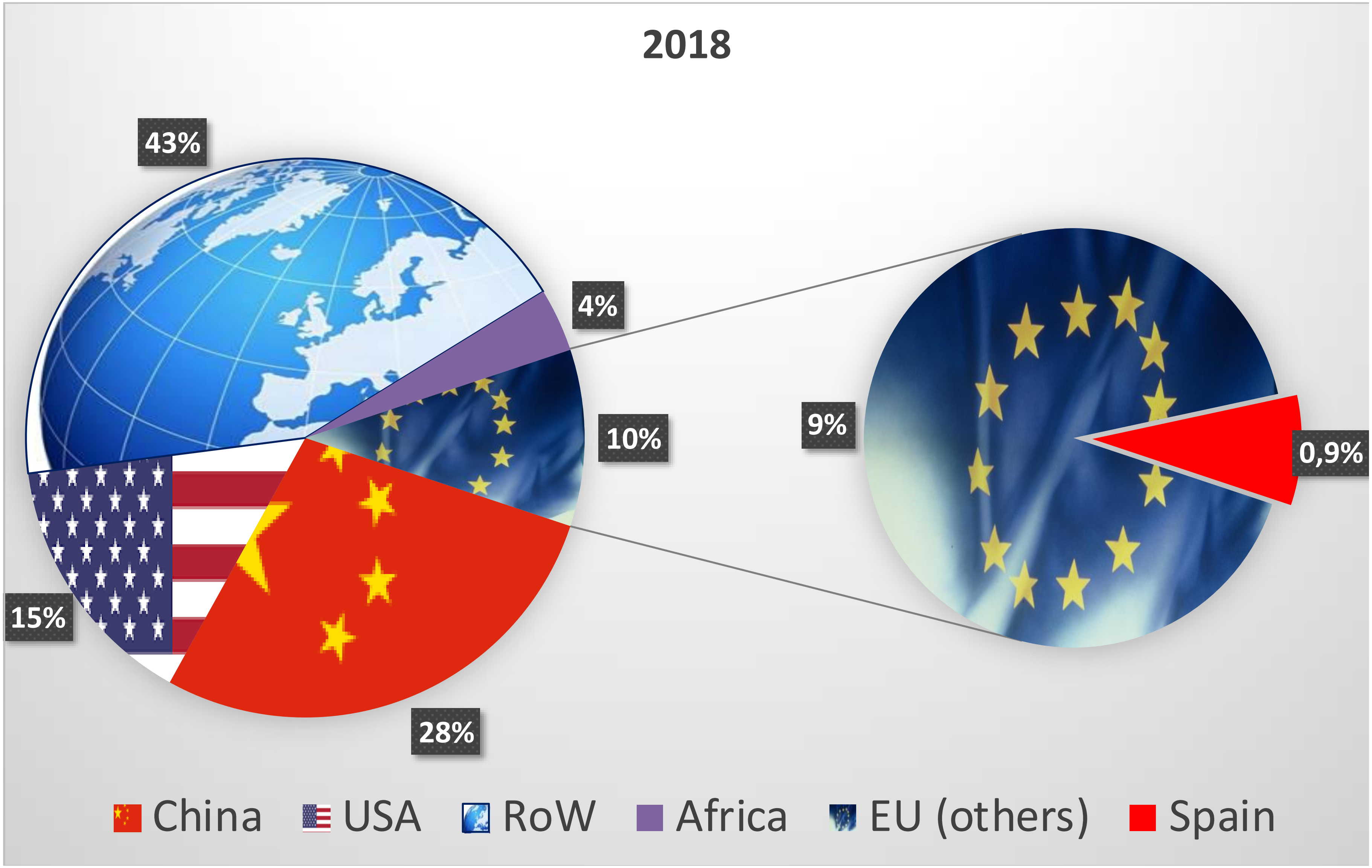


Who grows up ?

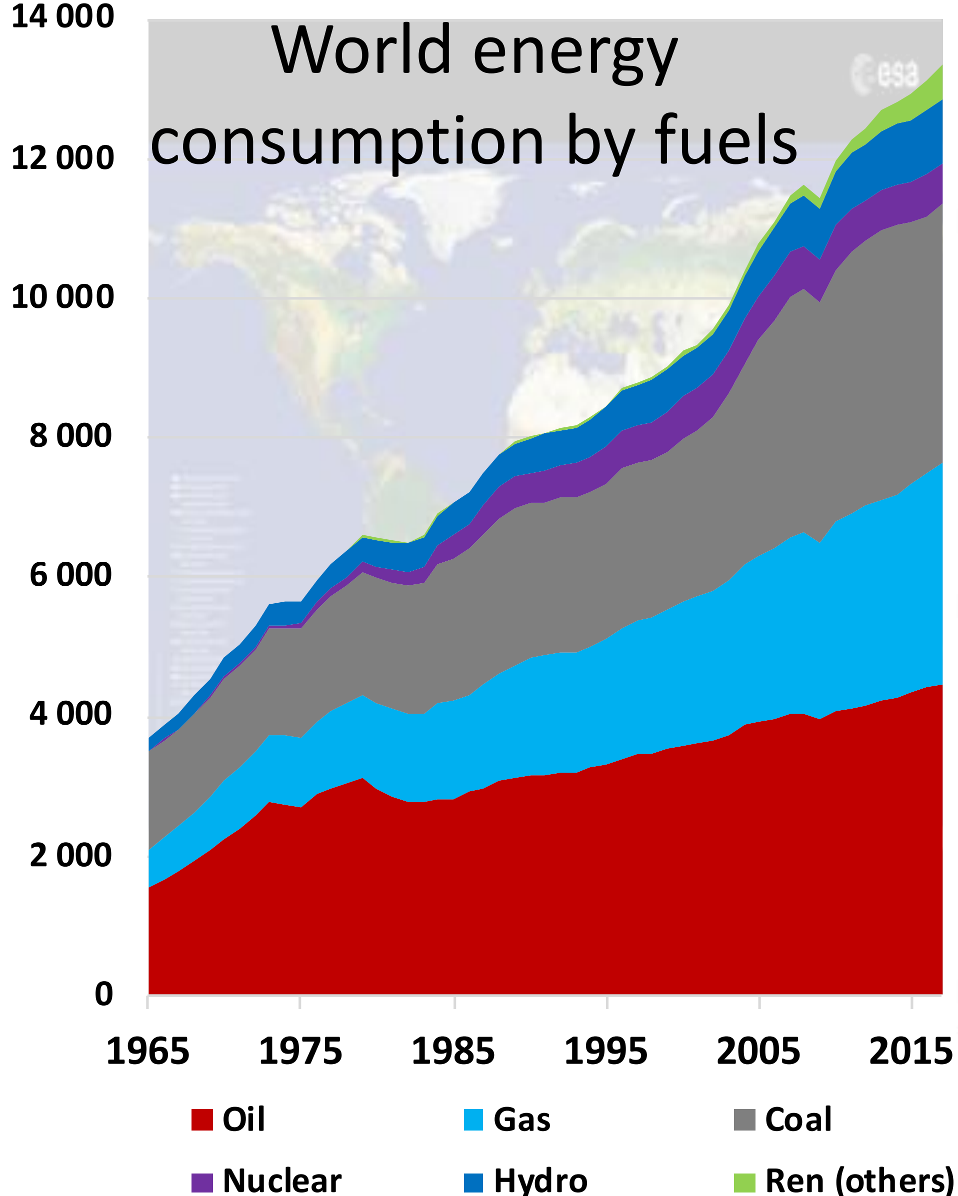


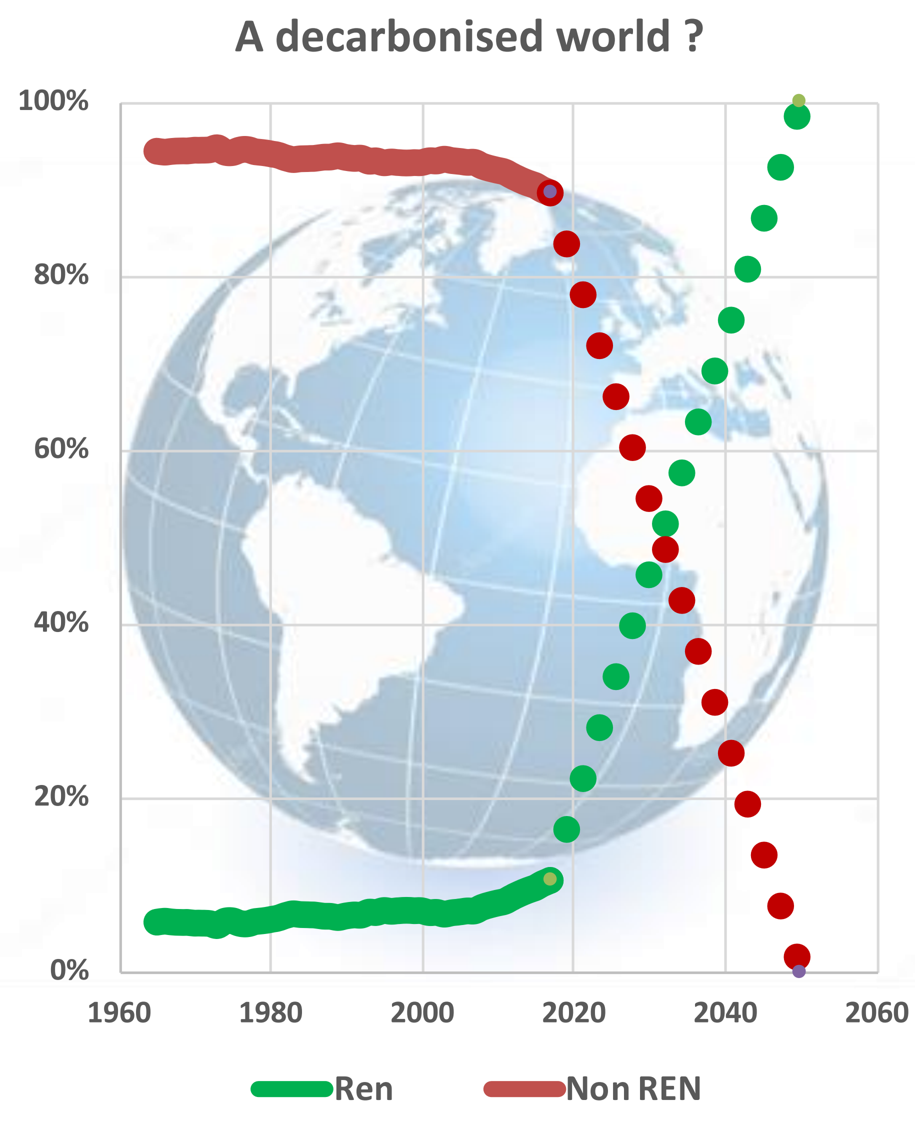
CO₂ emissions (1990=100)
More than 3%/y since 2006 – doted line = OECD
1100%
1000%
900%
800%
700%
600%
500%
400%
300%
200%
100%
1990
1995
2000
2005
2010
2015
Vietnam
Qatar
Bangladesh
Oman
Sri Lanka
China
India
Indonesia
United Arab Emirates
Singapore
Pakistan
Chile
Saudi Arabia
Philippines
Peru
Egypt
Brazil
Colombia
Algeria
New Zealand

World CO_2 emissions



Towards the energy transition?





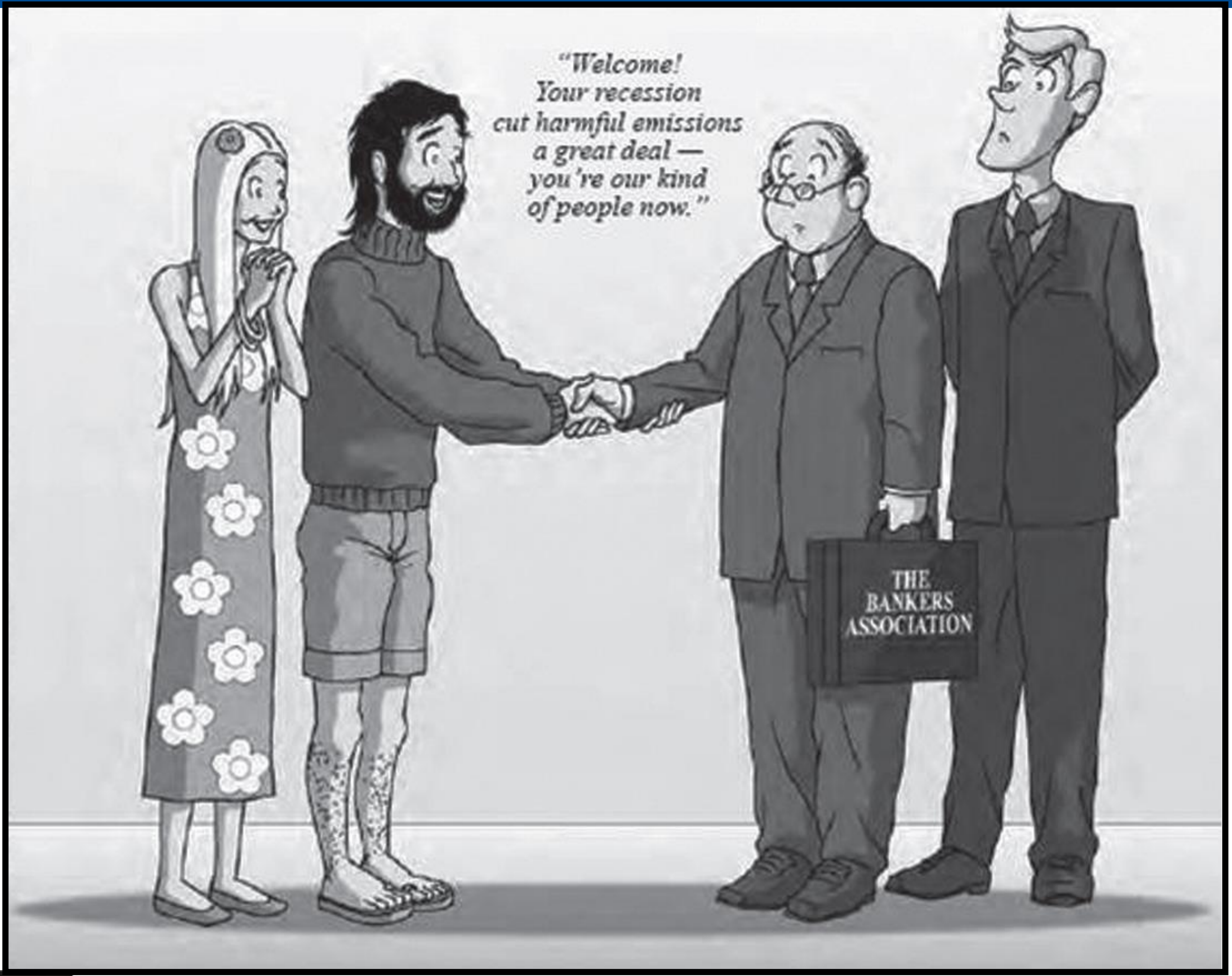
Data : BP 2018

¿Como reducer el CO_2?

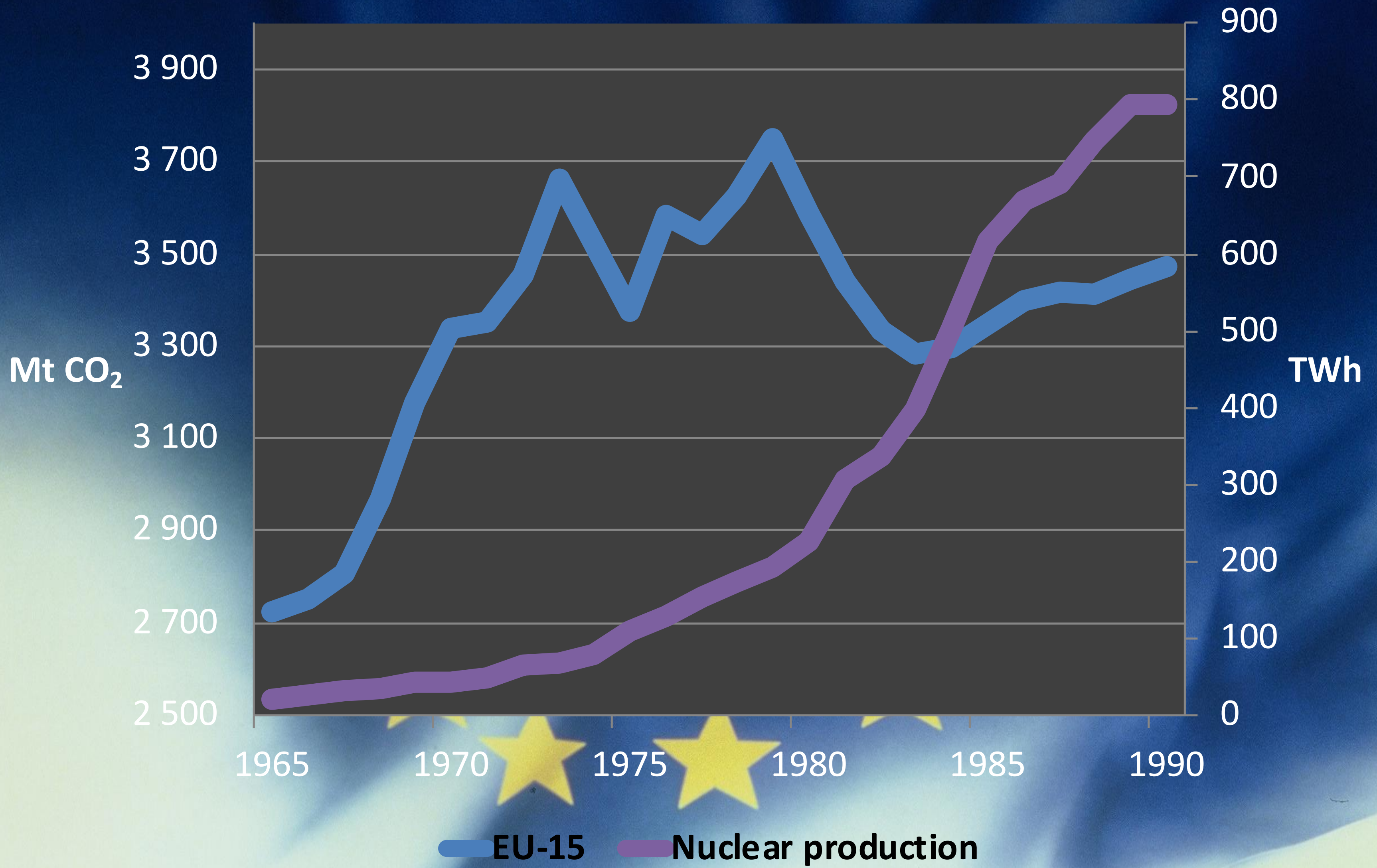
$$CO_2 = (People \; x \; \frac{GDP}{People} \; x \; \frac{Energy}{GDP} \; x \; \frac{CO_2}{Energy}) - storage_{(ccs\,;\,trees)}$$

Factor	Individual choice	Rational	Technology	Market	Government
Peoples	✓		✓		✓
Growth			✓	✓	✓
Energy intensity	✓	✓	✓	✓	✓
Carbon intensity			✓	✓	✓
Storage			✓		✓

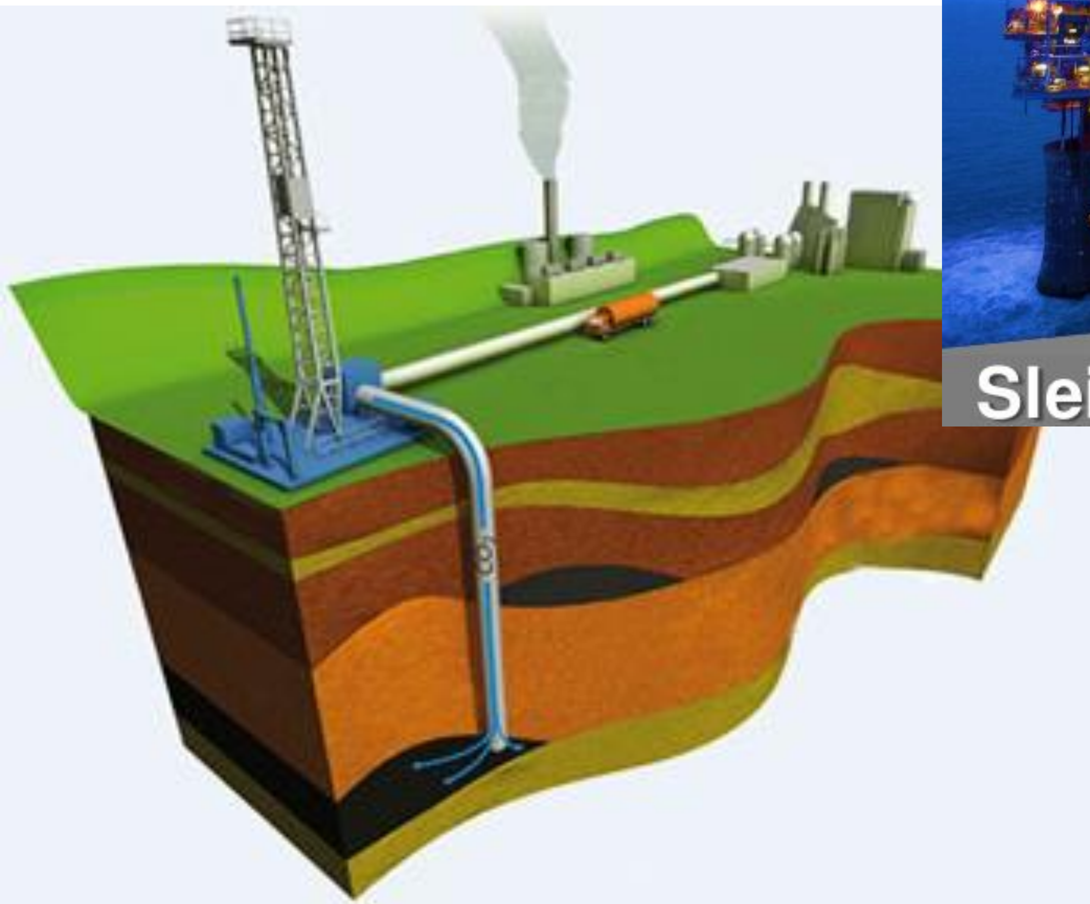
1° método : recesión



2° método : nuclear

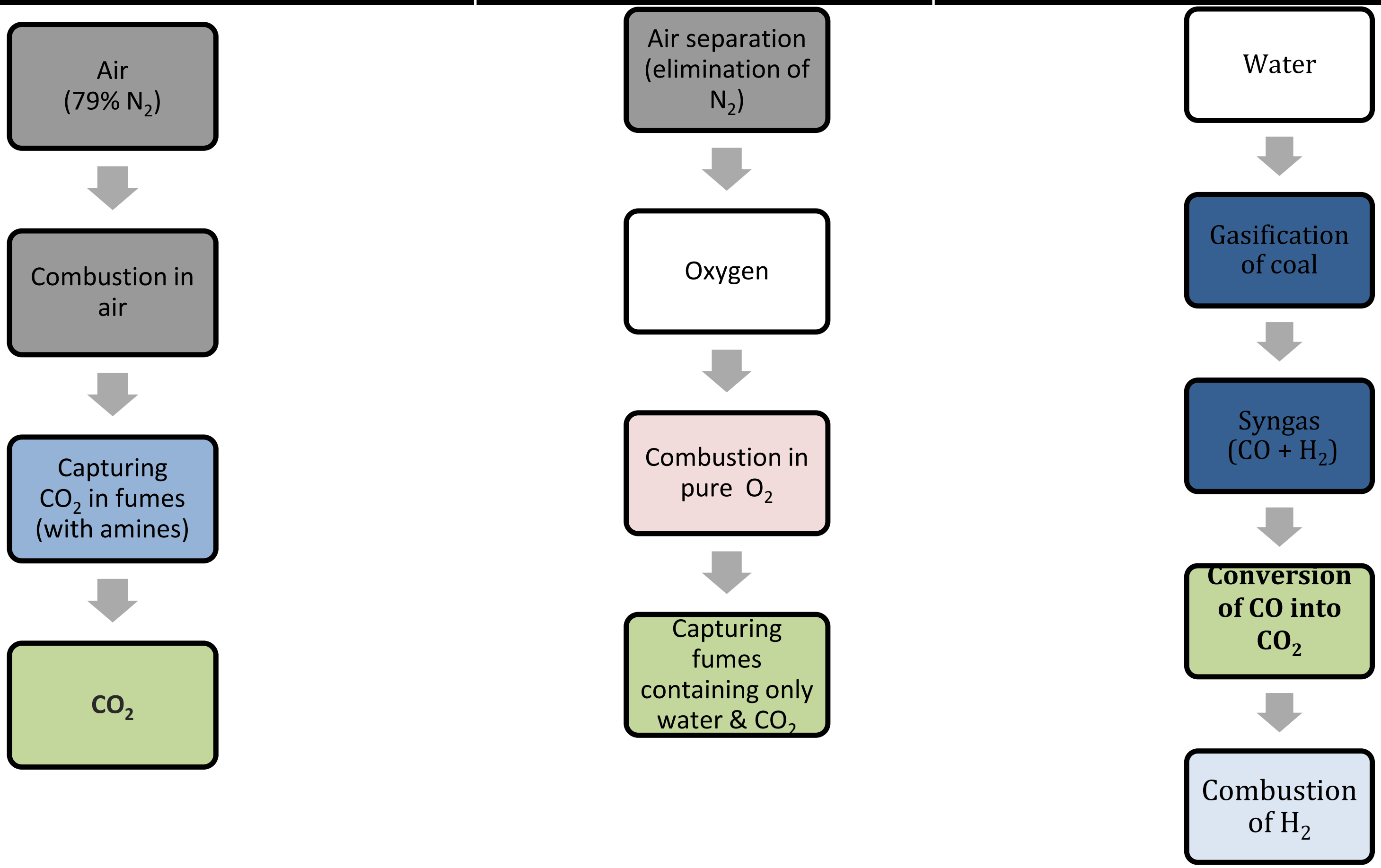


3°método : **CCS/CCU**



Procedimientos para eliminar la CO_2 de la combustion

Post-combustion	Oxy-combustion	Pre-Combustion



Cleaning of a large volume of flue gas	Cleaning of a small volume of flue gas	Elimination of CO_2 before combustion

¿Se puede reutilizar la CO_2 ?

La oxidación (combustión) del metano

$$CH_4 \quad + \quad 2\ O_2 \quad \rightarrow 2\ H_2O + CO_2$$

libera

$$\Delta H° \quad = \ - \ 802{,}88 \ \ kJ \ \ a\ 25°\ C$$

La reducción de la CO_2 en metano con las dos ecuaciones siguientes y sucesivas

$$2 \ \ x \ \ (2\ H_2O\ (gas) \ \rightarrow \ 2\ H_2 + \ O_2)$$

$$\underline{4\ H_2 + CO_2 \ \ \rightarrow CH_4 \ + \ 2H_2O\ (gas)}$$

$$2\ H_2O \ + \ CO_2 \quad \rightarrow \quad CH_4 \quad + \ \ 2\ O_2$$

requiere para la primera ecuación

$$\Delta H° \quad = \quad 2 \ \ x \ \ 483{,}88 \ = \ 967{,}76 \quad kJ \quad à\ 25°C$$

y para la segunda ecuación

$$\Delta H° \quad = \quad - 164{,}88 \ \ kJ\ à\ 25°C$$

por lo tanto, un total de

$$\Delta H° \quad = \quad 802{,}88 \ \ kJ \ \ à\ 25°\ C$$

¿Limitar la reducción?

La reducción de la CO_2 en metanol con las dos ecuaciones siguientes y sucesivas

$$3 \times [2\ H_2O\ (gas) \rightarrow 2\ H_2 + O_2\ ]$$

$$\underline{2 \times [3\ H_2 + CO_2 \rightarrow CH_3OH + H_2O\ (gas)]}$$

$$4\ H_2O + 2\ CO_2 \rightarrow 2\ CH_3OH + 3\ O_2.$$

requiere

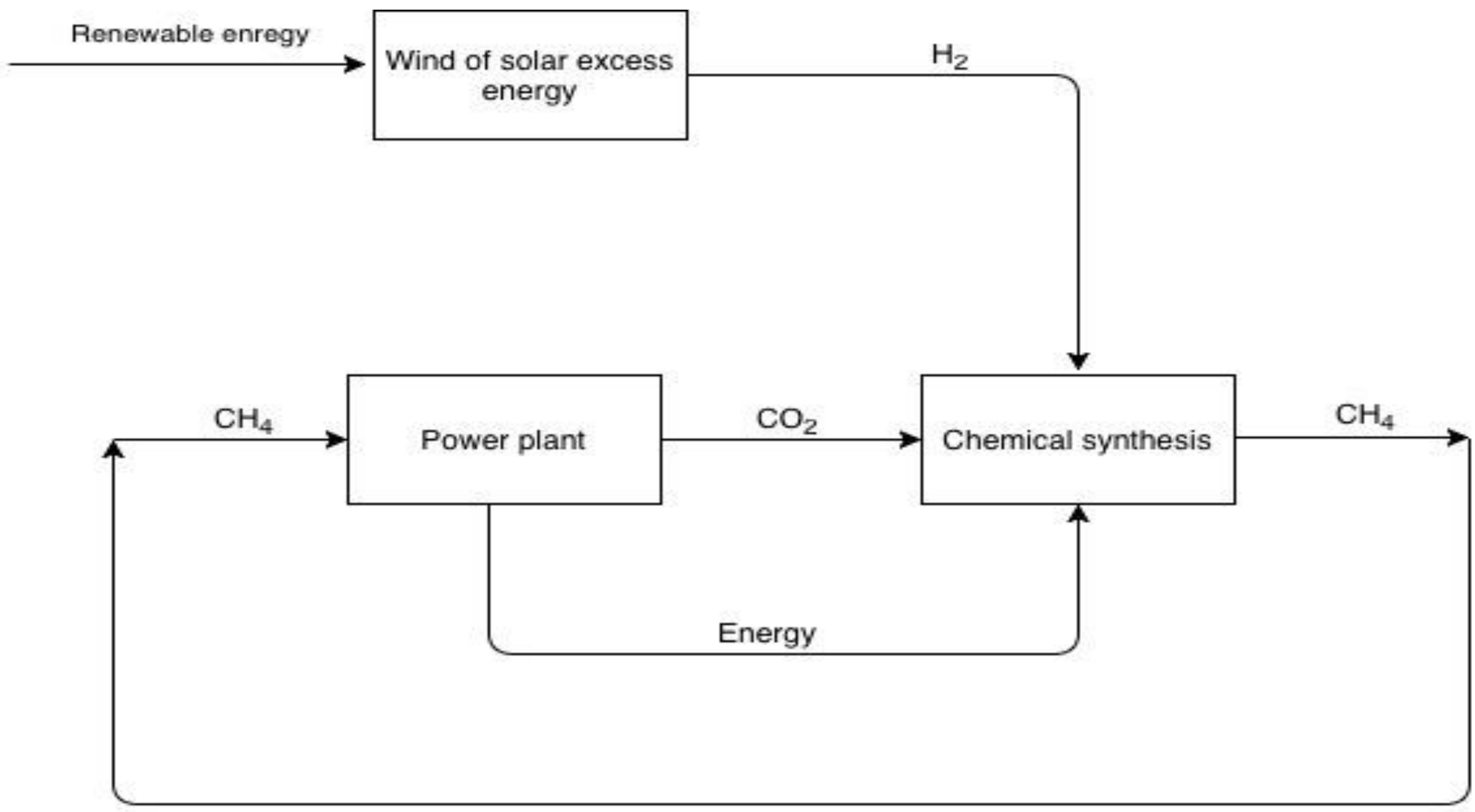
$$\Delta H° = 3 \times 483{,}88 = 1451{,}64\ kJ\ à\ 25°C$$

$$\Delta H° = 2 \times (-\ 87{,}02) = -\ 174{,}04\ kJ\ à\ 25°C$$

por lo tanto, un total de

$$\Delta H° = 1277{,}6\ kJ\ à\ 25°\ C$$

En total, es necesario proporcionar 638,8 KJ por mol de CH_3OH formado o por mol de CO2 transformado.


Renewable enregy
Wind of solar excess energy
H_2
CH_4
Power plant
CO_2
Chemical synthesis
CH_4
Energy