Fossil Fuels in the CPLP
Some Comments

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Workshop Lusofonia Energética
February 25, 2015

Comments

- Very interesting paper of Alves da Rocha. Not often can you find such a synthesis of different energy situations in countries with a wide spectrum in human and economic development but having language as common denominator
- The reserves of fossil fuels are important in the five CPLP countries analyzed in the paper. Will these countries continue benefiting from their resources for decades? Fossil fuels for ever? Or, is James Canton's statement valid?

The Stone Age did not end for lack of stone. And the Oil Age will end before the world runs out of oil.

James Canton

Institute for Global Futures

Forecasting Energy Future: a Difficult Job

- Where stands the competition for replacing fossil fuels? Some analysis is possible but don't forget that the evolution of the global energy system is essentially chaotic in the sense of Ilya Prigogine. When describing the future of the system, one relies on segments of deterministic progression (dictated by technological advancement, industrial and regulatory time lags, availability of financial resources, etc.) punctuated by points of bifurcation

The Chaotic Behavior of the Energy System (1)

En ces points {de bifurcation}, le comportement du système devient instable et peut évoluer vers plusieurs régimes de fonctionnement stables. En de tels points, une "meilleure connaissance" ne nous permettrait pas de déduire ce qui arrivera, de substituer la certitude aux probabilités

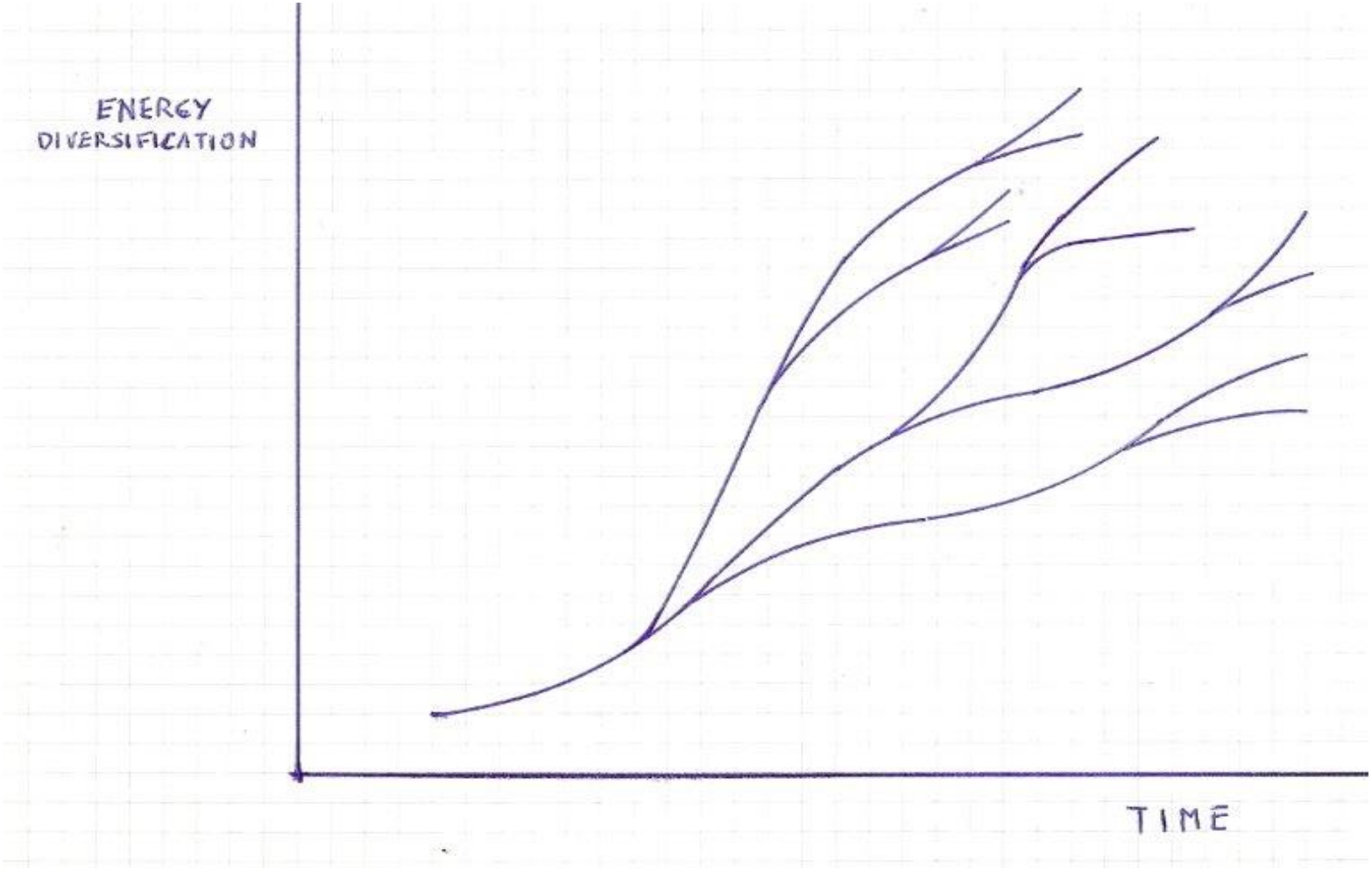
(Ilya Prigogine et Isabelle Stengers

Entre le Temps et l'Eternité)

The Chaotic Behavior of the Energy System (2)

- When bifurcations occur, governments and civil society in different countries react in different ways; the stakeholders act according to their emotions, their social and political environments and traditions. This leads to increasingly fragmented systems, to further chaos rather than to a stabilized new system

The Chaotic Behavior of the Energy System (3)



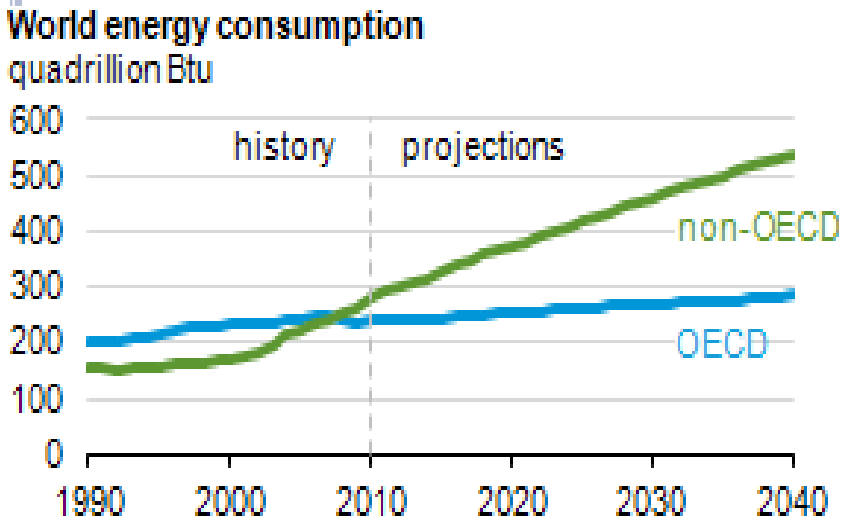
The Chaotic Behavior of the Energy System (4)

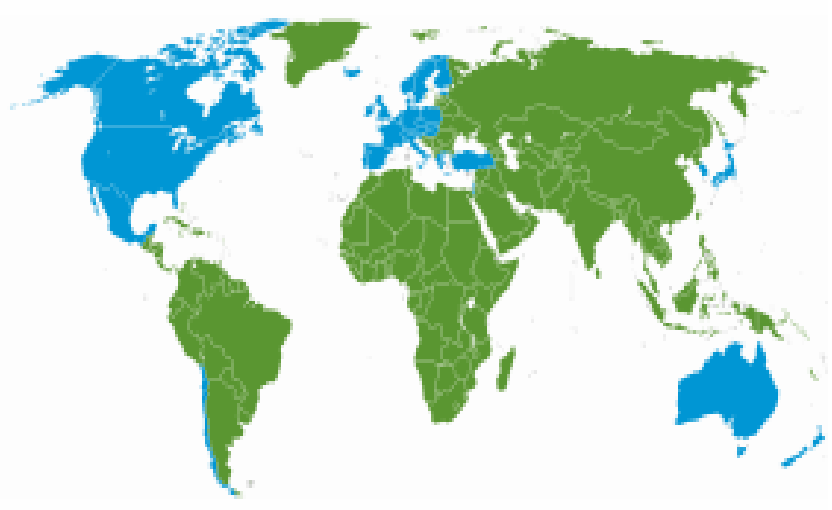
- Significant points of bifurcation have been:
  - The exploitation of oil (1863)
  - The peaceful use of nuclear energy (1950)
  - The use of natural gas for energy purposes (1960)
  - The oil crisis (1973)
  - The large scale use of renewables and of cogeneration (1990s)
  - Chernobyl (1986) and Fukushima (2011)
  - The reduction of subsidies to renewables following the financial crisis (2009)
  - The exploitation of tight and shale gas (2010)
  - The exploitation of clathrates (2012) (?)

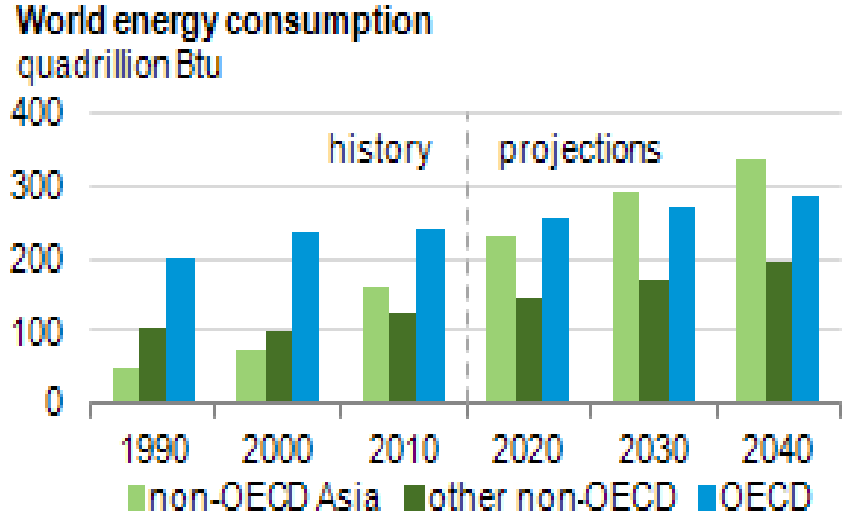
Future of Fossil Fuels (1)

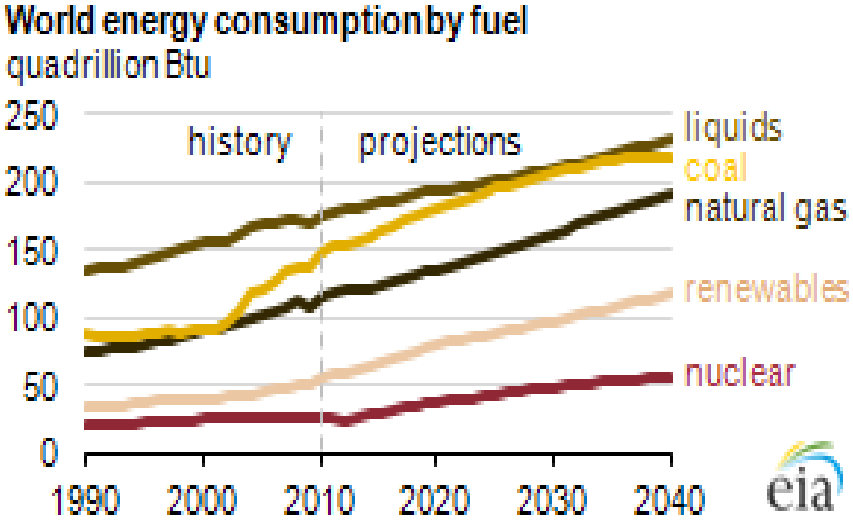
- So far, points of bifurcation have been in favor of fossil fuels and in the current overall deterministic context, their future looks bright; they should remain the major source of energy for decades to come as shown on the following graph prepared by the U.S. Energy Information Agency. The IEA World Energy Outlook 2014 goes in the same sense, underlining still substantial investments in fossil fuel systems within its "New Policies Scenario". Investments are a key factor for forecasting further growth

The U.S. Energy Information Agency projects that World Energy Consumption will increase 56% by 2040



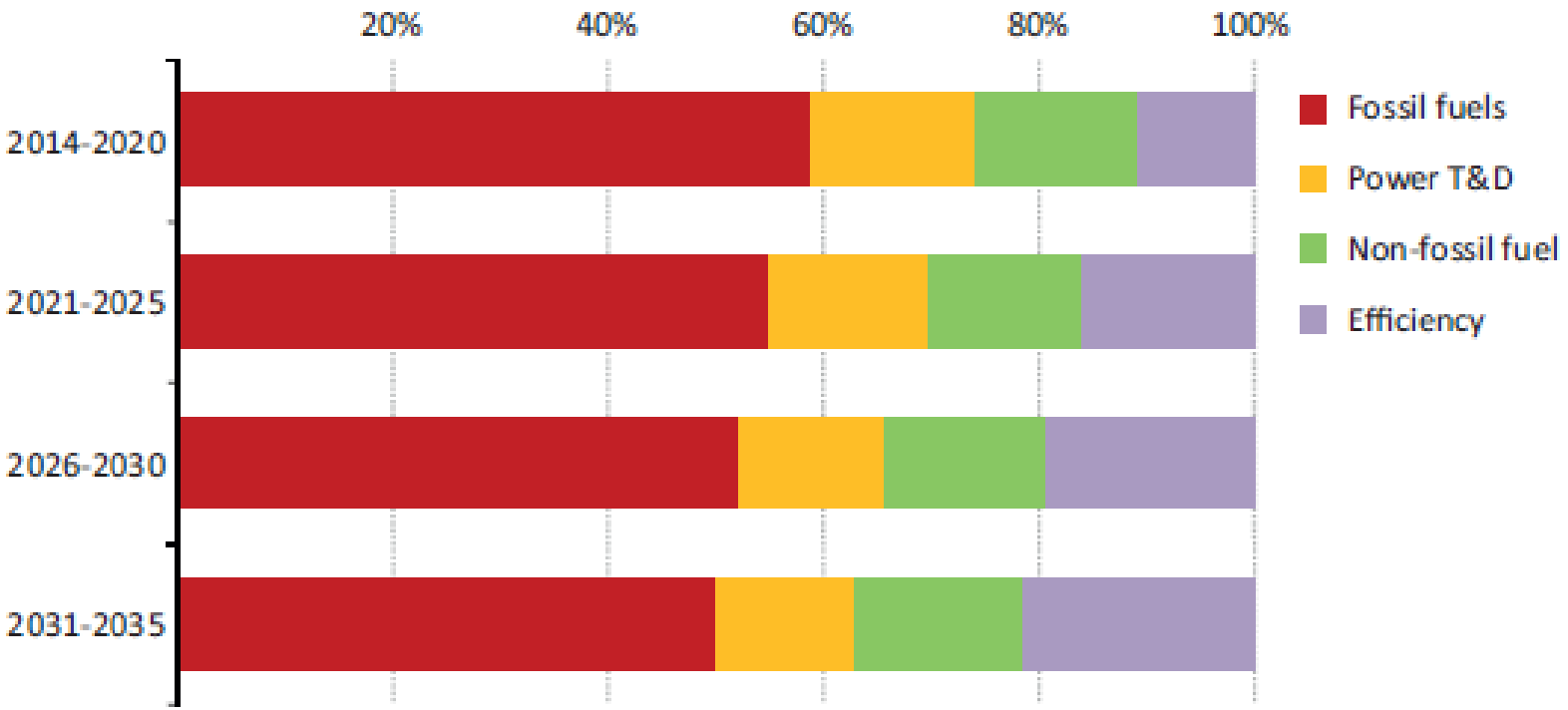






IEA World Energy Investment Outlook 2014

Figure 1.6 ▷ Shares of total global average annual investment in the New Policies Scenario



Notes: Non-fossil fuel includes all renewable technologies, nuclear and biofuels. Power T&D is transmission and distribution for the power sector: this cannot be assigned to either fossil-fuel or non-fossil fuel use.

Future of Fossil Fuels (2)

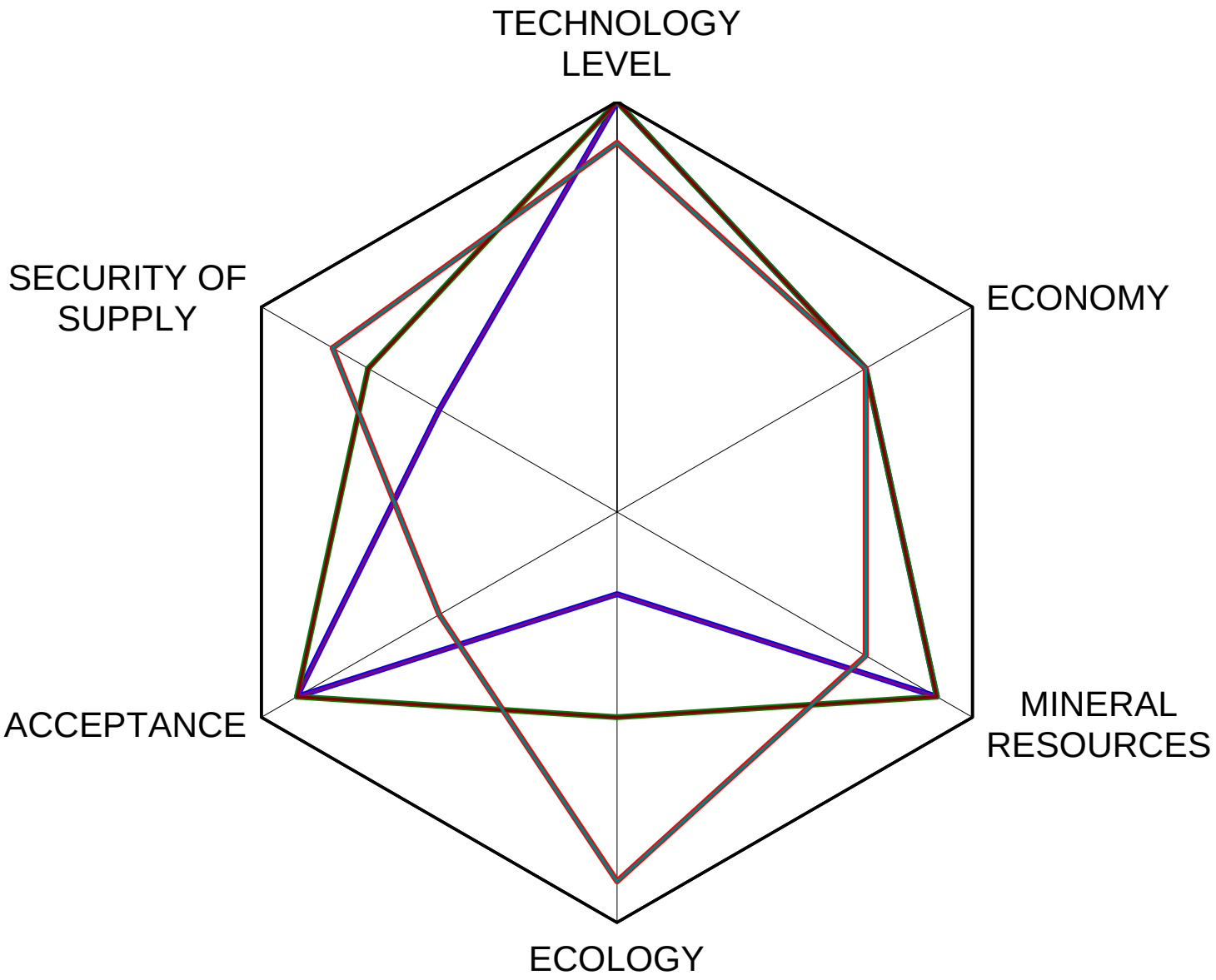
- Hence, where are the factors which might hinder this bright perspective? Energy sources are chosen according to several criteria which don't have the same weight for all countries, for all enterprises. This explains the existence of a large diversity of energy systems which should be respected. "One size fits all" is not the solution to the world energy problem

Selection Criteria (1)

- So far, countries and enterprises have reacted to several challenges when selecting their energy sources:
  - Energy security, availability
  - Maturity of technology for production, utilization
  - Economic performance including job creation
  - Ecology i.e. environmental friendliness: climate change but also local pollution
  - Acceptance, safety as determined by experts being overshadowed by its perception by Society-at-large
  - Mineral Resources availability determining utilization of materials in energy systems

Selection Criteria (2)

- These criteria constitute the vertices of a hexagon. Each energy system fits within this hexagon creating different figures (represented in different colors in the following slide) according to the relative importance granted to each of the six criteria. Technological maturity does not constitute a deciding factor; the same applies to economy with no large differences in cost for most systems. The differences come essentially from security of supply, acceptance and ecology. For mineral resources, the factor is not a leading one for the time being


TECHNOLOGY LEVEL
ECONOMY
MINERAL RESOURCES
ECOLOGY
ACCEPTANCE
SECURITY OF SUPPLY

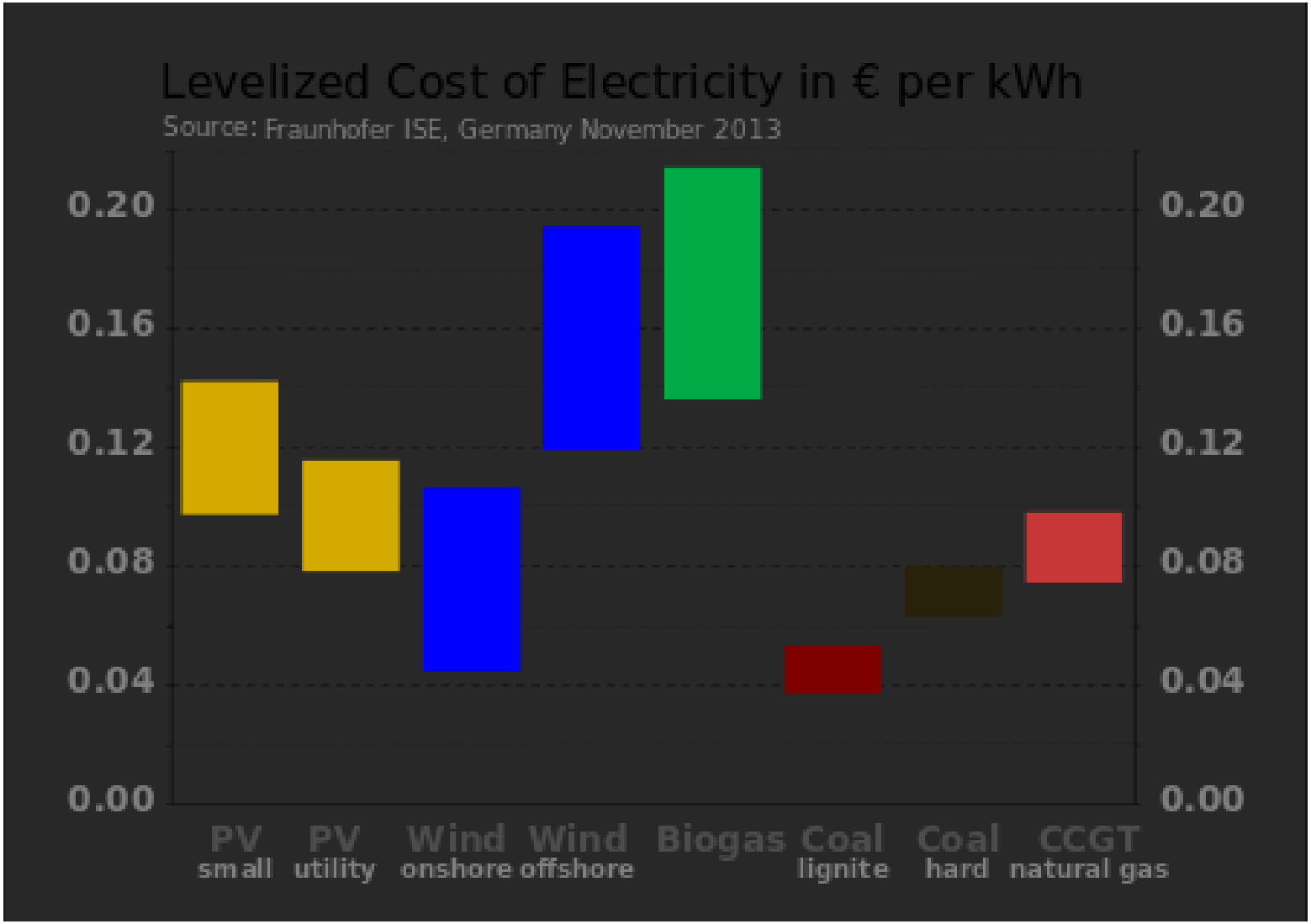
Position of Fossil Fuels (1)

- Most criteria are favorable to fossil fuels
- For oil, transport (air, rail, road and sea) constitutes still a captive market. Non-energy utilization of oil (and gas) as a chemical remains essential in spite of the increasing competition of bio-sources (revival of agriculture)
- Coal constitutes an indigenous asset for many countries and its importance persists: it will rejoin oil as top energy in 2030. Use of coal has skyrocketed in emerging economies in the past 50 years

Position of Fossil Fuels (2)

- Gas is the ascending energy source: it is much cleaner than coal and oil in terms of GHG emissions and could be used, with new technologies, in sea and rail transport
- Some countries joined recently the club of conventional gas producers, e.g. Israel, transport of LNG attracts again the attention
- The real revolution comes from unconventional gas, fracking gas (followed maybe by methane hydrates). The production of fracking gas in the US has changed not only energy fluxes but also geopolitics

Example of a *levelized cost of electricity* (LCOE) comparison for some newly built renewable and fossil-fuel based power stations in Germany, 2013



Cost Comparison of Energy Sources in the U.S. (from U.S. EIA April 2014)

Power Plant type	Cost in $/kWh
Coal	0.10 – 0.14
Natural gas	0.07 – 0.13
Nuclear	0.10
Wind	0.08 – 0.20
Solar PV	0.13
Solar Thermal	0.24
Geothermal	0.05
Biomass	0.10
Hydro	0.08

Emissions in kg CO^2eq/MWh (UK source)

TYPE	EMISSION
Coal	870
Oil	650
Gas	487
Geothermal high enthalpy	100
Solar	72
Hydropower	10-30
Wave	18
Nuclear	16
Wind	11
Geothermal low enthalpy	10

Position of Fossil Fuels (3)

- An evolution of utilization technologies which could displace some applications towards other sources, renewables notably, is on its way but slow and facing several hurdles
- Energy savings which constitute the most promising alternative for the future could only dampen the further growth of fossil fuels but not replace them

Position of Fossil Fuels (4)

- Stronger environmental considerations could be the key obstacle to the future development of fossil fuels: if the target of at least 50% chance of keeping warming below 2°C throughout the twenty-first century would be really aimed at, through the effective implementation of strong limitations in GHG emissions, most of the known reserves in fossil fuels would not be exploited, creating a real limitation in the future availability of these fuels and affecting the countries and companies future balance sheets (see Nature **517**, 187-190, 08 Jan. 2015)

Position of Fossil Fuels (5)

- Another threat comes from militant environmentally-driven investment funds which could divest massively from companies involved in the production of fossil fuels (e.g. Stanford University endowment fund divesting from coal mines)
- So far, the environmental preoccupations of nations have been overshadowed by other considerations, essentially political and economical, but will it last?

Position of Fossil Fuels (6)

- One way to reinforce the chances for the further utilization of fossil fuels is using the trump card of Carbon Capture and Storage

In Conclusion

Thank you to the speaker for drawing our attention on the importance of fossil fuels for some CPLP countries

Nobody can make hard predictions for the development of the global energy system in the decades to come but most indicators are favoring the continuation of a bright future for fossil fuels at world level

Addendum

The Trump Card: CCS (1)

- There is a trump card for a sustainable future of fossil fuels: Carbon Capture and Storage. Its development requires good knowledge in chemistry and in geology
- Beyond its physical storage, direct utilization of CO^2 in the chemical/ food industry as well as chemical and bio transformations of CO^2 can be considered (algae)
- In October 2013, Shell's CEO Peter Voser mentioned that CCS, along with biofuels and natural gas for transportation, "could be the bedrock of our future competitiveness"

The Trump Card: CCS (2)

- Again in October 2013, Dirk Smit, a Vice-President of Royal Dutch Shell, emphasized the expertise of oil companies in geophysics which could be key to developing CCS. "For pumping CO^2 underground, no one has a better head start on knowing how to do it than oil companies. One unresolved issue relates to how long the CO^2 can be stored. The experience of oil companies in characterizing reservoirs could help answer the question"

Synergies of Technologies

- Offshore Oil and Gas exploration and exploitation are driven towards going further deep, implying the use of new technologies capable of facing a hostile environment and mastering remote operation in such an environment
- It appears that there is an analogy of requirements for the exploration of outer space; hence, there should be an advantage in creating synergies between the two types of technological development. Portugal increased involvement in ESA programs could be a driving force there

Mineral Resources (1)

- In the future, there will be the need to take strongly into account mineral resources. Managing adequate mineral resources becomes a new technological challenge for energy production. Secondary (recycled) rather than primary materials should be the choice for the future but it might take another 20 to 30 years before exploiting the right technologies for recycling

Mineral Resources (2)

- Study by B. Goffé (U. Aix-Marseille) and O. Vidal (U. Joseph Fourier Grenoble) of the limitations for renewable energies development through availability of earth mineral resources (Pour la Science, n°431, Sept. 2013)
- Last generation wind generators consume per kWe produced, 20 to 40 times more steel and 6 to 15 times more concrete than a nuclear reactor of the EPR type

Mineral Resources (3)

- The production of renewable energy systems require notably Fe, Cu, Al, concrete (cement, sand), glass (sand plus various minerals, with high purity for guaranteeing transparency), chemicals derived from hydrocarbons (resins, plastics), In (for PV panels), Nd and Dy for wind energy electric generators
- Ores are getting lower in useful concentration due to exhaustion and they require increasing quantities of energy for extraction and processing: in 2010, they represented 22% of the energy consumption of the world industry (US DoE)

Job Creation

- In some European countries, employment created by a greater recourse to renewables is considered as an important factor. In Belgium, if the transition to an energy system based at 100% on renewables in 2050 would be made, the job creation would be between 21 000 and 65 000 full time equivalents before 2030, a non negligible figure as the number of unemployed in 2012 was 368 000. BUT, even taking account technological progress, the cost of such a system would be 20% higher than a system still using fossil fuels. Where is the equilibrium point?