

THE FIFTH KONDRATIEFF WAVE: THE FOSSIL FUELS APOGEE

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Abstract: The primary energy sources are associated to the major technological transformations and consequently associated to the structural long waves (frequently known as Kondratieff Waves or simply K-waves). Through this paper, it can be concluded that a substitution of the Non-solid Fossil for the alternative energies sources will happen in the future. Our study points out to the leadership of the alternative energies as the main primary energy by 2050-2070. Even if the long structural waves cannot be considered as a forecast tool, they can aid on tendencies extrapolation, given the substitution of the wood by coal and coal by NSF. In this sense, this study to point out a coincidence of the market share peak of a new primary energy source with each third wave, indicating a coincidence of the peak of the alternatives with the peak of the 6th KW. In this sense, we can foresee the fossil fuels apogee for this fifth K-Wave.

I. STRUCTURAL WAVES AND THE ROLE OF THE PRIMARY ENERGY SOURCES

Energy needs are related to three main factors: population growth, economic development and technological progress. Figure 1 presents the evolution of the primary energy sources market share. It is convenient to enhance two great transitions that were responsible for the structural transformations that occurred in energy systems. First, the steam engine (associated to coal) and, second, the increase of diversification of the final use technologies and the energy sources diversification. The first transition is related to the first and second technological transformations, while the second transition is, even if not exclusively, linked with the third and fourth technological transformations, to highlight electricity as means of energy transportation and internal combustion engine associate to oil. Figure 1 also shows some points that must be enhanced. From these there can be stood out the following ones:

- The long and gradual substitution among the primary energy sources, such as the substitution of wood (traditional renewable fuel) for fossil fuels;
- The domain of coal during a long period of time, reaching more than two thirds of the consumed primary energy;
- The almost simultaneous introduction of oil and natural gas, this last firstly as a product resultant of the oil production and later as a primary energy source;
- The peak of oil consumption in the seventies,

coincident with the oil crisis;

- And finally, some turbulence in the consumption dynamics of the primary energy sources during the last two decades.

In technological terms, it was during the last 250 years that five major technological transformations happened. These transformations appeared intermittently within a period of about a half-century and are linked with waves in the economic activity, and that result from the convergent development on several fields during the past 250 years. The first transformation (1770-1800) was linked with the substitution of wood for coal as a primary energy source, with consequences in iron-making, in fuelling the first steam engine, in building the first canals and in mechanizing cotton spinning. The second transformation (1830-1850) was related to the use of the steam power to the textile industry and to transportation (railways and steam boat). The third transformation (1860-1900) was a complex one: it centered itself on steel making and on the mechanization of manufacturing, on illumination, telephones, electrification and on the internal combustion engines. It was also characterized by the beginning of the substitution of coal by oil as primary energy source. The fourth transformation (1930-1950) was centered on synthetic materials and electronics. Finally, the fifth, beginning around 1990, centers itself on the convergence of computers, telecommunications and news technologies. This is to say, the first three had a greater influence on industry, being nicknamed as

“industrial revolutions”. However, the fourth transformation had larger impact on the consumer, given the great amount of new products. The fifth one will influence the industry as much as the consumer, due

to the emergence of new products and industrial technologies (also new industries) that will lead this wave.

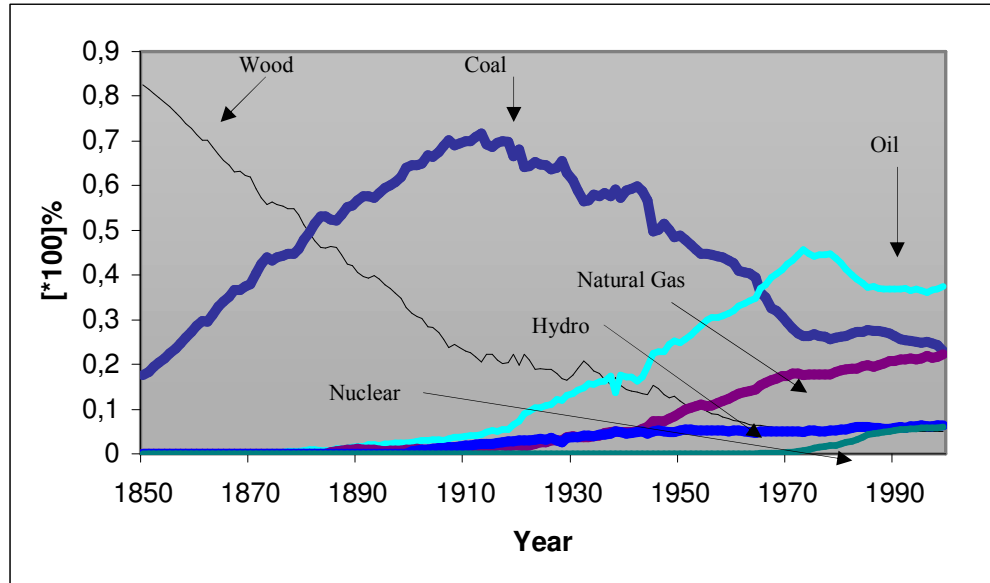


Figure 1 - Market share of primary energy sources evolution (1860-2000)

Bearing in mind these data, there are no doubts that the primary energy sources are associated to the major technological transformations and consequently associated to the structural long waves (frequently known as Kondratieff Waves or simply K-waves). Coal began to substitute wood in the eighteenth century (1st technological transformation, responsible for the economic expansion of the 1st K-wave), being diffused in the nineteenth century (it surpassed wood in the peak of the 2nd K-wave), reaching the stagnation (beginning of the decline) in the twentieth century (it reached the maximum point in the peak of the 3rd K-wave). During the period from 1800 to 1920, coal went from providing around 10% to over 60% of the world's total commercial energy requirements, being linked to the iron and steel industries, being the primary energy source of the first and second technological transformations. However, the non-solid fossils (NSF - oil and natural gas) began to substitute coal in the nineteenth century (3rd technological transformation, responsible for the economic expansion of the 3rd K-wave), being diffused in the twentieth century (they surpassed coal in the peak of the 4th K-wave), being

foreseen the reach of stagnation in the present century (the maximum point (turning point) in the peak the 5th K-wave). During the period from 1920 to 1973, the oil market share grew from 10% to around 50%, being mainly linked to the automobile industry, being the primary energy source to the 3rd and 4th technological transformations.

II. FUTURE PERSPECTIVES

In the past, it was possible to observe a relationship between primary energy sources substitution and socio-economic development, and consequently a relationship between primary energy sources substitution and K-waves. And in future how will it be? Making use of two of technological forecasting tools, namely the logistics curve and the Delphi technique, three long-term scenarios were built: an exploratory one, using the multiple substitution logistics, an Delphi-based indicative one, and another one resulting from combination of the two previous one (hybrid scenario) [1]. Notice that, and bearing in mind some presuppositions related with the technologies diffusion time, oil and natural gas

are grouped (NSF) in logistic substitution, as like as alternative totality energies (renewable energies without traditional wood and nuclear energy). For the Delphi-based scenario were selected 180 international energy experts. In 1st round answered 78 panelists, and in the end of the 3rd round the final panel was summarized to 68 experts (50% of Western Europe, 16% of North America, 13% of Asia and Oceania, 12% of South America, 6% of Eastern Europe and 3% of Africa).

This paper presents only the combined scenario, due to the incorporation of a complementarity between two different techniques. However, notice that one of the reasons for the Delphi technique use (group judgmental technique) was to verify if it is possible to represent the energy systems behavior through logistic substitution among primary energy sources. In the comparison between exploratory scenario and Delphi-based one it is verified a change dynamics convergence, but there isn't a convergence of "occurrence timing". In other words, the indica-

tions of the Delphi survey confirm the dynamics of the logistic substitution, even if considering different time spans, despite of the differences are not very significant [1]. Thus, the hybrid scenario goal is to use the information integration of several sources on different ways in a simple presentation, being grouped the extrapolations results and experts' appreciation. In this way, it was built a scenario that uses a combination between the logistic substitution and the Delphi-based indications. Unlike what it was done for the exploratory scenario (deterministic), there were not chosen identification periods (reference periods for forecasting) for the best data fitting. For each primary energy source, or energy sources groups, it was considered the identification period, which represents the dynamics substitution future, bearing in mind Delphi-based orientations, as well as other kind of indications. Figure 2 shows the substitution between primary energy sources, while Table I presents the market share forecasting for the next decades.

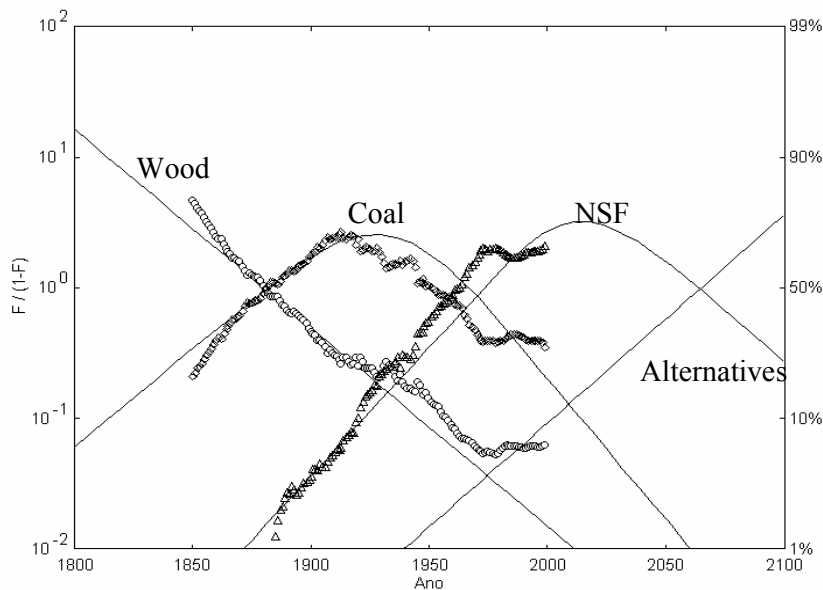


Figure 2 - Logistic substitution between primary energy sources (1860 – 1999) and the market share forecasting for hybrid scenario [1]

However, and in spite of only being explicitly presented the hybrid scenario, through the three scenarios it is possible to point out the following indications [1]:

- Wood will have its "dusk" (market share $\leq 1\%$), as traditional energy, by 2010-2015;
- Coal will have its "dusk" between 2040 and 2060;

- Among the NSF, natural gas can surpass oil by 2040-2050, but it will be difficultly assumed as main primary energy, if the alternative energies are considered in the totality, being assumed as a NSF “up-grade”, being assumed as a transition fuel;

- NSF can stay in the leadership up until 2050-2070, moment in which they will be surpassed by the group of the alternative energies;

- Nuclear fission will remain as a source of energy, even having the possibility to increase its market share, being very important for the consolidation of the alternative energies, even if not in short terms;

- Nuclear fusion, as commercial energy, will be difficultly available before 2050-2060;

- In short terms, the most effective way to reduce the greenhouse effect is to improve the fossil fuels combustion efficiency

Table1 - Market share forecasting for hybrid scenario [1]

Year →	2025	2040	2045	2050	2065	2075	2100
Source ↓							
Wood	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Coal	6%	3%	2,5%	2%	<1%	<1%	<1%
FNS	75%	68%	64,5%	61%	50%	41%	22%
Alternatives	19%	29%	33%	37%	50%	59%	78%

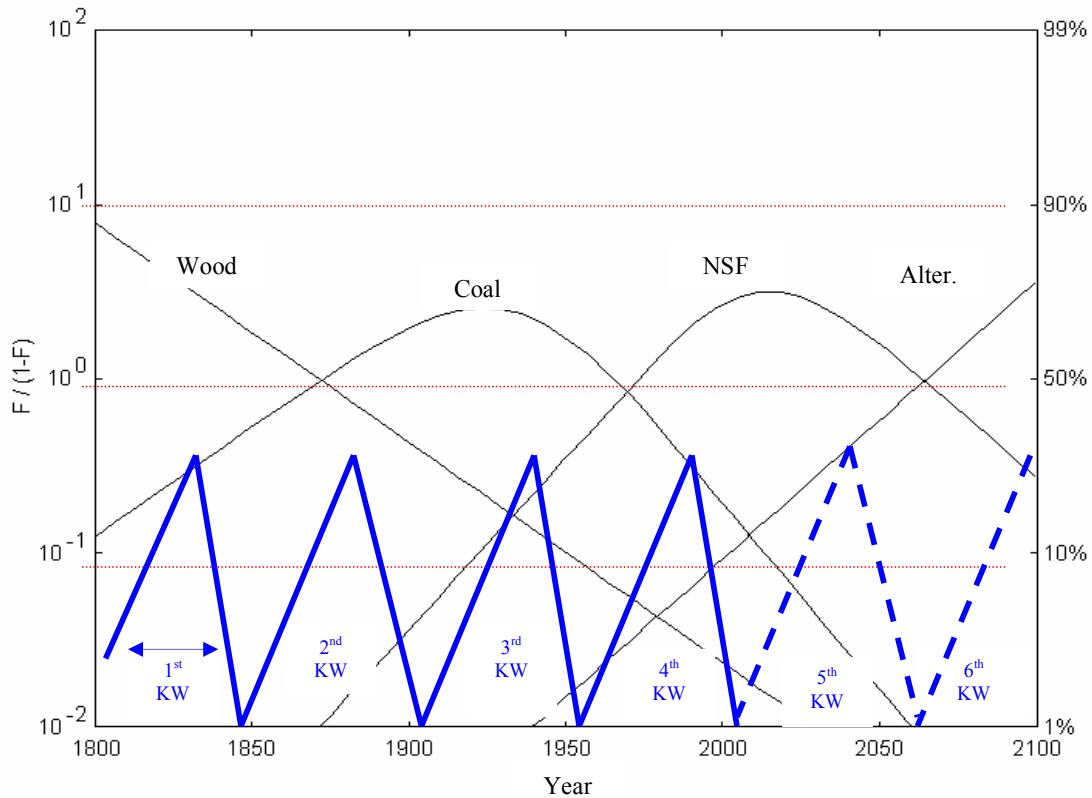


Figure 3 – Correspondence between Primary Energy Sources Substitution and Structural Long Waves (K-Waves).

III. CONCLUSIONS

In general terms, the indications of the Delphi survey confirm the dynamics of the logistic substitution. Thus, it can be concluded that a substitution of the NSF for the alternative energies sources will happen in the future, considering the NSF grouping and the alternatives cluster. Our study points out to the leadership of the alternative energies as the main primary energy by 2050-2070. Even if the long structural waves cannot be considered as a forecast tool, they can aid on tendencies extrapolation, given the substitution of the wood by coal and coal by NSF, such as we can observe in the figure 3.

This figure seems to point out a coincidence of the market share peak of a new primary energy source with each third wave, indicating a coincidence of the peak of the alternatives with the peak of the 6th KW. In this sense, we can foresee the fossil fuels apogee for this fifth K-Wave.

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- [1] J.C.O Matias. Scenarios Building for the Primary Energy Sources [in Portuguese – Construção de Cenários Futuros para as Fontes de Energia Primária]. Doctoral Dissertation, University of Beira Interior, Covilhã, 2002.