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Abstract: The aim of the article is to understand how the drivers for investment decisions in the capacities of electricity production have evolved over time, from 1945 to the present day, in the specific context of Europe facing wars and conflicts, scientific and technological progress, strong political and academic developments.

We study the electric investment decisions by comparing the history of the European electricity markets with the successively dominant economic theories in this field. Therefore, we highlight differences between rational behaviors, such as described by the theories, and actual behaviors of investors and governments. Thus the liberalization of electricity markets in the European Union, more than twenty-five years ago, parts of a rationalization prescribed by new economic theories. It is clear that liberalization is being discussed. First, it remains very heterogeneous, which complicates the goal of creating a large single market for electricity in the Union. Second, we see a recent *re-centralization* of energy policy in the European Union (EU), which takes the form of a new regulation mainly relating to climate and renewables. However, this *re-regulation* is different from centralized control experienced by all European electricity markets until the mid-1980s.

Keywords: European Electricity Market, Electricity Investments, European Energy Market Liberalisation, Climatic issues, Renewables.
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1. Introduction

The article addresses the issue of investment in electricity generation capacities in Europe from 1945 to the present day through an approach both theoretical and historical. Over this period, the drivers for investment decisions have evolved in the context of Europe facing wars and conflicts, scientific and technological progress, strong political and academic developments. Today, electricity investment is subject to new mutations, due to the still ongoing process of European market liberalization and the recent breakthrough of climate change issue, the latter imposing to reduce greenhouse gases (GHG) emissions, in particular through planned integration of renewables in the generation mix.

Over the considered period, we will compare the economic theories of the time to the actual decisions that were made, in order to shed light on the differences between the rational behavior described by theory and the actual behaviors of companies and governments. Of course, the generation mix of a state is, in the end, determined by the investment decisions of electricity companies. However, these decisions are influenced by many exogenous factors and follow drivers that are very different according to historical and geographical context.

What were the main drivers for investors' decisions on European electricity markets? How did they evolve with time? What are the results of the liberalization process? What are the new stakes regarding regulation? How would they influence the liberalization process itself? We will answer these questions based on the experience of the five countries representing 65% of EU27 electricity generation: France, Germany, United Kingdom, Spain and Italy.

What are the main results of this paper? First, it should be acknowledged that the liberalization process initated in the EU about 25 years ago parts of a rationalization prescribed by economic theories of the 1980s and 90s. Morevoer, it is now clear that this liberalization is being questioned. It has indeed given heterogenous results regarding market structure, prices or power quality (i.e. continuity in production and sufficient generation). One can also notice a recent *re-centralization* of energy policy, in the form of new regulation regarding climate and renewables, and of programmed investments in grid interconnections for EU member countries. This *re-regulation* is very different from the centralized driving Europe used to know until the 1980s, since it does not question the liberalization process per se. It aims at allowing heavy investments and providing more support to the electricity market for instance through new taxation tools (carbon tax, research and development subsidies…) aiming at *internalizing external effects*.

In the end, two main historical periods single out and structure the article:

- The 1945-1986 period (Section 2), during which national generation mix get formed in European countries, according to considerations often in contradiction with one another such as economic optimization, priviledging local resources, Ramsey-Boiteux rule, etc.;
- The 1986-2013 period (Section 3), marked by important mutations: the objective of liberalizing the electricity sector ending up in different degrees of competition in EU countries; new climate stakes and recent development of renewables.

2. 1945-1986, from European reconstruction to oil shocks: a crucial period for the constitution of current power generation mix

a. Nationalization or integrated model?

In a post-war context, the first goal of European countries is reconstruction. For the electricity sector, the priority is thus to go back to previous levels of generation as soon as possible. In order to do so, governments take measures that end up with giving them an increased control on the electricity sector.

In France, nationalization of power company is voted in 1946, which leads to the creation of *Electricité de France* (EDF) (Beltran and Bungener, 1987). In the United Kingdom, nationalization is also decided according to the *Electricity Act* voted in 1947. The *British Energy Authority* is created in 1948 and becomes *Central Electricity Generating Board* (CEGB) in 1957 (Grand and Veyrenc, 2011). Italy also chooses to nationalize the electricity sector in the Constitution in 1946, but national operator *Enel* is created only in 1962 (Grand and Veyrenc, 2011) due to industrial reluctance in the sector: nationalization indeed means that *Enel* has to absorb the 1270 historical power operators. The processus will be completed in 1995 (*Enel website*). In these three countries, the electricity sector has thus become a state monopole. Governments have direct control over tarification and technology choices.

The situation in Germany and Spain is different: they do not create state monopolies nor centralized planning (Grand and Veyrenc, 2011; Ibeas Cubillo, 2011). Their electricity industry corresponds to an integrated model. The German electricity sector keeps its structure including local and regional companies, due to the particular structure of federal German state itself – being divided in powerful *Länder*. Yet the sector is very integrated on both vertical and horizontal scales through numerous exclusivity contracts between power generators and grids, generators and distributors, but also from generator to generator. In the end the electricity sector in Germany is not submitted to competition and the 1935 Energy Act controls prices indirectly. Technology choices are adopted at a federal level.

In Spain, electricity sector integration happens through the coordination of private companies by themselves (Ibeas Cubillo, 2011). In 1944, 18 electricity companies create the *Asociación Española de l'Industria Electrica (UNESA),* in order to promote a real national electricity grid by developing more interconnections to ensure better supply (Asociasion espanola de la industria Electrica, 2013). Like in Germany, the Spanish government controls prices indirectly through the *Unified limited rates system* established in 1951 that sets maximum prices and regular tariff harmonization in the differents areas of the country.

European states thus take control of the power industry either through a monopoly called "natural monopole" by economic theory, either through an integrated model where potential entrants and prices are influenced by the state.

b. Cost-Benefit Analysis: the dominant economic theory over the period

In the aftermath of World War II, the *Cost-Benefit Analysis* is the dominant theory regarding electricity investment all over Europe. It justifies and supports the settling of monopoles and integrated markets. This theory was issued by works of *marginalist* economists and stems from the Welfare Economics founded in the 1930s and 1940s by Allais (1943), Hicks (1939), Pigou (1924), and Samuelson (1943). In the 1950s, the Cost-Benefit Analysis is initiated in France and other European countries by Massé (1953) and Boiteux (1956). This analysis implies assessing in an explicit way the total expected costs and total expected benefits for one or several electricity investment projects, in order to determine which one is the best or the most profitable.[1]

Technically, electricity supply at the time relies on two technologies: hydroelectric plants and thermal plants. Debates on the profitability of both technologies lead to important conceptual breakthrough, in

[1] The first optimization model based on Cost-Benefit Analysis was developed in 1955. Massé said at the time: "The electricity industry has found a purel objective tool in order to take investment decisions withtout personal bias", Beltran and Bungener (1987).

particular regarding complete cost assessment of a technology (including the lifecycle analysis for the facility), choice of a relevant discount rate, and ability of the supply to ensure peak consumption.

Power generation is per se capital-intensive due to grid and plant investments that are needed. This is why Cost-Benefit Analysis comes along with integrated markets or monopoles, the latters being called *natural* according to the *Ramsey-Boiteux rule*. This rule demonstrates that a company with initial fixed costs (as in the electricity sector) undergoes losses if its price is equal to marginal cost (perfect competition); whereas in a natural monopole, it can reach equilibrium thanks to second order pricing superior to marginal cost and inversely proportional to demand elasticity (Boiteux, 1956).

c. The lack of risk and uncertainty assessment in Cost-Benefit analysis

In Massé's works for optimal electricity investment determination, the main risks at stake are discussed. It is yet clear that they are not enough integrated in the modelling or only in a very limited way (Massé, 1953).[2]

It is after the Suez crisis in 1956[3] (Chick, 2007) that the first lacks of Cost-Benefit analysis are clearly identified. Indeed, exogenous risks like supply risk on imported oil like in the Suez crisis and its cascading effects are not correctly anticipated in this theory (Denant-Boèmont and Raux 1998; Massé 1953).

Economic theories on risk are nevertheless developed at the same time. In the 1940s and 1950s, Neumann and Morgenstern (1944) and Friedman and Savage (1948) address the issue of *decision maker's rationality when confronted to the risks at stake.*[4] This progress is however exluded from marginalist modelling for electricity investment.

d. The initial competition between oil and coal

Oil and coal are the two main resources at the time for thermal power plants. European coal producers feeling threatened quickly demand protection against foreign oil imports. They argue that high risk resides in the political instability of Middle East, jeopardising supply, transportation and prices altogether. Did domestic coal producers get any protection in the 1950s and 1960s from cheap foreign oil imports?

In France, EDF had no obligation to use more coal than needed. It was easy given that France had few resources in coal compared to Germany and UK. Indeed, in the 1950s and 1960s, coal production reached 100 million tons in Germany (133 million in 1957) and 200 million tons in UK (197 million in 1960), whereas France's maximum production reached 59 million tons in 1958 and could never ensure selfsufficiency (National Coal Mining Museum n.d.; Office statistique des Communautés européennes n.d.). Moreover, marginalist economists (who did not take into account the supply risk) recommended reducing coal production in France and increase oil imports.

Contrary to France, United Kingdom and Germany, who had relatively important resources in coal, took measures to protect domestic coal production. In the UK, the government created a tax on oil imports in 1962, banned Russian oil and American coal imports, and from 1963-1964, imposed quantified coal use targets to CEGB (Chick, 2007). In Germany, such measures will occur later, after the oil shock, but are part of the same approach.

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[2] To be more specific:

- The risks related to operational costs and especially fuel costs were assessed by using past data: no changes in future trends were considered;
- The risks related to investment costs were mainly due to construction risks associated with the land on which the plant was being built: it was considered as a mathematical expectation that was added to the investment cost as a security expense;
- The risks related to financing programmes (volatility of public decisions) were identified but not taken into account;
- The risks related to the expenses of financial compensation offered due to damages caused by plant construction gave us a first glimpse of the internalisation of externalities, but again no modelling was considered since it was too risky to be assessed.

[3] The conflict occurred between Egypt and an alliance with Israël, France and the United Kingdom, after the nationalization of the Suez Canal by Egypt, the canal being a strategic step for oil imports.

[4] Weisbrod, Arrow et Henry completed these theories in the 1960s and 1970s by addressing the issue of public decision in uncertain environment: Arrow (1965); Henry (1974); Weisbrod (1964).

e. From *Peak oil* to developing alternative technologies to oil

After the two oil shocks in 1973 and 1979, a transitory period starts in Europe. In reaction to high oil prices, all countries take measures to reduce their dependency to black gold, including France that had not made this choice from the beginning.

A predictable effect of *peak oil* is the return to coal for some electricity producers. This happens mainly in Germany, where the *Kohlpfennig* is established in 1974: it is a tax on electricity consumption, used to support domestic coal. In 1977 the *Jahrhundertvertrag* (literally "the contract of the century") makes it complulsory for power generators to get part of their supply from domestic coal producers.

The search for substitutes then develops, being very different from one country to the other. For instance, the United Kingdom quickly starts to explore the North Sea for new fossile resources, like gas, while France invests massively in civil nuclear energy.

Electro-nuclear program thus develop in France and Europe: their success or failure depend strongly on how national economies and companies resist to oil shocks, succeed in strategic and industrial nuclear deployment and manage public acceptance (or even public support).

In France, the high cash flows of EDF allow limiting the impact of high oil prices on consumers (Francony, 1979). EDF also manages to have low financial costs for the building of its nuclear fleet. For purely economic reasons, the choice is made to go with the American Pressurized Water Reactor (PWR) technology and buy the corresponding Westinghouse license in 1969 rather than French Graphite Gas Reactors developed by the French Commission for Atomic Energy (CEA). The French nuclear program (Plan Mesmer) is thus launched in 1974.

The United Kingdom adopts the opposite approach. The nationally developed Advanced Gas Reactor (AGR) is chosen for the nuclear program (Grand and Veyrenc, 2011). However the program must then be abandoned in the middle of the 1980s for want of competitiveness. An alternative program based on the Westinghouse PWR technology is then launched in 1982 but will be abandoned again after the building of only one reactor in 1988 (*Sizewell B*) due to cuts in public budget and drifting costs.

In Germany, the technologies chosen by the companies are Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR) developed loccaly by a *Siemens* subsidiary. Nuclear energy grows rapidly in Germany, although contested by the public from the start (which was not the case in France).

Between 1980 and 1986, Italy builds only four reactors and Spain five.

Besides, public acceptance of power generating technologies becomes more and more vital over the years. Local opposition for environment protection first focuses on coal, demanding that coal-fired plants were built outside cities. The phenomenon quickly reaches civil nuclear, in particular in Germany where the opposition to the building of a nuclear plant in Wyhl in the 1970s, successfully leading to abandoning the project in 1975, becomes an example for all anti-nuclear movements (Mills and Williams, 1986).

The rejection of coal-fired plants by one part of European population is first addressed by the development of the first Combined Cycle Gas Turbine (CCGT) in the United Kingdom in 1991. This technology allows building smaller facilities than coal and nuclear plants, but still ensuring high profitability. It will also be favored by the end of the Cold War (in the late 1980s) since it means direct access to abundant and cheap Russian gas - indeed Russia is in 1990 the first gas producer worldwide with 629 billion m^3 (Enerdata n.d.). Electricity producers using CCGT thus achieve competitiveness on the market thanks to accepted and moderate investment and thanks to cheap gas.

Such new entrants stimulate competition on the electricity markets until then integrated or monopolistic. However, the liberal mutation of Europe regarding electricity is more due to a combination of theoretical breakthroughs and political decisions.

3. 1986-2012, from the process of European liberalization to climate change mitigation considerations: towards a mutation of electricity markets

a. Theoretical questioning of natural monopolies

In the aftermath of World War II, Cost-Benefis Analysis has shaped electricity investment choices in numerous European countries. It has stayed the major approach until the 1980s, although already theoretically contested in the 1960s. These works first question the efficiency of monopolistic and integrated model, and identify empirically their negative effects. First, a tendency to over-capitalize is revealed – it is the Averch-Johnson effect (1962)[5]; then the absence of competition also fails to encourage efficiency (Leibenstein, 1966). Besides, the relationship between the regulator and the electricity sector can lead to protect the interests of the monopoly rather than the interest of consumers (Buchanan, 1975); Peltzman, 1976; Stiglitz, 1976).

This questioning goes further with Kahn, Baumol et Sharkey who address the issue of how to define a natural monopoly (Baumol, 1977; Kahn and Eads, 1971; Sharkey and Reid, 1983). According to these authors, in a grid sector such as the electricity sector, natural monopoly does not apply to the whole sector but only to activities related to grid management. Competition can thus be introduced in other activites of the sector, such as production and distribution, for the benefit of consumers. This argument is the one later raised by EU and is at the root of the liberalization process in grid industries.

Last, in the 1990s, Laffont and Tirole (1993) emphasize these results by showing that a monopolistic company has an asymmetrical relationship with the regulator: the company's interest is thus to take advantage of this situation regarding information on key points in order to increase their revenue.

b. From the European Coal and Steel Community to the Directive relative to internal electricity market

With the political construction of EU initiated in the 1950s, several European Communities for trade and economy are created. These communities lead in 1986 to the Single European Act and in 1996 to the creation of a single European electricity market – or rather to the creation of such an objective – thanks to the EU Directive on *common rules for the internal market in electricity*.

The United Kingdom was considered as a model for this market reform, since it was chronologically speaking the first European country to experience electricity market liberalization (Glachant, 2000).

The creation of an internal market in Europe has two goals. First, competition is expected to lower electricity prices for the consumers. Second, a European market allows to broaden the perimeter for resources in order to have better system optimization (Grand and Veyrenc, 2011). In practice, the reform allows member states to choose whatever measures they see fit to meet the objectives. They can either open the market to new entrants, either stop controlling prices, either create an independant regulator for every activity open to competition, etc. (Newbery, 1997; Perrot, 2002).

Given the heterogeneity of insitutions, markets and industries in differents European countries and given also the flexibility of European Commission Directives, results end up being very heterogenous.

This liberalization can first be assessed through the market concentration index: Herfindahl-Hirschman Index (HHI)[6]. Market concentration is often used to evaluate the degree of competition (we shall discuss this assertion later). Table 1 sums up the HHI of the five countries studied in this article.[7]

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[5] This effect measures the tendency of companies to engage in excessive capital accumulation in order to increase the volume of their profit.

[6] The HHI index is the sum of the squares of market shares of N the companies present on the market:

$$H = \sum_{i=1}^{N} s_i^2$$

s_i represents the market share of the firm i in the market, and N the number of firms.The lower HHI is, the less the market is concentrated, and the higher HHI is, the more the market is concentrated.

[7] Indexes were calculated for year 2010 using Eurostat data and European power companies' annual reports (own calculus).

	France	*Germany*	*Italy*	*Spain*	*United Kingdom*
HHI	7651	1354	943	1139	878

Table 1: HHI per country, *own calculus*.

Two groups are to be distinguished at first glance. On the one hand, France stands alone with a very high HHI equal to 7651, which indicates a very concentrated market. On the other hand, the four other contries under study have HHI between 878 and 1354 and reflect contrasted situations, from not concentrated (>1000) to concentrated markets (<1000).[8]

Today, the British market has an HHI of 878 and is thus acknowledged as competitive. This result can be explained by an institutional approach (Glachant, 2000) since, to achieve liberalization, some institutional configurations seem more favorable than others. This is why quick changes are easier to realize for very integrated companies or monopolies than for a group of several private decentralized companies. A state in which the government has a strong influence on legislation, rather than a federal state such as Germany, also is quicker to make decisions that will affect the whole country. Such an institutional combination is thus considered ideal and corresponds to the profile of United Kingdom: CEGB is a national integrated company, in an institutional environment staging a strong government.

It is though important to notice that HH Index has srong limits when it comes to describe a company's market power, since it does not take into account the different kinds of companies (private/public) nor the demand elasticity, neither the threat of potential substitute (Borenstein, Bushnell and Knittel, 1999). The electricity market thus has several characteristics that are not correctly represented by this concentration index. There are indeed different kinds of power generation companies (public firms, natural monopolies, private companies, etc.) who are likely to react differently in the same competition environment. Besides, electricity is a nessary commodity, but non-storable, with a pretty non-elastic demand obeying regular seasonal and hourly variations. Moreover, due to technical constraints, the ability of a producer to take a market share to another one is highly dependent on transmission facilities and existing grid, but also on base generation. HHI can also indicate the current repartition of power generation facilities in the company, but not the prices movements, neither the quality of delivered power.

c. The United Kingdom (HHI < 1000): a model for electricity sector liberalization?

The United Kingdom was historically the first country in Europe to deregulate its market from the mid-1980s, together with the United States of America on an international level. Today, we can take stock of the first results of this deregulation. The picture is a mixed one. Clearly, British deregulation has followed a specific process by starting from an integrated industry:

- Sorting of power plants according to technologies: *British Energy* got in charge of nuclear power plants and *Centrica* of others. *British Energy* historically stayed into generation without engaging into downstream activities. The selling activity focused on a few big clients (companies), the rest of its generation being supplied through independent marketers;
- Opening of the market to competition on different aspects of the value chain: generation and distribution;
- Grid networks have a mixed regime: they are regulated but they are allowed to be owned by actors of the competitive market.

What are the key constants to this day? The price of electricity is rather high compared on a European scale: 11.39 c€/kWh in UK against 7.71 c€/kWh in France (industry prices for 2013, Eurostat). Moreover, the electricity fleet is moving towards undersizing. It is now assessed that given the current pace of demand evolution and planned phasing out and building of power plants, the United Kingdom will not be

[8] Selon les lignes directrices de la Commission européenne sur la concurrence, un marché dans lequel le HHI est inférieur à 1000 est compétitif et peu concentré, alors que le marché dans lequel un HHI est supérieur à 2000 est très concentré et donc pas compétitif.

able to meet domestic demand – the planned phase outs being more reliable than planned constructions (Energy UK, 2013).

What are the factors explaining the situation? Let us first note that both factors are strongly correlated: when capacities decrease, prices should increase. Such prices can thus be explained by the relative decrease in supply capacities (compared to consumption). Today, power generators have to face a volatile market in a country where the main fuel for power generation is gas - 46% of generation, inherited from the North Sea resources. Gas prices rose during this period and since electricity prices are strongly correlated to gas prices due to substitution effect, electricity prices followed. An important volatility in prices came along with this rise. This volatility introduces important risks for wholesale electricity prices. Such uncertainty induces obvious risks for an investor regarding the decision to build new power plants. This risk affects the financing cost of new power plants, which is not always provided by wholesale market marginal cost pricing when it comes to peak capacities. The ability to cover investments thanks to market mechanisms thus seems limited: as a result, the market moves towards a reduction of installed capacity.

The issue of financing of new capacities is endemic to electricity market deregulation, since the required amounts for baseload power plants are high. One can reasonably assume that peak fuels volatility is not going to disappear. Besides, the British case also reminds that whereas the multiplication of supply sources is a *sine qua none* condition for competition, it does not automatically triggers the sink of prices. Today competition is intense between distribution actors who buy electricity from the producers. If the margin of these distributors is with no doubt submitted to high pressure due to competition, it does not affect most of costs, since they depend on power plants and grids, the capacities of plants declining. Fares could decrease or at least be competitive on the Bristish market when supply will be sufficient in terms of available capacities and performing compared to other European countries (i.e. compared to prices obtained with average costs pricing).

Is it though a reason to refute electricity markets deregulation? The question often ignores one the key contribution of market liberalization: financing of new power plants and grids is now private and not public, which protects the taxpayer from unprofitable investments. As a counterpart, investors are more reluctant to finance the building of new power plants… Liberalization certainly needs to evolve in order to take into account the necessity of ensuring investments in new capacities. Today, the United Kingdom seems to have to interfere directly on the market to ensure the necessary electricity investments. The 2013 agreement between the British government and French company EDF for the building of two *Evolutionary Power Reactor* (EPR) is a strong example (Department of Energy & Climate Change and Prime Minister's Office, 2013).

The liberalization of the Italian electricity market has also delivered visible results pretty quickly. The Italian state being favorable to liberalization from the start, it quickly auctioned part of the assets of historical oligopolies in order to favor new entrants. HHI of Italian electricity market is now 943. It is, with UK's HHI, the lowest among the considered countries. However, the importance of power company Enel on the Italian stage (28% of national generation) as well as the international stage shows that there is still a strong national champion; which is not the case in the UK. Electricity price in Italy reaches 11.22 c€/kWh in 2013 (same sources).

d. Germany (2000 > HHI > 1000): liberalized electricity?

The global attitude of Germany towards liberalization seemed favorable at first, but the process quickly introduced a reinforcement of state control over electricity operators, who were formerly used to auto-regulation. The market is still moderately concentrated with an HHI above 1000 and equal to 1354.

The current structure of the German electricity market is dominated by four companies: *E.On* and *RWE* ensuring 60% of generation[9]; *Vattenfall* and *EnBW* 20%. The relative failure of electricity market liberalization in Germany can be partially attributed to German state's will to protect the volume of

[9] E.on and RWE are historically *multi-utilities* and are very present on the gas market as well as the electricity market.

national electricity generation. The German electricity market has prices lower than the ones in UK, but higher than in France (8.6 c€/kWh in Germany vs 7.71c€/kWh in France). While Germany has abundant coal resources and coal is the cheapest fuel today, this higher price in Germany can be explained by strong penetration of renewables and high taxes on electricity prices.

Spain has adopted an attitude similar to Germany's: state control on prices, protection of historical operators (*Endesa* and *Iberdrola*) and strong support of renewables. HHI is equal to 1139, which describes a moderately concentrated market. Electricity prices reach 11.65 c€/kWh maingly for want of local resources.

e. France (HHI > 7000): an electricity market with no competition between actors but yet offering competitive prices

France is the country where liberalization was the less successful: there is one main operator regularly supported by French state policy in its application of European directives (the December 2010 NOME law for "*Nouvelle Organisation du Marché de l'Électricité*"). French HHI is equal to 7651, which is very concentrated and makes France a rather special case in the EU landscape. Of course, the fact that 75% of generation relies on nuclear can explain part of it. France thus avoided some of the mistakes of the integrated model. It did not protect coal in the 1960s when it was not competitive compared to oil, and chose in the 1970s the most profitable nuclear technology even though it was not the one developed nationally.

France is in a paradoxical situation: *EDF* is a largely integrated quasi-monopoly but electricity is one of the cheapest in EU. Under these conditions, one can legitimately question the opportunity to reform the French market and the need to break a monopoly ensuring more competitive prices than mupltiple actors in competition.

Two additional questions remain regarding the future of the French market. First, the *financing cost* of nuclear power plants (for addition or renewing of capacities): according to the two latest CEOs of EDF, the current price of electricity does not allow financing of the fleet renewing. Second, is competition possible with a monopoly in possession of a rent (difference between marginal costs of nuclear and other generation technologies)? And if it is desirable, should an artifact be used to implement it?

In France, the situation is thus atypical in the European landscape, since EDF owns the quasi-totality of generation capacities and 100% of baseload capacities through its nuclear power plants. The NOME law tried to open the market to competitors by giving them regulated access to historical nuclear electricity (ARENH). In the end, the relatively high price fixed by the government for entrants to buy this electricity seems profitable to EDF.

f. New stakes in climate change and renewables: back to centralized policy for the electricity sector?

Environmental concerns growed the past decades with the creation of Intergovernmental Panel for Climate Change in 1988, the signature of the Kyoto Protocol in 1997, or the Stern Report (Stern 2006, 2007). They leaded Europe to develop an ambitious plan for energy and climate: the Climat and Energy Package defined by the European Commission (2009a; b; c)[10]. New economic incentives can thus be expected to be put at use such as carbon tax or subsidies for research in renewables, in order to complete existing tools like the *European Union Emission Trading System*, and reinforcing the role of states in energy and electricity markets.

Regarding renewables, the need for investments coordination through new regulation is vivid in all European countries. The share of renewables is indeed growing in all generation mix over Europe, which raises several technical and economic issues (upon wich we will come back later). This new policy also includes societal issues. First, it will have to occur in spite of public's reluctance to more levies in time of

[10] It plans cutting greenhouse gas emission in 2020 (-20 % compared with 1990), increasing energy efficiency (+20 % more than *business-as-usual* projections for 2020) and objectives regarding the generation mix (20% renewable energies in the mix).

crisis. The fact that such levies could be redeployed, though theoretically viable, has little chances to be heard from a political point of view. This new policy will also have to face the recent rise in coal use (and the associated GHG emissions) occurring in countries reducing the share of nuclear in their mix (mainly Germany).

From an economic point a view, it is difficult to find a unified theory allowing to determine optimal pricing and optimal investment amount when renewables are rising (OECD and Nuclear Energy Agency, 2012). This rise indeed makes theories on optimal investment faulty for two reasons. First, incentives such as carbon tax, feed-in tariffs or green certificates distort the data for traditionnel models based on cost minimization issue from Massé's works. Such models structure costs in fixed costs (investments) and variable costs (operation and maintenance, and fuel). *Ramsey-Boiteux* optimal pricing is based on marginal costs and fixes investments from them. However, for unavoidable renewable energies, the variable cost is quasi-zero, so the marginal cost is also zero, which does not allow optimal pricing nor adequate price signal for investments. Besides, the fact that recent renewable technologies (wind, solar) are both unpredictable and intermittent are not yet correctly taken into account in existing models and are still under research. In reality, unpredictability and intermittence of renewable make it necessary to deploy demand response tools in order to compensate drops in generation like back-up gas-fired plants, and to develop interconnected grids on larger distances to take advantage of the geographical dispersion of renewables. Such heavy investments are only starting to be negociated or deployed in a few areas of Europe (like Scandinavian countries). For instance, models taking into account these new aspects in electricity fleet modeling are being developed: model MAEL (Dautremont and Colle, 2013), model MIXOPTIM (Bonin et al., 2013), the one developed by Bossmann, Pfluger and Wietschel (2013), etc.

4. Conclusion: towards restructuring of European generation mix?

We have conducted an analysis of drivers for electricity investments and of how these drivers have evolved over the six past decades. We thus have seen that a state's policy can follow standard economic theory like *Cost-Benefit Analysis*[11] of the one of *Natural Monopoles*, but mostly tends to be shaped by purely political and internal considerations. Today, electricity investment have to be undertaken under the frame of electricity markets liberalization, which was triggered by new theories at the times (Averch and Johnson, 1962; Leibenstein, 1966); Buchanan, 1975; Peltzman, 1976; Stiglitz, 1976; Baumol, 1977; Kahn and Eads, 1971; Sharkey and Reid, 1983; Laffont and Tirole, 1993).

The phenomenon of liberalization nevertheless bumps now into several hurdles. First, one has but to observe that electricity prices in Europe have not sinked but risen since the beginning of the process. Among the five countries under study, electricity prices for industry have on average grown from 6.31 c€/kWh in 2002 to 9.91 c€/kWh in 2013[12] (source: Eurostat). Critical situations in terms of electricity generation are also to be noted like in the United Kingdom. Besides electricity markets can stay little competitive and very concentrated due to peculiar institutional reasons (Germany, France) that can as well stem from a certain economic rationality.

Last, the need to mitigate GHG emissions and to increase the share of renewable in the mix makes the intervention of states and EU necessary to set up new regulations regarding energy choices and investments. This *re-regulation* proves nevertheless very different from the centralized driving Europe used to know until the middle of the 1980s. Indeed, it does not question the foundations of liberalization, but still consists in pretty strong market control through fiscal and economic tools.

We could not close this article without evoking one additional driver – the weight of which regarding investment decisions that should keep growing: the acceptance of electricity generation technologies by the European public, especially regarding nuclear power plants. Ever since the Fukushima accident in Japan in 2011 on March 11, and given the influence it has already had on some of the decisions of European

[11] For instance in France with nuclear investment: the choice was made of the most economically competitive technology even if it was a « foreign » technology (an American one).

[12] To be more accurate: from 6.14 to 11.39 c€/kWh in United Kingdom; from 5.62 to 7.71c€/kWh in France; from 6.85 to 8.60 c€/kWh in Germany; from 5.20 to 11.6 c€/kWh in Spain; from 7.76 to 11.22c€/kWh in Italy.

countries, this parameter cannot be neglected anymore. Nuclear phase out in Germany, Italy, and Switzerland is all the more important that it can have unexpected but major politicial impacts on neighboring countries.

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