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NETWORKS AND SUBSIDIES : THE HIDDEN SNAGS OF INTERMITTENT SOURCES OF ENERGY

by

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Overview

The development of alternative sources of energy brings with it economic and political difficulties which are often unexpected. As well as the generous feed-in tariffs put in place to encourage wind and solar power production, there are costs associated with developing networks in order to transport electricity from where it is produced to where it is consumed, and the need to finance the necessary capacity to satisfy the demand in electricity. In the light of the current debt crisis, will governments be able to continue to provide this assistance ? The installation of wind turbines and the construction of networks face opposition from local populations. In addition, because connections exist between European countries, these encourage some countries, such as Germany, to make their neighbours pay compensation for the intermittent generation of electricity by wind. After the crisis associated with the Euro, will Europe now have to cope with an electricity crisis ?

TALK : Aurélien Gay and Marc Glita

Aurélien Gay : Europe has a population of nearly 500 million and accounts for 15 % of global primary energy consumption. Gas and electricity are distributed by about thirty interconnected national networks. The European Union has a common set of rules which have been implemented on a national level by each member state to manage these networks. However, in a recent newspaper article in 'Les Échos', Jean-Pierre Clamadieu and Luc Oursel wrote 'until recently, European energy policy comes down to a race for deregulation which has made investment decisions difficult to take in such an unpredictable environment.' We came to a similar conclusion about European energy policy in our thesis, written as a result of our studies at the École des mines, entitled '*Le système électrique européen. Enjeux et défis*'.

The three fundamentals of energy policy

Marc Glita : The three fundamentals of energy policy are security of supply, economic competitiveness, and protection of the environment. Historically, in France priority was given initially to economic competitiveness. Coal, an energy source which was easily accessible and cheap, seemed like a good solution. Oil subsequently took the place of coal, and this quickly raised questions about the security of supply, and encouraged France to turn to nuclear energy sources. Eventually, problems associated with greenhouse gas emissions, fine particulate matter pollution, and issues arising from the production of nuclear energy emerged. A balance between the three fundamentals is always hard to find and subject to change.

European energy policy

Energy policy is not only defined on a national level, but also on a European level which adds complications. The European Union is not competent to deal with security of supply. This is paradoxical because the European community was founded on the need to avoid uncertainty concerning the supply of coal and steel to European countries. However, the European Union is expert in two fields which have quite a strong influence on national energy : environmental policy and competition regulation.

Putting the environment first

National energy policies are subject to the European Union's '20-20-20' target whose three objectives for 2020 are 20 % reduction in greenhouse emissions from 1990 levels, raising the share of the European Union's energy consumption produced from renewable resources to 20 %, and a 20 % improvement in the European Union's energy efficiency. These policies should also conform to Euro standards which fix the ceilings for pollution emissions for both diesel and petrol vehicles. National energy policies should also respect the Clean Air for Europe programme which fixes ceilings for various pollutants, this time with target values for air quality. When a member state does not respect these rules, it risks being punished with a fine.

On the other hand, a state will not be punished if it makes decisions which have a negative impact on the security of supply or the competitiveness of neighbouring countries, for example by fixing the price of electricity at a level very different from theirs. The fact that only the environmental part is subject to quantified measures including sanctions results in the predominance and priority given to objectives for protecting the environment, as opposed to economic, social and strategic objectives.

No consultation about supply or competitiveness

As a result, there is a lack of consultation in European governance about energy supply and competitiveness. For example, at a meeting of Central and Eastern European countries and Russia to discuss the supply of gas, Germany decided to bypass Poland by building a pipeline under the Baltic Sea. Similarly, Greece had received supplies for a long time from Iran, the last oil-producing country which agreed to deliver crude oil, while international sanctions against Iran were being discussed at the United Nations by diplomats of other member states of the European Union. Another example of lack of consultation occurs when different states set out their investment plans in the energy sector to the European Commission : nothing forces them to ensure that their planning is in line with that of their neighbours. For example, Germany might want to import 20 % of its electricity, but there is no way of checking whether this scenario is realistic.

Special features of electricity

Aurélien Gay : We will now discuss electricity which, given that the aim is to reduce greenhouse gases, is now forced to play an increasingly significant role in the global energy mix. It is, in fact, one of the energies which we can most easily 'decarbonise'.

Electricity management is unique : at any one moment, power supplied to the network must be equal to the power demanded. However, electricity demand can vary greatly. In France alone, there is a 60 to 70 GWh (gigawatt/hour) difference between electricity consumption in the depths of winter and during the warmest summer months. Demand is also very unpredictable : on the same day, it may vary by 30 GWh depending on the time of day.

The electrical system should include overcapacities in order to allow for a response to variations in demand at any time. In France, the average annual consumption is 60 GWh. The maximum is 102 GWh, and the total available capacity is 125 GWh. The establishment of new capacities is generally opposed by residents because of the need to construct power stations or to install high-voltage lines requiring governments to be involved.

Furthermore, electricity production technologies are relatively advanced, and increases in productivity, which one might hope for, are both limited and costly.

Another difficulty is that the profit margins are unpredictable because this industry is very capital-intensive. The construction of a nuclear power station (such as a European Pressurised Reactor station) costs between 5 and 6 billion Euros, and the investment must be organised several years before production can begin. Finally, emerging countries, especially Asian ones, drive up the price of raw materials throughout the world.

From monopoly to competition

Because of these characteristics which are specific to electricity, the electrical system of different European countries has been organised for a long time around a public monopoly covering production, transport, marketing and distribution. Regulated tariffs meant that all investments could be financed whether they were profitable or not. Political arbitration was applied to tariffs which were imposed on private individuals and manufacturers on the one hand, and the choice of an energy mix on the other.

Competition within a country

In an attempt to open the market to competition, the European Union adopted directives which led to the vertical disintegration of these monopolies. Activities such as transport and distribution, which were considered to be 'natural monopolies', are still entrusted to national companies, but are now regulated by commissions : in France, for example, these activities are handled by the 'Commission de régulation de l'énergie' (CRE). Production and marketing activities were opened up to new businesses.

Competition between countries

When the markets opened for competition within a country, the European Union established 'market coupling' in order to generate competition between member states.

There are now two large coupled markets in Europe. The first includes Sweden, Finland, Norway, Denmark and Estonia. The second includes France, Germany and the Benelux countries. Every day, the creators of each of these two markets produce their production and consumption forecasts for the next day. Depending on available connections between the countries, a stock exchange establishes the different variations which will take place, and the prices which will apply to the two markets. This process takes place as long as the connections between the countries are not saturated. When the connections are saturated, the prices are not related to the original stock market price.

Management of the chain

These measures led to the disappearance of the role of the person in charge of systems engineering, or the role of the person in charge of management of the entire chain which the person who held the monopoly assumed. Today, for example, the transport network for French electricity (RTE) checks to see whether the electricity supply is equal to the demand, but it does not have any means of solving a problem which might arise because it does not manage any production tool.

Effects on price

Making national producers compete against each other has resulted in a sort of price convergence. For example, the convergence rate between France and Belgium is 99.5 % which means that the difference between the two prices, measured every hour, is less than 1 Euro centime for 99.5 % of the time. Between France and Spain (markets which are not coupled), this rate is only 20 %.

This convergence, however, concerns the wholesale price which only represents between 30-and 40 % of the bill for private individuals. The remaining 60 or 70 % is then divided between 10 to 15 % for transport, 30 % for distribution, and the rest for VAT and taxes aimed at supporting renewable energy. Therefore, there may be large differences between prices charged to private individuals. In Germany or in Denmark, there may be a difference of more than 200 Euros per megawatt/hour (MWh), whereas the difference is about 130 Euros per MWh in France or in England. The change in electricity prices for an average size European household over the past twenty years shows that the vertical disintegration of the different monopolies has led to a small decrease in tariffs. However, the prices quickly bounced back, in particular due to the development of alternative energy such as wind or solar power the production costs of which are much higher than the average costs of traditional energy production.

When competition entered the market, other results were expected. The arrival of new operators meant that it was possible to finance the creation of trading rooms and the installation of new power stations. However, this has actually only been apparent in the construction of coal-fired power stations and combined-cycle gas plants which are among the most flexible means of production and the least costly investments. Similarly, in terms of energy efficiency, the opening of markets to competition has meant that only the most profitable investments are being financed.

Finally, the intervention of governments remains essential in order to support the development of renewable energies, to subsidise the work necessary to increase energy efficiency, to make the methods of making middle-level and peak load production profitable, and to develop nuclear sites.

Financing the development of renewable energies

The restrictive, legal objectives fixed by the European Union indicate that by 2020 20 % of the total energy mix will be in the form of renewable energies. Approximately half of this must be generated in the electricity sector, and the rest can come from other sources of energy such as renewable heat.

Production costs for renewable electricity are higher than for other electricity sources. Wind power costs 82 Euros per MWh, solar power costs more than 200 Euros per MWh, whereas the usual cost of nuclear energy is 42 Euros per MWh, and the average cost of electricity on the market is between 45 and 50 Euros per MWh.

Specific feed-in tariffs have been established to encourage producers to invest in renewable energies. For example, if a producer operates a wind turbine for 15 years, EDF, the energy supplier, will guarantee a purchase price for the electricity produced during this entire period of 82 Euros per MWh, with no ceiling limit to the amount produced. These conditions were the same for solar energy a year ago. Connections could be provided to individual photovoltaic systems, and a purchase guarantee of the entire electricity production at a very attractive rate existed. The additional cost incurred is charged to customers : this is called the CSPE (Contribution au service public de l'électricité) tax.

Negative effects

The negative consequences of this system include the 'politicisation' of certain reports which are forced through by MPs ; deadweight effects ; the impossibility of controlling the cost because the volumes of energy purchased are not determined beforehand ; and the artificial and short-term increase in some technological sectors.

Above all, this system led to a marked increase in the CSPE. This included one part for tariff averaging (which enables all consumers to pay for electricity at the same price whether they live in flat or mountainous areas, or even in French overseas territories), one part for subsidising the combined heat and power system (CHP), and one part for financing the development of renewable energies. Between 2010 and 2011, the tariff averaging doubled, the combined heat and power system component remained stable, the wine turbine part grew, and the photovoltaic part greatly increased. However, the government, which was clearly concerned to maintain the purchasing power of the French population, did not raise the CSPE as much as it should have done in order to cover the purchasing price of electricity sourced from renewable energies. Between 2010 and the second half of 2012, the price of electricity increased from 4.50 to 10.50 Euros/MWh, whereas it should have been priced at 13.50 Euros/MWh in order to cover all the subsidies granted.

In Spain, where the economic situation makes any increase in energy tariffs very delicate, the amount of debt accumulated in the electricity sector amounted to 22 billion Euros in May 2011. One third of this debt was the result of costs linked to the network which had not been charged to consumers, and two-thirds to subsidies granted for the development of renewable energies.

Clearly, the financing of renewable energies by means of the purchasing tariff, and without any ceiling on volumes produced, is not a long-term solution. It is the reason why, in several countries, subsidies have been reduced. In Germany, many companies in the solar energy sector have had their margins squeezed between, on the one hand competition from emerging countries especially China, and, on the other, a reduction in state subsidies which has resulted in a large number of bankruptcies.

Intermittence and economic imbalance

Marc Glita : One of the characteristics of photovoltaic or wind electricity production is that it is intermittent. Not only is there no sun at night, but when a cloud passes, production stops. Wind speed is also variable, and generally speaking there is less wind at night than during the day because the sun does not heat the ground during the night.

In Germany, during the week of May 28th to June 4th, 2012, photovoltaic production was measured at 18 GWh on the Tuesday and only 8 GWh on the Sunday. Wind power production reached 15 GWh on the Friday compared to only 5 GWh on the Wednesday. If one adds these two energy outputs for each day during the week in question, there is a difference of 25 GWh between daytime on Tuesday and the night of Tuesday to Wednesday. Normally there is generally less consumption during the night, but the peak demand is always around 7pm when, in wintertime, it is already dark. This is the time when people get home from work, turn on the lights, put on the heating (if they turned it off when leaving in the morning), prepare the evening meal, and turn on the television.

Production should not only cover variations in consumption, but also production variations in intermittent energy. Basic production works all the time : it is ensured by nuclear power stations, hydroelectric dams, and some coal-fired power stations. Middle-level production follows changes in demand throughout the year. Peak production corresponds to demand made at the peak-time of 7pm and during the coldest days.

In France, EDF is forced to buy solar power and wind-powered energy, and it is consequently the middle-level and peak load production capacities which have to compensate for the variations in renewable energy production. On an economic level, those who use the middle-level and peak load capacities are clearly disadvantaged compared to producers of renewable energy who are both subsidised and are given priority to provide electricity.

The disadvantages of geographical dispersion

Renewable energies are often associated with the myth that each person consumes the amount of electricity he produces. In reality, the intermittent nature of renewable energies makes it necessary for all producers and consumers to be connected to the network.

Because residents are often hostile to the installation of wind turbines in their back yards, they are often installed offshore, far from factories and cities. Production power stations are therefore spread throughout the country which leads to an additional cost for the network, and further conflicts with residents.

In their plan to complete the network by linking the Baltic coast (where the wind turbines are situated) with Bavaria (where the factories are located), the German government has to lay approximately 4,000 kilometres of high-tension cables between now and 2020. However, over the past fifteen years, they have only managed to install 100 kilometres of lines due to opposition from residents. This small number of lines means that there has been an increasing number of forced stoppages of wind turbines : there were 1,085 in 2010 compared to 285 in 2009.

Connections with neighbouring countries

To cope with the variability in electricity demand and in the production of renewable energy, one can either generate additional help or mobilise resources in neighbouring countries.

Analysis of import and export of electricity between France and Germany during the week in 2012 mentioned earlier shows that when the Germans produce a great deal of renewable electricity they export it to neighbouring countries, and when they do not produce enough to

cover their domestic needs, they import electricity. It is clear that if all countries decided to develop renewable energies as extensively as Germany, the system would not be able to survive especially because the connections between national networks are inadequate.

According to the EDF subsidiary RTE, in order for the French network to withstand important fluctuations it would need to create 8 GW of connections between France and its neighbours between now and 2020 or 2025. This would only be possible if RTE – and also local authorities – started pulling their weight.

The European Commission considers that the connections between France and its geographical neighbours ought to be approximately 18 GW which seems feasible. It took 25 years to manage to make an connection with Spain, and this has since not been improved upon.

Conclusion

According to the results of our study, European energy policy is handled with badly adapted tools the priority of which is the protection of the environment rather than the problems of competitiveness and the security of supply.

Paradoxically, the policy of opening up markets and decentralisation by making electricity companies weaker also makes the transition from traditional energy to renewable energy more difficult. When EDF had the monopoly in France, the government decided relatively quickly to construct nuclear power stations. If we were in the same situation today, it could equally quickly decide to develop renewable energies, and give itself sufficient means to connect all the production sites. But this is not the case.

Finally, managing the system solely by using fiscal leverage has proved to be costly and industrially inefficient.

We suggest three solutions in an attempt to rectify these shortcomings. The first consists of identifying the environmental objectives and their financial means by paying more attention to economic and social realities. The second involves co-ordinating national projects using a planning scheme between European countries which incorporates production and transport investments. The last suggestion is to establish a capacity mechanism within Europe by integrating the physical capacity of interconnections and of the network in order to cope with peak consumption and variable demand.

DISCUSSION

Storage

Question : *You have not covered the question of electricity storage, and yet this is a solution which is often used to solve the problem of intermittent usage.*

Marc Glita : Our approach is to analyse what takes place in the past rather than being concerned about the future in order to cause the minimum amount of controversy. Currently, storage remains marginal in the electrical system.

There is a very good example of how to manage storage on a grand scale in order to deal with renewable energies. Denmark has installed a large number of wind turbines which provide 20 % of the country's electricity needs. The network is well connected to Norway's network. Norway is a country which is mountainous and rainy and therefore is a great source of hydroelectric power (HEP). When the Danes produce excess wind-generated electricity, the Norwegians stop producing HEP and buy Danish power cheaply. When the Danes do not have enough wind to turn their turbines, they have to resort to using imported coal which is expensive and releases a great deal of CO_2. Therefore, they prefer to buy hydroelectricity from their Norwegian neighbour even though this is more expensive than the wind-generated electricity which they sold to the Norwegians. This system is so profitable for the Norwegians that they are thinking of creating new connections with England, the Netherlands and Germany. The cost of the installation of a cable between Norway and the Netherlands, for example, would pay for itself after two years.

Having said this, building new dams today would certainly be more difficult than installing high-voltage power lines.

Q. : *There is another solution for storage on a grand scale which consists of drawing off water during off-peak hours from a lower reservoir to fill a higher reservoir upstream and then releasing the water during peak hours. Unfortunately, studies have shown that the price paid by EDF to RTE for using electricity during the night does not make the operation profitable. There would need to be a much larger difference in price between day and night, or preferential tariffs for EDF.*

M. G. : This would not have been the case if EDF and RTE had remained in the same company...

Q. : *In any case, nobody wants to make HEP stations any more. As for chemical storage, it is very expensive and severely damages solar energy's profitability.*

Q. : *The SNCF (French national railway) increased fourfold its investment in innovation and research into storage. It intends to install electrochemical schemes for storage in its stations with capacities of several MWh in order to recoup energy from the braking systems of trains.*

Q. : *The technology of thermodynamic solar power stations consists of transforming solar energy to a high temperature and then converting this heat into electrical energy. Heat is much easier to store than electricity. These power stations have a certain inertia which allows them to function during the night and thereby deal with the problem of intermittent usage. These power stations must be built in very sunny, dry areas, for example in Maghreb countries. They could still be connected to European networks.*

M. G. : This is conceivable, but these countries are not very stable politically, and this poses a problem regarding the security of supply.

Electricity consumption shedding

Q. : *An alternative solution for increasing production consists of 'shedding' part of the consumption at the most advantageous time. This is a strategy put forward by the Voltalis company. Pierre Bivas, the CEO, presented Voltalis' business model at a talk at the École de Paris*[1].

M. G. : Apart from industrial shedding, and the shedding of individual boilers both of which have taken place over a long time, we can shed part of the electrical consumption of radiators. However, it is not possible to interrupt the functioning of televisions, computers or cookers which account for a very large part of the 7pm electricity consumption peak.

Q. : *At the talk given by Pierre Bivas, I understood that EDF was not in favour of paying for the supply of shedded kWh, in other words, the kilowatts which were not consumed…*

M. G. : There are trading rooms in which we can use tools which are much more sophisticated than those suggested by Voltalis. The principle of these tools consists of buying goods at a pre-fixed price, then either using them or selling them to the highest bidder. In the scheme suggested by Voltalis, the company does not take any risk because it does not buy electricity in advance. It is understandable that it has difficulties in justifying its request for payment.

Global warming

Q. : *In your talk, you did not mention global warming. The Germans use solar power to reduce their coal consumption, but the Chinese-made solar panels which they install are made with electricity produced using coal. The 'pay-back' time to get a positive figure in terms of greenhouse gas emissions is between twelve and twenty years !*

Q. : *As far as solar panels made in France are concerned, the pay-back time would only be two months because the electricity produced in France uses very little coal.*

M. G. : It is a fact that the German have made more greenhouse gas emissions since they decided to phase out nuclear energy. Having said that, in any case, the drive for the fight against global warming is in China, not in Europe.

Q. : *China consumes much less CO_2 per head than Europe or the United States.*

M. G. : Of course, but France's population is about the same as that of the town of Chongqing and its suburbs. Even if our country managed to 'decarbonise' its economy completely, the effect would be a drop in the ocean compared to the greenhouse gases produced by developing countries. And yet the investment necessary to reach this result would be colossal and the French economic situation hardly allows one to envisage this.

Q. : *It is a fact that China is in the process of catching up Europe and the United States in terms of pollution, but it also has the largest wind farm in the world, and it is China which is actively implementing technologies for the future in terms of keeping the environment secure.*

Q. : *If the aim was really to fight against global warming, we could use methods which are much less costly and more efficient than solar panels, wind turbines or electric cars. However, these methods are not backed by pressure groups which are vocal.*

M. G. : In Germany, the nuclear risk is judged to be more important than the climatic risk. Furthermore, the German population's enthusiasm for wind power is undoubtedly due to the fact that they make wind turbines.

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[1] Pierre Bivas, 'La production d'effacement : comment offrir des économies d'électricité à des millions de foyers' (*Les Annales de l'École de Paris*, vol XVIII).

Aurélien Gay : Putting the problem of climate change to one side is a general phenomenon. The current price of a ton of coal is ridiculously low : 6 or 7 Euros. Before Fukushima, it was between 13 and 15 Euros. And three years ago, it was about 30 Euros.

The impact of the development of the electric car

Q. : *A solution which is often put forward to ease the problem of intermittent usage consists of using the batteries of electric cars via the smart grid. I am very sceptical about this. Going from combustion powered cars to electric cars will increase electrical consumption and its variations to a considerable degree.*

M. G. : It is a fact that the commercialisation of a significant number of electric vehicles will require a great deal of electricity which is not available today. It is hard to see how Europe would be capable of producing and managing twice as much electricity as is currently the case. Luckily, estimates show that in 2020 the number of electric vehicles will not account for more than 10 % of the total number of vehicles.

Furthermore, a battery's life can be evaluated in terms of cycles whether the battery is completely discharged and recharged or not in the course of a cycle. Because the price of a battery is one-third that of the vehicle, it would not be very profitable to use the battery for additional electrical storage.

Q. : *A few hundred thousand vehicles which each have a 15 to 20 kWh battery represent an amount of energy similar to peak-time electricity shedding. This is a significant amount of electricity. As far as the additional amount of electricity which will be consumed is concerned, we do not necessarily need as many new capacities since not all the existing capacities are currently being used. It is possible to programme the time at which the vehicles are recharged so that this operation does not start before 10pm.*

Q. : *The Chinese government announced that it would reduce the price of batteries by a quarter from now until 2020 and, in general, it keeps its promises. If the price of storage was also greatly reduced then this would completely change things in terms of the profitability of renewable energies.*

Additional capacities

Q. : *Is there not a problem of finance for additional capacities which, by definition, are not profitable ?*

M. G. : It is true that a power station was recently closed as a result of bankruptcy. The company had signed a contract to buy gas, and the money from the sale of the electricity was not sufficient to pay for the gas. Other gas or coal-fired power stations have also been closed because they have been unable to handle investment levels imposed by the European directive concerning large combustion plants which aims to reduce sulphur dioxide, nitrogen dioxide and dust. However, these 'additional load' or 'back-up' power stations are essential not only to deal with peak times, but to provide additional power when wind farms and solar-generated power stations cannot. And yet they do not receive any subsidies.

Q. : *I run a company which produces electricity from gas and diesel-fired power stations. It is inaccurate to state that back-up power stations are not financed. In fact, no power station is built to serve purely as an additional 'topping up' source as it would not be profitable. The back-up power stations are former power stations which were originally designed for basic production before they became dated, and are now only used for peak-time supply. With the onset of the economic crisis, declining consumption and the development of renewable energies, some of these old power stations are no longer profitable even if they were bought at knock-down prices, and so their owners prefer to close them.*

The day when there is a shortage of electricity, back-up power stations will be very much in demand and will become profitable again. In my opinion, there is no point in subsidising back-up power stations : the market plays a very good regulating role.

Electricity and democracy

Q. : *I think that the management of electricity needs an authoritarian regime, in other words a body which takes extremely centralised decisions regardless of the lack of comprehension of the masses. According to the saying, France is 'a dictatorship tempered by 'Le Canard enchaîné', (a satirical newspaper) and consequently France was able to equip itself with the best nuclear plant in the world. This is not at all true for Germany. Are the inconsistencies and bad management which you have highlighted a consequence of democracy ?*

M. G. : We could perhaps blame this on a form of democracy in which it is no longer the executive which decides on the opportunity to install a new infrastructure, but a judge who determines the legality of a project.

Generally speaking regarding these questions, democracy takes a very unrefined form : the government puts measures in place for a year or two ; the Chancellor of the Exchequer points out that in order to maintain them one must increase taxes by a certain amount ; the government backs down, and the Chancellor decreases the incentives. Democracy is reduced to the willingness of the people to pay.

Q. : *The price of train tickets varies markedly depending on when one travels. Could the price of electricity also vary by a factor of three, for example depending on the time of day ?*

Q. : *This is exactly the principle behind the smart grid which is supposed to send price signals.*

M. G. : When people hear that gas prices are going to go up by 5 %, they are angry, but at least the message is clear. If we decide that there are no more rules and that each person has to manage his own smart grid all the time in order to know when he should consume energy, we run the risk of causing a scandal similar to that with mobile phone subscriptions which were supposed to be for unlimited calls, but some customers who had not read the small print received huge bills.

Presentation of the speakers :

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Marc Glita : graduate of the École Normale Supérieure and the École des Mines. He is the head of regional economic development at the DIRECCTE (Direction régionale des entreprises, de la concurrence, de la consommation, du travail et de l'emploi) in the Haute-Normandie region and a special advisor in charge of economic development to the Prefect of the region. He is a co-author of 'Le système électrique européen. Enjeux et défis' with Aurélien Gay.

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