NGI101x - Connecting the dots: Germany

Welcome back!

We have shown three series of web lectures this week. The first part was about complexity in general: what is it and what consequences does it have? In the second part, we showed you the physical complexity of infrastructures. This physical complexity interacts and interferes with the social complexity, which we explained in part 3 and vice versa. Now we will explain all this on the basis of one concrete example: Germany's so-called Energy Transition.

What is going on in Germany? Recently there have been substantial investments in renewable energy in Germany, particularly in wind and solar energy. You can see the effects if you drive through Germany. Everywhere you go you can see PV solar panels. There are also lots of wind turbines, both onshore and offshore. German people and businesses were attracted to investing in solar and wind energy. This is not just because they like the idea of renewable energy. It is also because they see it as an attractive investment. Any power they produce in excess of their own demand will be purchased at an attractive feed-in tariff. Investing in renewable energy offers far better returns than a saving account with interest rates at an all time low.

Yes, but that's not the whole story. The German green energy transition was given an extra boost when the nuclear power plant in Fukushima was hit by the tsunami. Following the melt down, the German government decided to immediately close seven nuclear power plants dating from before 1980. The ten remaining nuclear plants will have to be closed by 2022. That decision was a big deal for Germany. Nuclear power plants supplied as much as 23% of the country's electrical power needs.

At first glance, this may seem like a straightforward decision with predictable consequences. You would expect the power producers to be eager to fill the gap created by the closure of the nuclear plants. After all, the demand for electricity is only increasing. However, as it turns out, the power producers are not willing to take the bait. Why not?

For the energy companies, the forced early closure of their nuclear power plants, implies that they have to write them off at an accelerated rate. Another costly problem for them is that green electricity is given priority access to the grid, at the expense of the traditional, sometimes lignite fired power plants. Such power plants need to operate at least at 30 or 40% of their capacity to be economical. They cannot easily be shut down. It will take more than a day to get them restarted. Frequent shutdowns and restarts will severely reduce the technical lifetime of the plants. More and more, it happens that Germany's wind parks and solar panels supply enough electricity to meet German demand. This results in excess supply and even negative electricity prices because the lignite fired power plants cannot operate below their minimum working capacity.

The consequence of all this is that the major German energy companies face serious financial problems. For them, there is no sense of urgency when it comes to investing in new power generation capacity. However, they do need to invest. At least 15 new plants will be required to make up for the closure of the nuclear power plants. After all, the availability of wind and solar power is not guaranteed at all times.

It is even more complicated than that. Since the German grid is not an island, but part of the continental European grid, the consequences of closing the German nuclear plants reach far beyond the German border. Neighboring countries are confronted with large fluctuations in the power flows on their national grids since Germany is dependent on the international grid for transport of electricity between the North and the South. Neighboring countries thus also feel the price fluctuations. As in Germany, their energy companies are not willing to invest despite the urgent need to invest in generation capacity that can be easily adjusted to the fluctuations in wind and solar power. Gas fired power plants are the best solution. But because of the high gas prices and the low electricity prices, gas fired power plants are not economical. They are being shut down. Instead, for example, new power plants being built in the Netherlands are coal fired.

What I would like to add is that the Netherlands not only receives occasional cheap electricity from Germany, it also receives cheap coal from the USA. What is happening there? The successful shale gas programs in the United States have made the US self sufficient in its gas demand, forcing out coal as a source of energy. American coal is therefore cheaper than ever, and finds its way into other countries, including the Netherlands. The combination of cheap coal from the West and cheap power from the East has virtually eliminated any incentive for the Netherlands to invest in renewable energy.

Coming back to this course, the developments just described can well be described in terms of complex socio-technical systems. Different systems interact with each other as a result of which relationships between artefacts and actors are influenced in unexpected ways, leading to unanticipated emergent behavior of the electricity infrastructure.

Firstly, the economic system interferes with the physical system. The economic system balances the supply and demand of electricity where the balance is reached at a specific price. The physical system needs to balance the actual generation and use of electricity, at all times. The contracts between suppliers and clients in the economic system represent financial transactions. They do not represent real power flows in the physical system. The actual flows are dictated by the net result of all the transactions between the economic actors, and each of these transactions represents an estimate of the projected power supply and use, by a specific producer and a specific user, at a specified time in the future, necessitating corrections to be made close to real-time in the physical system. The fluctuating flows that the Netherlands occasionally have to deal with result from transactions between German actors, in which Dutch actors have no part. This makes the physical system unstable.

Let me add that the technical system interferes with the system of actors. The logic of the technical system suggests that the closure of the nuclear power plants must result in the construction of new plants. But actors, reasoning on the basis of their own interests, reach very different conclusions, partly as a result of the current incentive structure .Furthermore, technical characteristics of power plants, create situations of excess supply, occasionally resulting in negative electricity prices. This makes the economic system unstable.

Furthermore, national systems and different energy systems interfere with each other, even if their electricity systems are not directly coupled. Events in one country have unforeseen consequences in other countries. The nuclear disaster in Japan encouraged the German government to initiate the accelerated closure of its nuclear plants. The global economic crisis resulted in extremely low interest rates in Germany, which in turn accelerated the adoption of PV solar panels in German homes. Germany's Green Energy Transition periodically causes an excess of cheap power in neighboring markets, and threatens the stability of the electricity system, within and beyond German borders. In the Netherlands, the supply of cheap power interferes with the cheap coal shipped from the United States, which in turn is a consequence of the shale gas revolution in that country.

In short, seemingly unrelated events and developments in Japan and the US turn out to interfere with the German and wider European electricity infrastructure in unanticipated ways, causing the electricity infrastructure of Germany and its neighbors to move to near-critical operating conditions. The earthquake in Japan triggered a virtual earthquake in the European electricity system. It is hard to imagine a better illustration of co-evolution and emergent behavior of complex systems: it is almost like the proverbial butterfly in China that causes a hurricane in the United States.

Where do we go from here? What should the government do? What should the regulator do?

Thank you for your attention.