When the vital systems fail: enacting electricity infrastructure breakdowns

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1 Introduction

> "The bottom line of this essay, then, is about things being thick with politics. And I mean politics with a lower-case 'p': not the politics of politicians, but broad range of politics from micro to macro scale, and relating as much to the power of humans, as to the power of ideas and things." (Bijker 2007.)

Things are thick with politics as Wiebe E. Bijker points out. During the whole existence of large infrastructure systems, one question that has indeed provoked

a broad range of politics from micro to macro scale, and related as much to the power of humans, as to the power of ideas and things, is the problem that infrastructures should not break down – which is to say, the lights should stay on, the traffic should not be completely congested, the tap water should stay drinkable, trains should run, bank services should not be disrupted and so forth. The issue has again gotten increased public and political attention due to two developments: first, the major government and EU initiatives regarding critical infrastructure protection and second, the institutional restructuring of infrastructures in European countries under the headings of privatization and liberalization (de Bruijne & van Eeten 2007; Collier 2006; Collier & Lakoff, forthcoming). The very mundane question, often brought to the fore in the reader sections of newspapers, has become: "Can those infrastructures which are critical to nation states be handled by the instrumental rationality of a global free-market capitalism?"

The question may beem simply enough, but finding consensus about it has not been an easy fare. In this paper, the often problematized relationship between a public and a private service is studied in the energy sector in Finland. A model is proposed with which one can study the different rationalities (from instrumental to substantive, habitual and affectual) of a Finnish energy company's control room where energy production and consumption is balanced according to the Nordic power market principles. Some initial results of the analysis are also suggested.

The background to my paper is formed by economic-political developments of the electricity sector which are reviewed in the case of the EU. As the whole Nordic power markets are being connected to the European markets and as awareness of electricity supply as a critical infrastructure is raising especially in the EU, these economic-political debates form an interesting backdrop to be reflected on the often neglected points of view and practices of the control room actors in the energy organizations.

2 The public and the private services

2.1 A liberalized provision of energy[1]

In the 19th and early 20th century electricity utilities were organised as private companies, supplying electricity locally. The situation shifted during the World Wars and especially after the Second World War, as networks grew and as state intervention and state-investments into electricity distribution became normal. Infrastructure investment was considered the principal tool for economic development of states and the infrastructure provision was almost always handled by national or local infrastructure monopolies. (Collier 2006; Graham & Marvin 2002; Silvast & Kaplinsky 2007, 11.)

It should be properly emphasized that unlike it is often believed, electricity provision was never a fully state-led project, save for the Soviet Union. As Stephen Collier (2006, 10-11) has observed, other countries took other paths to infrastructural modernity that were in some cases self-conscious responses to the Soviet model. This self-consciously liberal infrastructure development was concerned with "limiting the state intervention when possible and with carefully justifying state intervention where it was unavoidable" (ibid, 11) – a concern which was resolved in several different national styles, like in the case of other welfare services. The distinction between today and the monopoly period of electricity provision is thus not so much about how many state-led or private institutions are involved, but rather, on how the service of an energy provision is practically governed.

As was explained in a recent whiter paper where I was involved (Silvast & Kaplinsky 2007, 11-16), the current liberalization of electricity provision means that electricity generation, transmission and distribution are separated into a number of different segments open to competitive entry. In the monopolistic model, planning of electricity generation, transmission and distribution was done centrally

[1]Parts of this chapter were originally released as part of the white paper Silvast & Kaplinsky 2007. Original pages of the white paper are pointed out through references.

and on a national basis. Producers and consumers signed long-term contracts that guaranteed electricity provision. Even today in Germany most municipal distribution companies are supplied under long-term contracts with a duration of 20 or more years. Building new generation capacity generally required major administrative processes and in many cases was not possible for private companies. A tendency to over-investment in generation capacity was also characteristic of a centralised planned electricity industry.

After the liberalization process, on the other hand, electricity generation becomes open to independent power producers, who enter the market with range of technologies (e.g. small renewable or conventional generation) and compete with incumbent generators. Electricity transmission and distribution retain their natural monopoly status – it is not economically feasible to have more than one electricity grid in one geographical area. However, a variety of economic mechanisms create competition, for example by allowing the end users to switch the utility with whom they contract for consumed energy. At the same time the electricity users have been configured new identities as consumers (Summerton 2003), who are required to "play their role" in managing their demand through new techniques, such as interruptible electricity contracts, real-time energy metering, switching their energy suppliers and obtaining personal emergency power generators for disruptions of supply (e.g. EurElectric 2004).

The EU has repeatedly stated that the aspiration for the internal energy market is the creation of one truly integrated competitive market which would provide the EU with secure energy supply. Basic to this is the development of cross-border trading within the internal market. Though it is improbable that mandatory targets for cross-border trading will be set, the European Council has asked that the member states with interconnections achieve at least 10% of electricity and gas interconnection capacity by 2010 (Commission of the European Communities 2007).

From purely technical point of view, synchronous electricity regions over several countries are not new. The Union for the Co-ordination of Transmission of

Electricity (UCTE) had already connected several European countries, including Austria, Belgium, France, Netherlands and Italy by 1951. However, due to the present market rationality, the European electricity networks have to accommodate increased electricity flows over longer distances. Pioneering in this shift have been the Nordic countries, where energy stock exchange Nord Pool was opened on 1996 as the world's first multinational exchange for trading and clearing financial power contracts. Today this exchange consists of Finland, Sweden, Denmark and Norway and its physical market accounts for over 60 per cent of the total value of the Nordic region's power consumption. In 2004, Nord Pool region added with Poland was declared as one of the electricity regional market projects that aim to integrate the European electricity markets.

Aside the market liberalization itself, several other contemporary issues also bring energy services to the fore. The present electricity infrastructure was mostly put in place during the post-second world war economic expansion of the 1950s to 1960s and many of these components that are reaching the end of their design lifetimes (Silvast & Kaplinsky 2007, 22). There are substantial worries on demographic ageing and recruiting young personnel for utility companies (ibid, 18). The total number of persons employed in the electricity, gas and water sectors in the EU-25 dropped by over 200 000 persons between 1999 and 2003 (ibid, 20). Much of this decrease is due to network planning, network monitoring, maintenance and in some cases the customer service being outsourced from the electricity utilities to private companies that operate with fewer machines and facilities, and a smaller workforce than before (ibid, 16-17). This organizational fragmentation (de Bruijne & van Eeten 2007) has lead to opposition from the workforce, uncertainty in the work environment and morale problems. Also, one cannot belittle the role of infrastructure risks, the possibility that something unpleasant will happen to infrastructures due to for instance sabotage, natural catastrophes, extreme weather or energy import disruptions, in creating contemporary concerns.

2.2 A new manifestation of an old problem[2]

Whether collective goods like energy can be handled by the competitive markets is a question that sparks the public imagination. In 2007, 87 per cent of Finns were certain or quite certain that the private electricity companies are deliberately raising electricity prices in order to gain profit (Finnish Energy Industries 2007). But as tempting as it seems to be to claim that the infrastructural sector is now for the first time facing "the retreat of the state from the infrastructural sector, the intensifying encouragement of liberal competition, powerful and transnational alliances and mergers, and private infrastructure firms who need to attract investments from pension funds, institutional investors and private shareholders" (Graham & Marvin 2002, 96), at least three kinds of problems are inherent to the claim.

First of all, the problematization of whether utilities are public or private is far from novel. On the contrary, the dialogue of privacy and closure versus openness and mixing has been played out since the beginning of urbanisation. For instance, closed and private streets were common in Victorian London (Graham & Marvin 2002, 386-387), and the problem of the form of ownerhip of electric utilities (municipal, private or mixed company) was also as urgent a question in the 19th century Helsinki as in any other large city (Hietala 1987, 246). To claim that energy companies are especially greedy today and should act more like public services is to repeat an argument that has been employed for – and that has not been resolved in – well over hundred years.

Secondly, with all the claims to liberalization, it should be stressed that the tide has yet to turn towards full-blown "deregulated" competitive electricity markets in the EU. On the contrary, to avoid situations where the market mechanisms fail to deliver competitive and secure electricity, almost all EU member states regulate the electricity companies' operation. The regulator is an authority that monitors the operation of transmission and distribution companies and gives incentives for

[2]Parts of this chapter were originally released as part of the white paper Silvast & Kaplinsky 2007. Original pages of the white paper are pointed out through references.

the companies to compete with each other. Up until about 2000, regulation usually took the form of price-caps for electricity distribution and transmission prices. A new form of regulation, which has received increasing attention and has been already adopted by growing number of European regulators, is to regulate the quality of electricity – a reform which is often backed up with familiar-sounding arguments about providing for the security and the welfare of the consumer (see also Collier 2006). But the tightening regulation has not been accepted easily by the industry. The European industry union EurElectric (2006) have protested that regulatory demands incur substantial financial burdens. EurElectric (2006) also consider it is not clear whether customers are prepared to pay for higher quality of supply. (Silvast & Kaplinsky 2007, 23-26.)

Thirdly to make the previous point slightly more general, the benefits of liberalized and open markets are not as wholeheartedly agreed on as the EU internal energy market directives would make it seem. The European Regulators Group for Electricity and Gas (2006) point out that political support for liberalization seems to be counterbalanced by companies' perceived risks of being held responsible for potential underinvestment, weakened security of supply and high prices. In an ideal market situation, electricity supply and demand would be balanced by the price of electricity. However, there are many exceptions to this logic: for example Spain, and the Iberian Peninsula generally, mostly lacked cross-border electricity interconnections to Europe in 2007, and the Iberian electricity market is practically isolated from the rest of Europe. According to Commission of the European Communities (2007, 4), the necessary degree of co-ordination between national energy networks in terms of technical standards, balancing rules, gas quality, contact regimes, and congestion management mechanisms, which are necessary to permit cross-border electricity trade to work effectively, is at present largely absent. These challenges have not diminished the political-economic aims for EU's energy integration, though: after the large blackout in Europe in November 2006, EU Energy Commissioner Andris Piebalgs could again underscore how the events confirmed the need for a proper European energy policy, as energy se-

curity is “better delivered through a common European approach rather than 27 different approaches" (EU 2006). (Silvast & Kaplinsky 2007, 53.)

All in all, it seems the dialogue of privacy versus openness in the case of energy is not a simple question to resolve. Criticism of competitive markets which is too generalizing runs the risk of missings its target. This motivates to seek academic discussions to gain understanding of the problem at hand.

2.3 Actor’s point of view

On trying to make systematic sense of the public and private utilities, one faces the problem of finding an explanatory model with suitable scale and scope. There is a lot of material on which one could diagnose the present society’s shift to another epoch, which could then be claimed to be the root cause of the problematic questions of electricity. Some useful concepts for this from the Cambridge Dictionary of Sociology include: *globalization* (to concentrate on the global system of interconnected energy networks which is being driven by capital free of national and geographic identity); *neoliberalism* (to concentrate on how economic policies are advocating the reduction of direct government participation in the economy and the privatization of supply of goods and services); *consumer society* (to concentrate on how utility providers are engaging with their users primarily as consumers; that is to say the capacity to purchase services becomes the principal frame in which reliable electricity supply is thought about); or *risk society* (to concentrate on the undermining of the insurance paradigm for security and the increasing reflexivity which offers the prospect of an ongoing management, if not resolution, of techno-ecological problems).

These diagnoses do serve as punctual and critical guides to the societies at present. Capital free of national and geographic identity has indeed an important role in the current transnational power exchanges. Direct state intervention to infrastructure provision is rarely considered justified, as states and the EU aim to make the actors self-responsibly competitive and providers of good quality electricity through the

new techniques of regulation. The infrastructure customers are very often thought about as consumers. And new forms of risk strategies, like decentralized local emergency power generators, can indeed only promise a probably less hazardous future but not the complete resolvement of energy problems.

But the diagnoses' problem is that they only handle free-market capitalism as an entity and a global actor of its own. Conversely, they have little to say on how capitalism affects the subjective minds of persons and actions in organizations. That is why the general diagnoses can be practical for pointing out macro-scale configurations of the society, which could offer important insights for, for example, a policy audience. But they are equally impractical in pointing out almost anything about the important level of everyday life which is social action. The specific problem is that the diagnoses tend to presuppose that each and every person is constantly getting more reflective about the transformations of a late modernity (see Archer 2007); but they leave unresolved whether reflectivity exists in a practical sense, which is a question that needs to be answered empirically.

The claim of my research project is that it is very useful to scrutinize the level of social action of providing energy: the thinking, actions and practical tools of those professionals who are already making decisions and anticipating the future of energy systems in their everyday work. My focus shall be on the concrete action that can be observed and for which the actors themselves give subjective meaning (though they do not necessarily have to). This focus on action is a methodological choice: as Max Weber famously said, the reality is endlessly plural, whence theoretical concepts can only exaggerate it by building ideal types which are overly simplified. As long as these choices are not turned into ontological presuppositions of the properties of social life, one can do them in a scientific study. To underscore: I do not claim that there is no society but only action; the political-economic discussions in the previous chapter hopefully also emphasize that. But I do claim that action is a domain through which one can find interesting new understanding of my research problem.

I have chosen to study in this paper the energy control room, as while the importance of centralized planning for energy has diminished, the real-time operators have much more seminal place than before (see de Bruijne & van Eeten 2007). As an analytical tool, I am going observe the *rationalities* of the control room. Studying social action as types of rationalities is another one of Weber's innovations: his classical work mapped out ideal types of rationalities, which are abstract because they apply universally and limited because they refer to the actor's subjective understanding of individual acts (e.g. motives, incentives, assets, meanings; though as I shall argue further on, there needs not always be subjective understanding in order for the action to be successful). The rationalities are oriented and dependent on other people, whose action is understood as being guided by similar types. These four ideal-typical rationalities are:

1. Formal rationality, which comprises of actions to instrumental goals by efficient means. It usually involves calculations according to generally applicable norms or rules. An example of this in the control room could be brokering on the Nordic energy markets or balancing the technical supply-demand.

2. Substantive rationality, which is the patterns comprising actions oriented to constellations of values, often regardless of the impacts of the action. It is oriented through demands and guidelines that the actor places on himself or herself. A substantive rationality may also surplus a formal rationality when different means for ends are compared. An example of this in the control room could be thinking about the customer's security and welfare.

3. Habitual rationality, which comprises of actions by which individuals solve problems without regards to such strict formal disclipine which is used in the case of formal rationality. These actions gain their firmness because of repetition, though repetition does not mean they are completely automatic behaviour. An example of this could be the hunches and intuitions one employs whilst working in the control room.

4. Affectual rationality, which is action guided by personal emotions. An example of this in the control room could be the action during an exceptional situation.

2.4 Towards an analysis

Walking upon the main premises of the energy company I am studying, it becomes apparent why infrastructures like energy networks have sometimes been referred to as the city's underground realm. The company is located just off the city centre, but surrounded first by a busy road from the other side and a lake from the other side, and then a fence. The gate (figure 1) reads: "Electricity utility. Trespassing and unauthorized entering prohibited" and next to it in another sign: "Guarded area. Camera supervision". It seems the city's underground realm is difficult to reach.

From this outset it is surprising that the site of my research, the energy control room, is anything but a concealed place. I am taken from the company lobby to the two spacious rooms above where energy consumption and production is constantly being balanced. The workers in the room are sitting in front of numerous computer screens and using rolling office chairs to move from one monitor to the other. Two large windows fill the room with natural light, opening into an attractive view of the lake side near-by. Presently the most visible and audible part of the room, though, is the opening ceremonies of the Chinese olympics which a group of people is viewing and commenting from a broad television screen.

"We are allowed to watch television", the worker I am interviewing explains to me, switching off the smaller television screen in his own room as he speaks. "It does not affect our work in any way, but our boss admits that it serves as an important breathing place", he goes on. That breathing places can be necessary in this type of work is not hard to believe. The energy company has two control rooms: one for the management of electricity supply systems and another one, which I am presently studying, for electrity markets and production. The room where I am at

Figure 1: Outside the energy company

has seven monitors that display different technical and market information of the energy system (figure 2). One of the most dominating element, probably because my interviewee keeps glancing at it, is a large wall clock which is located just above the monitors. The work happens in three shifts: the morning shift, the late afternoon shift and the night shift. Both rooms have a supervisor 24 hours, 7 days a week, and this work is carried out by about a dozen people.

At first the work itself is hard to distinguish from that done in just about any other modern working place. The routine consists mainly of using computers, a lot of it which appears to the outside as idling with bursts of activity every even hour. Be that as it may, the mundance surface can be deceiving. It is in these workers' practical decisions that different complex social, organizational and technical systems are intertwined, from weather systems to business organizations, electrical distribution systems, power generators, Nordic power exchanges and the behavioral patterns of the energy users.

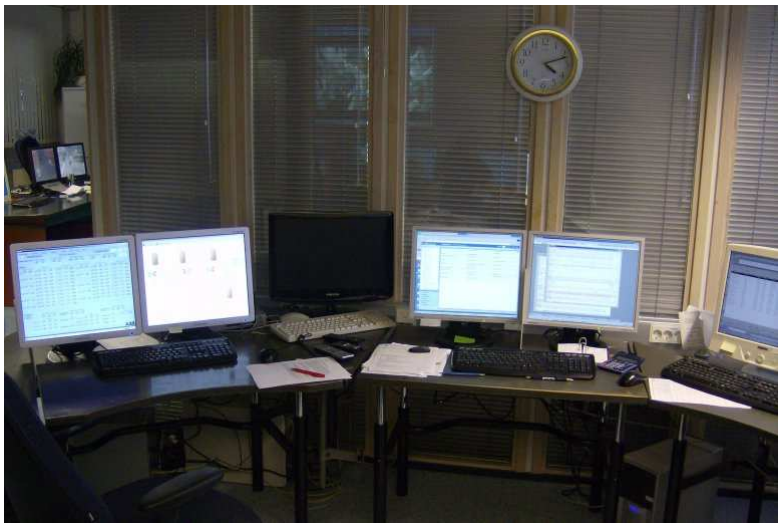

Figure 2: The energy market control desk

The morning shift in this room begins by planning the production, purchase and selling of energy for the following day. The company has statistics of the consumers' electricity use from several years, and these typical load curves are utilised to predict the energy demand for each hour. Based on the predictions and on the situation of the generating units, the supervisor decides how much energy is produced with the company's own units and how much is purchased from the electricity stock market "ElSpot". Extra produced energy can also be sold to the stock market. There are three variables that the optimisation is based on: the price of electricity, the price of fuel and the price of emission permits. The goal is to both supply enough energy and maximize the profits of the company. It is now late afternoon, so I cannot see this procedure, but two of the screens have spreadsheet upon which the optimisation has been based on.

After the plan has been sent to the electricity stock market in the morning, a real-time phase of the supervision begins. In the right-side screen of the supervisor, there are graphs that display both the predicted balance and the actual balance between energy demand and production. The company has an obligation to keep this difference below certain level. According to the interviewees, by and large

the predictions are usually correct. However, there are minor incidents that affect the balance all the time. Central of these seems to be the weather. For instance, the street lights of the town can switch on at variable times; it can be dark enough for the lights' automatic sensors to react at 17:50 as well as 18:00. Also rain and sunlight have a direct relation to the demand of energy. Such rapid contingencies – the changes can be visible in a matter of minutes – cannot be predicted even by meteorologists, though the supervisor is of course using weather predictions routinely during the planning phase.

However, there are several mechanisms through which the balance can be corrected. Firstly, the company's own generating units can be requested to produce more energy. The supervisor has one screen that is dedicated to the units, with information on their power capacities. The second option is to use an online electricity stock market called "ElBas" to purchase or sell electricity. One screen displays this market place, with the company's own purchasing and sellings appearing with green-colored text. At the moment, there are already several of those. Along with the two market places already introduced, there is also a third market from which the company can purchase electricity up to three years ahead. All in all, the contigencies seem quite manageable and the operation of the company stays technically adequate and economically profitable in spite of them. In this sense, the electricity grid supervisors resemble financial analysts, who have to vacillate between stock predictions and real-time response to market data. The workers in the room are indeed called "energy brokers".

So far I have done two interviews and sets of observations in the control room, so the results hereforth are only preliminary. I still think it is useful to end this paper by formulating some research questions and proposing answers to them.

My first research question is: *in this control room, which is the dominating form of rationality that is being employed?* At the outset – but only then – the answer seems simple: it is a mix of technical and economic instrumental rationality which is in command. One worker even compares the markets to a "command bridge" of a ship, which makes decisions, and the energy production and supply to an "engine

room" of a ship, which sets the technical limits. In contrast, the complicated energy use of the domestic, civic, agricultural, industrial and public sectors only enters the operation as a technical load curve which is entered to an Microsoft Excel sheet. When I try to ask whether there is an affectual or a substantive rationality to the work, a worker simply seems to think that the question is out of place.

Secondly: *how is it reflected that two forms rationalization – technological and economic – intersect in the work?* For all practical purposes, it does not seem to be reflected that often at all. The workers do notice that these are differentiated spheres of decision-making: some of the decisions as regards them are made in different sites, often even different organizations, and a worker points out to me that one should study *both* power mechanics *and* power markets in order to work at the room. But the workers do not seem to find this differentation that problematic in their practical work. To exaggerate a bit: Making the Nordic power exchanges almost has some quality which removes it from its technical and material underpinnings. It is telling that one of the workers I am interviewing tells me that he seldom has to think it as problematic that the energy is always technically transferred with the same grid and the markets are only a virtual add-on to this.

I then try to raise the stakes and ask directly, how can a welfare service be handled in the markets, and is not there a risk of loosing security because of the ends of the Nordic common market. A worker has a surprisingly straight-forward answer: the markets were liberalized in order to *increase welfare* of the region through decreasing electricity prices. And the company is not even allowed to make extensive profits; it has a monopoly position as the electricity grid of the region and is hence regulated by authorities.

Thirdly: *what form of rationality this techno-economic action actually is*? The previous example already indicates how important it is to stress that this rationality is not as instrumental and as calculative as some of economic theory would have it. Other forms of rationality mix up with it in the empirical persons the workers: there is for instance a clearly substantive welfare aspect to providing service on

the competitive markets. But one has to "translate" welfare to the code of prices before it can be discussed. Thus, whenever I try to ask too directly about what is the welfare or security rationality of the work, a worker says that those aspects are not handled at all in his room. To phrase Annemarie Mol (2002, vii), it almost seems that the energy control room workers have to enact their objects of concern in a familiar frame in order to manage them.

Another aspect worth stressing as regards my third research question is that the techno-economic rationalities are not only comprised of abtract formal disciplines like engineering science and economics. On the contrary, the work has a strong practical habitual rationality to it. A good working routine to the room can only be built in a long run, and this is the most problematic aspect of it according to one of my informants: that at first he made many mistakes, although he later learned the routine. The education to the supervision is mostly not even done at schools, but at the actual control room: a senior worker shows how to operate the room to a new worker and after a while of teaching they switch places. Experiental knowledge and habits seem to assume a central role in the actual decisions. The room thus withholds an active performing of the markets and the technological system itself (Callon 1998, 23). One manifestation of this is the attitude towards new software programs, which allow the prediction of energy supply-demand; apparently the workers refuse to use the software because they think good working habits are much more effective for predicting the future. As de Bruijne and van Eeten (2007) put it in their own study of an energy control room: "real-time resists formalization".

Finally and to continue from the previous point, the management of an energy system has a strong element of embracing the risks of natural incidents and the built environment. If there is a substantive or perhaps even an affective value to the work, it is shown most directly when the workers start to discuss respecting the unforeseen incidents of this material sphere: the changes in weather, the seasons in the city, the building which store heat during the summer but not during the winter and various other things which affect their daily work. These risks can

simply not be averted completely nor can there be a functioning defence against the risks – even while this defence against risks is the most frequent end of critical infrastructure protection policies (de Bruijne & van Eeten 2007).

To conclude, the work in the control room is perhaps best described as the real-time taming of chance in the nature and the built environment with techno-economic means and for welfare ends. I believe one has to bring all of these actors – from risks to chance, and from markets to welfare – and not just some of them into the discussion before the question of a public and a private service can be better understood.

References

Archer, Margaret (2007). Making Our Way Through the World: Human Reflexivity and Social Mobility. Cambridge University Press.

Bijker, Wiebe E. (2007). Dikes and Dams, Thick with Politics. Isis.

de Bruijne, Mark & van Eeten, Michel (2007). Systems that Should Have Failed: Critical Infrastructure Protection in an Institutionally Fragmented Environment. Journal of Contingencies and Crisis Management, 15 (1).

Callon, Michel (1998). Introduction: The Embeddness of Economic Market in Economics. In Callon, Michel (ed). The Laws of the Market. Oxford: Blackwell.

Collier, Stephen (2006). Infrastructure and Reflexive Modernisation. Presentation at the Helsinki Research Collegium.

Commission of the European Communities (2007a). Priority Interconnection Plan. COM(2006) 846 final, SEC(2007) 12.

ERGEC (European Regulators Group for Electricity and Gas) (2006). Assessment of the development of the European Energy Market 2006.

EurElectric (2004). Security of Electricity Supply. Discussion Paper.

EurElectric (2006). Comments on the CEER 3rd Benchmarking Report on Quality of Electricity Supply 2005.

European Union (2006). Energy Commissioner Andris Piebalgs reacts to Saturday's blackouts. Press release.

Finnish Energy Industries (2007). Energy Attitudes 2007.

Graham, Stephen & Simon Marvin (2002). Splintering urbanism: networked infrastructures, technological mobilities and the urban condition. London: Routledge.

Hietala, Marjatta (1987). Services and urbanization at the turn of the century the diffusion of innovations. Helsinki : Suomen historiallinen seura.

Mol, Anne-Marie (2003). The Body Multiple. Duke University Press.

Silvast, Antti & Kaplinsky, Joe (2007). White Paper on Security of European Electricity Distribution. Project UNDERSTAND, Leonardo da Vinci, EU Education and Culture. Link `http://www.understand.se/docs/White_Paper_EN.doc`

Summerton, Jane (2004). Do Electrons Have Politics? Constructing User Identities in Swedish Electricity. Science, Technology & Human Values, 29 (4), 486-511.