Thinking About the Future

System Dynamics and the Process of Electricity Deregulation

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Introduction

The deregulation of energy markets in general, and the electricity and gas markets in particular, over the last two decades has created a large number of new challenges and opportunities for companies in this sector, as well as for companies who might diversify into the sector. Thirty years back, there were few who believed or even discussed the possibility of a large-scale deregulation of the electricity sector. Most of the issues discussed at that time concerned how to improve various aspects of the existing monopolistic structure of the industry, not how the whole sector could be transformed, as has happened in many countries over the last 10–20 years (Munasinghe and Meier 1993; Helm 2003). As deregulation spread across the world, companies in the sector have found that competitive complexity and intensity are increasing significantly as deregulated companies find themselves competing in newly created industries, with new rules, often with new owners, against unfamiliar competitors, and with rules and regulations that are often poorly understood by all the stakeholders. A wide range of competence-destroying innovations are making the links between the past and the future increasingly tenuous for electricity and gas companies, and a new wave of disruptive changes may be just around the corner as the industry is beginning to consolidate in some regions (Lomi and Larsen 1999). What kind of competencies should electricity companies build to prosper in an institutional and competitive environment in which the past seems to contain so little information about the future (Dyner and Larsen 2001)?

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While we have accumulated more than 20 years of experience of deregulation, we might have learned only relatively few general principles. There are a number of reasons why this may be so, which we shall discuss later in this chapter. However, we can also see this by looking at the various problems that deregulated markets have had over this period of time. If we had learned from the "deregulation experience" across the world, we should have expected to "move down the learning curve" and there should have been fewer and fewer problems with deregulation—i.e. we should have learned to manage the process. However, there is currently no indication that this has happened (Sioshansi and Pfaffenberger 2006). Recent deregulations do not seem to be taking place more smoothly than deregulations that took place 15 years ago. This should not be misunderstood as saying that deregulation has not been a success in many of the countries where it has taken place—it definitely has been a success, and it has solved many problems that might otherwise have created major disruptions; however, there seems to be little learning taking place at the "process" level (Sioshansi and Pfaffenberger 2006). Why is this so?

One element that makes this question difficult to answer is that learning is required at many different levels, e.g. both at the institutional level, the actual design of the deregulation framework, and also at the company level. At the institutional level, it turns out that apparently small national differences and history might make large differences in the future performance of the system, e.g. generation technology (Dyner and Larsen 2001). At the company level, thriving in the new competitive world of electricity seems to imply a paradoxical combination of organizational learning and lack of experience (Lomi and Larsen 1999). One direct implication of this argument is that companies should reconsider the value of their typically large investments in backward-looking information systems, or at least see them as complementary to new *kinds* of forward-looking decision technologies (Dyner and Larsen 2001; Lomi and Larsen 1999).

It is also clear that traditional economics is not adequate for a full understanding of the new deregulated markets. Economics provides only a partial answer to many of the issues at the macro level (i.e. design of the deregulated market) and offers much less guidance as to how companies can make sufficient sense of these new markets to make the early investment required to "keep the lights on", and eventually exploit the markets to grow profitably. In this chapter, we try to classify the types of problem that many companies face when they are part of a deregulation, problems that seem to be quite similar across countries although the exact manifestation might differ from country to country.

The chapter is organized in the following way: We start with a short summary of the changes in the electricity sector that motivate our classification of problems, followed by a brief review of System Dynamics, the one methodology we will draw on in this chapter. We then discuss the three types of problem we have identified, as well as how System Dynamics can help in this process. Finally, we conclude the chapter with some observations on how companies should approach deregulation.

Types of Risk Associated with the Transition to Deregulated Markets

Many types of risk have long been acknowledged as critical in relation to energy markets; chief among them the financial and technical risk. Financial risk relates, among others, to the trading of energy, e.g. the loss of more than US$ 5 billion on natural gas by Amaranth Advisors, a Connecticut-based hedge fund, after making an estimated US$ 1 billion on similar trades the previous year. Another aspect of financial risk is the investment risk associated with investing in newly created markets, e.g. political risk, as seen in Argentina where interventions in the gas sector have created a number of market imperfections (Ponzo et al. 2011). Technical risk also has large-scale consequences, such as the blackouts in New England and Italy in 2003, as the transmission systems were unable to cope with the sudden changes in load. Other types of risk, in particular those associated with the transformation from monopolies to deregulated markets, are much less explored and less well understood (Larsen and Bunn 1999). In many cases, these risks are at least as serious as, if not, in many cases, even larger than the risk associated with the technical and trading arrangements in the market, as we shall discuss below. Furthermore, from a systemic point of view, these other risk factors might significantly increase the financial and technical risk in the deregulated market. In this chapter, we discuss some of these non-financial and technical risks associated with deregulated electricity markets, and methods that might be used to mitigate such risks. The way we classify the risk here is based on the experience of a large number of companies that have gone through this transformation, with more or less success. We conceptualize these issues as "risks" rather than "problems" because—if appropriately managed—they may provide unique opportunities for a company to establish the foundations of a sustainable competitive advantage (Lomi and Larsen 1999; Larsen and Bunn 1999; Emmons 2000). The three types of risk that we focus on here are:

- *Regulatory Risk*: The risk that is inherent in all markets where a regulatory institution has significant influence, as is the case with most deregulated electricity markets. The short- and long-term consequences, and the frequency of interventions in the market, are often poorly understood.
- *Market Risk*: The risk arising from having to learn to operate in a competitive market, where, before, the company was a monopoly and as such was in control of most aspects of the industry in the region or country. This is made more difficult due to the structure of most electricity markets and the limited understanding of the long-term consequences of the rules and regulation that are governing the industry after deregulation.
- *Organizational Risk*: The risk associated with the internal transformation most incumbent companies need to go through to adjust their structure, routines, practices, and understanding of the newly deregulated industry.

One might argue that there is a fourth type of risk, institutional risk, related to the design and implementation of the deregulation. While this risk is at least as important, we focus in this chapter on the three types listed above as they relate more or less directly to participants in the deregulated market. It should be clear that institutional risk is an indirect part of these company risks, and can increase these risks considerably. For more discussion about the institutional setting see Amobi (2004). In the following sections, we will outline one method that can help in limiting some of these risks by creating a better understanding of the issues in newly deregulated markets; we will then in turn discuss how System Dynamics can help to mitigate some of these risks.

Simulation in the Deregulated Electricity Sector

The traditional planning methods used within most electricity companies have been operational research methods, such as optimization using integer, linear, and dynamic programming. The models developed and used over a period of 30 years have proved to be extremely successful. It is probably fair to say that the electricity industry is one of the least disputable success stories of operational research (Dyner and Larsen 2001). However, as the industry changes, planning methods also need to change significantly. System Dynamics has many of the characteristics that make it a desirable addition to the toolbox of a deregulated electricity company.

When an industry undergoes disruptive change, incumbent companies face a difficult and dangerous transition. While managers may realize that their companies need to undergo massive transformation, they have no managerial experience or cognitive models that can meaningfully bridge the gap that they face. In this chapter, we argue that this challenge can be successfully addressed through a System Dynamics-based simulation approach that facilitates organizational learning about post-disruption behaviours and their consequences. We argue that System Dynamics can be used to create a rich learning experience that helps managers to more accurately understand the risks they face and the concrete steps they need to consider in order to avoid them. Our observations suggest that the use of this technique not only provides better and more informed decisions, but also produces higher levels of decision-making commitment.

Although deregulation typically is introduced stepwise, investment in, e.g. the electricity industry, has typically a lifetime of at least 30 years, and if the decision made by the companies in the (often very long) transition period is wrong, it has major consequences. This is true if the companies invest too much (low prices and possible bankruptcy) or if they do not invest enough (shortage and possible blackouts—with the accusations that follow from that). System Dynamics, as a method of feedback modelling, offers one of the only ways in which a management team can think through the consequences of these types of major disruption.

There is a long tradition in System Dynamics of using modelling for learning (e.g. Morecroft and Sterman 1994), which is needed in this case where we do not have the data or understanding of how the industry might evolve. Even when we are well into the deregulation period, new challenges arise that might change the competitive environment significantly, e.g. a number of countries, such as Switzerland and Germany, have decided to close their nuclear power plants in a relatively short time span (as a consequence of the Fukushima nuclear accident in Japan in 2011). Deregulation of the electricity sector has many of the characteristics that make the use of the modelling-for-learning framework applicable, including:

Lags: The building time, including planning permission, etc., for a small CCGT power station is 3–4 years, while for a large hydro plant or nuclear plant it can be up to 10 years. The economic lifetime is typically of the order of 25–30 years for conventional plants, and significantly longer for large hydro projects.

Unclear rules: Nobody knows what the long-term implications of a set of "new" liberalized rules are. In the UK, 10 years after deregulation, the market rules and the price setting were changed fundamentally.

Interdependence: Most decisions in this industry are highly interlinked: The regulatory framework influences the behaviour of the players in the industry, which will influence the investment, pricing, type of technology, fuel choices, etc., so that it is difficult to get an overview of the causal chain due to the lags in the reactions of the different segments.

You cannot just do one thing: There will always be a tendency to try to solve problems as they arise, a tendency that has become stronger as "evolving regulation" has emerged as the preferred way of controlling the industry. However, this way of setting up and regulating the industry will increasingly lead to unanticipated consequences, which then in turn will require even more selective changes, etc.

Many "stakeholders": Where before a deregulation the stakeholders have more or less aligned interests, not only are there new stakeholders added by deregulation, e.g. financial institutions, new competitors, electricity traders, etc., but also the nature of the interactions will change in many cases, making for a more hostile and confrontational environment.

System Dynamics can deal with these aspects of uncertainty. When change is rapid and past experience is irrelevant for navigating the future, we argue that simulated experience is a useful and necessary substitute. By "simulated experience" we mean allowing executives to play-out the future of their company with computer simulations. This way of rehearsing change through simulation is already widely accepted in many professions, but not in management where, arguably, it has the most to offer. Consider how architects, urban planners, engineers, and military strategists regularly use simulators to help them imagine and design new-yet-feasible buildings, highways, aircrafts, and battle plans. These days, even children design and build imaginary cities and homes using Sim-City and other Sim products

System Dynamics has a long history of being used in the energy sector, including Nail (1977), Ford (2001, 2002), Bunn and Larsen (1992) and Bunn et al. (1997). For a review, see Ford (1997), and for models used in the last decade see Arango and Larsen (2011).

Understanding Risk

We now return to a more detailed discussion of the different kinds of risks utility companies face, and how some of these risks can be mitigated by the use of System Dynamics. It should be made clear that there are many other methods that should also be considered and used in the deregulated company, though previously they were not seen as essential, such as Financial Risk Modeling (Jorion 1997; Humphreys and McClain 1998), Game Theory (Ferrero et al. 1998; Day 1999), Competitive Analysis (Grant 1998; Dyner and Larsen 2001), Real Options (Alleman and Noam 2000; Brennan and Trigeorgis 1999) and Scenarios (Schwartz 1991; Smith et al. 2005). However, we can only focus on one method, to keep the chapter within reasonable length.

Organizational Risks

Organizational risks are associated with the transformation of the company from a traditional monopoly to a commercial or market-oriented organization. A traditional monopoly is more like a governmental agency than a commercial company, particularly with respect to the amount of uncertainty it faces and the organizational structure. Most of the employees, including the middle and senior management, tend to have strong technical competencies or be political appointees. However, deregulation changes this significantly: the company will need to achieve a much greater focus on commercial aspects of the business, as the environment will become increasingly volatile, e.g. price and the need for change in the organizational structure to become more responsive. In many monopolies there are too many employees, as cost is not one of the major concerns; this fact led, in England and Wales over a period of 5 years, to a 60 % reduction of the workforce in the generation sector (Bunn 1994), and in Colombia too (Cavaliere et al. 2007). These changes are by no means trivial; the organizational changes that we have observed in the electricity industry are probably among the largest restructuring events recorded in any industry over the last 50 years. In fact, in discussions with managers of utilities companies, we observe that such companies (and people working in them) still behave as monopolies nowadays in Colombia, even after around two decades of deregulation. These transformations create organizational risks, as new capabilities have to be introduced, while at the same time the workforce has to be reduced without losing the technical competencies, which is a major challenge.

A number of other changes are summarized in Table 1. The result of all these changes and the corresponding adjustments within the company is a higher level of uncertainty, which for many former monopolies is a very uncomfortable situation. There are no easy ways in which this overall transition can take place. However, it is also clear that the faster the company can adjust to the new situation, the better off it will be. As pointed out earlier, in the formulation of strategy and the raising of finance, these companies were behaving as agents of government policy, and were

Table 1 Examples of changes taking place in the organization in the transition from monopoly to competitive market. (Larsen and Bunn 1999)

Attribute	Monopolistic market	Competitive market
Company focus	Best technical solution	Best cost-efficient solution
Management focus	Technical	Commercial
Customer focus	The customer has no choice	Retail competition forces a customer focus
Stakeholders	Relatively few, mainly government, and regulator	Many, including shareholders, customers, regulators, financial markets, NGOs
Planning methods	Classic operational research (OR) planning methods used successfully	New methods linking strategic thinking, uncertainty, and limited information
Level of uncertainty	Relatively low	High (price, demand, investments, etc.)
Outsourcing	Little or none	Increasing interest
Business rational	Social optimum	Shareholder value

relatively inexperienced in risk taking. Such companies have often been accustomed to receiving government subsidies, which together with monopoly power, encouraged them to increase assets and manpower instead of becoming leaner and more productive, as has been the experience in, e.g. the UK, as described above. Similar experiences can be found in many other countries such as, e.g. Colombia and Spain, and show that a successful transformation can take place, however painful it might be.

How can simulation and System Dynamics help in this situation? The use of simulation here is mainly in two areas: communication and management development/training. In both cases the simulation models are normally combined with a user-friendly interface to create what is known as a microworld, which is a sort of computer game developed and designed for use with teams (Dyner et al. 2009; Sterman 2000; Graham et al. 1992). Microworlds can be used both as a tool for communicating why certain actions needs to be taken, and also as a general tool for management development. For example, the Colombian market operator, ISA, was concerned about the missing depth and volume in electricity trading. After investigating, their conclusion was that this was in part because many potential participants felt that they did not understand the market, and in particular the risk involved in trading (Dyner et al. 2009). To help solve this problem, the EnerBiz microworld was developed, which has since been used to teach both trading and risk management in the Colombian market (Dyner et al. 2009).

Market Risks

The second type of risk, market risk, represents another major set of problems in the deregulation process. In a monopolistic electricity company, price formation is well understood, customers are captive, tariffs are negotiated with—or imposed by—the government, a relatively large amount of information about the industry is public, and as there is only one or a limited number of suppliers, expansion is based on a centralized planning process. Competition is not something that the management is focused on or even considers relevant, as exemplified by the quote below from a mid-level manager in a state-owned monopoly, when he was asked about competition:

> Competition may be good and well in many sectors, but how can we possibly do better than we are doing now? After all, if we have been doing this for a long time without major changes it is because we must be doing something right. (Lomi and Larsen 1999)

This type of statement shows the typical "mindset" of managers in monopolies (while this quote came from an electricity company, it is much the same in most other monopolies). This way of thinking makes the transition to a market-based organization even harder, as competition creates—among other things—consumer choice, price volatility, asymmetric information, new and possibly aggressive entrants, financial uncertainty, and the loss of "cost-plus" pricing leading to variable rates of return (Dyner and Larsen 2001). Much research has shown that it is very difficult to change the way in which managers think about their organization. This ultimately leads to an increasing level of stress, both for the individual managers but also for the organization as a whole. If the managers are not able to adapt to these changes they will eventually be replaced, as has been observed in many electricity companies, where the incumbent management has been replaced by managers with experience of competition from outside the electricity industry.

This problem with the necessary shift in management thinking comes together with a large number of other "problems" at the industry level that the company faces at the moment it becomes deregulated; to some extent, these are problems that are also shared with the regulator of the industry. A number of these problems are collected in Table 2. Such problems are related to the way in which the industry functioned under monopoly, as compared with operation under a deregulated regime.

Among the issues in Table 2, market power and investment decisions might have received the most attention. For long periods, market power was the focus of the regulator in England and Wales, companies in the England and Wales market were constantly under scrutiny from the regulator; every move they made was looked at through the lens of market power, forcing them to justify commercial strategies in greater detail than would have been expected, and limiting their options. Similar concerns have been raised in many other deregulated markets, such as California and Colombia. Nowadays, investment decisions have been increasingly important due to the concerns about long-term security of supply (Arango and Larsen 2011); this issue has been raised from the very beginning of deregulation in England and Wales (Bunn and Larsen 1992).

Another equally important, but not yet as-much-discussed issue, is the issue of energy savings: where initiatives such as demand-side management made perfect sense in a monopoly market, the logic breaks down when the industry becomes deregulated. From a rational or economic point of view, the companies in the industry have lost all incentives for contributing to energy saving and can only justify this in terms of corporate social responsibility. The first step towards a market-based

Table 2 Changes taking place at industry level when an electricity sector is deregulated. (Larsen and Bunn 1999)

Attribute	Monopolistic market	Competitive market
Business environment	Stable with only gradual adjustment, technically driven changes. Uncertainties in demand and costs	Unstable, volatile prices, new stakeholders, with diverse objectives. Market, corporate and regulatory environment
Information	Open and public domain information. Planned future	Information becomes secret. Future signals misleading
Investment decisions	Central long-term planning, based on optimization (minimize total system cost)	Agent-based decisions, based on firm's strategy to maximize profits
Regulatory environment	Concerned with social welfare	Awkward balance between interests of customers and new entrants
Market power	Not an issue as there was a regulated monopoly	Now crucial for regulators and companies
Conservation and environment	Easily incorporated into energy policy	Adds one more layer to regulatory risk
Public research and development (R&D)	Public R&D was seen as an important part of long-term obligation	Companies cannot justify public domain R&D

environmental policy has been taken by emissions trading, but there is still a long way to go before all the policies that were rational in a monopoly have been replaced with truly market-based policies.

We can describe the initial period after deregulation (although it is measured in years) as a state in which companies have to function suspended in time, without any relevant history that can guide decision making (Lomi and Larsen 1999). This situation, where there is no relevant history to learn from, creates major problems for most of the companies that become deregulated. An agreed upon past provides the basis for an understanding of how both competitors and customers behave and react to changes, and how prices might move given certain demand and supply conditions. The newly deregulated industry has not evolved over time as most industries, where a co-evolution between the companies and the industry has created a mutual adjustment and understanding. The deregulated industry has been "designed" by the regulator and the government, and there is no history that can guide the decisions of the company, as the industry did not exist as a competitive market place "yesterday". This uncertainty is not only affecting the companies, but also the regulator and the political institution that has been involved in the organization of the industry. The challenge for the company is thus to understand how the industry works and the nature of its weaknesses and strengths, enabling it to develop strategies either for competitive exploration or for political lobbying to influence future change.

Simulation can provide understanding of market risk in two ways: first, by making up for the lack of history or future plausible market evolutions, and second, in evaluating strategies. There is a need for companies to understand the possibilities and threats that they face in a deregulated industry, and to create long-term strategies and visions of where the company is heading. However, to be able to do this, a structured way of understanding the future is needed, without having access to a past (that does not exist). There is also a need to capture the dynamic elements and unintended consequences in the artificial market, i.e. a market made up of partly free and partly regulated market elements. Deregulated industries can be seen as complex systems, with many unanticipated consequences that the conventional economic and financial analysis will have difficulties in anticipating or discovering. An approach based on feedback, with explicit recognition of delays and representation of decision rules, as well as soft variables, has the necessary ingredients to be useful in an analysis of a situation such as this. Furthermore, simulation models at an early state in a deregulation cannot be validated empirically (as no data exists), but they can be developed to represent how the system is designed to operate and therefore, from such a prototypical basis, generate insights into the strategic opportunities created by the market's potential instability to shocks, parameter uncertainties, and market imperfections. Such models can thereby identify the sorts of business risks that might follow from a variety of scenarios for market structure and behaviour.

There are a number of examples of the use of System Dynamics (SD) for this purpose, including modelling of the England and Wales market (Bunn and Larsen 1992). The SD model of the England and Wales market highlighted at an early stage the potential problems that might arise as investment in generation capacity would become cyclical, following the pattern of capacity in similar capital-intensive industries (Larsen and Bunn 1999; Arango and Larsen 2011). Other examples include Colombia (Arango 2007), and California (Ford 2001, 2002), and many others listed in Arango and Larsen (2011).

Regulatory Risk

The final risk in our typology is regulatory risk. As electricity is a critical resource in all countries, after deregulation the power system maintains a regulator in some form (normally as an independent or semi-independent body), watching to see that the deregulation is carried out in the way it was intended. Typically, the function includes monitoring the market for anti-competitive practices, making adjustments to the regulation as the market evolves, etc. The regulator must choose how to balance controls on prices, investment, divestment, anti-competitive behaviour, security of supply, and protect possible remaining captive customers as well as moving the market forward. These duties have to be performed in the same uncertain and poorly understood markets the companies operate in; furthermore, the regulator is likely to have even less information than the companies operating in the industry, as the companies will tend to disclose only the absolute minimum amount of information required. From the point of view of individual companies, regulators become less predictable, and in many countries, the regulatory institution has the power to change, at least within some boundaries, the market and its competitive and organizational context within which companies operate (Cross 1996). Given these potential, and to some degree unpredictable changes, it is important for the companies to understand, as far as possible, how the regulator may react to any future incidents and to start thinking about regulation in strategic terms.

The use of simulation in this area has many similarities with the use in the market risk area. Again, the reason for using simulation in this case is that it might alert thinking and understanding to various unintended consequences that might trigger the regulator, or government, into reaction. An example of a simulation model used to explore the regulatory problems is Bunn et al. (1997). Here, a simulation model was used to explore the consequences of arbitrage across the short-term electricity and gas markets. The model showed how a dominant generator could influence prices in both markets and how the regulators in gas and electricity will have difficulties in dealing with it as long as they are separate institutions. The dominant generator can gain by creating increasing volatility in the electricity pool, thereby increasing the quantity of contracts that the customers are willing to sign at a premium to the otherwise "fair" price. If the generator owns any retail business, they will not suffer so much by this and will be in a better competitive position. Other case studies can be found in Ford (2001), Arango (2007), and Ponzo et al. (2011), among many others.

Discussion and Conclusion

In this chapter, we have outlined some of the common problems that most incumbent companies face when a deregulation takes place. While the exact manifestation of these risks might vary from country to country, the types of problem discussed above can almost always be found. Furthermore, in most deregulated systems these problems exist long after deregulation initially took place (Dyner and Larsen 2001). This is consistent with the view expressed earlier, that the transition period from monopoly to fully competitive industry is a very long one, in most markets.

The transition is even more complicated due to the interaction of these types of risk, i.e. the organizational transformation has to take place at the same time as the newly deregulated market is evolving and the regulatory institution is trying to understand its role, powers, and responsibility. In fact, the co-evolution of companies, markets, and regulation is a delicate balancing act, to which all the stakeholders in the power system need to pay careful attention. At a more theoretical level, it might be possible to argue that the problems, which we have observed in Chile and California, have resulted from this co-evolutionary process getting out of balance, as one part of the market developed faster than the other parts. Deregulation is a process rather than an event, i.e. the day on which deregulation takes place is just the beginning of a journey towards a well-functioning electricity market. As the market develops, companies get reorganized and begin learning to act in the new scheme, regulators understand the problems and opportunities to be found within the regulatory framework, and customers and other stakeholders start to explore the possibilities open to them. However, during these processes, there will be a number of unintended consequences resulting from the way in which the deregulation was implemented and the regulatory framework was composed, so that the market's functioning will have to be adjusted and, in some cases, will require significant changes. Sometimes, the lack of such adjustment would lead to the emergence of major problems at a later stage. For example, this is the case in England and Wales, where there is now a widespread consensus that there were too few companies created when the industry was deregulated in 1990 (Helm 2003). The regulator had to solve this problem 6 years later by providing incentives to the incumbent companies to sell off some of their generation capacity in return for being allowed to own distribution companies (Helm 2003).

The other two types of risk are much harder to understand via comparisons with other countries that have gone through the deregulation process. Colombia adapted the regulatory framework used in England and Wales (Arango et al. 2006), and it would be sensible to believe that Colombian companies could have learned from the experience of the English companies as England deregulated 5 years prior to Colombia. However, there is little in common between the evolution of the electricity price in England and Colombia, even though they have had the same market system. The main reason for this is the very different proportions of hydroelectric generation: only 4 % in England, as against 70 % in Colombia, which produces completely different price dynamics. For a comparison of the (very different) evolution of countries in Latin America, see (Arango et al. 2006).

While we related the risks and the possible mitigation of them to the use of System Dynamics, there are other simulation frameworks that provide insights into the working of new markets. As we pointed out earlier, we do not go through all the possible ways in which new markets can be modelled, but nor do we want to leave the reader with the impression that System Dynamics is the only way. Like all methods, System Dynamics has advantages and limitations. It is particularly strong when dealing with complex problems influenced by lags and feedback, where the rationality of decision is explicitly modelled. However, it is a method that builds on aggregated entities and structural relationships that need to be more or less constant during the period of study (Dyner et al. 2003). Recently, agent-based models have also been used in utility markets, and there are many other types of simulation that can be used.

While deregulation continues around the world, we need to improve our understanding of the long-term consequences. We have pointed out the areas that seem to us to lead to the main problems when electricity sectors are deregulated. Liberalized markets are significantly different from country to country, based on natural resources, generation technology, industry structure, network topology, etc. (Larsen and Bunn 1999). This means that there will be a need for each country to adapt or combine existing models, or invent a model that is suited to itself, and for each electricity company in each country to understand, learn, and develop efficient strategies tailor-made to that country. Simulation models should play a major role in this development; in particular, this development can benefit from the behavioural, high-level, and feedback characteristics of System Dynamics to deal with the special modelling challenges of restructured industries.

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