# POLICY CHANGES IN THE SWISS ELECTRICITY MARKET: A SYSTEM DYNAMICS ANALYSIS OF LIKELY MARKET RESPONSES

**Patricia Ochoa**
HEC Lausanne, Switzerland
patricia.ochoa@unil.ch

## ABSTRACT

*The Swiss electricity market - as well as the European electricity markets, is now facing a period of fundamental structural changes. Emergent liberalisation is taking place, and nuclear dismantling is being debated. Given this scenario, it is important to evaluate market response to those changes in terms of security of supply and the viability of international exchanges - imports and exports of electricity from and to neighbouring countries.*

*The approach we adopt to analyse various aspects of security of supply in Switzerland differs from the traditional economic methodology which focuses on equilibrium of outcomes as opposed to on how the new situation is reached. We use system dynamics simulation models, which incorporate information feedback and behavioural policies, to study scenarios of the transient period currently faced by the Swiss electricity market.*

**Keywords**: Electricity Markets Policies, Emergent Liberalisation, Nuclear Power, Security of Supply, Switzerland.

## 1 INTRODUCTION

The original purpose of national electricity industries is to guarantee electricity supply to both households and industrial consumers. In order to guarantee electricity supply, the system must be able to manage demand peaks; that is, the supply of electricity must be sufficient to fulfil the highest point of the demand curve. Capacity of supply might be understood as the local installed generation capacity; however, contracts for importing electricity from neighbouring countries might also be considered as a source of reliable electricity supply.

Under governmental monopolistic structure demand is captive and sufficiently predictable to allow planning of capacity expansion in the long term. But this advantage is generally lost when liberalisation takes place, because companies then need to predict their market shares in a competitive environment. Security of supply appears then as a crucial matter: market structure must be carefully designed in order to avoid disturbance on price evolution and the problems that could result from a shortage of electricity in modern life. Given the critical importance of electricity in our everyday life, any disruptions might prove to be very costly (as experienced in Italy and the Northeast of the USA in 2003, and California in 2000).

Security of supply in liberalised electricity markets has been widely studied. Authors like Borenstein, Bushnell, Helm, and Ford, among others, have analysed security of supply problems in the European and North American markets. Nevertheless, the aim of this paper is to understand the implications of different policies for electricity capacity planning for the Swiss electricity market.

The Swiss electricity market is a fairly interesting market. Even if the industry is supposed to remain regulated and competition is theoretically forbidden, some kind of liberalisation - which we call emergent liberalisation - has taken place since Migros - one of the major retail chains in Switzerland - has won the right to be supplied by Watt Suisse AG instead of the incumbent supplier FEW/EEF (Power in Europe, 2003). The Swiss electricity law does not forbid competition; furthermore, the Swiss Cartel Law protects third party access to the network.

In addition, even if Switzerland does not intend to be part of the single European electricity market, it has a strategic geographical position - Switzerland is in the middle of the core area of the European Union, thus, Swiss power producers maintain electricity exchanges (imports and exports) with neighbouring countries. These exchanges represent an important source of revenue for Swiss utilities.

Finally, nuclear dismantling has been debated in Switzerland since the early 1980s. People have not yet accepted the dismantling proposition, so there is actually no law banning the construction of new nuclear plants, but given the current attitude of the population and the politicians any new nuclear investments are most unlikely. This uncertainty of the future of nuclear generation added to the emergent liberalisation, creates an important risk of under-capacity in the next ten to twenty years.

The purpose of this paper is then to illustrate the impact that policies like nuclear phase-out and emergent liberalisation could have on the Swiss electricity market in terms of supply reliability, capacity expansion, and international electricity exchanges (imports and exports). This is important from a policy point of view for both the government and utility companies; however, there is relatively little understanding of the changes that are taking place in the Swiss market and how they will influence energy policy and capacity expansion in the coming years.

This article presents a model that helps understanding the logic of the dynamic behaviour of the Swiss electricity market from a systemic point of view, and illustrates the rationale of politicians and decision makers involved in the market planning process, as well as the possible consequences of the implementation of different policies. The purpose is not to forecast or quantify market response, but to identify and understand possible scenarios for market behaviour.

First, a description of the state of research in the field is presented. Section 2 provides a description of the Swiss electricity market and its technical characteristics. Section 3 covers the impact of the European changes over the Swiss electricity markets, while section 4 explains the dynamics of capacity expansion in the Swiss electricity market. A discussion and conclusion are presented in section 5.

## 1.1 BACKGROUND

Liberalisation in electricity markets is a recent phenomenon and thus a relatively new area in the academic world. The area first caught the attention of academics in the eighties as a mainly theoretical topic (Beesley, 1992), but it did not become a major area of interest until deregulation started to take place in the nineties. Nowadays, there is a large literature on energy deregulation, spanning a wide area ranging from policy type publications (Navarro, 1996; Green and Newberry, 1997) through economic models (Kahn, 1998; Armstrong, Cowan and Vickers, 1994) to detailed simulation studies (Bunn and Day, 2001; Lyneis, 1997; Dyner and Larsen, 2001).

A general description of deregulation and the use of economic models can be found in Hunt and Shuttleworth (1996). A description of the deregulation process in the US can be found in Hirsh (1999), and one for the UK in Surrey (1996). Further case studies of countries can be found in OECD publications (1997). Non-technical discussions can be found in Kahn (1998), and Sidak and Spulber (1998). Some of the implications for business can be found in Weiner, Nohria, Hickman and Smith (1997). A discussion of technical issues can be found, among others, in Laffont and Tirole (1994).

Most of the literature on market design has been dealing with either the theoretical design of the markets or with analysing the implications of a given market structure, mostly with respect to market power (Bunn, Day and Vlahos, 1999). Electricity markets have proven to be more difficult to restructure than many other markets that served as models for deregulation - natural gas, airlines, trucking, telecommunications, among others, due to the unusual combination of extremely inelastic supply and extremely inelastic demand, combined with the non-storability of electricity, and the need for real-time supply/demand balancing to keep the grid stable (Borenstein and Bushnell, 2000; Borenstein, 2002).

In addition to being an important commodity, electricity is vulnerable to supply-demand imbalances (because storage costs are prohibitive). For that reason, if one supplier fails to meet the demands of its customers, not only will those customers lose service; all customers sharing the distribution grid will lose power as well (Borenstein et al, 2000, Brennan, 2003).

The confluence of the latter characteristics gives rise to an interesting matter in the analysis of electricity markets: the requirement to construct and maintain extra capacity for generating electricity (Brennan, 2003), in order to avoid the risk of blackouts.

Articles in this area are relatively recent as deregulation of the electricity industry has tended to start with a grace period of energy surplus inherited from the previously expansive coordinated economies (Finon et al, 2004). According to Finon, the regulatory challenge has therefore primarily been to allocate existing generation to consumers in an efficient way. However, as energy demand increases, due to economic growth, the challenge of providing new capacity surfaces, and thus the subject draws the attention of market observers.

Several authors have published descriptive articles with qualitative observations about security of supply. Helm in 2002, analyses security of supply in liberalised markets. He states that privatisation did not change the dominant role played by the government in the UK electricity industry, it only changed the form of interventions; the mechanisms of influence shifted from the boardrooms of nationalised industries to more explicit policy instruments and regulatory control.

Helm emphasizes that one major issue in which energy policy should concentrate is the security of supply problem; however, he argues that given that supply can almost always be made equal to demand (because only in extreme circumstances is energy physically unobtainable), then an appropriate definition for security of electricity supply refers to the desire for relatively stable prices over time, in line with people's investments in durables, housing and capital stock at any point in time. Helm's paper also mentions that the opening up of retail markets to full competition broke the link between long-term sunk investments and the guarantee of cost recovery from customers; financial markets will not be in a position to hedge longer-term contract risks efficiently, especially as consolidation takes place.

Shuttleworth et al (2003), consider whether markets are likely to respond effectively in managing current or expected risks to energy security; they conclude that markets might be able to manage supply risk and that governments should only intervene when barriers -market or political failures- impede effective risk management.

Frei (2004) argues, based on historical evidence, that access to energy, supply security, energy costs, environmental issues and social acceptance are not subject to trade-off, but to a hierarchy that underlies the importance of satisfying lower-order needs before addressing the higher-order needs. His paper introduces the concept of an "energy policy needs pyramid" inspired on the Maslow's pyramid of needs. According to Frei, historical observation of national energy policies shows that once access to commercial energy is obtained, the first priority is supply security, followed by cost efficiency.

This paper builds on a different stream of literature, which takes a systemic view. The general method is known as system dynamics or business dynamics, and incorporates non-equilibrium assumptions, delays, and bounded rationality, which are more suitable for evaluating markets during transition from monopolies to liberalisation. As Gary and Larsen state (2000), traditional economic equilibrium models do not adequately address the issues facing newly deregulated industries in the shift toward liberalised market competition. Equilibrium assumptions break down in the out-of-equilibrium transition to competitive markets, and therefore these assumptions must be replaced with endogenous behavioural policies in order to guide management in these periods (Gary et al, 2000).

The tradition of using system dynamics to analyse energy related issues goes back to the seventies (Nail, 1977) where several large models were developed. Some of these models have been updated and where still in use during the 1990's (e.g. used by the Department of Energy in the US (Nail, 1992)). These models have been used in many instances to increase the general understanding of energy policy, such as The Pacific Northwest Hydroelectric System (Ford and Bull, 1989; Ford and Geinzer, 1990). They have been tested extensively during the last 20 years and have compared favourably to other modelling approaches (Electric Power Research Institute, 1981; Amlin and Backus, 1996).

More recently, system dynamics models have been used to improve understanding of deregulated markets. Examples include detailed studies of deregulation and potential problems in California (Ford, 2001), and in the UK (Bunn, Dyner and Larsen, 1997) and a general framework for understanding deregulation in the US (Lyneis, Bespolka and Tucker, 1994; Amlin and Backus, 1996).

Ford (1999) used system dynamics simulation for studying the cycles in competitive electricity markets. He focuses on capacity expansion cycles in Western US electricity markets, and describes the potential for power plant construction to appear in waves causing alternating periods of over and under supply of electricity. In this paper, Ford uses computer simulation to show the influence of a constant capacity payment alongside the market clearing price for energy. The paper concludes with an examination of the consumer impacts of a constant capacity payment.

Gary and Larsen (2000) used simulation to demonstrate the differences between adopting equilibrium assumptions versus feedback through behavioural policies. In their article, they present a feedback simulation model developed to examine firm and industry level performance consequences of new generation capacity investment policies in the deregulated UK electricity sector. Their model explicitly captures behavioural decision policies of boundedly rational managers and avoids equilibrium assumptions; they conclude that the inclusion of behavioural policies in the place of equilibrium assumptions is fundamental for gaining understanding of the dynamics of the industry. According to Gary and Larsen, there is a very real danger that strategic decisions based on equilibrium analyses could result in extremely costly mistakes in out-of-equilibrium markets.

As our purpose is to understand and conceptualise the implications of different policies on the Swiss electricity market behaviour, we use a systemic point of view. We present a simulation model (System Dynamic Model in Vensim® software) to understand market trends and to conceptualise possible scenarios for the evolution of the Swiss electricity market - we want to "visit possible futures".

There has been comparatively little written about the consequences of the implementation of different energy policies, like nuclear phase-out, in the Swiss electricity market. Traditional equilibrium models, aimed at analysing the economic impact of the implementation of the reforms proposed by the initiatives "Stop the Nuclear" and "Moratorium Plus", can be found in Böhringer, Wickart and Müller (2003), Pfaffenberger and Gerdey (2001) and Prognos (2001).

Other countries in Europe are also studying the viability of a nuclear phase-out. Hoster (1998) presents a dynamic optimisation with a large scale multi-period, multi-region linear programming model of the European power systems which is used to analyse the consequences of a nuclear phase-out in Germany. Welsch and Ochsen (2001) present a general equilibrium model for analysing the dismantling of nuclear power in Germany from a macroeconomic point of view. Andersson and Hådén (1997) discuss the consequences of a phase-out of the Swedish nuclear power, combined with different

$CO_2$ emission goals; Andersson and Hådén model in detail the relationship between the national Swedish electricity market and the regional markets for heating, in a dynamic partial equilibrium environment. These types of analysis make a number of assumptions about the rationality of the agents, and the feasibility of reaching equilibrium.

Liberalisation of the Swiss electricity market has been debated by both its supporters and its opponents. Detailed information can be found in the articles of the Swiss Federal Administration (Assemblée Fédérale de la Confédération Suisse, 2002; Chancellerie Fédérale, 2002 and 2003; Conseil Fédéral, 2002; Office Fédéral de l'énergie, 2002; Swiss Federal Administration WebPages, and Swiss Federal Office of Energy WebPages). Jengen and Wüstenhagen (2001) present the state of mind of how the central political actors in Swiss energy policy think about key issues of market liberalisation and sustainable development, on the basis of a descriptive analysis. Fillipini and Banfi (2002) present a study based on the comparison of the actual cost structure of a sample of hydropower firms with expected market prices for ten years under the assumption of market liberalisation.

The next section gives a general description of the current structure of the Swiss electricity market in terms of demand attributes and generation characteristics.

## 2 THE SWISS ELECTRICITY MARKET

Switzerland is a trading hub for electricity in the centre of Europe, with a share of exports, measured against domestic consumption, of approximately 50% - the largest in Europe (SFOE WebPage). Furthermore, Switzerland depends on imports, mainly from France, to cover electricity demand during the winter season. It is therefore essential for the Swiss electricity market to be prepared for the new market rules.

### 2.1 CURRENT STRUCTURE OF THE SWISS ELECTRICITY MARKET

The Swiss electricity industry is theoretically a regulated market; however, since the 1990s the government is planning to liberalise it; furthermore, in the last two years emergent liberalisation has taken place. Further discussion on emergent liberalisation is included in the next section.

A diagram of the market structure is presented in Figure 1. Currently, according to the Swiss Federal Office of Energy, all the customers in this market - Industrial and Residential - should be treated in the same way whatever the level of consumption they have. They are obliged to purchase electricity directly from the regional distribution at a price that is fixed by the government.

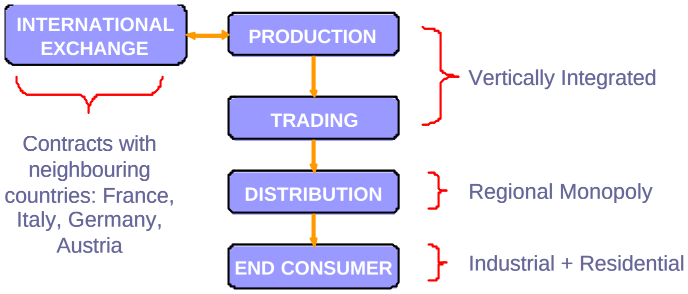



Figure 1. Swiss electricity market structure

Distribution is a regional monopoly; the retailer has a passive role of intermediation between traders and consumers, he has no power position in this market. Traders and generators are vertically integrated and they are the only ones who can import and export electricity from and to neighbouring countries.

### 2.1.1 Demand

Swiss electricity demand is quite stable. According to the Swiss Federal Office of Energy (Statistique Suisse de l'électricité, 2002), electricity demand in 2002 was 54,000 GWh, 34% of which were consumed by industrial consumers, 30% by residential consumers, 26% by services, and the remainder was split between transport and agriculture (Figure 2).

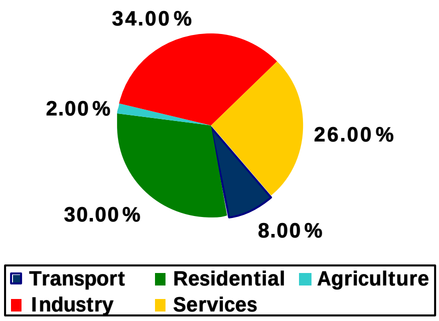



Figure 2. Electricity consumption in Switzerland

Demand in the winter represents 54.2% of the total demand in Switzerland, and the monthly summer demand is about 20% lower than the winter one because of temperature differences.

### 2.1.2 Production

Switzerland has about 2300 power stations, but 57% of the production is generated by the 25 largest power stations - mostly nuclear and hydro storage based plants - and the production of almost 2000 little stations together reaches less than 1% of the total electricity production of the country. Thus, despite the appearances, the Swiss electricity production is a concentrated industry.

The most significant source of generation is Hydro (Figure 3) which accounts for 60% of the installed capacity, split between storage based power stations with 35% of the total capacity and run-of-river plants with 25% of the total capacity (Statistique Suisse de l'électricité, 2002).

The second most important source of generation is Nuclear with a share of 37% of the national generation capacity.

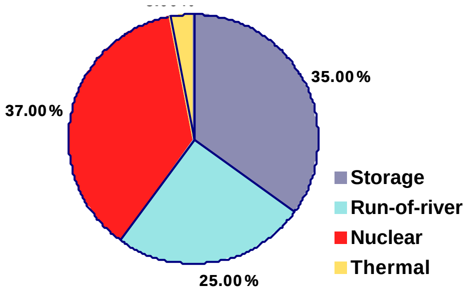



Figure 3. Installed capacity in Switzerland

In the summer, there is sufficient water in the run-of-river power stations and in the storage based ones, thus, nuclear plants can be closed down for maintenance and there is still excess production that can be exported mainly to Italy where prices are always higher than those in Switzerland.

In the winter, demand increases by about 20% and Swiss generation is not sufficient to match demand, so it is necessary to import energy, mainly from France and Germany who have important nuclear capacity that lets them produce low cost electricity during the winter season (Figure 4).

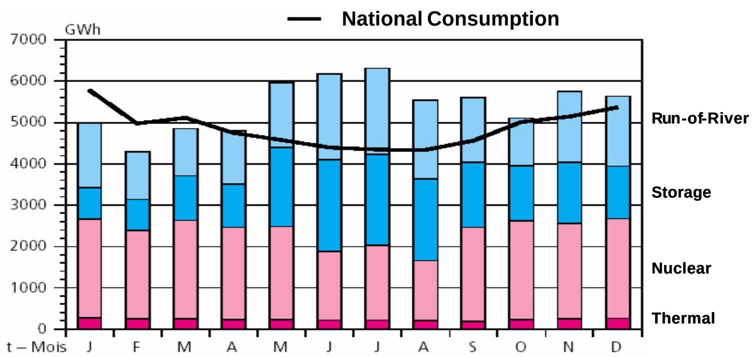



Figure 4. Electricity demand versus generation during the year

International exchanges between Switzerland and its neighbouring countries occur throughout the whole year, however, exports to Italy are always higher than imports from France (Figure 5). Switzerland acts as a transit between Italy and France because of the insufficient physical interconnection between those two countries.

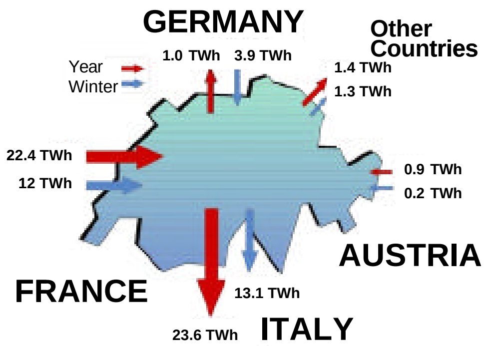



Figure 5. Transmission capacity between Switzerland and neighbouring countries

Given the importance of international transactions of electricity for the Swiss electricity market, the European energy policy must be taken into account when defining the Swiss policies. Thus, it is crucial to understand the structural changes of the European market as well as their influences on the dynamics of the Swiss electricity market.

## 3 POLICY CHANGES IN THE SWISS ELECTRICITY MARKET: EMERGENT LIBERALISATION AND NUCLEAR PHASE-OUT

The introduction of a single competitive European electricity market will have a significant effect on power systems throughout Europe, both within and out of the European Economic Community. Given its geographical position, and the high level of physical and economic transactions of electricity with the members of the European Union, the Swiss electricity market will certainly be affected by the liberalisation and unification of European markets. The creation of a single - deregulated - European market may force liberalisation in Switzerland, with significant consequences on security of electricity supply. Under a governmental monopolistic structure demand is captive and sufficiently predictable to allow planning of capacity expansion in the long term. This advantage is generally lost when liberalisation takes place.

The process of liberalisation is much more complicated in Switzerland than in any other country because of the Swiss democratic system. The adoption of a new law is a complex and often lengthy venture. The route for a new law has five stages (Chancellerie Fédérale, 2003):

*The Initiative Stage* where the idea is presented by any one who sees the need for a new law.

*The drafting stage* where the Federal Council formulates a first draft law, forwards it for consultation to the cantons, parties and associations and to other groups with a particular interest in the subject.

*The verification stage* where the new law is debated and voted by the National Council and the Council of States.

*The final decision stage* where the new law adopted by Parliament enters into force unless a referendum is sought within one hundred days. To be valid, the signature of 50,000 electors must be obtained in favour of a popular ballot. The referendum is similar to a veto and has the effect of delaying and safeguarding the political process by blocking amendments adopted by Parliament or the Government or delaying their effect - the referendum is therefore often described as a "brake" applied by the people. A vote must be held in such cases and the majority of the votes cast is sufficient for adoption.

*Entry into force:* If a majority of the voters approve the new law, it is included in the collection of laws and duly takes effect.

The National Council adopted the law for the electricity market - LME (abbreviation of *Loi sur le marché de l'électricité*), on the 20th March of 2000, and it was accepted by the Parliament on December 15th of 2000. It was intended to enter into force by 2001, but by the 9th May of 2001 a Referendum succeeds with 67,575 signatures. The law was then subjected to popular vote on the 22nd august 2002, and was rejected by a small majority of 52.6% of the voters with participation in the election of 45% of the population (SFOE, 2002).

However, as we have already mentioned in the introduction of this article, even if the electric power law -LME, that would have created a controlled opening up of the Swiss market, was rejected by people in 2002, in June 2003 the Swiss Federal Tribunal admitted that the electric energy market - at least with respect to the power transmission (third party access to power grids) - can be opened via the Cartel Law (Bernheim and Cohen, 2004). The decision of the Swiss Federal Tribunal has lead the market to a stage of emergent - uncontrolled - liberalisation in which only wholesale consumers with high bargaining power can choose their electricity provider and negotiate tariffs.

According to Bernheim and Cohen, the decision was based on the following facts: In 1999, Migros (the Swiss retail chain) decided to no longer renew its existing energy supply contracts with Freiburger Elektrizitätswerke - FEW. Instead, Migros, after carrying out a bidding procedure, decided to enter into new energy supply contracts with Watt Suisse AG. In order for Watt to deliver its electric power to the business establishments of Migros located in Canton Freiburg, Watt would have required an electric power transmission right through the electric power network of FEW. FEW, however, rejected Watt's request to transmit electric power, for a fee, over the electric power network of FEW. Both the Competition Commission and the Appeals Commission judged the refusal of electric power transmission to be in violation of the Swiss Cartel Law.

According to the Article 7 of the Cartel Law (Assemblée fédérale de la Confédération Suisse, 2004), the conduct of an enterprise that holds a market-dominating position is illegal if the enterprise abuses its position in the market by hindering other enterprises in the commencement or exercise of competition or by discriminating the market counterparty.

The Cartel Law does not explicitly exclude the electricity market from its scope of application; furthermore, the lack of special legislative rules requires the continual application of the Cartel Law. The *de facto* monopoly that FEW holds with respect to the supply and distribution of electricity in Canton Freiburg due to the fact that it is the only entity entitled to erect an electric power network does not mean that competitors are excluded from the use of this electric power network subject to payment of appropriate compensation. Rather, the energy supply in a canton can be safeguarded even if energy is provided by several suppliers - including, in particular, electricity providers domiciled outside the cantonal territory - who are granted access to the fixed network.

This situation of emergent liberalisation is advantageous for industry and large consumers - with important bargaining power, because they may have lower-price electricity contracts. Producers and distributors, on the other hand, are facing a difficult situation: they must reduce selling prices in order to keep their clients; they need to improve efficiency.

There are two main approaches for increasing efficiency of the existing generation plants: modernisation of existing plants, and implementation of new generation technologies. Both approaches involve high capital investments; under a structure of public ownership of generation plants, those investments are the responsibility of the government.

Given the current financial constraints of the Swiss government and the fact that significant investment in Switzerland must follow the democratic process described before and must gain people's approval, public investments in capacity improvement, if any, would take a long time to materialise. Furthermore, private investments are not possible as long as the market remains regulated.

A final alternative to compensate the revenue lost because of large consumer price reductions is to charge more to small captive consumers who do not have the option of switching provider so they are obliged to buy electricity from their regional distributor.

Under this situation, re-regulation of the Swiss electricity market is compulsory if the market wants to retain the low household prices without endangering the viability of existing companies and security of supply.

Market rules are then uncertain for the near future of the Swiss electricity market. Being in a transition stage, prices and demand are mostly unpredictable. International exchanges, which are one of the major sources of revenue for Swiss utilities, are highly dependent on international relationships and may be affected by the creation of the single European electricity market which will impose total liberalisation of electricity markets in member countries by 2007.

Another controversial debate in electricity markets nowadays regards the electricity generation structure and particularly the use of nuclear power. Germany, Belgium, Sweden and Japan have been studying the decommissioning of nuclear electricity plants (Welsch & Ochsen, 2001; Verbruggen, 2004; Andersson & Hådén, 1997; Viklund, 2004; Nakata, 2002), for safety and environmental reasons.

In Switzerland, five referendums concerning the future of nuclear generation have taken place since the early 1980s. The first one, in 1984, proposed to ban the construction of new nuclear plants, and to forbid the enhancement of thermal power of the existent nuclear plants. This referendum was rejected by a small majority of 55% of the voters. Despite the rejection, the proposition was resubmitted in 1990 accompanied with another referendum on the same day proposing the gradual dismantling of the existing nuclear facilities. This time the proposition of stopping the construction of new nuclear power plants during ten years (Moratorium) was accepted by 54.5% of the voters, while the proposition for a gradual dismantling of nuclear plants was rejected. The last referendum to date took place in 2003, and consisted of two propositions regarding the extension of the moratorium approved in 1990, as well as the gradual dismantling of the existing plants. None of the propositions was accepted in 2003; nevertheless, the debate goes on and the question will surely reappear in the coming years.

The future of nuclear generation is crucial for the Swiss electricity market. As mentioned before, nuclear plants represent about 37% of electricity generation in Switzerland, and nuclear generation is the cheapest source of large-scale electricity production.

As mentioned before, under the current structure, Switzerland has enough generation capacity during the summer to cover its internal demand and still has excess production that could be exported, but in winter demand rises and generation capacity decreases, so Switzerland has to import electricity from neighbouring countries to match its internal demand.

What could be the consequences of a closedown of nuclear generation in Switzerland? The most obvious consequence will be a shortage of generation capacity; there will be no excess production to export and Switzerland will be obliged to import electricity to satisfy its internal demand, even during the summer. This will represent an important loss of revenue for Swiss public utilities.

Nuclear generation being the less expensive technology for large-scale electricity generation - as nuclear power reactors operate past the period of paying off their capital costs - closing down nuclear plants will result in increased prices unless another inexpensive source of electricity is discovered.

Uncertainty of market rules and the risk of nuclear phase-out are a threat to Swiss security of supply in the near future. In the next section we discuss some of the most important aspects that influence the dynamics of capacity expansion, and we analyse the impact of nuclear phase-out and emergent liberalisation on the incentives for building capacity, as well as the influence of international exchanges – imports and exports of electricity – on security of supply in the coming years.

## 4 DYNAMICS OF CAPACITY EXPANSION

In order to understand the behaviour of complex systems, it is important to understand the dynamics of the interaction between the components of a system. According to Sterman (2000), all dynamics arise from the interaction of just two types of feedback loops, positive (self-reinforcing) and negative (self-correcting) loops. Positive loops tend to reinforce or amplify whatever is happening in the system, while negative loops counteract and oppose change.

The feedback structure of a system generates its behaviour. Causal loop diagrams are an important tool for representing the feedback structure of systems. A causal loop consist of variables connected by arrows denoting the causal influences among the variables. They provide a language for articulating our understanding of the dynamic feedback structure of a system. As stated by Kim (1992), we can think of causal loops as sentences which are constructed by linking together key variables and indicating the causal relationships between them. By stringing together several loops we can create a coherent story about a particular problem or issue.

Each causal link in the loop is assigned a polarity, either positive (+) or negative (-) to indicate how the dependent variable changes when the independent variable changes (Sterman, 2000). A positive link means that if the cause increases, the effect increases above what it would otherwise have been, and if the cause decreases, the effect decreases below what it would otherwise have been. A negative link means that if the cause increases, the effect decreases below what it would otherwise have been, and if the cause decreases, the effect increases above what it would otherwise have been.

Link polarities describe the structure of a system. They do not describe the behaviour of the variable. That is, they describe what would happen *if* there where a change; they do not describe what actually happens.

In this section, causal loops are used to illustrate the analysis of the dynamics of capacity expansion in the Swiss electricity market. As mentioned before, the Swiss electricity market is still a public monopoly, and even though emergent liberalisation is taking place at trading level, the electricity generation industry remains regulated and capacity investment is a governmental decision.

Under this structure of public administration, decisions regarding capacity expansion are based on security of supply concerns. Figure 6 illustrates the dynamics of capacity expansion in the current Swiss electricity market.

In this diagram, four major loops may be observed. The first one (number 1 in Figure 6) is a positive loop linking imports and exports growth. When imports increase, the marginal cost of electricity goes down, thus increasing exports, which will cause imports to increase in order to assure supply.

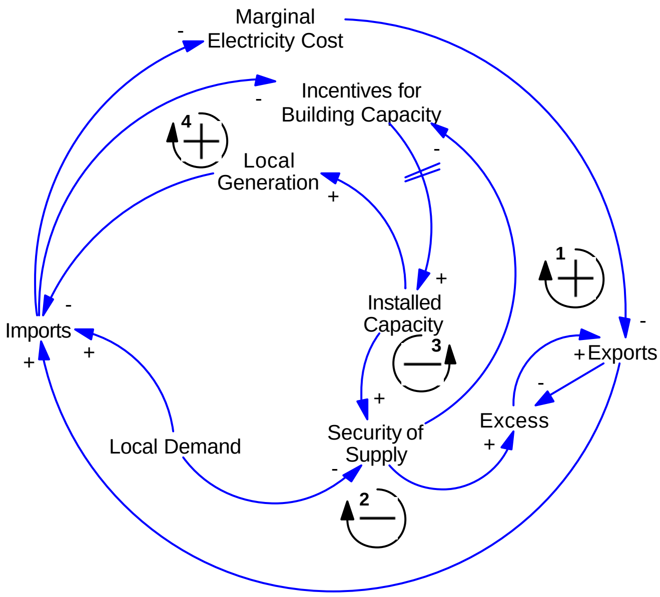



Figure 6. Dynamics of capacity expansion - Causal Loop

The second loop, a negative one, controls exports increase. Imports may affect incentives for building capacity. As the French nuclear power price is usually lower than the Swiss marginal cost of generation, and availability of imported electricity is immediate (Borenstein and Bushnell, 2000) – compared to the time required to build new generation plants in Switzerland, there is little incentive for capacity expansion when imports can be increased. Thus, installed capacity is not sufficient anymore to cover local demand, and security of supply is reduced, decreasing exports. A decrease of exports means less total demand, thus imports might be reduced, increasing the incentives for building new capacity in the country.

The third loop shows that when the security of supply margin goes down, incentives for building capacity increase, incrementing installed capacity. Security of supply decreases when local demand increases, but when security of supply margin is sufficient to avoid blackouts, this means that Switzerland has excess capacity that may be exported. Export increases may be reflected in import increases, lowering the marginal cost of electricity, which may increase exports again.

Finally, in the fourth loop one can observe that an increase in imports causes a decrease in the incentives for building capacity, decreasing installed capacity, which means that local generation may decrease, thus stimulating imports. This is a positive loop that will create ever increasing dependence on imports, which is not desirable from a political and strategic point of view.

Nuclear phase-out represents a reduction of installed capacity, as well as an increase of the marginal cost of generation. Nuclear power represents about 37% of electricity production in Switzerland; it is also one of the less expensive sources of electricity. Given that renewable sources are not sufficiently developed in Switzerland, and that environmentalists are strongly opposed to the expansion of traditional sources like coal or hydro, gas combined cycle plants seem to be the more realistic scenario for nuclear capacity replacement.

A reduction of nuclear capacity will represent an increment of the marginal cost of generation (Figure 7), given that nuclear capacity is one the most stable sources of power generation. A nuclear phase-out will also produce an increase of thermal capacity which has a higher marginal generation cost. The higher the marginal generation cost, the lower the local generation. When local generation decreases, import increases.

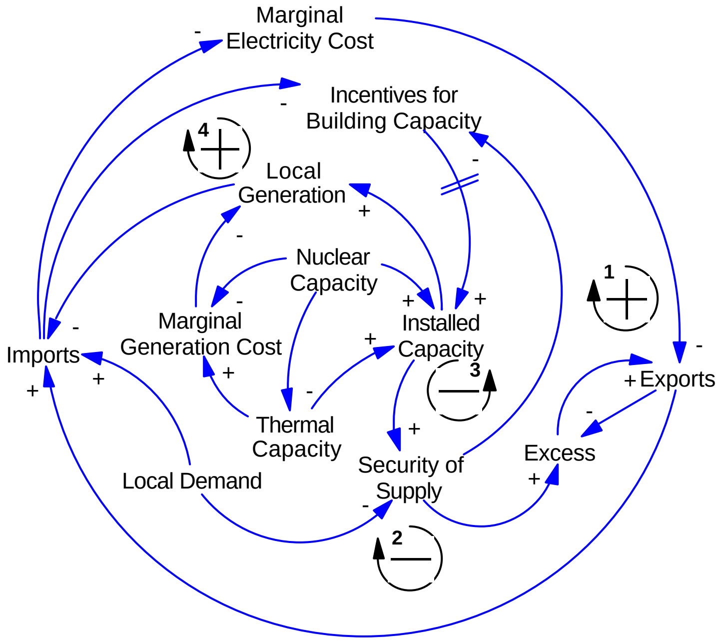



Figure 7. Impact of nuclear generation over capacity expansion dynamics

Cost volatility may also be increased in the case of a nuclear capacity reduction. Generation costs for thermal plants depend on fuel price which is highly volatile.

Switzerland has long-term take or pay import contracts with France - France has a considerable excess of nuclear capacity. Those contracts may be considered as an inexpensive alternative for maintaining an acceptable margin of security of supply.

In the short term, nuclear phase-out in Switzerland will increase import contracts rather than build additional plants in the country. But this policy may have a negative impact on exports as Switzerland will no longer have excess capacity. Long term export contracts in a situation in which local installed capacity is insufficient to match demand would introduce blackout risks in the Swiss market.

Given that exports are an important source of revenue for Swiss public utilities, and that a reduction of public income may be reflected in tax increases, it is therefore necessary to provide incentives for capacity construction.

However, import capacity may be restricted, as a result of transmission constraints (Borenstein and Bushnell, 2000); as a consequence of demand increase in the source country (e.g. low temperatures during the winter of 2005 forced France to limit its electricity exports); or as a consequence of policy efforts to avoid import dependence in a period of fundamental structural changes in both the Swiss and the European markets.

A policy to avoid import dependence is illustrated in Figure 8. Under this policy, imports are no longer considered as an alternative for capacity expansion, so we removed the link between those variables in the diagram, which removes the second and the fourth loop. Incentives for building capacity are no longer affected by changes of import level.

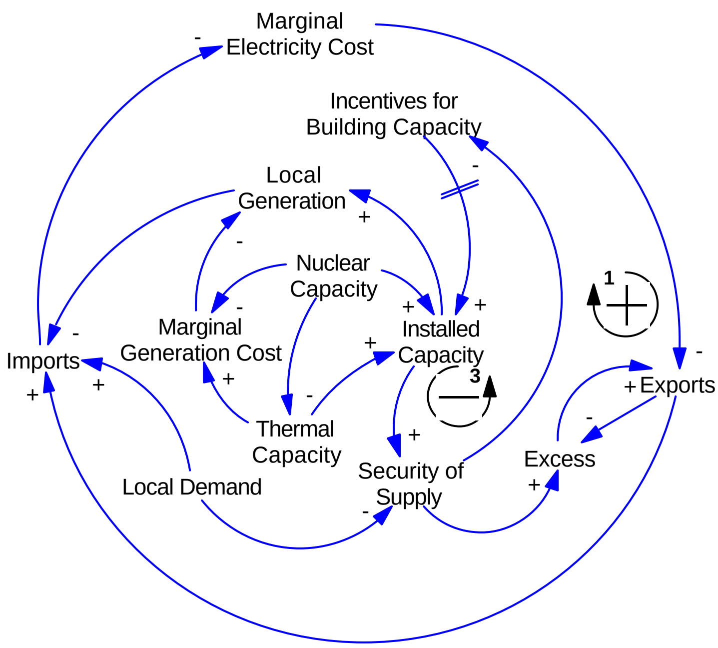



Figure 8. Avoiding import dependence

In this scenario, a withdrawal of nuclear plants will decrease installed capacity, thus decreasing security of supply which may increase the incentives for capacity building (loop 3 in Figure 8); installed capacity may be expanded thus increasing security of supply and exports. Export increases may increase imports. Exports may continue to grow as long as they do not threaten Swiss security of supply. Imports may also grow in this case as it is an inexpensive source of electricity; but in this scenario, imports will only be used for lowering electricity cost and enabling exports – imports are no longer considered as a local source of electricity.

The next section provides a description of the system dynamic model. This section also presents simulation results for different scenarios regarding capacity expansion, nuclear phase-out and imports/exports policies.

## 5 SIMULATION AND RESULTS

We use system dynamics for modelling the current structure of the Swiss electricity market - based on the causal loops diagrams described in the previous section, to analyse market behaviour in response to fundamental changes of market structure such as withdrawal of nuclear plants and the effects of liberalisation on international exchanges.

An overview of the model is presented in this section. First, there is a description of the main model structures. This is followed by an analysis of several scenarios which were selected based on their current relevance. A detailed model description can be found in Ochoa and van Ackere (2005).

## 5.1 BRIEF DESCRIPTION OF THE MODEL

The simulations run 20 years, from 2004 to 2024, with a monthly step. This horizon includes the total nuclear phase-out - as proposed on the 2003 referendum. The monthly step enables us to observe seasonal variations of demand and supply. The model is composed of five main sectors: demand, available capacity, price comparison, dispatch, and capacity investment.

Demand is composed of local demand and exports demand. Local demand is captive because of the current structure of the Swiss electricity market, so final users are obliged to buy electricity from their regional distributor.

The model has a policy component for modelling international exchanges which are limited by existing transmission capacity. The decision to change the level of export contracts is based on two criteria: security of supply and price comparison. Figure 9 shows the decision tree, and the policy diagram (for details see the supporting Vensim® model). We assume that Swiss producers will only export if there is enough generation capacity to cover internal demand and existing export contracts. Nevertheless, even if there is over capacity, export will not be increased if prices in the buying country - usually Italy - are lower than prices in Switzerland.

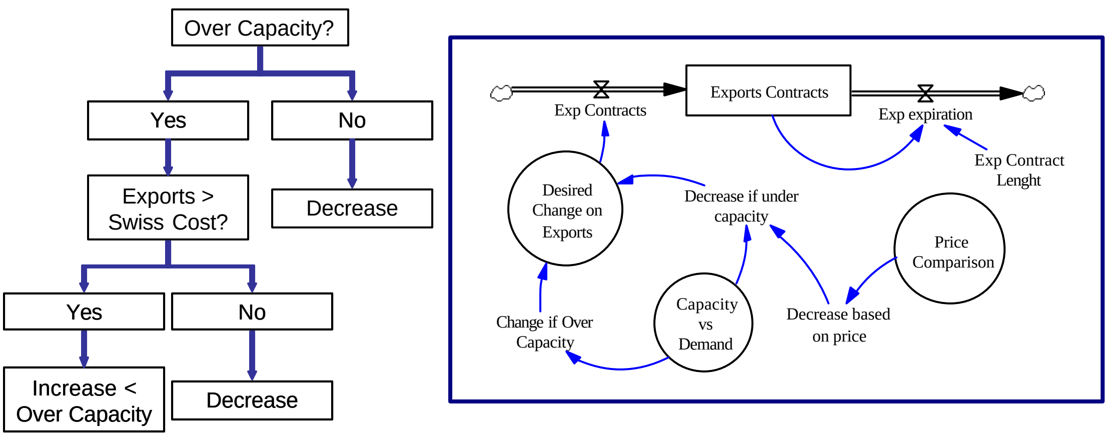



Figure 9. Criteria for export level change

Swiss installed capacity is mostly hydro - storage and run of river, and nuclear, but there are also long term import contracts which act as generation plants on the national dispatch. Policy for long term import changes is modelled in the same way as export changes: if there is under-capacity at a certain moment then imports will be increased no matter the prices; otherwise, the decision is taken based on a comparison between the selling price - usually in France and Germany - and the generation cost in Switzerland.

To model hydro-storage availability we introduce an opportunity cost which will prevent the use of hydro plants when there are water shortages in order to keep capacity for peak demand. This opportunity cost is calculated based on current storage level and the expected future water inflow to the reservoirs.

Investors make capacity expansion decisions based on two criteria. On the one hand, we consider the situation where the Swiss market remains a public monopoly which means that capacity expansion is motivated by security of supply concerns; on the other hand, we introduce market reasoning which means that investors will be motivated by both prices and supply/demand behaviour. Once the desired investment is calculated (Figure 10), the investment allocation decision between the different generation technologies is based on several criteria such as marginal cost of generation, cost of construction, environmental and political policies.

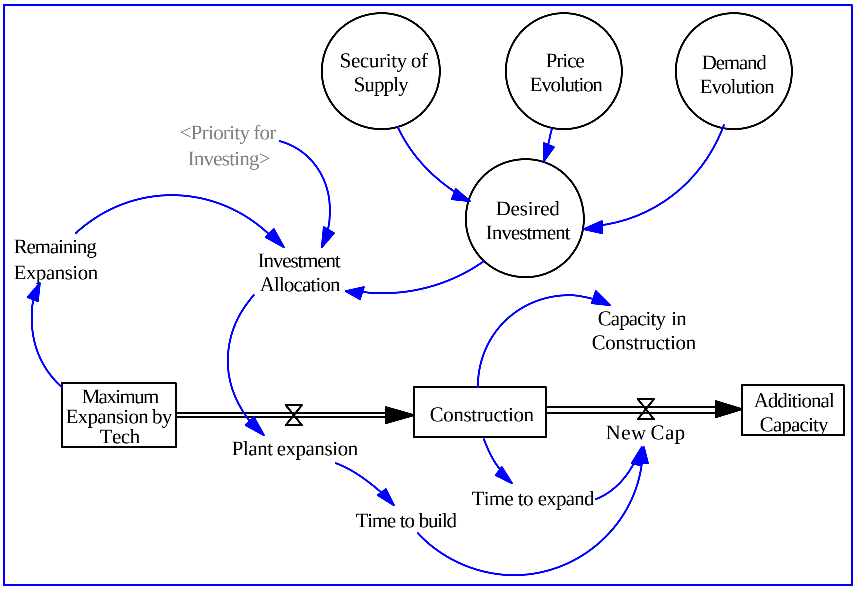



Figure 10. Policy diagram for capacity expansion

Thermal combined cycle (TCC) plants are used as the replacement source of generation, because of the insufficient development of renewable sources in Switzerland, and the opposition of environmentalists to the expansion of coal or hydro power plants.

Finally, we have merit order dispatch to decide the amount of electricity produced by each source of generation.

## 5.2 NUCLEAR PHASE-OUT SCENARIO

We model gradual nuclear phase-out as proposed in the 2003 referendum, which means withdrawal of 34% of nuclear capacity (approximately 12% of total installed capacity) two years after referendum approval, 30% of nuclear capacity in 2009, and the remaining 36% in 2014, thus, out of the five existing plants, the oldest two will be immediately closed-down, and the remaining three plants will be closed-down after 30 years of operation.

As a first case we assume that political relations with neighbouring countries remain stable so it is possible to increase international exchanges until capacity limits are reached. We assume that the electricity generation industry in Switzerland remains a public monopoly; thus, capacity expansion is motivated by security of supply concerns, as explained in the previous section.

As benchmark case we use the situation in which existing nuclear plants remain operational but the construction of new nuclear plants is not allowed.

In Figure 11a one can see Exports behaviour in both the nuclear phase-out and the benchmark scenario. As expected, exports contracts are lower in the nuclear phase-out case than in the base case, given that the technology used for replacing the nuclear capacity - thermal generation, has a higher marginal generation cost than nuclear power.

Figure 11b shows long term import contracts which are rapidly increasing in both scenarios; as long as installed capacity is sufficient to match local demand, Swiss generators will prefer to increase imports rather than significantly expand capacity because imports are a cheaper source of electricity. As one can expect, capacity expansion Figure 11c) is faster in the nuclear phase-out scenario, as the lost capacity needs to be replaced.

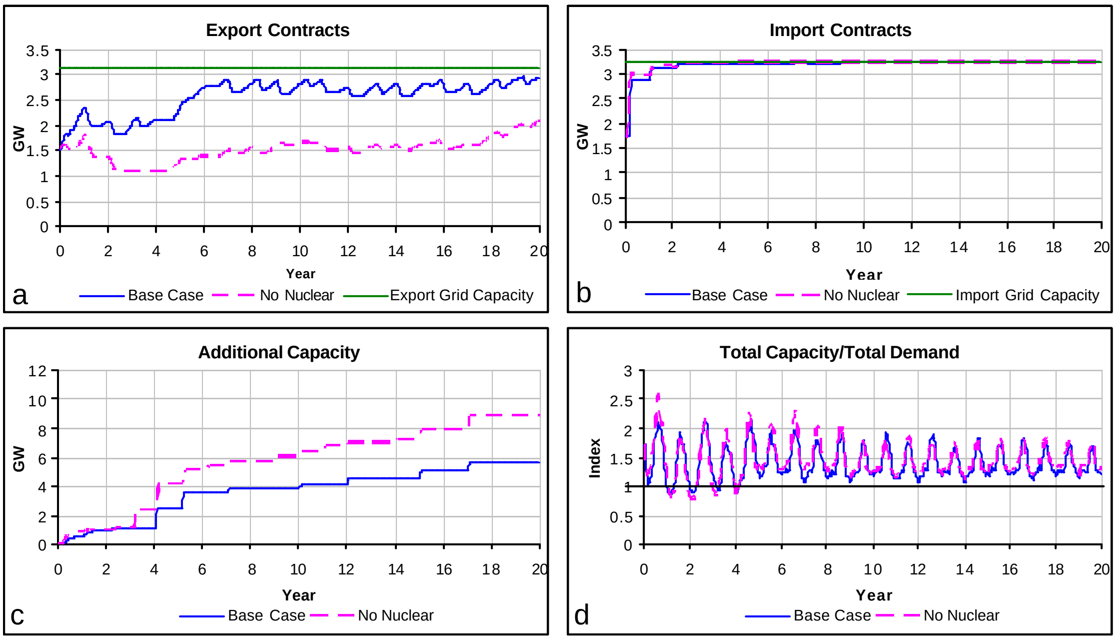


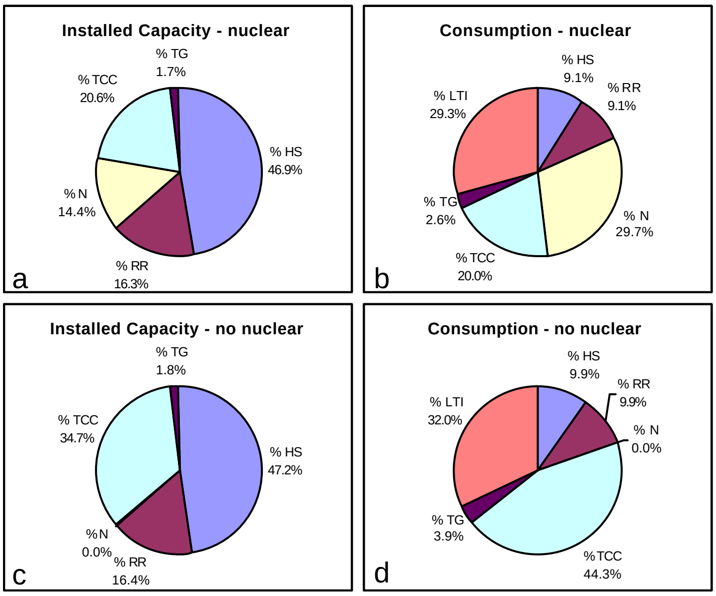

Figure 11. Simulation results with and without nuclear capacity

Figure 11d shows the ratio Total Capacity/Total Demand for the two scenarios. We can observe under-capacity stages (when Total Capacity/Total Demand < 1) during some periods (after year 1 in the graph), which means that companies will have to import last-minute electricity in order to ensure exports during that period; in any case, capacity at those points will still be sufficient to match internal demand, thus avoiding blackouts.

In the case of a nuclear phase-out new capacity is installed as nuclear replacement, and demand growth is met by the increase of long term imports. There is some excess capacity that could lead to exports but, given that the cheaper source of electricity - nuclear power - is no longer available, the exportable electricity is expensive, thus exports are lower in this scenario..

When nuclear capacity remains constant - benchmarking scenario, demand growth is met, in the long term, by capacity expansion. Imports increase in the short term to match demand while new capacity is build. In Figure 11c one can see that capacity expansion starts to grow faster after year 3 in the nuclear phase-out scenario, in order to compensate the withdrawal of nuclear power. This extra capacity will permit exports to increase, yet exports in the benchmark scenario remain higher than those in the nuclear phase-out scenario.

Figure 12 shows the comparison between installed capacity and consumption (local consumption plus exports) by generation technology in both the benchmark case (graph a and b) and the nuclear phase-out scenario (graphs c and d). In the benchmark case - with constant nuclear power over the 20 years simulation, even though new thermal capacity has been installed, imports are used for exporting and for supplying internal demand with low cost electricity. Thus, even though new thermal capacity is available (20.6% of installed capacity), Switzerland prefers to import electricity because it is less expensive. Net imports at the last year of simulation represent about 9% of local consumption.




HS: Hydro Storage, RR: Run of River, N: Nuclear, TCC: Thermal Combined Cycle, TG: Thermal Gas, LTI: Long Term Imports

Figure 12. Average capacity and consumption at year 20

In the second scenario, with the withdrawal of nuclear power, both the new capacity and the imports contracts are necessary to cover demand (Figure 12d), thus, exports of electricity are lower because of the higher marginal cost of generation. Net imports in this case reach 19% of local consumption..

Imports are an important source of electricity for Switzerland. In the case of a nuclear phase-out there is an important risk of import dependence. Simulation of the nuclear phase-out scenario shows that imports may rise to 32% of total consumption (local demand + export) by the end of the simulation. In the base case, with constant nuclear capacity, imports represent 29.3% of the final consumption, in a period where 29.7% of the electricity is produced by nuclear plants.

Imports may certainly help lower the cost of electricity, but, as mentioned before, it is not politically desirable to create a dependence on European relationships to supply local electricity demand. Switzerland may introduce policies to avoid import dependence. In the next section we present simulation results for such policy.

## 5.3 AVOIDING IMPORTS DEPENDENCE

In the nuclear phase-out scenario we consider imports as a source of capacity expansion; thus, when there is under-capacity risk - as a consequence of demand growth or capacity decrease (i.e. nuclear phase-out), imports appear as an alternative to plant construction. In the *avoiding imports dependence* scenario, imports are no longer considered as an alternative for capacity expansion, this means that we will only increase long term import contracts when it is economically desirable - when the prices in Europe are lower than generation costs in Switzerland. Local capacity construction becomes unavoidable whenever expansion is needed.

Figure 13 shows simulation results for the case where nuclear capacity remains constant during the 20 years of the simulation with the *avoiding imports dependence* policy. We again use for comparison the benchmark scenario - the base case where nuclear power is constant and imports are considered as a source for capacity expansion.

In Figure 13a one can see that if plant construction cannot be avoided, this leads to a stronger increase of exports after 4 years of simulation. One can also observe that variations during the year are stronger in the base case, which is due to the more strategic use of hydro generation - the fact that there is a large amount of available imports allows companies to keep the water into the reservoirs in order to produce in peak load periods, thus hydro power generation follows a seasonal pattern, while in the case where imports are limited, hydro generation is mandatory during certain periods, thus water cannot be stored and the maximum generation is reduced, which implies a decrease of the excess of capacity having as a consequence a more constant level of exports.

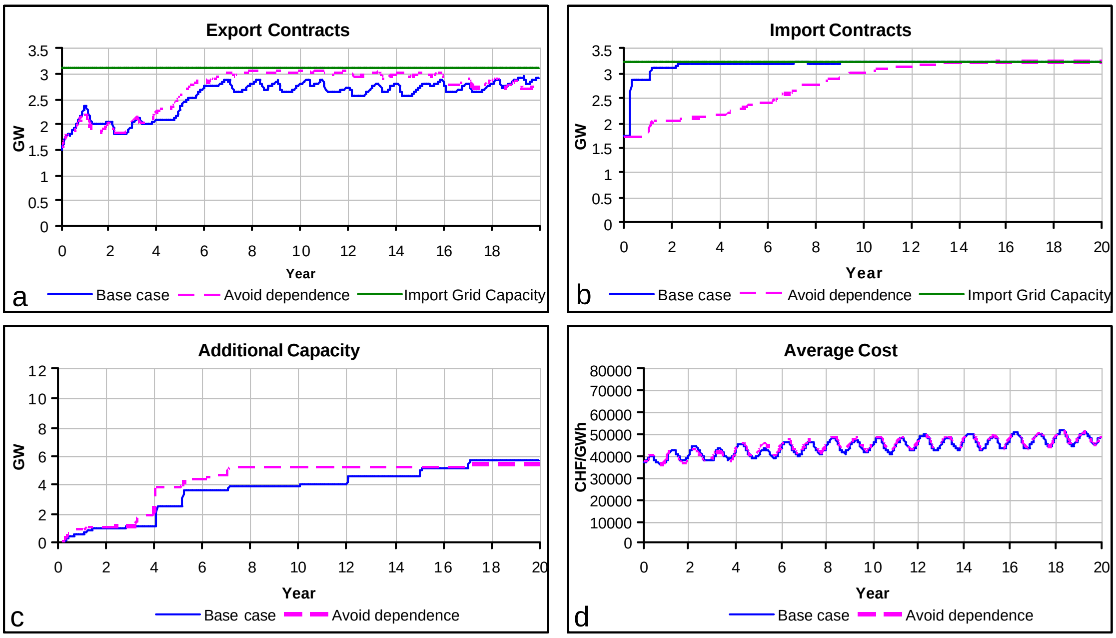



Figure 13. Simulation results for the avoiding import dependence scenario

The fact that long term imports cannot be increased to solve under-capacity problems encourages capacity building (Figure 13c). Once capacity has been expanded and supply is guaranteed, then exports may be increased without endangering internal supply. Average cost of electricity in Figure 13d seems slightly higher when capacity building cannot be avoided but this is explained by the increase in demand as a consequence of export increase.

If we run the model with both the *avoiding imports dependence* policy and the scenario of gradual nuclear dismantling, we obtain similar results (Figure 14). Obviously, exports (graph a) are not growing at the same pace because generation costs are higher - as we use thermal generation to replace nuclear power.

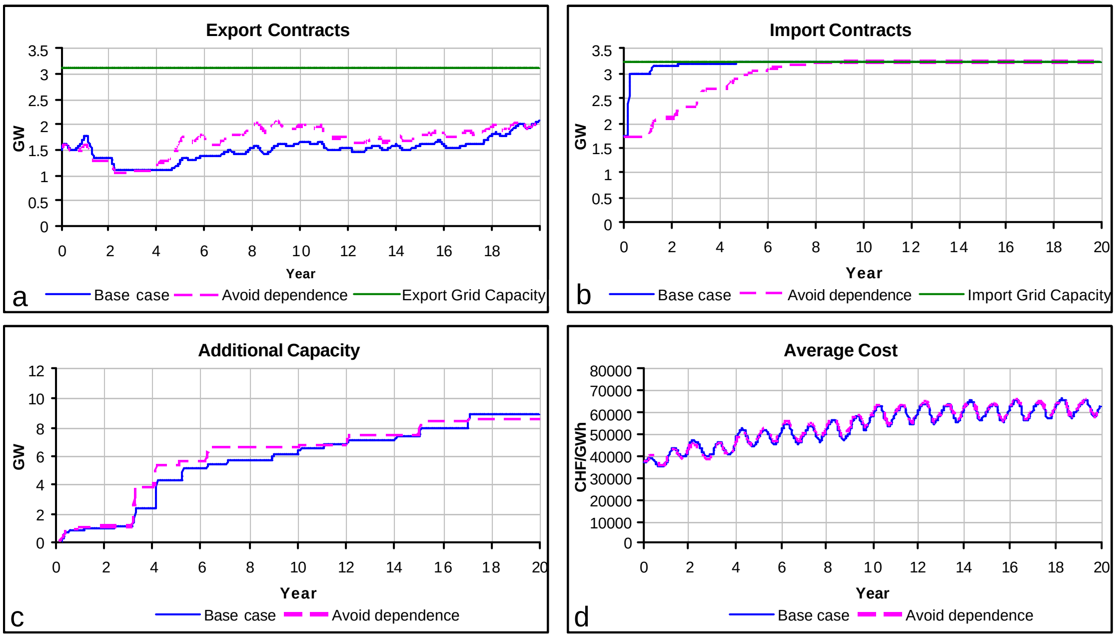



Figure 14. Simulation results for the avoiding import dependence in nuclear phase-out scenario

Thus, analysing the simulation results one can see that import dependence is not only politically undesirable, but that it may also threaten exports.

## 6 DISCUSSION

Even though Swiss installed capacity is, at the moment, sufficient to match local demand and there is still excess capacity during the summer that may permit exports to neighbouring countries, this situation may change in the near future.

Currently, there are no significant projects for building new plants in Switzerland (Swiss Federal Office of Energy, 2003), so the market is not prepared to face sudden changes of supply or demand. Any change will prevent Switzerland from continuing to export electricity to Italy and will involve a high risk of placing the market in a situation of import dependence – similar to Italy, which is not optimal for any market.

The scenario of import dependence presented in this paper may seem unrealistic, but actually the emergent liberalisation that is taking place in the Swiss market may produce the same results. In this unregulated situation, competitors from the European Union (or from other Swiss cantons) may sell electricity to Swiss consumers; this will lower local prices, on the one hand, and distort under-capacity signals, on the other hand. Demand for local producers will be lower, reducing incentives for building new capacity.

International exchanges represent an important source of profits for the Swiss electricity industry. Imports from France are exported to Italy, and they are also used for domestic consumption in order to keep hydro capacity for peak load demand and thus lower the cost of electricity in Switzerland. But this successful policy of international exchanges will no longer be possible in the absence of clear and reliable market rules. Uncertainty about the future of nuclear generation as well as the lack of regulation and emergent liberalisation may prevent capacity expansion from taking place. Furthermore, as regional markets evolve, Switzerland might no longer able to continue to arbitrate; the contracts might be negotiated directly between Italy and France, and Switzerland might only be able to wheel electricity through - a situation that would be much less profitable for Switzerland.

With respect to security of supply, international transmission capacity may not seem crucial. However, imported electricity helps to lower the Swiss average cost of electricity, and the electricity imported from France stimulates Swiss exports – as long as installed capacity is sufficient to match demand. Therefore transmission capacity becomes an important issue for the future of the Swiss market.

The model presented in this article helps to understand the logic and dynamics of the Swiss electricity market. The simulation of the implementation of different policies - nuclear phase-out, incentives for building capacity, helps to anticipate and analyse possible market responses to these policies in a transition period between different market structures, like the period between public monopoly and market liberalisation in which the Swiss electricity market currently operates.

# 7 REFERENCES


- Andersson, B. and E. Hådén, 1997. Power production and the price of electricity: an analysis of phase-out of Swedish nuclear power. *Energy Policy*, Vol. 25, No. 13, pp. 1051-1064.
- Amlin, J. and G. Backus, 1996. Utility Models for the new competitive electric markets, *Systems Solutions Inc*. 543 E. Dayton - Yellow Road, Fairborn, Ohio 45324.
- Armstrong, M, S. Cowan, and J. Vickers, 1994. *Regulatory Reform*, Cambridge MA, MIT Press.
- Assemblée Fédérale de la Confédération Suisse, 2002. Switzerland.
- Assemblée Fédérale de la Confédération Suisse, 2004. Loi fédérale sur les cartel et autres restrictions à la concurrence - Loi sur les cartels, LCart [online]. Switzerland. Available from: http://www.admin.ch/ch/f/rs/c251.html.
- Beesley, M., 1992. Privatization, *Regulation and Deregulation*, London; Routledge.
- Bernheim, M., and Cohen, E., 2004. Liberalization of the Electric Energy Market via the New Cartel Law? *Staiger, Schwald & PartnerNewsletter*, Switzerland.
- Böhringer, C., M. Wickart, and A. Müller, 2003. Economic impacts of a premature nuclear phase-out in Switzerland, *Swiss Journal of Economics and Statistics*. Vol. 139 (4), 461-505
- Borenstein, S., 2002. The trouble with electricity markets: Understanding California's restructuring disaster. *The Journal of Economic Perspectives*, Vol. 16, No. 1, pp. 191-211.
- Borenstein, S., and Bushnell, J., 2000. Electricity Restructuring: Deregulation or Reregulation? *Regulation*. Vol. 23, No. 2, pp. 46-52
- Brennan, T. J., 2003. Electricity capacity requirements: Who pays? *The Electricity Journal*, Vol. 16, Issue 8, pp. 11-22
- Bunn, D.W and C. J. Day, 2001. Divestiture of generation assets in the electricity pool of England and Wales: A computational approach to analyzing market power *Journal of Regulatory Economics*, vol. 19:2, 123-141
- Bunn D. W., C. J. Day and K. Vlahos, 1999. Persistence of market power, in Bunn D., W., (ed.) *Strategic price risk in wholesale power markets*, London; RISK
- Bunn D. W., I. Dyner, and E. R. Larsen, 1997. Modelling latent market power across gas and electricity markets, *System Dynamics Review*, Volume 13(4):271-288
- Chancellerie fédérale, 2002. *La Confédération en bref*, Switzerland.
- Chancellerie fédérale, 2003. *La Confédération en bref*, Switzerland.
- Dyner, I. and E. R. Larsen, 2001. From planning to strategy in electricity markets. *Energy Policy*, Volume 29, Issue 13, November 2001, Pages 1145-1154.
- Electric Power Research Institute, 1981. Case study Comparison of Utility Corporate Models, *Report EA-2065*, Palo Alto, CA 94304.

- Fillipini, M. and S. Banfi, 2002. Impact of the new Swiss electricity law on the competitiveness of hydropower. *CEPE Working paper* Nr.12
- Finon, D., Johnsen, T.A., and Midttun, A., 2004. Challenges when electricity markets face the investment phase. *Energy Policy*, Vol. 32, pp. 1355-1362.
- Ford, A., 1999. Cycles in competitive electricity markets: a simulation study of the Western United States. *Energy Policy,* Vol. 27, pp. 637-658.
- Ford, A., 2001. Waiting for the boom. *Energy Policy,* Vol. 29, pp. 847-869.
- Ford, A. and M. Bull, 1989. Using system dynamics for conservation policy analysis in the pacific Northwest, *System Dynamics Review*, 5, 1-16.
- Ford, A. and J. Geinzer, 1990. Adding uncertainty to least cost planning, *Energy Policy*, 331-339.
- Frei, C.W., 2004. The Kyoto protocol -a victim of supply security? Or: if Maslow were in energy politics. *Energy Policy*, Vol. 32, pp. 1253-1256.
- Gary, S. and E. R. Larsen, 2000. Improving firm performance in out-of-equilibrium, deregulated markets using feedback simulation models. *Energy Policy,* Vol. 28, pp. 845-855.
- Green, R. and D. Newberry, 1997. Competition in the electricity industry in England and Wales. *Oxford Review of Economic Policy*, 27-46.
- Helm, D., 2002. Energy Policy: Security of supply, sustainability and competition. *Energy Policy,* Vol. 30; pp. 173-184.
- Hirsh, R. F., 1999. Power Loss, The origins of Deregulation and Restructuring in the American Electric Utility System, Cambridge MA, MIT Press.
- Hoster, F., 1998. Impact of a nuclear phase-out in Germany: results from a simulation model of the European Power Systems. *Energy Policy*, Vol. 26, No. 6, pp. 507-518.
- Hunt, S. and G. Shuttleworth, 1996. Competition and Choice in Electricity, Chichester, Wiley.
- Jegen, M., and R. Wüstenhagen, 2001. Modernise it, sustainabilise it! Swiss energy policy on the eve of electricity market liberalisation. *Energy Policy* 29, 45 - 54.
- Kahn, A. K., 1998. The Economics of Regulation, Cambridge MA, MIT Press.
- Kim, D.H., 1992. Guidelines for drawing Causal Loop diagrams. *The Systems Thinker,* Volume 3, Issue 1.
- Laffont, J. J. and J. Tirole, 1994. A Theory of Incentives in Procurement and Regulation, Cambridge MA, MIT Press.
- Lyneis, J. M., 1997. Preparing for a competitive environment, in Bunn D.W. and Larsen E. R. (eds) *Systems modelling for energy policy*, Chichester, Wiley.
- Lyneis, J., C. Bespolka, and B. Tucker, 1994. Planning for a competitive environment – The Prospects for America's Electricity Utilities, *Proceedings of the 1994 International System Dynamics Conference*, University of Stirling, Scotland.

- Nail, R., 1977. Managing the Energy Transition, *Ballinger Publishing Company*, Cambridge, MA
- Nail, R., 1992. A system Dynamics Model for National Energy Policy Planning, *System Dynamics Review*, 8(1), p. 1-19
- Nakata, T., 2002. Analysis of the impacts of nuclear phase-out on energy systems in Japan, *Energy* 27, p. 363-377
- Navarro, P., 1996. Electric utilities: the case for radical regulation. *Harvard Business Review*, 112-125
- Ochoa, P., van Ackere, A., 2005. The Swiss electricity market: security of supply, nuclear power, and emergent liberalisation. *HEC Lausanne Working paper*.
- Pfaffenberger, W. and H. J. Gerdey, 2001. Volkswirtschaftliche Auswirkungen des Ausstiegs der Schweiz aus der Kernenergie, commissioned by *Unterausschuss Kernenergie der Überlandwerke*, Bremen.
- *Power in Europe*, 2003. Migros relents; London: Dec 8, 2003, Iss. 415; pg 24.
- Prognos, 2001. Szenarien zu den Initiativen "Strom ohne Atom" sowie "Moratorium plus", *commissioned by the Swiss Federal Office of Energy*, Bern.
- SFOE: Office Fédéral de l'énergie, 2002. [online] Available from: http://www.energie-schweiz.ch/internet/00071/index.html?lang=fr
- Shuttleworth, G., MacKerron, G., and Hough, D., 2003. Security of Energy Supply, *Energy Regulator Brief*, National Economic Research Associates - NERA - Economic Consulting, London.
- Sidak, J. G. and F. F. Spulber, 1998. Deregulatory Takings and the Regulatory Contract, Cambridge University Press.
- Sterman, J., 2000. Business Dynamics - Systems thinking and modelling for a complex world, *McGraw-Hill*, USA.
- Surrey, J., 1996. The British electricity experiment. *Earthscan.*
- Swiss Federal Administration webpage [online] Available from: http://www.admin.ch/ch/pore/va/20030518/indx.html
- Viklund, M., 2004. Energy policy options - from the perspective of public attitudes and risk perceptions, *Energy Policy* 32, p. 1159-1171.
- Verbruggen, A., 2004. Tradable green certificates in Flanders (Belgium), *Energy Policy* 32, p. 165-176.
- Weiner, M., N. Nohria, A. Hickman, and H. Smith, 1997. Value Networks – The future of US electric utility industry. *Sloan Management Review*, 21-34.
- Welsch, H. and C. Ochsen, 2001. Dismantling of nuclear power in Germany: sectoral and macroeconomic effects. *Energy Policy* 29, 279 - 289.