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ERIC BENJAMIN SEUFERT

ELECTRICITY MARKET LIBERALIZATION, PRICE STABILITY, AND ENERGY SECURITY:

THE CASE OF ESTONIA

MASTER'S THESIS

Supervisors: Arunas Molis, Baltic Defense College and Ivo Palu, Tallinn Technical University

UCL Student Number: 829688

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(name, signature and date)

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INTRODUCTION

Having been incorporated into the European Union on May 1st, 2004, Estonia is obligated to follow the policy procedures laid out in EU directive 2003-54-EC, *Internal Market in Electricity Directive*[1]. The purpose of this directive is to establish common rules applicable to all EU member states for the administration and participation in an internal market for electricity.

EU directive 2003-54-EC was enacted in 2003 to replace EU directive 96-92-EC, which initiated the process of electricity market liberalization within the EU in 1996[2]. The purpose of EU directive 96-92-EC was to “unbundle” – that is, separate – the administrative activities of vertically integrated electricity system operators, presenting a “separate balance sheet for each activity [balancing voltage supply, maintaining voltage level, and restarting the system upon complete collapse]” (Meeus, Purchala, and Belmans 2005, pg. 28). EU directive 2003-54-EC goes a step further, requiring vertically integrated electricity system operators to unbundle these activities to the extent that they are carried out by separate legal entities (ibid.). The stated aims of EU directive 2003-54-EC are[3]:

- to maintain a secure, reliable and efficient electricity distribution system in its area with due regard for the environment;
- to ensure non-discrimination between system users;

[1] Eesti Riigikogu, "Estonian Electricity Sector Development Plan", Regulation No. 5 of the Government of the Republic of Estonia, 3 January 2006 (p. 2)

[2] Meeus L., Purchala K., Belmans R., "Development of the Internal Electricity Market in Europe", *The Electricity Journal*, Volume 18, Issue 6, July 2005, p 25-35 (p. 26)

[3] European Union (Europa), "Internal market for energy: common rules for the internal market in electricity", *Europa*, 5-29-2009, Accessed on 10-3-2010, <http://europa.eu/legislation_summaries/energy/european_energy_policy/l27005_en.htm>

- to provide system users with the information they need for efficient access to the system;
- to give priority to generating installations using renewable energy sources or waste or producing combined heat and power;
- to procure the energy they use to cover energy losses and reserve capacity in their system according to transparent, non-discriminatory and market-based procedures;
- to take energy efficiency/demand-side management and/or distributed generation measures that supplant the need to upgrade or replace capacity.

Estonia faces several challenges in implementing the procedures laid out in the *Internal Market in Electricity Directive*, but this thesis will explore one challenge in particular: the effect of electricity market liberalization in Estonia on its electricity security. This will be undertaken by addressing the central research question of this thesis:

What effect does electricity market liberalization have on a country's energy security?

Organization of this thesis

This thesis comprises an introduction, six chapters, and a conclusion. The introduction will establish the practical groundwork of the thesis by outlining and defining the main topics of discussion: electricity markets, electricity market liberalization, and energy security. The introduction will also identify the purpose of using Estonia to address the research question, the main contributions of this thesis to the existing academic literature, and the research focus, hypothesis, and methods of this thesis.

The first chapter will outline the theoretical framework of this thesis. A theoretical framework is important for contextualizing a topic that bridges abstract economic theory with political determinants and empirical research. The theoretical framework is one of the main contributions of this thesis. The second chapter outlines Estonia's energy situation, including its resource usage and access, its connection to the

Baltic electricity grid, and its dependence on Russian energy supplies. The third chapter discusses the electricity market reforms mandated by the EU, both past and present. This includes an overview of the two initial electricity market reforms and their effects (on electricity supplies, market concentration via mergers and acquisitions, and energy security) as well as a thorough outline and analysis of the third EU electricity directive. The fourth chapter introduces the Nord Pool electricity market – both the physical market and the financial market -- of which Estonia became a member in 2010. This chapter also surveys the prevailing academic pricing models of the Nord Pool electricity market. The fifth chapter presents an empirical volatility model of Nord Pool electricity prices for the years 2008 and 2009. This empirical model is another contribution of the thesis. The sixth chapter provides an analysis of the empirical qualitative and quantitative findings of the thesis in relation to the research focus of the thesis. The conclusion addresses the research question, evaluates the hypothesis, and identifies directions for further research on this topic.

What is an electricity market?

Broadly speaking, an electricity market can be considered to be the interplay between three distinct yet integrated markets: "a physical market for spot energy (the pool), markets for risk-sharing (the contract and EFA [Electricity Forward Agreement] markets which trade financial instruments) and a market for capacity"[4]. Like other commodity markets, an electricity market is governed by basic economic principles; indeed, "the physical aspects of supply and demand play a prominent role in power markets"[5]. Some peculiarities about the nature of electricity transmission present fundamental differences between the spot market for electricity and the markets for other commodities, however. The first is that electricity is costly to store; because of this, "market-clearing prices are volatile because inventories cannot be used to smooth supply or demand shocks", allowing for "predictable intertemporal [variations] in

[4] Newbery, D.M., 1995, "*Power markets and market power*", Energy Journal, Vol. 16, No. 3, pg. 39 – 66 (pg. 43)

[5] Stoft, S., Power System Economics, New York: Wiley Interscience 2002.

equilibrium prices"[6]. Because demand shocks cannot be smoothed by allocation and reserves, and because of "the extreme inelasticity of supply and demand"[7], the market for electricity is susceptible to extreme price swings. Stoft notes that "demand is almost completely unresponsive to price in most power markets because wholesale price fluctuations are not usually passed on to retail customers" where prices are regulated (Stoft 2002, pg. 43).

Another feature of electricity transmission which affects its spot market is the ability to gauge and price it in real time. This leads to the "wholesale markets for electricity [being] inherently incomplete and imperfectly competitive"[8]. Despite a near-ubiquitous lack of real-time metering and pricing, this demand-side feature of the electricity market – contracted as opposed to instantaneous pricing – is merely an industry standard and not a necessity of the transmission network. As Borenstein notes, "while the technology to monitor consumption on an hourly, or even 10-minute, basis is widely available, and has even been installed at many industrial and commercial locations, no electricity market in operation today makes substantial use of real-time pricing, *i.e.* charges a customer time-varying prices that reflect the time-varying cost of procuring electricity at the wholesale level" (Borenstein 2002, pg. 196). Commercial and industrial electricity consumers may pay Time-of-Use (TOA) prices, which "are designed to be high when demand is high" but are set years in advance and "miss the crucial weather-driven demand fluctuations that cause most problematic supply shortages" (Stoft 2002, pg. 44).

The large capital requirements involved in generating and transmitting electricity also contribute to price volatility in the electricity spot market. This is because "a significant part of generation costs are fixed" (Borenstein 2002, pg. 196), rendering marginal costs lower than the average costs of production when a plant is operating below capacity – and incentivizing firms to generate electricity so long as this remains the case. The result is excess production which puts downward pressure on prices,

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[6] Bessembinder, H. and M. J. Lemmon, 1999, "*Equilibrium Pricing and Optimal Hedging in Electricity Forward Markets*," The Journal of Finance, Vol. 57, No. 3, Jun. 2002, pp. 1347-1382 (pg. 1348)

[7] Borenstein, Severin, 2002, "*The Trouble with Electricity Markets: Understanding California's Restructuring Disaster*," Journal of Economic Perspectives, Volume 16, No. 1, pg. 191–211 (pg. 193)

[8] Wilson, Robert, 2002, "*Architecture of Power Markets*," Econometrica, Vol. 70, No. 4, pg. 1299–1340 (pg. 1300)

reduces the average price of production to below the marginal cost, and produce losses for generators (ibid.).

The difficulties inherent in electricity storage also affect the market for its risk-sharing. According to Bessembinder and Lemmon:

> "The inability to store power means that the no-arbitrage approach to pricing derivative securities cannot be applied in the usual manner. The well-known cost-of-carry relationship links spot and forward prices as a no-arbitrage condition. However, the arbitrage strategies required to enforce the cost-of-carry relationship include purchasing the asset at the spot price and storing it for subsequent sale at the forward price. Since this strategy cannot be executed in power markets, forward prices for electricity need not conform to the cost-of-carry relationship" (Bessembinder and Lemmon, 1999).

Contextualizing this point requires an examination of both the market for commodity futures and the cost-of-carry relationship between a commodity's spot and forward prices. Working defines trading in commodity futures as "trading conducted under special regulations and conventions…which serve primarily to facilitate hedging and speculation by promoting exceptional convenience and economy of transactions"[9]. Because electricity cannot be stored inexpensively, the speculation function is not fulfilled by its futures market; Bessembinder and Lemmon conclude that, "although power futures contracts are traded, activity levels are extremely low" (Bessembinder and Lemmon 1999, pg. 1354) and that "the power markets are not well-integrated with the broader financial markets, that is, that outside speculators are not a significant presence in these markets" (Bessembinder and Lemmon 1999, pg. 1378).

Bessembinder and Lemmon ascribe this "lack of integration" to two phenomena: the high informational setup-costs associated with "learning about power markets" and the lack of "good benchmark price indices on which to base cash-settled derivative contracts" (ibid.). To the first point, Yang, Bessler, and Leatham argue that an "exact functional relationship exists between cash and futures

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[9] Working, H., 1953, "Futures Trading and Hedging", *The American Economic Review*, Vol. 43, No. 3, pg. 314-343 (pg. 315)

prices for storable commodities as described by the cost-of-carry model, whereas no such exact relationship exists for nonstorable commodities"[10]. This implies that the informational setup costs described by Bessembinder and Lemmon might in fact be so elusive as to be unattainable, as the myriad, byzantine determinants of electricity prices might convince speculators that attempting to forecast futures prices with any authority is futile. Because speculators must rely on the "use [of] other methods (eg. weather correlations, consumption prediction) for pricing such derivatives"[11], the informational setup costs in electricity forward and futures contract speculation are necessarily high.

The cost-of-carry relationship is a "standard model of futures pricing" which "uses a no-arbitrage argument by factoring in the carrying costs involved in holding an underlying asset until maturity"[12]. Because electricity cannot be stored – and "generally, the costs involved in carrying a financial futures contract include the interest costs imputed in holding the underlying asset until its delivery date" as well as "storage and convenience costs" (ibid.) – the cost-of-carry relationship does not strictly apply to the spot and futures prices of electricity. Indeed, "for contracts written on electricity the cost of carry is very large (or infinite) compared to the value of the delivered commodity" (Weron 2000, pg. 130).

The impediments to the development of a robust market for risk sharing can thus be classified as informational (in that the determinants of demand – weather events, behavioral trends – cannot be predicted with certainty) and storage-related (in that the cost of carry is large and merely theoretical). For these reasons, the pricing of derivative contracts on electricity is not conducted under no-arbitrage assumptions, which state that a forward price "should equal today's price plus interest paid to the bank for lending the money plus the cost of carry" (ibid.).

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[10] Yang, J., Bessler, D., and Leatham, D., 2001, "Asset Storability and Price Discovery of Commodity Futures Markets: A New Look", *Journal Futures Markets*, No. 21, pg. 279-300 (pg. 280)

[11] R. Weron, 2000, "Energy price risk management", Physica A, No. 285, pg. 127–134 (pg. 130)

[12] Sequeira, J. and McAleer, M., 2000, "Testing the risk Premium and cost-of-carry hypotheses for currency futures contracts", *Applied Financial Economics*, Vol. 10, pg. 277-289 (pg. 278)

What is electricity market liberalization?

Electricity sector liberalization is not universally recognized as a positive development: "In many countries electricity sector reforms are incomplete, either moving forward slowly with considerable resistance or moving backward, despite the success of these reforms in…other countries and regions"[13]. This is because electricity sector liberalization attempts have not all produced their intended consequences – indeed, the electricity market liberalization reforms in California have been described as a "substantial failure"[14].

Broadly speaking, liberalization is meant to increase the number of participants in a competitive market by decreasing government participation in and regulation of that market (Armstrong and Sappington 2006). The prevailing pro-liberalization argument contends that "market forces produce a better allocation of resources and greater effectiveness in the supply of services, the principal beneficiary being the consumer, who gets better quality at a lower price"[15]. Historically, electricity markets, along with other public utilities, existed as "vertically integrated, typically state-owned, franchise monopolies"[16] – but, beginning (comprehensively) with the UK in the mid-1980s, many countries began implementing liberalization reforms in an effort to reduce the price of electricity (Joskow 2008, pg. 11). The stated goal of these reforms was to "create new institutional arrangements for the electricity sector that provide long-term benefits to society and to ensure that an appropriate share of these benefits are conveyed to consumers through prices that reflect the efficient economic cost of supplying electricity and service quality attributes that reflect consumer valuations" (ibid.). The ideal end result of network utility liberalization reforms is "for competition to provide both the incentive for

[13] Joskow, P.L., 2008, "Lessons Learned from Electricity Market Liberalization", *Energy Journal*, Vol. 29, pg. 9-42 (pg. 9)

[14] Armstrong, M. and Sappington, D., 2006, "Regulation, Competition and Liberalization," *Journal of Economic Literature*, Vol. 44, pg. 325-366 (pg. 326)

[15] European Commission, 1996, "Services of general interest in Europe", Accessed 16 March 2010 <http://ec.europa.eu/consumers/cons_int/serv_gen/serv_int_gen06_en.pdf> (pg. 3)

[16] Newbery, D.M., 2002, "Problems of liberalising the electricity industry", *European Economic Review*, Vol. 46, pg. 919-927 (pg. 919)

efficiency and the means to transfer the gains to consumers, so that there are no rents left for renegotiation and hence no threat to the credibility of the arrangement"[17].

Laur, Soosaar and Tenno describe the liberalization process as comprising three distinct phases: "privatisation, unbundling and market deregulation"[18] (Joskow outlines a more nuanced liberalization prescription consisting of 11 components). Privatization is accomplished through the conversion of state-owned assets into private enterprises, either fully or partially. Unbundling, as described by Meeus et al., is effected by separating the transmission and distribution mechanisms from the production and supply mechanisms (Meeus et al. 2005, pg. 28). Laur, Soosaar, and Tenno term these mechanisms the *monopolistic functions* (transmission and distribution) and the *competitive functions* (production and supply) (Laur, Soosaar, and Tenno 2003, pg. 213). As explained earlier, unbundling can take two forms: a vertically-integrated monopoly is split up into separate private companies along the functional boundaries of each of its operational mechanisms, or a vertically-integrated monopoly remains in tact but separates its accounting functions along those same boundaries. Joskow describes this internal separation as a "Chinese wall" (Joskow 2008, pg. 12).

The last phase – market deregulation – can be affected in "many different permutations…to suit national requirements" (Laur, Soosaar, and Tenno 2003, pg. 214). These national requirements are predicated on infrastructure robustness and economic responsiveness to market reforms, and the benefits of competition are "influenced by technology and initial endowments, and may not be sustainable in every utility, nor in all circumstances" (Newbery 1997, pg. 359). Whatever the prescription or starting condition, the goal of deregulation can be defined without much equivocation: "Deregulation must provide customers with a choice of supplier and introduce price competition" (Laur, Soosaar, and Tenno 2003, pg. 215). But because "market deregulation" as a concept is expansive, vague, and situation-specific, identifying a precise set of implementation measures is difficult. Joskow

[17] Newbery, D.M., 1997, "Privatisation and Liberalisation of Network Utilities", *European Economic Review*, Vol. 41, No. 3-5, pg. 357-384 (pg. 365)

[18] Laur, A., Soosaar, S., Tenno, K., 2003, "Development of Electricity Markets – Options for Estonia", *Essays in Estonian Transformation Economics*, pg. 211-244 (pg. 213)

provides an umbrella description for the measures which can be classified under the market deregulation banner: to "promote efficient access to the transmission network by wholesale buyers and sellers in order to facilitate efficient competitive production and exchange" (Joskow 2008, pg. 13).

But Jaskow is also quick to point out that some regulation is needed to ensure the proper functioning of a competitive electricity market. Joskow asserts that "the performance of the regulated segments [of a liberalized energy market] can have important effects on the performance of the competitive segments since the regulated segments provide the infrastructure platform upon which the competitive segments rely" (Joskow 2008, pg. 23). Measured deregulation, as opposed to a complete abandonment of government regulation, has been a key component of successful electricity market liberalization efforts (Jaskow 2008, pg. 25). And it can be said that overzealous deregulation has been at the heart of some failed liberalization efforts: "Germany and New Zealand's initial decisions to proceed with a liberalization initiative without any sector regulator at all, relying instead on negotiated prices and the constraints of competition law, were clearly a mistake" (ibid.).

The term "de-regulation" in this context is misleading and somewhat counter-intuitive. The process could more aptly be called "re-regulation", which better describes its purpose: establishing an independent regulatory authority and providing it with "power over the key elements of electricity regulation to promote an effective market"[19]. The point of this phase is not to abandon regulation altogether, but rather to erect regulatory mechanisms sufficient to facilitate the market's competitive operation. Green et al. describe the four fundamental responsibilities of an independent regulator within a liberalized electricity market: "set network access conditions (and thus not to arbitrarily deny market access to new competitors); resolve disputes between parties (particularly between generators and network companies); determine regulated prices in advance (thus providing clearer incentives to regulated firms and reducing the scope for lobbying); and acquire relevant information from companies" (ibid.).

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[19] Green, R., Lorenzoni, A., Perez, Y. and Pollitt, M., 2006, "Benchmarking electricity liberalisation in Europe", Electricity Policy Research Group Working Papers, No. EPRG 06/09 (pg. 12)

The saliency of a regulator based upon whether they were appointed or elected has been explored academically by Besley and Coate. They describe the prevailing literature as assuming that "that regulators should be more pro-consumer if they are directly elected"[20] – and, indeed, their empirical analysis finds that "electing regulators will produce more pro-consumer regulators" (Besley and Coate 2003, pg. 1200). They determined that appointed regulators are more likely to "reflect the preferences of stakeholders in the regulated industry than those of the voters at large" (ibid.) because regulation is not an actionable issue for the average voter in a general election. Working with data from the United States, they conclude that "states that elect their regulatory commissioners have lower electricity prices and raise prices by a lower amount when costs increase" (Besley and Coate 2003, pg. 1201).

What is energy security?

Upon deciding to change the power source of the British navy's fleet of ships from coal to oil on the precipice of World War I, Winston Churchill famously said: "Safety and certainty in oil lie in variety and variety alone"[21]. Contemporary energy security policy is more expansive than military supply certainty, however; it must provide for, at the national level, "the reliable supply of energy at an affordable price"[22]. This broad statement serves to define energy security in an abstract sense, but two words – *reliable* and *affordable* – create problems of application that engender the need for a more nuanced (i.e., nation-specific) approach to the topic. Yergin contends that, "although in the developed world the usual definition of energy security is simply the availability of sufficient supplies at affordable prices, different countries interpret what the concept means for them differently" (Yergin 2006, pg. 70).

One distinction to make when attempting to define the theme or prevailing focus of a country's energy security policy is whether it is a *net-exporter* or *net-*

[20] Besley, T. and Coate, S., 2003, "Elected versus Appointed Regulators: Theory and Evidence", *Journal of the European Economic Association*, Vol. 1, No. 5, pg. 1176–1206 (pg. 1178)
[21] Yergin, D., 2006, ''Ensuring Energy Security", *Foreign Affairs*, Vol. 85, No. 2, pg. 69–82 (pg. 69)
[22] Hughes L., 2009, ''The four 'R's of energy security". *Energy Policy*, Vol. 37, pg. 2459–2461 (pg. 2459)

importer of energy. This is because the security concerns for net-exporting and net-importing countries are fundamentally different. For net-exporting countries, the "'security of demand' for their exports" (Yergin 2006, pg. 70) plays a role in their energy security strategy in that it represents security of government revenues. In this way, securing transmission and production capacity and reliability for export is no less important than securing domestic access.

An interesting case study when considering the energy security strategy of a net-exporter of energy is Denmark. Because of its relatively large oil reserves and its government-led initiative toward reducing energy intensity and utilization of alternative energy sources, Denmark is a net-exporter of energy[23].

Table 1: Denmark's import and export of energy products for 2008[24]

Imports and Exports of Energy Products, 2008		
	Imports	**Exports**
Crude Oil [1000 Tonnes]	2364	8657
Oil Products [1000 Tonnes]	4460	4675
Natural Gas [Million Nm3]	0	5516
Electricity [GWh]	12815	11360

Data: Danish Energy Agency, Author: Eric Seufert

According to the Danish Energy Agency, the Danish "degree of self-sufficiency" as it relates to energy production was 130% in 2008 (Danish Energy Agency 2009, pg. 23). In the same year, "Danish energy exports reached record heights, [totaling] 64 billion DKK, which is 19% more than in 2007"[25]. The sheer value of this excess production capacity underscores the importance that energy exports have to the Danish economy and identifies the dual nature of energy security:

[23] European Commission, 2007, "DENMARK – Energy Mix Fact Sheet", accessed online 24/03/2010 at <http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_dk_en.pdf>

[24] Danish Energy Agency, 2009, "Energy in Denmark 2008", accessed online 24/03/2010 at <http://www.ens.dk/en-US/Info/FactsAndFigures/Energy_statistics_and_indicators/Annual%20Statistics/Documents/Energy%20in%20Denmark%202008.pdf>

[25] Climate Consortium Denmark, accessed online 26/03/2010 at <http://www.energymap.dk/Pages/Statistics/Danish-Energy-Statistics>

as a policy initiative, it exists not only for importers protecting supply but also for exporters protecting export revenues.

But most commonly, the term *energy security* is used to refer to a country's "energy supplies, the infrastructure required for producing, distributing, and possibly storing the energy, and the associated costs to the consumer" (Hughes 2009, pg. 2459). This definition is more common simply because it is more relevant, especially in Europe: "the EU members possess only approximately 0.6 per cent of the world's proven oil reserves and 2.0 per cent of proven natural gas reserves, and these limited reserves are largely concentrated in the North Sea"[26]. For the majority of European countries, access to and consistency of supply are more appropriate concerns than continuity of energy export revenue. Using this broad, Europe-centric approach, the supply component of "energy security" in this dissertation will refer to "the security of supply from the global fossil fuel markets" (Bahgat 2006, pg. 964) and not to the consistency of energy export revenues.

Multiple approaches exist for ensuring the security of supply. Hughes outlines a four-part methodology for explaining the concept of energy security (the four 'Rs' of energy security): "review (understanding the problem), reduce (using less energy), replace (shifting to secure sources), and restrict (limiting new demand to secure sources)" (Hughes 2009, pg. 2459). The *review* component involves conducting a survey of both supply and demand factors, evaluating the time frame for each (such as the expected lifetime of a source of energy or the changes in demand over time), and the infrastructure requirements of secure transmission. Hughes specifically emphasizes the relationship between supply and infrastructure, as each is rendered irrelevant in the absence of the other. The *reduce* component is achieved through a reduction in consumption, either through conservation (decreased energy-intensive activity) or increased efficiency (decreased intensity of energy activity). Of the two, Hughes points to efficiency as being the more sustainable, albeit time- and cost-prohibitive, of the two options. Hughes also notes that there are limits to the extent that reduced energy consumption can affect energy security. The *replace* component is undertaken by diversifying energy supply or altering the energy transmission

[26] Bahgat, G, 2006, "Europe's energy security: challenges and opportunities", *International Affairs*, Vol. 82, No. 5, pg. 961 – 975 (pg. 963)

infrastructure to allow for the employment of alternative sources of energy, or both. Finally, the *restrict* component refers to new sources of energy when demand is increasing (such as during an industrialization period) and dictates that new sources of energy should be limited to those that are understood to be secure. Again, Hughes notes that there are limits to the efficacy of this approach, as a jurisdiction is more likely to utilize an insecure source of energy than curtail its growth. While intuitive and accessible, Hughes' methodology is meant to be a primer for the general public and not a policy or economic manifesto: his approach has "been employed as a means to explain energy security and climate issues to members of the general public, and provincial and federal politicians in Canada" (Hughes 2009, 2461).

As was pointed out in the case of Denmark, the concept of energy security is not limited to the supply of imports – and, as such, an energy security strategy and policy prescription is a necessity for every modern economy, whether or not it is a net importer of energy. The focus of this dissertation is Estonia, and the larger purview within which this discourse takes place is the European Union and not the global market for energy. But to address the energy security concerns of Estonia or the European Union, the distribution of the world's energy resources and the dynamics of the trade in those resources should be explored. As this does not fit within the scope of an analysis of electricity market liberalization, a thorough overview of worldwide energy dynamics is included in Appendix Section 1.

Justification for Estonian case

This thesis explores the relationship between electricity market liberalization and energy security, using Estonia as the backdrop against which the effects will be evaluated. Estonia was chosen as a case study for two specific reasons:

Electricity independence

Estonia is electricity independent, importing less electricity than it exports. For this reason, Estonia presents an excellent study of the effects of electricity market liberalization on energy security because any changes to the competitive atmosphere or production mechanisms can be attributed to external forces. Changes in price or supply to a previously self-sustained market after liberalization, given no other fundamental changes in internal dynamics, can be accredited to the impact of new market constraints engendered by a more competitive marketplace. For this reason, Estonia presents an opportunity to observe the effects of electricity market liberalization without having to account for the pre-existing external factors influencing electricity prices in a country that imports electricity from abroad. In other words, the "noise" affecting the relationship between electricity market liberalization and energy security in Estonia is minimal, rendering it a prime candidate for academic study.

Ideal starting point for liberalization

Estonia has one energy supplier: the state-owned, vertically-integrated *Eesti Energia*. This means that, from a liberalization point of view, Estonia is starting from a position of near-abstract market concentration. This also renders measuring the effects of liberalization easier because the process has yet to be seriously undertaken. The privatization of *Eesti Energia*, which may take place as early as June 2010[27], will represent the beginning of the process of electricity market liberalization in Estonia.

The EU electricity market directives affect all EU member states. Estonia was chosen specifically as the subject of this thesis because its characteristics offer a more "pristine" starting point than in other countries where the process of liberalization has progressed farther. This "starting point" condition offers a better opportunity to draw theoretical, as opposed to situational, conclusions. Electricity market liberalization was chosen because it is a dynamic process currently being mandated and undertaken within the EU. The EU electricity market directives render this topic attractive for academic study because they present a clear standard of proper implementation, providing an objective benchmark for success.

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[27] Hõbemägi, Toomas, "Eesti Energia IPO may come in June", Baltic Business News, 18/02/2010, News Article, Accessed 17/05/2010 at < http://www.bbn.ee/article/2010/02/18/Eesti_Energia_IPO_may_come_in_June>

Research focus, hypothesis, and methods

Electricity market liberalization programs face special considerations and challenges as a result of electricity's unique physical characteristics. Because electricity cannot be stored and supply must constantly and simultaneously be matched with demand, abuses within a system completely bereft of regulatory oversight can have considerable economic and social impact – the infamous rolling brown- and black-outs in California over the summer of 2000 prove how drastic the consequences of mismanaged electricity market deregulation can be[28]. And these consequences are exaggerated by security concerns when the deregulated market for electricity is applied at the national level; a liberalized electricity market must be capable of meeting "the over-riding requirement of security and continuity of supply" (Newbery 1995, pg. 49).

The focal research question of this dissertation is: *What effect does electricity market liberalization have on a country's energy security?* The context of this dissertation will be bounded by the current liberalization program being implemented in Estonia. The Estonian situation was chosen as a case study because the liberalization process was started from the point of "a monopolistic electricity market" (Laur, Soosaar, and Tenno 2003, pg. 216) wherein the production of electricity is accomplished through significant reliance on one indigenous resource: oil shale. Because of this, Estonia's liberalization presents serious energy security concerns and allows a clear link to be drawn between liberalization and the security of supply.

Some concepts will be narrowly defined for the strict purposes of evaluating this dissertation's hypothesis:

Electricity market liberalization will be used to refer to the process of liberalizing the electricity market within the Baltic and Nord Pool electricity grids. While the longer-term goal of the EU's energy directive is to incorporate all EU member states into a common electricity system, the more immediate result of Estonia's liberalization reforms will be the unbundling of vertically-integrated

[28] Sioshansi, F., 2001, "California's dysfunctional electricity market: Policy lessons on market restructuring", *Energy Policy*, Vol. 29, No. 9, pg. 735-742

electricity providers within the region and the introduction of competitive elements into the market so that customers can choose the providers from which they purchase electricity. The larger EU-wide ramifications of liberalization will not be explored.

Energy security will be used to refer to the adequate supply of electricity at a stable price. While the security of supply of other resources, such as crude oil and natural gas, are an important component of a country's energy security strategy, the research question will be evaluated based on the supply and price of electricity alone.

Given the concepts defined above and the characteristics of Estonia's electricity supply and energy mix, this dissertation posits the following hypothesis:

Hypothesis: The implementation of electricity market liberalization reforms in Estonia will increase prices and contribute to greater price volatility and therefore have a negative effect on its energy security.

The hypothesis will be tested empirically through a time-series model of Nord Pool electricity prices over the time period of 2008-2009. This model aims to measure price trends and volatility characteristics (price spikes, seasonality, etc.) of the Nord Pool market, which represents the nearest-term implementation of electricity market liberalization for Estonia. This model will be used to test the hypothesis; that further integration of the smaller Estonian (and greater Baltic) electricity grid into the larger Nord Pool market will drive spot prices and price volatility toward the Nord Pool standard.

Contributions of this thesis

The contributions of this thesis come in two forms: empirical and theoretical. The empirical contribution is an updated Nord Pool pricing model, contributing new data to the academic study of electricity market price volatility. While academic study of the Nord Pool electricity market has been conducted, it was mostly undertaken during the period starting from the establishment of the Nord Pool market through the first expansion phase, from the early 1990s to the early 2000s. The new pricing model presented in this thesis will use data from 2008-2009, informing future academic study of the Nord Pool market or of electricity markets in general with contemporary price data.

The theoretical contribution of this thesis is broader. As explored in the next chapter, which discusses the theoretical framework used for this thesis, the topic of energy security is ambiguously defined in the prevailing academic literature, focusing primarily on the supply side of natural resources. This thesis will contribute a new framework for measuring energy security by including a liberalization element in the evaluation mechanism. The prevailing literature identifies two components of energy security: supply adequacy and affordability. But this thesis will define energy security with a third component, price stability, which can be directly influenced by the degree to which a market is liberalized. The theoretical contribution of this thesis, therefore, is a more specific, contemporarily-relevant definition of energy security which incorporates a liberalization element.

1. THEORETICAL FRAMEWORK

The prevailing academic literature exploring the topic of energy security identifies two components of principle significance: an adequate supply of energy on which the infrastructure of a consuming entity can function, and a price point for energy which is equally conducive to this functionality (Yergin 2006, pg. 69). But the theoretical framework of this thesis is the proposition that a third factor should be included in the energy security conceptual consideration: price stability, or the ability to capably predict and hedge prices into the future to assure consistent functional infrastructure operation.

1.1 Volatility and liberalization

Volatility, when considered in the context of a commodity market, refers to the "unpredictable fluctuations of a process observed over time in everyday life"[29]. De-regulated electricity markets exhibit a high degree of volatility as a result of the characteristics of electricity. These characteristics include electricity's non-storability, its inelastic demand, its steep supply function, and the pronounced reactions of electricity prices to unpredictable exogenous factors including weather patterns and natural disasters[30]. Price shocks in the electricity market can be substantial as a result of the need to instantaneously match demand with supply in the electricity market; "the English pool price has moved from £11/MWh to £1100/MWh over a single 24-hour period, and even more extreme price spikes have been seen in

[29] Zareipour, H., Bhattacharya, K., and Canizares, C., 2007, "Electricity market price volatility: the case of Ontario," *Journal of Energy Policy*, to appear

[30] Deng, S.J., Oren, S.S., 2006, "Electricity derivatives and risk management", *Energy*, Vol. 31, pg. 940–953 (pg. 940)

the US" (Newbery 2002, pg. 923). Additionally, many liberalization efforts in Europe have led to market concentration through mergers and acquisition deals, as is explored in detail in Section 4.4 of this thesis. Market concentration in a liberalized electricity market can further exacerbate price volatility: "price spikes are more likely to occur when the expected load is high and the level of market power is at its greatest…in general, market power will make prices more volatile when a uniform price auction is used, and all restructured markets for electricity have adopted this type of auction"[31].

Electricity market liberalization within a political and regulatory environment where preventing market concentration is infeasible or impractical creates a situation where extreme, short-term variations in price are unavoidable. Part of this is inherent in the characteristics of electricity; part of this is attributable to the abuses of market power that "[exacerbate] the volatility of prices and further [reduce] the chance that prices will remain in a reasonable range" (Borenstein 2002, pg. 196). Market power can be addressed by a regulatory authority, which will be discussed further in Chapter 4 of this thesis. But without massive capital expenditures to both provide excess capacity in the event of demand spikes and prevent bottlenecks from forming on congested transmission routes, the properties of electricity that lend an electricity market to significant price volatility are difficult to overcome. And in a liberalized market, producers are discouraged from investing in capacity infrastructure: producers are incentivized – and, perhaps, even beholden by their shareholders – to offer only marginal capacity during demand spikes (Newbery 2002, pg. 923). Yet when supply and demand are mismatched favoring consumers, producers fear that the marginal cost of producing electricity might fall below the average cost of plant operation given investment in new capacity, as is discussed in Section 1.1. Therefore it is the combination of electricity market characteristics and the incentive structure of a liberalized market that render price volatility inexorable.

[31] Mount, T., 1999, "Market power and price volatility in restructured markets for electricity", in *Proc. Hawaii Int. Conf. Syst. Sci.*, pg. 2

1.2 Price signaling and risk hedging in a liberalized electricity market

Regulated, centralized electricity markets do not exhibit the same erratic price behavior as liberalized, de- or re-regulated electricity markets because "price variation is minimal and under the strict control of regulators, who determine prices largely on the basis of average costs"[32]. As opposed to in regulated markets, producers in liberalized markets price electricity at the *marginal* cost, and electricity is sold at the market-clearing price (Borenstein 2002, pg. 198). As markets have de-regulated and liberalized, volatility has "skyrocketed" (ibid.), leading to the creation of energy derivatives used by energy producers and consumers alike to hedge price risks. These financial instruments were created primarily for the purposes of price signaling and price discovery, but some "exotic forms of electricity options can meet specific needs for hedging and speculation" (Deng and Oren 2006, pg. 951).

The effectiveness of electricity derivatives in hedging risk has been questioned in the prevailing academic literature as a result of the fundamental differences between electricity markets and other commodity and financial markets; "the number of papers addressing these problems is still scarce and the suggested solutions are usually not universal or unsatisfactory"[33]. Some of these differences, such as seasonality, are explored in Section 5.3, which surveys models of the Nord Pool market. But the others – such as "an overall high level of (sample) volatility, oscillating volatility–volatility correlations, daily volatility profiles, multi-seasonality, and price level-dependent volatility"[34], as well as the mean-reverting nature of electricity prices following short-term spikes —render electricity market spot and forward price models (and their associated derivative products) difficult to model. These models are also generally incapable of predicting price spikes originating from the supply side, which can be caused by any number of factors: planned outages, sudden generator failures, unpredictable congestion, and market

[32] Knittel, C. R., Roberts, M.R., 2005, "An empirical examination of restructured electricity prices", *Energy Economics*, Vol. 27, pg. 791–817 (pg. 793)

[33] Weron, R., Simonsen, I., Wilman, P., "Modeling highly volatile and seasonal markets: evidence from the Nord Pool electricity market, in Takayasu, H. (ed.), The Application of Econophysics, Springer, Tokyo, 2004, pg. 182-191 (pg. 190)

[34] Simonsen, I., 2005, "Volatility of power markets", *Physica A: Statistical Mechanics and its Applications*, Vol. 335, No. 1, pg. 10–20 (pg. 19)

manipulations[35]. Data informing demand-side models is more readily available but can be vastly more voluminous, especially when weather patterns and general behavioral patterns need to be considered at the regional scale (ibid.). While Pirrong and Jermakyan acknowledge that "the price process for power is not well-captured by standard models"[36] used to price interest rate and equity derivatives, they assert that demand-side models based on the fundamentals of power consumption can accurately predict electricity spot prices if they incorporate a demand risk premium, which they find is based primarily on seasonality. This, again, renders short-term risk hedging difficult and calls into question whether short-term pricing models "are sufficiently robust to support actual trading decisions" (Kirschen 2003, pg. 523).

It is also unclear whether price signaling can have an appreciable effect on demand given the operation of the retail electricity market and the necessity of electricity for almost every industrial and residential function. Very large customers may purchase electricity directly from retailers at the spot rate, but for small customers, the costs incurred in metering and monitoring electricity consumption would outweigh the potential benefit engendered by scheduling activities to coincide with periods of lower-cost electricity (Kirschen 2003, pg. 522). For large-scale consumers of electricity with access to metering technology, price signaling only provides a benefit on the short-term when production can be postponed or labor can be re-allocated to periods of lower-cost electricity. Kirschen calls this temporal demand shift a "form of storage" (ibid.) that must be present to take advantage of short-term price signals. He asserts that demand elasticity resulting from demand-side response to price signaling would help to smooth price spikes and contribute to the more efficient operation of the electricity market, but ultimately concludes that the monitoring technology required for this short-term responsiveness is not available to or viable for the majority of consumers.

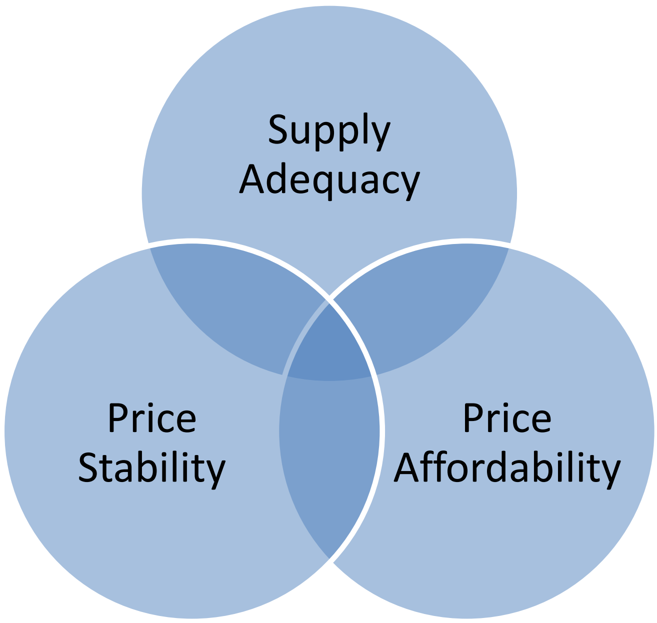
[35] Kirschen, D., 2003, "Demand-side view of electricity markets", *IEEE Transactions on Power Systems*, Vol. 18, No. 2, pg. 520-527 (pg. 523)

[36] Pirrong, C., Jermakyan, M., 2008, "The price of power: The valuation of power and weather derivatives", *Journal of Banking & Finance*, Vol. 32, No. 12, Pg. 2520-2529 (pg. 2520)

1.3 The case for price stability as a component of energy security

The two-component model of energy security is inadequate for describing the preconditions necessary for the continuity of operations of an energy-dependent state. Given the price volatility inherent in a liberalized electricity market, and given the shortcomings in electricity market price models and energy-based derivatives in forecasting prices and hedging risks, this thesis proposes a new qualitative energy security model consisting of a third component – price stability.

Model 1: A three-component model of energy security



Author: Eric Seufert

Price stability – including the ability to forecast prices and adequately hedge against price risks – is an integral element of energy-based infrastructure stability. Significant price swings coupled with the mean-reverting nature of electricity markets renders price forecasting ineffective; this, in turn, inflicts substantial input price risk upon electricity-intensive industry participants. And because the market-clearing behavior of profit-seeking electricity generators is asymmetrical – that is, high prices are passed along to consumers during price spikes, but electricity is sold at the market clearing price even when the marginal price of production for the generator is lower than the competitive price – consumers of electricity in a highly-volatile electricity market are exposed to unavoidable one-sided price pressure.

Because of the influence of electricity market liberalization on price volatility, this proposed model implicitly acknowledges market liberalization as a factor in determining energy security. Market liberalization forces can play a role in the determination of a state's energy security vis-à-vis their contribution to material price spikes in that state's electricity market. This qualitative model posits that electricity market liberalization has a negative impact on energy security by proxy of the unique characteristics of a de- or re-regulated liberalization market that lead to price volatility and potential market concentration.

2. THE ESTONIAN ENERGY SITUATION

Estonia is relatively energy-independent; nearly 70% of its primary energy supply is of domestic origin[37]. The main sources of this domestic energy supply are oil shale, firewood, and peat moss; while the roles of wind and solar energy continue to grow, they do not yet enjoy an appreciable share of Estonia's energy mix.

A decrease in industrial activity over the period from 1990-1993 precipitated a significant drop in energy consumption, but consumption has consistently increased since that time (ibid.). Owing to its reserves of oil shale, Estonia is less dependent on energy imports than many EU states; that said, key dependencies – especially on oil and natural gas imports, which are almost exclusively from Russia – present vulnerabilities to Estonia's energy supply (Kasekamp 2006, pg. 6):

- Most of the liquid fuels consumed in Estonia are imported;
- The entirety of Estonia's natural gas supply is imported;
- Estonia's electricity grid is shared between the other Baltic states, Belarus, and Western Russia;
- Estonia's production of thermal energy is dependent on the water level in the Narva reservoir, which is controlled by Russia.

These four vulnerabilities pose critical energy security risks to Estonia and are manifested out of both political and supply-oriented uncertainty.

[37] Kasekamp, A. (ed.), 2006, "Energy Security of Estonia in the Context of the Energy Policy of the European Union", Estonian Foreign Policy Institute, accessed online 17/2/2010 at <http://www.evi.ee/lib/Security.pdf> (pg. 5)

2.1 Estonia's energy mix

Estonia's domestic energy supply is mainly concentrated in oil shale, of which there are 960 million tons of active consumption resources (Kasekamp 2006, pg. 11). As a matter of *domestic* policy – which is in contrast with EU policy (Laur, Soosaar, and Tenno 2003, pg. 216) – the use of oil shale as a source of primary energy will not be significantly diminished in the near-term future. Nowhere is this policy better highlighted than by the fact that *Eesti Energia*, the state-owned, vertically-integrated Estonian energy company, produced a record-breaking 100 million barrels of shale oil in the fiscal year 2008-2009. According to Eesti Statistika, this represented a 2% production increase over 2007-2008[38]. It is interesting to note, however, that the use of oil shale in electricity production actually fell from 2007 to 2008 – this is because a greater amount of shale oil (more than half) was exported, mainly to the United Kingdom, Finland, Sweden, Belgium, and Latvia[39]. Estonia's official stance on oil shale production is articulated clearly by Raul Mälk, the former Estonian foreign minister and permanent representative of Estonia to the EU. Mälk has said that "Estonia thinks that oil-shale-based electricity production must be maintained, but its share in total production will decrease step-by-step"[40].

Estonia was granted a transition period from the European Commission concerning EU directive 2001/80/EC, which mandates emissions levels from large combustion power plants – in the case of Estonia, oil shale-fired power plants. The transition period will expire at year's end 2015, after which Estonian power facilities will have to comply with EU emissions regulations. In light of this, Estonia has begun to outfit its oil shale power plants with new, circulating fluidized bed combustion technology to reduce carbon emissions (Laur, Soosaar, and Tenno 2003, pg. 216). Despite these improvements, the mining of oil shale and production of oil shale-based energy products has a tremendously negative impact on the environment. Greenhouse gas emissions from oil shale production activities are released in greater relative

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[38] Eesti Energia, 2009, "Eesti Energia Annual Report 2008/2009", accessed online 31/03/2010 at <http://www.energia.ee/fileadmin/files/dokumendid/annual_report/Eesti_Energia_annual_report_2008-2009.pdf> (pg. 5)

[39] Eesti Statistika, 2009, "Statistical Yearbook of Estonia 2009", Tallinn (pg. 346)

[40] Mälk, R., 2007, "Energy security – Estonian interests in the EU", *Estonian Ministry of Foreign Affairs Yearbook* (pg. 64)

amounts than those from the production of other fossil fuels. This is because oil shale production is inherently dirtier than the production of other fossil fuels but also because the production of oil shale is less efficient than for other fossil fuels (Laur, Soosaar, and Tenno 2003, pg. 216). This has resulted in Estonia having one of the highest levels of $C0_2$ emissions per-capita in the EU: in 2000, at 10.21 tons, Estonia was third behind only the Czech Republic and Finland in $C0_2$ emissions per capita (Laur, Soosaar, and Tenno 2003, pg. 239).

Table 2[41] below presents Estonia's energy balance sheet for the year 2008. The only energy product for which Estonia was a net exporter in 2008 was electricity; it exported 941 GWh against imports of 1369 GWh and total resources[42] of 11950 GWh. The table also reveals that, as a percentage of total yearly resources, the year-end reserve stock amounts for each resource are relatively small – only the year-end reserve of oil shale exceeds consumption in 2008, and that is only because final consumption does not include consumption for conversion to other forms of energy (in the case of oil shale, this is the generation of electricity – oil shale accounts for 90% of electricity production in Estonia (Laur, Soosaar, and Tenno 2003, pg. 229)). If this line item is added back into the final consumption equation[43], then year-end reserves would fall far short of consumption.

[41] Data gathered from the website of Eesti Statistika, accessed on 31/03/2010 <http://pub.stat.ee/px-web.2001/I_Databas/Economy/07Energy/02Energy_consumption_and_production/01Annual_statistics/01Annual_statistics.asp>

[42] Total resources = beginning stock (which, in the case of electricity, is always 0) + production of primary energy + production of converted energy + and imports

[43] Final consumption (observed) = beginning stock + production of primary energy + production of converted energy + imports – exports – marine bunkering – ending stock – consumption of conversion to other forms of energy – own use by energy sector – losses – consumption for non-energy purposes

Table 2: Estonian Energy Balance Sheet, 2008

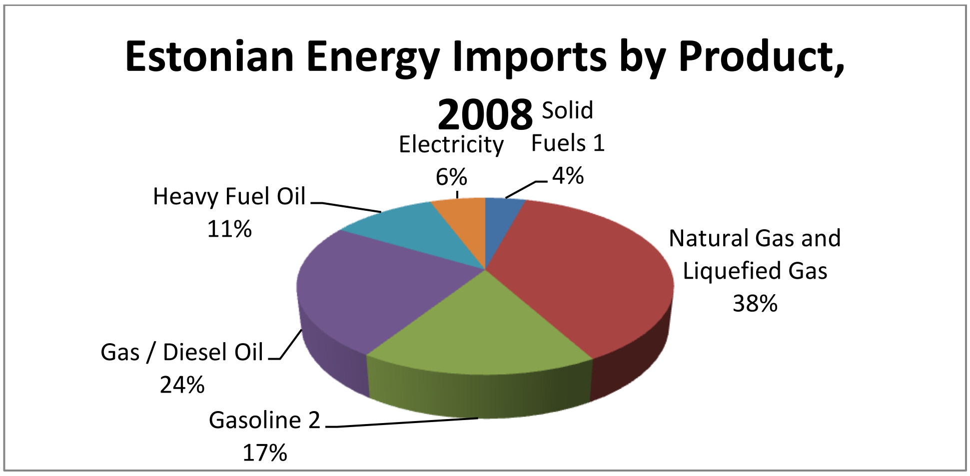
Energy Balance Sheet, 2008	Coal [1]	Oil shale [1]	Natural gas [2]	Liquefied gas [1]	Heavy fuel oil [1]	Light fuel oil [1]	Diesel [1]	Motor gasoline [1]	Aviation gasoline [1]	Electricity [3]
In stocks at the beginning of the year	79	758	0	0.60	19	4	75	49	4	0
Production of primary energy	0	16117	0	0.00	0	0	0	0	0	158
Production of converted energy	0	0	0	0.00	1	86	0	0	0	10423
Imports	123	31	962	7.90	232	48	482	309	28	1369
Resources of energy	202	16906	962	8.50	251	138	557	359	33	11950
Exports	0	0	0	0.00	0	25	0	0	0	2310
Net Imports	123.00	31.00	962.00	7.90	232.00	23.00	482.00	309.00	28.00	(941.00)
Marine Bunkering	0	0	0	0.00	238	0	20	0	0	0
In stocks at the end of the year	73	1202	0	0.60	8	9	37	38	5	0
Supply of energy	129	15704	962	7.90	5	104	499	321	28	9640
Consumption for conversion to other forms of energy	5	15410	575	0.10	4	28	7	0	0	12
Own use by energy sector	0	0	13	0.00	0	0	13	0	0	1592
Losses	0	0	0	0.00	0	0	0	0	0	1130
Consumption for non-energy purposes	0	8	145	0.00	0	0	0	0	0	0
Final consumption observed	124	286	229	7.8	2	76	480	320	27	6906

[1] Amounts in Thousand Tons
[2] Amounts in million m
[3] Amounts in GWh

Data: Eesti Statistika, Author: Eric Seufert

Russia supplies the majority of Estonia's oil and all of its natural gas (Kasekamp 2007, pg. 6; European Commission 2007b, pg. 1). Graph 1 below illustrates the ratio of imported energy products to total energy imports; natural gas and oil imports are roughly equal as a share of total imports (Eesti Statistkia 2009, pg. 345). The main use of natural gas in Estonia is heating, and the main use of oil imports is fuel (Eesti Statistika 2009, pg. 346-347).

Graph 1: Estonian Energy Imports by Product, 2008



Data: Eesti Statistika, Author: Eric Seufert

2.2 Electricity production in Estonia: now and going forward

As has been pointed out, the vast majority of Estonia's electricity is produced with oil shale. Table 3 below outlines the fuel consumption in Estonia for electricity generation by source for 2008. While Electricity generated with oil shale represents 98% of electricity generation, electricity generated through renewable resource consumption makes up only 0.07% of total electricity generation for 2008. This amount is projected to increase, but the Estonian government has not historically made electricity generation through renewable resources a priority: in 2004, Andrus Ansip, then Minister of Economic Affairs and Communications and now Estonia's Prime Minister, predicted that renewable electricity would make up 5.1% of Estonia's gross electricity consumption by 2010, with that number reaching 10% by 2020[44]. The remaining 90% of electricity consumption is predicted by Ansip to be provided in 2020 by natural gas (15%, up from 6.1% in 2002) and oil shale (75%, down from 91.2% in 2002).

Table 3: Estonian Consumption of Fuels in Power Plans for Power Production, 2008

Estonian Consumption of Fuels in Power Plans for Power Production, 2008				
	Total consumption	Percentage of Total	Consumption for electricity generation	Percentage of Total Electricity Generation
Oil shale, thousand t	12075	95.96%	11451	98.48%
Peat, thousand t	39	0.31%	7	0.06%
Wood waste, thousand m^3	30	0.24%	22	0.19%
Heavy fuel oil, thousand t	0	0.00%	0	0.00%
Shale oil, thousand t	13	0.10%	9	0.08%
Diesel, thousand t	0	0.00%	0	0.00%
Natural gas, million m^3	212	1.68%	54	0.46%
Renewables, thousand tce	49	0.39%	8	0.07%
Shale oil gas, thousand tce	165	1.31%	77	0.66%
Total	**12583**	**100.00%**	**11628**	100.00%

Data: Eesti Statistika, Author: Eric Seufert

These figures reveal an Estonian electricity sector dominated by the production of oil shale products through 2020. While circulating fluidized bed combustion technology implements at Estonia's oil shale production facilities in Narva are thought

[44] Ansip, A., 2004, "Long-term fuel and energy sector development plan until 2015", accessed online 05/04/2010 at <http://www.legaltext.ee/text/en/X90006.htm>

to reduce emissions and bring the production of oil shale within the EU's emissions guidelines, no guarantee can be made that this will happen: the two power generation blocks that the Estonian government hopes to upgrade would be the first of their kind (Ansip 2004). Recognizing this, Ansip states that "a final position on the further development of electrical production capacities is formed only after the circulating fluidized bed combustion technology has been applied in Narva power stations" (Ansip 2004) – meaning that a forecast of the energy mix providing electricity in Estonia can only be accurately undertaken after the ability of this new oil shale production technology to decrease emissions is evaluated.

Ansip identifies three alternative electricity production options in addition to the implementation of emissions-reducing circulating fluidized bed combustion technology on oil shale production facilities:

1. Applying *other* emissions-reducing and / or efficiency improving technology to Estonia's oil shale production facilities, such as "combustion under pressure, mixing of oil shale with other (e.g. also renewable) fuels, large-scale production of shale oil and application thereof on the basis of the principle of distributed energy production" (Ansip 2004).
2. Abandoning oil shale as a source of electricity production and fundamentally re-engineer Estonia's electricity apparatus, focusing on another source of energy such as natural gas or coal.
3. Engaging with other countries in the region, such as in cooperating with Lithuania in the construction of a new nuclear power plant there.

Each of these options brings with it a set of unknown and unknowable factors. The second and third options are roughly consistent with the options discussed by Koskela et al.[45] and are classified there as the *Natural Gas Scenario* and *Nuclear Scenario*, respectively, and predict the shares of electricity consumption by energy source for the year 2020. The *Natural Gas Scenario* entails importing natural gas from Russia as a substitute for oil shale – bringing the share of natural gas as a source of

[45] Koskela, S., Seppala, J., Lipp, A., Hiltunen, M-R., Põld, E., Talve, S., 2007, "Estonian electricity supply scenarios for 2020 and their environmental performance", *Energy Policy*, Vol. 35, No. 7, pg. 3571–3582 (pg. 3573)

electricity production up to 61% (with oil shale's share being reduced to 28.5%) (Koskela et al. 2007, pg. 3574). The *Nuclear Scenario* involves importing nuclear electricity from a neighboring country as opposed to investing in domestic infrastructure and brings the share of nuclear power as a source of electricity product up to 43%.

Both the *Natural Gas Scenario* and the *Nuclear Scenario* replace the share of domestic source of electricity production (oil shale) with that of a foreign source (natural gas from Russia; nuclear electricity, presumably from Finland or Lithuania). Neither of these scenarios, as envisioned by Koskela et al., foretell a precipitous rise in the share of renewable resources above and beyond what was predicted by Ansip in 2004: for each scenario (including a third *Oil Shale Scenario* wherein the share of oil shale electricity production is reduced to 70%), the share of electricity produced by renewable resources is consistent at 10%. It can reasonably be concluded, therefore, that any future reduction in electricity produced through domestic oil shale must be met with an increase in the use of a foreign source of electricity (outside of the predicted increase to a 10% share of consumption by renewable sources of electricity).

2.3 The EU's energy imports from Russia

Prior to the Arab oil embargo of 1973, there was little international interest in relying on the Soviet Union for energy imports: authoritative, trustworthy information was not readily forthcoming from the Kremlin, and political tensions between the Western World and the Soviet Union made any level of energy dependence dangerous[46]. This is not the case today: Russia is the world's largest exporter of natural gas, the second-largest exporter of crude oil, and the fifth-largest exporter of coal. Russia also holds the most natural gas reserves of any country in the world, the eighth most reserves of crude oil, and the second-largest reserves of recoverable coal[47].

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[46] Smith, K., 2004, *Russian Energy Politics in the Baltics, Poland, and the Ukraine: A New Stealth Imperialism?*, Washington, DC: Center for Strategic and International Studies, 2004 (pg. 9)

[47] Energy Information Administration (US Government), 2010, "Russia Energy Profile", Accessed 08/04/2010 at <http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=RS>

Russia's status as a globally-significant supplier of energy is relevant not only to the energy security of Estonia but to the EU as a whole. EU natural gas production is in decline; the bulk of the EU's gas reserves in the North Sea will be depleted in 2015[48], and the European Union predicts that gas imports will make up 80% of demand by 2030[49]. But dependence on Russian natural gas within the EU is not evenly distributed: many Central and Eastern European states – including Estonia – are totally dependent on Russia for natural gas imports, but the Iberian peninsula imports no natural gas from Russia and the UK, which represents the largest market for natural gas in the EU, has only imported Russian gas in small quantities (Stern 2007, pg. 89). Table 4 below lists the major importers of Russian natural gas within the EU and CIS for the year 2007[50].

The 20-20-20 initiative endorsed by the EU in 2008 – which seeks to increase energy efficiency and the share of renewable resources in the EU-wide energy mix (as compared to 1990 levels) by 2020 – should reduce acceleration of demand for natural gas within the EU. Liuhto et al. forecast two natural gas demand scenarios in 2020 given the adoption of the 20-20-20 initiative. In the first, with the average price of oil at $61 / barrel over 2008 – 2020, the demand for natural gas increased by only 30 bcm per year by 2020. In the second, with the average price of oil at $100 / per barrel, the demand for natural gas actually decreases (Liuhto 2009, pg. 6). These scenarios do not take into account the "dash for gas" precipitated by the EU Emissions Trading Scheme (EU ETS), which incentivizes the use of natural gas over other fossil fuels (ibid.). The effects of the 20-20-20 scheme on natural gas imports may be negated by the effects of the EU ETS; the competing forces muddle forecasts of natural gas consumption.

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[48] Liuhto, K. (Ed.), 2009, "The EU-Russia Gas Connection: Pipes, Politics and Problems, Electronic Publications of Pan-European Institute", Turku School of Economics, No. 8, pg. 3-22 (pg. 5)

[49] Stern, J., 2007, "The new Security environment for European Gas: Worsening Geopolitics and Increasing Global Competition for LNG", *Energy Politics*, Vol. 12, pg. 85 – 127 (pg. 88)

[50] Energy Information Administration (US Government), 2010, "Russia Energy Data, Statistics, and Analysis – Oil, Gas, Electricity, Coal", Accessed 08/04/2010 at <http://www.eia.doe.gov/emeu/cabs/Russia/NaturalGas.html>

Table 4: Recipients of Russian Natural Gas, 2007

Recipients of Russian Natural Gas Imports, 2007	
Country	**Imports (bcf/y)**
Ukraine	2,240
Germany	1,378
Turkey	828
Belarus	763
Italy	742
France	346
Czech Republic	247
Poland	247
Baltic States - Total	**243**
Hungary	226
Slovakia	223
Austria	191
Finland	166
Romania	138
Lithuania	122
Bulgaria	120
Greece	111
Serbia & Montenegro	74
Latvia	72
Armenia	71
Estonia	**49**
Georgia	36
Croatia	35
Kazakhstan	32
Slovenia	18
Switzerland	11
Macedonia	4

Data: Energy Information Administration, Author: Eric Seufert

The geographic disparity in dependence on Russian natural gas imports within the EU, coupled with the EU-wide emphasis on alternative sources of energy, puts Estonia in a difficult position regarding its ability to negotiate energy imports with Russia. As Mälk states, "the issues of external energy relations and of the connection between energy and national security, which greatly worry Estonia, form only a relatively small portion of the EU decisions" (Mälk 2007, pg. 63). Where the European Union has made concerted efforts to wean itself from imports of Russian natural gas – both as a result of the oil and gas crises between Russia-Ukraine and Russia-Belarus and in an attempt to fight climate change through reduced emissions – the imbalance in dependency on Russian imports has left Estonia with a weaker position from which to engage Russia. Lucas notes that "the crucial imbalance is that the Kremlin does not need to worry about small East European countries as gas or oil customers. But those countries do need to worry about Russia as supplier"[51]. This lack of leverage underscores the precarious position Estonia finds itself in with regard to energy prices. In 2008, Estonia (along with the rest of the Baltic States) paid $280 / thousand cubic meters (mcm) for imported natural gas from Russia – significantly less than the $370 / mcm European market price (Energy Information Administration 2010). With regard to electricity, Estonian consumers pay the second-lowest prices in the EU; Lithuanian consumers pay the lowest[52].

This highlights one schism within the EU between the larger, more economically powerful states and the newer member states in Central and Eastern Europe. With regard to energy imports from Russia, the newer member states look to the EU for collective action for greater leverage, whereas the larger states wish to maintain their autonomy so as to ensure their own security of supply[53]. The EU has established two primary institutional mediums through which to address energy issues with Russia: the Energy Charter Treaty and the EU–Russia Energy Dialogue (Belkin 2007, pg. 87). The EU-Russia Energy Dialogue was created in 2000 and was the formative discourse over energy between the EU and Russia; the Energy Charter Treaty, which has not been ratified by Russia, would require Russia to implement a legal framework to govern the trade, transit, and investment in energy resources. And despite Russia's non-ratification of the Energy Charter Treaty – or perhaps precisely because of it – a number of EU member states have pursued direct, bi-lateral energy agreements with Russia (ibid.). Germany and Italy have both entered into supply contracts with Russia to ensure supply quantities; Slovenia, Hungary, and Belgium have negotiated pipeline and gas distribution projects with Gazprom, Russia's largest company. Not surprisingly, new member states such as the Baltic states and Poland have objected to these bilateral

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[51] Lucas, E., 2008, *The New Cold War: How the Kremlin Menaces both Russia and the West*, London, UK: Bloomsbury, London (pg. xxiii)

[52] European Commission, 2007b, "ESTONIA – Internal Market Fact Sheet", accessed online 12/04/2010 at < http://ec.europa.eu/energy/energy_policy/doc/factsheets/market/market_ee_en.pdf>

[53] Belkin, P., 2007, "The European Union's Energy Security Challenges, CRS Report for Congress", Congressional Research Service, Accessed 08/04/2010 at <http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA473788&Location=U2&doc=GetTRDoc.pdf> (pg. 85)

agreements (ibid.), claiming that they will provide Russia with increased influence over the EU decision-making process.

Liuhto posits that the power dynamic manifested of the energy trade between the EU and Russia is asymmetric and not one of mutual-dependence, claiming that: 1) Russia has a greater possibility of diversifying its exports than the EU has of diversifying its imports; 2) Russia is a unified seller, whereas the EU is a divided buyer (evidenced by the bi-lateral agreements noted above); 3) the EU is more dependent on Russian energy than Russia is dependent on EU goods; 4) Russian leadership is free to make politically-unpopular decisions, whereas European leadership is not (Liuhto 2009, pg. 120-122). Belkin echoes these sentiments, adding that EU energy independence (or, rather, decreased Russian dependence) can be achieved in two ways: 1) diversifying its energy supply from other regions, such as Norway, the Caspian Sea, and the Middle East; and 2) exerting increased regulatory pressure on Gazprom as it becomes a more substantial player in the European energy market (Belkin 2007, pg. 88).

It should be noted that Estonia's natural gas supply does not constitute an electricity production issue. As detailed in table 3, electricity consumption in Estonia is almost completely dependent on oil shale, with the share of natural gas as a percentage of electricity consumption being only 0.46% in 2008. But while it is not a significant component of electricity production, natural gas is a crucial component of the production of heat: in 2006, 46% of all district heating supply in Estonia was provided by natural gas, and in some large towns – such as Tallinn, Rakvere, Jõgeva, and Põlva – district heating supply was 100% dependent on natural gas[54].

2.4 The Baltic electricity grid

The electricity grids of Estonia, Latvia, and Lithuania are interconnected and jointly managed. The infrastructure is a relic of the Soviet Union; it also includes the Kaliningrad Oblast of Russia, Belarus, and North-Western Russia and was originally built as the north-western common power system for the Soviet Union (Estonian Competition Authority 2008, pg. 12). The Baltic energy grid operates in parallel on a

[54] Estonian Competition Authority, 2008, Estonian Electricity and Gas Market Report, Tallinn (pg. 93)

synchronous AC grid with the United Power System of Russia and the Power System of Belarus; the electricity grid is made up of five high-voltage transmission lines (of 330 kV, 500 kV, and 750 kV) which form a power loop that can be observed below in Map 1. In January 2005, the total capacity of the Baltic grid was 8.99 GW, whereas the peak demand in 2005 was only 4.12 GW[55]

The Baltic electricity grid's infrastructure is considered strong – it is the only electricity grid within the EU which does not experience "transmission power deficit and the so-called bottle-necks" (Estonian Competition Authority 2008, pg. 14). The only connection that the Baltic electricity grid has with another EU member state is a 350 MW DC sea-cable connection (Estlink) between Estonia and Finland. Estonia specifically has four external electricity grid connections: one with Latvia with a capacity of 750 MW, three with Russia for a combined capacity of 1550 MW, and the aforementioned 350 MW connection with Finland (ibid.).

Map 1: The Baltic electricity grid

Source: Estonian Competition Authority

[55] Moora, H. and Lahtvee, V., 2009, "Electricity Scenarios for the Baltic States and Marginal Energy Technology in Life Cycle Assessments", *Oil Shale*, Vol. 26, No. 3 Special, pg. 331–346 (pg. 333)

The Estlink connection began operating in 2006 and is operated by *AS Nordic Energy Link*, which is a joint venture between four firms: *Eesti Energia AS* (Estonia), owning 39.9%; *Lietuvos Energija AB* (Lithuania), owning 25%; *VAS Latvenergo* (Latvia), owning 25%; and *Finestlink* (Finland), owning 10.1% (Estonian Competition Authority 2008, pg. 17). Both the Finnish and Estonian electricity regulatory boards, as well as the EU, have granted Estlink an exemption from providing third party access to the energy it transmits until 2013. The entirety of the available capacity transmitted through Estlink is distributed between its owners on a contractual basis; however, if the owners do not utilize their contractually-determined capacity, they are obligated to make the remainder available to third parties. This is achieved through a next-day "residual capacity" auction; project parties submit their usage statistics for the next day, and any residual capacity is available for purchase at auction. Nordic Energy Link, a subsidiary of Eesti Energi, estimates the capacity available at auction to be 700 MW per day, although the actual daily amounts depend on the usage of project parties[56]. Upon the expiration of Estlink's joint exemption in 2013, unimpeded access to Estlink capacity will be granted to third parties (Estonian Competition Authority 2008, pg. 17). On April 1st, 2010, the "Estlink bidding area", a spot market for electricity, opened[57]. The Estlink bidding area is operated by Nord Pool Spot AS, the Nord Pool grid operator, and adds further liquidity to the Baltic electricity market by connecting it with the Nordic countries of Sweden, Denmark, Norway, and Finland.

Each Baltic state has a unique electricity production program. The generation of electricity in Estonia has already been covered, so it will not be re-tread here. Electricity production in Latvia is accomplished primarily through to co-generation of fossil fuels (chief among them, natural gas and coal) and hydro-power. Prior to 2010, the dominant source of electricity production in Lithuania was nuclear energy – specifically, the Ignalia Nuclear Power Plans (NPP), which was closed on December 31st, 2009 in accordance with Lithuania's EU accession agreement (Moora and Lahtvee 2009, pg. 333). The Ignalia plant, which relied upon the same model of nuclear reactors used at

[56] Nordic Energy Link, "Estlink User Guide", Accessed 22/04/2010 at <http://www.nordicenergylink.com/fileadmin/Estlink_User_Guide.rtf>

[57] "Estonian market successfully opened during Easter", Nord Pool Spot AS, 06/04/2010, press release, Accessed 22/04/2010 at <http://www.nordpoolspot.com/Market_Information/Exchange-information/No-242010-NPS--Estonian-market-successfully-opened-during-Easter/>

Chernobyl, the site of the worst nuclear catastrophe in history, supplied more than 70% of Lithuania's electricity. Before shutting the plant, the total production capacity in Lithuania amounted to more than 5000 MW, representing more than double the country's consumption. But the Lithuanian government predicts that electricity prices in Lithuania will rise by more than one-third in 2010 as a result of the plant being shut down. To compensate for the electricity once generated by Ignalia, the Lithuanian government will increase production at the *Elektrenai* fossil fuel power plant and augment its energy imports from nearby countries: electricity from its Baltic neighbors as well as the Ukraine, Belarus, and Russia, the latter of which it will also look to for additional natural gas imports[58].

The majority of the Baltic electricity grid's power is contributed from base load power stations, such as the Estonian oil shale processing plant *Narva Elektrijaamad*. These base load power stations help regulate the capacity within the grid, as Latvian and Lithuanian hydroelectric power stations cannot consistently deliver a sufficient supply of electricity. Russia also helps to stabilize the system by contributing electricity from its own hydroelectric power stations (ibid.). Short-term tests of system stability have been conducted wherein Russia has been disconnected from the Baltic grid; however, Russia has not relented to longer-term tests because it would render the Kaliningrad Oblast's electricity needs entirely dependent on Baltic supply. This reaction evidences Russia's stake in the Baltic energy grid with regard to the Kaliningrad Oblast's connectivity: while Russia commits capacity to the grid to ensure sufficient supply during peak loads, it also is able to exert influence over the functioning of the grid.

Russia may be given more opportunities to exert influence over the Baltic electricity grid in the near- and medium-term future. Before the closure of the Ignalia NPP in 2009, both Estonia and Lithuania were net electricity exporters. But Estonia is now the sole Baltic net electricity exporter – and because of the interconnectedness of the Baltic grid, dependence of one country on electricity imports renders the entire system dependent on electricity imports. Lithuania's increased dependency on Russia for natural gas and electricity imposes a supply security burden on all three Baltic

[58] "Lithuania to shut Soviet-era nuclear plant", Reuters UK, 31/12/2009, news article, Accessed 09/04/2010 at <http://uk.reuters.com/article/idUKLDE5BU0IC20091231?sp=true>

States, although the Baltic States and Poland have investigated the possibility of replacing the Ignalia NPP in Lithuania between 2015 and 2020 (Estonian Competition Authority 2008, pg. 92).

2.5 Impact of liberalization on Estonian energy sources

The Estonian energy situation is explored in this chapter within the context of the research question: '*What effect does electricity market liberalization have on a country's energy security?'*. Given Estonia's reliance on internal resources, predominantly oil shale, in its production of electricity, it faces no supply limitations or cost constraints concerning energy security. But the liberalization process will have an impact on both of these factors. As discussed, Estonia must decrease its dependence on oil shale in electricity production as a condition of its EU accession – and since the vast majority of Estonia's electricity production is accomplished through the use of oil shale, and the Estonian government does not predict that alternative energy sources will make up a substantial portion of its energy mix through 2020, it will have to look to other – external – sources of electricity to fill the production gap. Additionally, with the shut-down of Ignalia NPP, the integrated Baltic grid may face a production deficit. As liberalization efforts develop, strengthening not only the internal links within the Baltic grid but also the links between Estonia and the Nord Pool market, the Baltic grid, within which Estonia is inextricably integrated, could potentially face dependence on external suppliers. This will inevitably drive the cost of electricity up: Estonian electricity provided by oil shale is cheaper than what is sold on the Nord Pool market. Likewise, further dependence on Russia will have an effect on the supply component of energy security for the reasons outlined above.

The core effects of liberalization on Estonia's electricity production resource profile will be increased external dependencies and upward price pressure. External sources will be needed to fill the void created by a shift away from the use of oil shale, and the cost of these sources will be higher than what can be produced internally. Both of these effects will have a generally negative effect on Estonia's energy security given the model proposed in Chapter 1.

3. ELECTRICITY MARKET REFORMS MANDATED BY THE EUROPEAN UNION

The European Union's electricity market reforms are among the most ambitious and sweeping in the world[59]. The origins of liberalization reform in Europe can be traced to the early 1990s; they were catalyzed by the ending of the Cold War, which rendered natural gas imports from Russia more stable. Liberalization in this environment incentivized the construction of new gas-fired plants, which resulted in a surplus of supply that further supported liberalization reform. Jamasb and Pollitt describe the initial reforms as being implemented through two parallel processes. The first involved requiring EU member states to make a number of key changes to their national energy markets by a prescribed date. The second involved facilitating the establishment of new electricity trading rules between states and establishing new links between member states through which electricity could be traded. The new trading rules have generally been the domain of industry participants, but the EU itself has subsidized some transmission lines between member states. The overarching purpose of these policies was to allow electricity providers from across the EU to compete with "national incumbents" as well as to reduce the transmission costs of electricity throughout the EU – and the broad motivation behind both of these factors was to increase competition (Jamasb and Pollitt 2005, pg. 6).

The first EU electricity market directive[60] focused primarily on promoting competition through the unbundling of production and transmission operations; it wasn't

[59] Jamasb, T. and Pollitt, M., 2005, "Electricity Market Reform in the European Union: Review of Progress toward Liberalization & Integration", MIT Center for Energy and Environmental Policy Research (pg. 1)

[60] 96-92-EC, hereafter referred to as *the 1996* directive, full text available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0092:EN:HTML>

until the second EU Electricity Market Directive[61] that the promotion of regulatory authority was included as a major component of liberalization reform. In the 2003 directive, regulators were given agency over cross-border trade and electricity distribution; the 2003 directive also called for the legal separation of vertically-integrated electricity providers (as opposed to the accounting separation mandated by the 1996 directive) and provided all non-household consumers a choice of supplier by 2004 (with an expansion to all consumers in 2007). Jamasb and Pollitt posit that the EU liberalization reforms deviated from "textbook models" in that they did not prescribe independent regulatory oversight *ex ante*; rather, they claim that EU regulatory emphasis came late in the liberalization process, "after the market structure and rules were established" (ibid.), which led to a disparity in regulatory oversight across the EU-15 member states. Another diversion from textbook models that they identify is a lack of mandated privatization: in some member states, such as France, the incumbent monopoly electricity provider has been unbundled but remains owned by the state.

This chapter will investigate the content and the consequences of the EU electricity market directives. The first section will outline the specific prescription of the directives within the context of the three components of liberalization reform and the extent to which they have been achieved. It will then proceed into a discussion of the effects of the EU's liberalization reforms in terms of electricity prices, energy security, and market concentration. The chapter will end with an overview of the third EU electricity market directive, which will be made effective in March 2011.

3.1 Prescriptions and implementation of the EU electricity market directives

While many member states have implemented the prescriptions of both EU Electricity Market directives through national legislation, the EU has been forced to take legal action against others for non-compliance. Specifically, the European Commission issued infringement procedures against 25 member states for electricity concerns and 21

[61] 2003-54-EC, hereafter referred to as *the 2003 directive*, full text available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0054:EN:HTML>

member states for gas concerns in June 2009[62]. Vasconcelos presents a helpful c hart which contrasts the way in which the 1996 and 2003 reforms differed[63]; it has been recreated in Table 5 below. As mentioned above, the 2003 directive added greater regulatory authority to liberalization reforms, as well as mandating choice for more customers and instituting the legal unbundling of electricity market operators. It also ended the single-buyer model for distribution utilities and mandated regulated third-party access to distribution networks, thus contributing to a more competitive landscape.

The European Commission passed a third EU Electricity Market Directive on July 13th, 2009 which contains five new legal acts and strengthens the regulatory framework of the internal European electricity market; however, EU member states are not obligated to adopt the measures of the third directive until March 3, 2011.

This section will proceed with an overview of each of the three elements of reform comprising the liberalization process prescribed in the two EC directives – privatization, unbundling, and re-regulation – along with a "benchmark" of how successful each of those reform measures has been.

Privatization

The purpose of the privatization phase is to convert state-owned electricity market operators into private enterprises, thus replacing a monopolistic market with a competitive one. The key motivating factors behind privatization are to drive prices down and allow customers the ability to choose their providers. To this end, while the first two EU Electricity Market directives do not mandate the privatization of state-owned firms, they do stipulate that all EU customers be eligible to choose their supplier of electricity. The directives very explicitly provided for the protection of "vulnerable" consumers, including measures designed to protect their access to electricity as well as institute suppliers of last resort. The directives also emphasized contract transparency, mandating that consumer contracts include enough information to make educated

[62] European Commission, 2009, "Report on progress in creating the internal gas and electricity market", Report from the Commission, COM/2010/84, Brussels (pg. 2)

[63] Vasconcelos, J, 2004, "Services of General Interest and Regulation in the EU Energy Market", Council of European Energy Regulators (CEER), Presentation at XVI CEEP Congress 17 June 2004, Leipzig

decisions about commercial offers and providing for the resolution of conflicts between consumers and providers out of court.

Table 5: A breakdown of EU Electricity Market Directives (1996 and 2003)

EU Electricity Market Liberalization Directives			
	Most Common Form pre-1996	1996 Directive	2003 Directive
Generation	Monopoly	Authorization and Tendering	Authorization
Transmission and Distribution	Monopoly	Regulated TP, Negotiated TPA, and Single Buyer	Regulated TPA
Supply	Monopoly	Accounting separation	Legal separation from transmission and distribution
Customers	No Choice	Choice for eligible customers (approx. 1/3)	All non-household (2004), All (2007)
Unbundling T/D	None	Accounts	Legal
Cross-Border Trade	Monopoly	Negotiated	Regulated
Regulation	Government Department	Not specified	Regulatory Authority

Data: Vasconcelos 2004, Author: Eric Seufert

Because full privatization is not a specifically stated mandate of the directives (Jamasb and Pollit 2005, pg. 13), its implementation is difficult to benchmark. One method is concentration and market share, which can be measured through the Herfindahl-Hirschman Index (HHI), which is calculated by the European Commission with a sum of squared shares of individual companies. From 2008-2009, 10 member states experienced decreases in HHI (European Commission 2009, pg. 7), although this statistic isn't revealing of the overall success of privatization implements. A breakdown of EU member states by HHI categorization is found in Table 6 below[64].

[64] European Commission, 2009, "Technical Annex: Report on progress in creating the internal gas and electricity market", Accessed 13/04/2010 at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2010:0251:FIN:EN:PDF> (pg. 12)

Table 6: Countries grouped by Herfindahl-Hirschman Index

Countries by Herfindahl-Hirschman Index	
Very Highly Concentrated (HHI above 5000)	BE, FR, GR, LV, LU, SK
Highly Concentrated (HHI 1800 - 5000)	CZ, DE, LT, PT, SI, RO, HU, DK, NO
Moderately Concentrated (HH 750 - 1800)	FI, PL, UK, ES, IT, NL, AT

Data: European Commission, Author: Eric Seufert

Another method of benchmarking privatization is tracking the extent to which customers in a given member state's electricity market switched providers, which can be taken as a proxy measure of competition – or, at the very least, a customer base's access to more than one provider. From 2008-2009, only four member states – Sweden, Slovenia, Bulgaria, and Austria – experienced an increase in customers switching providers, whereas six member states experienced a decrease. Again, this is superficial analysis that does not reveal much about privatization reforms or their effects. If anything, it merely underscores the fact that privatization is difficult to benchmark, especially given the nuanced nature in which it is implemented through the directives.

Unbundling

The EU directives prescribe both legal and functional unbundling for transmission and distribution system operators. The unbundling of transmission system operators (TSOs) and distribution system operators (DSOs) have different benefits. Unbundling TSOs is important because they provide the marketplace for the trading of electricity, either through a day-ahead power exchange or through load balancing responsibilities. Additionally, TSOs are privy to market-sensitive information. These are functionally critical elements of an electricity market; if not acting independently from the commercial aspects of the market's operation, a TSO could discriminate against network users or customers through network access, real-time system operation, or the provision of crucial information. TSOs must also be incentivized to make capital investment decisions based on network need and not commercial viability, which is impossible if a TSO is not acting independently of commercial interests.

DSOs operate closer to consumers yet still play a critical role in the functioning of an electricity market. DSOs collect information from electricity meters and operate the exchange of data about suppliers which allows customers to choose their electricity provider. If a DSO is not acting independently of the commercial aspects of an electricity supplier, then they could influence the decisions of customers with regard to provider choice and thus depress the competitiveness of the market.

The 2003 directive mandated that TSOs be split into separate legal entities and be functionally and operationally independent by July 1st, 2007. DSOs with fewer than 100,000 customers were exempted from unbundling requirements (that is, unbundling of these DSOs was left to the discretion of the member states); DSOs with more than 100,000 customers were required to undergo the same unbundling efforts as TSOs under the same time constraints.

As of 2009, 15 TSOs within the EU had had implemented ownership unbundling, and some member states had gone further than the unbundling prescriptions of the directives. Most member states had made use of the unbundling exemption for DSOs with fewer than 100,000 customers; DSOs were slow to adapt the stipulations of the directives, but the status of TSO and DSO unbundling in the EU seems stable. It seems likely that many member states will have to accommodate their legal frameworks to meet the requirements of the upcoming third directive (European Commission 2009, pg. 10).

Re-regulation

The 2003 directive introduced the establishment of an electricity sector-specific regulator for the purpose of implementing *ex ante* network regulation. The directive calls for the establishment of at least one regulatory body in each member state as well as the establishment of a European Regulators Group for Electricity and Gas, the purpose of which is to help the member states coordinate their regulatory efforts and to facilitate cooperation among member states.

While a baseline set up responsibilities was laid out in the 2003 directive, many aspects of the establishment of a regulatory body were left vague and open for interpretation – such as the possibility of a member state establishing more than one regulatory body, or of the Ministry usurping regulatory authority from a member state's body (European Commission[65]. The directive broadly establishes the purpose of a member state's regulatory authority as "achieving a competitive, secure and environmentally sustainable market in electricity" (2003-54-EC, article 3.1). The directive does not give regulatory authorities explicit access to information held by market operators within their jurisdictions.

3.2 Electricity price trends after liberalization

Wholesale electricity day-ahead and spot prices rose precipitously within the EU from 2003 to 2005[66] -- the period directly following the adoption of the 2003 directive -- increasing by approximately €10 per MWh from early 2003 to May 2005. This price increase was characterized by early volatility, especially within the Netherlands, Spain, the UK, France, and Slovenia; by 2004, however, the wholesale price of electricity in most countries had stabilized. Forward prices for electricity, quoted on a "year-ahead" basis, also increased substantially throughout 2003 and 2004, with the most dramatic changes occurring in the Netherlands and the UK. The European Commission attributed these price increases to a perceived increase in demand in natural gas for heating over the winter of 2004-2005 but acknowledged that market participants could potentially have influenced competitive conditions sufficient to inflate prices (European Commission 2004, pg. 22).

Upward pressure on electricity prices within the EU continued through 2007. The price of electricity paid by industrial users increased by more 22% from January 2005 to January 2007, and the price paid by households increased by 14% over the same time period[67]. From 2007 to 2008, electricity prices for household consumers increased by 2%, although year-to-year price differentials varied widely across the European Union. During this time period, the five member states paying the lowest absolute

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[65] European Commission, 2005, "Report on progress in creating the internal gas and electricity market", COM/2005/0568, Brussels (pg. 85)

[66] European Commission, 2004, "Technical Annex: Annual Report on the Implementation of the Gas and Electricity Internal Market", COM/2004/0863, Brussels (pg. 20)

[67] Clement, E. and Goerten, J., 2007, "Electricity prices for EU households and industrial consumers on 1 January 2007", *Statistics in Focus (Published by EuroStat)* (pg. 6), Accessed 14/04/2010 at <http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-080/EN/KS-SF-07-080-EN.PDF>

household electricity prices all exercised price controls, and the member states which experienced the largest supply-demand disparity paid the highest absolute household electricity prices (European Commission 2008, pg. 8). When controlling for Purchasing Power Parity, however, the highest household electricity prices in the EU were paid in Hungary, Slovakia, Germany, Cyprus, Denmark, and Poland – all of which, excluding Denmark, regulate electricity prices.

The European Union considered in 2006 the notion that liberalization had not facilitated an ideally competitive electricity marketplace – and that the improvements to production and generation efficiency precipitated through liberalization reform had not yet impacted the end-user price of electricity, especially for large industrial consumers. The European Union questioned whether electricity prices were derived through a competitive process or dictated by large network operators with considerable market influence[68]

The electricity prices of 2008-2009 were affected by the global recession during the same period. Electricity prices rose concomitantly with the price of oil over the first half of 2008 but fell disproportionately after the start of the financial crisis. The price of Brent crude oil fell by over 70% from €92 / bbl in July 2008 to €27 / bbl at the end of 2008. The electricity price paid by industrial consumers decreased by, on average, 7 to 12% in the EU over the first half of 2009, but electricity prices were higher in most member states in the first half of 2009 than in 2008. The European Commission explained this peculiarity in pricing differences by the time lag through which oil prices affect end-user electricity prices, although it also questioned whether the drop in oil prices was fully manifested in electricity prices[69].

Many factors contribute to the price of electricity, and attributing a year-to-year rise in prices on one conditional change is not intellectually justifiable when looking only at broad trends. But the asymmetry in the decrease of electricity prices juxtaposed with the decrease in Brent crude prices in the wake of the 2008-2009 global financial crisis does raise systemic questions about market concentration and the efficiency of the

[68] European Commission, 2006, "Prospects for the internal gas and electricity market", COM/2006/0841, Brussels (pg. 3)

[69] European Commission, 2009b, "Report on progress in creating the internal gas and electricity market", COM/2010/84, Brussels (pg. 10)

internal market's competitive mechanisms. The EU acknowledged this in stating that there is "perhaps an insufficient level of market integration at retail level" (European Commission 2009, pg. 13).

3.3 Energy security trends after liberalization

The European Union identified two prevailing reasons that liberalization reforms would increase the EU's security of supply. The first is that a common internal market would provide greater incentives and support for infrastructure investment than a confederation of interconnected national networks. This assertion was supported by a surplus of generation capacity in 2006 despite year-on-year growth in peak load demand of 1.5-2%. The exception in this case were member states in which electricity prices were regulated despite growing demand; under these circumstances, inadequate infrastructure investment resulting from below-optimal pricing.

A second justification is that competitive markets encourage diversification, and that an integrated internal European market gives European energy suppliers more leverage when sourcing energy internationally. This point co-mingles with the first in terms of implementation because international energy delivery is predicated almost entirely on robust infrastructure. And while improvements have been made to this end, the existence of "energy islands" (poorly-integrated regions of the internal market) belie complete, pan-EU security of supply. This is being addressed, however, through efforts such as the European Energy Programme for Recovery (EEER), which will assist the most vulnerable regions of the EU through infrastructure investment from a €2.365 fund made available by the European Union (European Commission 2009, pg. 5). Additionally, regional connectivity initiatives have relieved transport congestion and contributed to optimal load balancing.

One example of such a regional initiative is the Baltic Energy Market Interconnection Plan (BEMIP), an agreement between Denmark, Germany, Estonia, Latvia, Lithuania, Poland, Finland, and Sweden to further integrate the electricity and gas markets of those countries. BEMIP was facilitated by the European Union and aims to strengthen the energy connectedness of the Baltic Sea region in an effort to bolster the overall capacity of the EU's internal energy market. BEMIP will be achieved in three ways: electricity market integration, electricity infrastructure projects to increase connectedness, and gas market and infrastructure development. With regard to market integration, BEMIP focuses on reduced concentration of supply, increased trading liquidity, free cross-border trade, equal market conditions across the region with effective universal third-party access, and increased transparency of information and capacity allocation[70].

The specific infrastructure projects undertaken as part of BEMIP were broadly based on the Nordic electricity market and detailed in an Action Plan "roadmap" by the participating countries[71]. Three initiatives form the foundation of the infrastructure element:

1. The Nordic Master Plan, which will comprise projects within the Nordic countries such as a link between Finland and Sweden (Fenno – Skan II), Sweden and Norway (Nea – Järpströmmen), Denmark and Norway (Skagerrak IV), and several intra-country development plans (Great Belt in Denmark and South Link in Sweden).
2. Plans linking the Baltic countries with the Nordic countries as well as strengthening their connections with each other. These include new links between Sweden and Lithuania, Finland and Estonia, and Poland and Lithuania, and are all generally considered commercially viable.
3. New connections between Poland and Germany. These connections are intended to reduce "loop flows" – flows of power into and back out of a grid – caused by variable wind-generated electricity.

The gas market and infrastructure initiative will focus primarily on diversification of supply routes and sources. The potential projects cited to fulfill this

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[70] European Commission, 2009c, "Memorandum of Understanding on the Baltic Energy Interconnection Plan", Brussels, Accessed 16/04/2010 at <http://ec.europa.eu/energy/infrastructure/doc/2009_bemip_mou_signed.pdf> (pg. 3)

[71] European Commission, 2009d, "The Baltic Sea Region States reach agreement on the Baltic Energy Market Interconnection Plan", IP/09/945, Brussels, Accessed 16/04/2010 at <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/945&format=HTML&language=en> (pg. 2)

objective are the construction of Liquefied Natural Gas (LNG) facilities, both new interconnections between countries and the development of reverse flow capabilities on existing connections, and the construction of gas storage facilities.

These efforts all contribute to increased EU energy security. An integrated grid prevents the existence of "energy islands" by enlarging supply coverage, and infrastructure projects lead to increased transmission efficiency. By integrating markets on the geographic periphery, the EU can alleviate supply dependence on Russia by extending spare capacity across the entire grid. Similar developments are unfolding across the European Union, with the most comparable agreement having been signed by seven Central and Eastern European states in December 2009[72].

3.4 Market concentration trends after liberalization

As described by Jamasb and Pollitt, the EU's deviation from standard textbook liberalization models and lag in mandating regulatory oversight created hurdles for the development of a competitive market. One effect of the lag in regulation was the accelerated financial integration of the European electricity market: in a survey of 135 electricity-market merger and acquisition deals from 1998 to 2003, Codognet et al. found that the pace of cross-border activity grew rapidly in the two years preceding the adoption of the 2003 directive, whereas it had been virtually nonexistent before 2000[73]. They determined that electricity providers who pursued cross-border M&A deals generally did so in two stages. The first stage is an initial foray into a foreign market which may serve only to establish a foothold; the second is further expansion through the previously-created foreign subsidiary. The most popular targets of cross-border mergers and acquisitions over this period were the Scandinavian countries, Germany, Italy, and the Netherlands. Codognet et al. attribute this to the high degree of

[72] European Commission, 2009e, "Memorandum of Understanding of the Central Eastern European Forum for Electricity Market Integration", Brussels, Accessed 16/04/2010 at <http://www.bmwi.de/BMWi/Redaktion/PDF/M-O/memorandum-of-understanding-ceee-forum,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf>

[73] Codognet, M-K., Glachant, J-M., Leveque, F., and Plagnet, M.A., 2002, "Mergers and Acquisitions in the European Electricity Sector", Paris: CERNA, Ecoles des Mines (pg. 150)

liberalization in these markets as well as their potential for growth (Codognet et al. 2002, pg. 156).

The data in Codognet et al. suggests that vertically-integrated electricity producers are the most active purchasers of foreign assets, whereas targets of M&A activity, while spanning the entire supply chain, are most commonly distributors (Codognet et al. 2002, pg. 159). Jamasb and Pollitt term this phenomenon vertical (re)integration and determine that national and supranational regulators have been remiss in preventing cross-border M&A activity by vertically-integrated providers despite its negative effects (Jamasb and Pollitt 2005, pg. 15). This is supported by Green et al., who find that only 17 of 135 M&A deals reviewed were subject to stipulations or conditions by a regulatory authority out of concerns over competition (Codognet et al., pg. 162). Remedies can be proposed by the active parties in the M&A deal at the end of the review process by the regulatory authorities; of the remedies proposed, divestiture of some asset were the most numerous.

The result of this M&A activity between 1998 and 2002 was increased market concentration in the hands of some of Europe's largest electricity providers. Codognet et al. identified a clear trend toward market concentration in the European electricity market in 2002, discovering that larger market share leads to correspondingly higher growth (Codognet et al., pg. 163 – 166). The crux of the regulatory dilemma in Europe is whether deference to prevailing national competition law is sufficient to prevent anti-competitive developments, or if an electricity-specific independent regulatory body is necessary. Bertram finds that complete deference to existing competition law in the case of regulating New Zealand's electricity and gas markets has resulted in uncompetitive prices, with UnitedNetworks, Ltd., New Zealand's largest electricity network operator, commanding a 347% return on equity in 2001[74]. Green et al. argue that the electricity sector specifically requires an independent regulatory body to enforce competition (Green et al. 2006, pg. 12), while Newbury contends that, as a classic network utility

[74] Bertram, G., 2004, "Deregulation and Monopoly Profits in New Zealand's Gas and Electricity Sectors", *Energy Studies Review*, Vol. 12, No. 2, pg. 208 – 227 (pg. 211)

characterized by a capital-intensive natural monopoly, an electricity market can deliver better outcomes to its customers if its regulated by an independent authority[75].

In 2008, the market share of the three largest market operators was more than 80% in 14 member states, in six member states only one operator existed with more than 5% market share, and in five member states the three largest operators controlled more than 90% of electricity capacity (European Commission 2009, pg. 13).

To this end, it can be said that the 1996 directive was not a totally effective implementation of liberalization reform. In fact, it precipitated a mergers and acquisitions land grab throughout the European electricity landscape which increased market concentration in the hands of a small number of large electricity operators. On a larger scale, and with complete, pan-European connectivity, cross-border M&A activity may not have posed a problem: a larger market would have been able to support more participants if their ability to reach customers across Europe was ensured. But by not enforcing regulatory oversight *ex ante* on a liberalized network that didn't yet enjoy physical inter-connectedness, the 1996 directive incentivized financial integration over physical integration and prompted anti-competitive behavior.

3.5 The third EU electricity legislative package

The European Parliament published a legislative package which included 2009-72-EC[76], a third directive governing the EU's internal electricity market, on August 14th, 2009, although a new directive had been proposed in early 2007. The third directive repeals the second directive, citing "obstacles to the sale of electricity on equal terms and without discrimination or disadvantages in the Community" and a lack of "an equally effective level of regulatory supervision in each Member State" (2009-72-EC, pg. 1) as the main shortcomings of the existing legislation. The most drastic changes in policy introduced in the third directive come in the form of operator unbundling, and these will be explored at length.

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[75] Newbury, D., 2005, "Regulation and competition policy: longer-term boundaries", *Utilities Policy*, Vol. 12, pg. 93 – 95 (pg. 94)

[76] 2009-72-EC, hereafter referred to as *the 2009 directive*, full text available at <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0055:0093:EN:PDF>

3.5.1 Operator unbundling

The third directive presents a new operator unbundling regime, consisting of three separate models: *ownership unbundling (OU)*, *independent system operator (ISO)*, and *independent transmission operator (ITO)*. Although the models differ in how a vertically-integrated electricity entity should be structurally altered, they are all meant to remove conflicts of interest between electricity producers, electricity suppliers, and electricity transmission system operators. The third directive states that the ISO and ITO models may only be chosen if, on September 3rd, 2009 (the date at which the rules laid out in the second directive came into effect), the member state's electricity transmission network existed as a vertically-integrated entity. The third directive defines a vertically-integrated entity as such: "an electricity undertaking or a group of electricity undertakings where the same person or the same persons are entitled, directly or indirectly, to exercise control, and where the undertaking or group of undertakings perform at least one of the functions of transmission or distribution, and at least one of the functions of generation or supply of electricity" (2009-72-EC, pg. 11) The member state may not prevent a vertically-integrated entity from undertaking ownership unbundling if it so chooses; at the same time, a vertically-integrated entity may not opt for the ISO or ITO models if the member state has deemed ownership unbundling the most appropriate. The three models are outlined below.

Ownership Unbundling (OU)

The purpose of *ownership unbundling* is to separate completely the network owner and operator from the vertically-integrated entity. This model defines a TSO as both the owner and operator of a network and separates its activities from those of the vertically-integrated company, which are concerned with the production and supply of electricity.

The OU model is achieved through ownership restrictions: both the TSO and vertically-integrated entity may not hold ownership stakes in one another, except where four key conditions are met (2009-72-EC, pg. 9). These rules apply universally to both public and private entities:

1) Ownership does not constitute a majority share;

2) Voting rights are not directly or indirectly exercised as a result of the ownership;
3) Through the ownership, the power to appoint members of bodies representing the entity are not exercised, such as appointing supervisory board members ;
4) The supplier has no direct or indirect control over the network operator and system, and *vice versa*.

Independent System Operator (ISO)

The fundamental difference between the o*wnership unbundling* model and the *ISO* model is that, under the ISO model, only the network operator is independent of the vertically-integrated entity. Under the ISO model, the ISO acts as a TSO and is responsible for the operation, maintainance, and further development of the transmission network, as well as for ensuring third-party access to the network. The network owners is not charged with granting third-party access to the network; likewise, it has no responsibilities as concern investment planning in the network, as these tasks fall under the purview of the ISO.

The main task of the network owner under the ISO model is to cooperate with the ISO so as to facilitate the full operation of the network. This includes the provision of necessary network information to the ISO as well as the financing of the investment decisions made by the ISO which have been approved by the regulatory authority. Additionally, the network owner should cover the ISO's liabilities as concerns the condition of the network (but not the management of the network, which is the sole responsibility of the ISO).

Independent Transmission Operator (ITO)

The rules governing an ITO focus primarily on autonomy; that is, while the ITO will remain a part of the vertically-integrated entity, it must make decisions independently from it. These rules draw five sets of boundaries between the ITO and the vertically-integrated entity[77]

[77] European Commission, 2010a, "Interpretative Note…The Unbundling Regime", Brussels, Accessed 19/04/2010 at <http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/2010_01_21_the_unbundling_regime.pdf>

1) **Separation of assets, staff, and identity of the ITO:** The ITO should be equipped with all "financial, technical, physical and human resources" (ibid.) necessary to its electricity transmission operations. This means that the ITO should be sufficiently capitalized and staffed to handle day-to-day operations (and that third-party corporate staff can only be retained under aberrant circumstances), that its assets should be separated from the vertically-integrated entity, and that it should be branded in such a way so as not to induce confusion with the vertically-integrated entity. In other words, the ITO should have the capacity for operation independent of the vertically-integrated entity.
2) **Capacity for independent decision-making:** The ITO must have the freedom to make strategic decisions based on market factors, and those decisions should not be influenced by the vertically-integrated company or its subsidiaries. This includes raising money from the capital markets, prohibiting subsidiaries of the vertically-integrated entity from direct or indirect shareholding in the ITO, enforcing market conditions on financial and commercial relations between the ITO and the vertically-integrated entity (including loans), and the prevention of influence by the vertically-integrated entity on the ITO as concerns external obligations. The ITO should ensure that these conditions are met by establishing a compliance regime which will interface with the regulatory authority.
3) **Independence of staff and management of the ITO:** The management and staff of the ITO must operate exclusively in the interest of the ITO. To achieve this separation, the third directive states that management and staff of the ITO may not have served in any position of responsibility or engaged in any business relationship with the vertically-integrated entity (aside from the ITO) for three years prior to their employment with the ITO; the same rules apply for a period of no less than four years after the termination of employment with the ITO. Additionally, management and staff of the ITO may not hold any position of responsibility or engage in a business relationship with another component of the vertically-integrated entity (including the holding of shares) during their employment at the ITO. Management and staff cannot derive any financial benefit from any part of the vertically-integrated entity aside from the ITO, and

remuneration of ITO employees cannot depend on the activities of the vertically-integrated company at large.

4) **Supervisory body:** A key condition of the ITO model is the establishment of a supervisory body charged with making key financial and strategic decisions, including levels of indebtedness, dividend issuance, and long-term financial plans. The employment rules above governing the ITO's management and staff apply to at least half of the supervisory board's members minus one, with an additional rule in place: decisions regarding the appointment, termination, and duration of a supervisory board's membership must be presented to the regulatory authority, which may object within three weeks of notification. The regulatory is charged with ensuring the professional independence of the ITO's supervisory board.
5) **Investment decision and network development independence:** In order to ensure that the ITO is making the necessary network investments, the ITO must present a 10-year investment report to the regulatory authority each year. The investment report should outline the elements of the infrastructure network that need to be built or repaired over the next 10 years and the timeframe in which these investments will be undertaken. It should also contain investment decisions that have already been made and which of these will be acted upon in the following three years. The regulatory authority will gauge the completeness of the investment report and may require that the ITO amend it where necessary. In the event that the ITO does not make an investment identified in an investment report as being necessary in the following three years, the regulatory authority can force the ITO to make the investment, to organize a tender procedure to outside investors for the specific investment, force the ITO to institute a capital increase to facilitate financing the investment and allow outside investors to participate in the capital increase, or any combination of the three.

The European Commission will evaluate the success of the ITO model and must submit a detailed report concerning its implementation to the European Parliament and Council on March 3rd, 2013.

3.5.2 Other prescriptions of the third legislative package

The third directive addresses three key policy areas in addition to operator unbundling: third-party access to gas storage facilities; retail markets; and regulatory authorities. As concerns third-party access to gas storage facilities, the directive states that storage system operators that take place in supply provision must be legally and functionally unbundled. It also is definitive in mandating how storage system operators must offer access to third parties, engineer congestion, and allocate capacity; to ensure compliance, the directive gives additional powers to the regulatory authorities for moderating third-party access to storage – both for traditional gas storage facilities and Liquefied Natural Gas (LNG) storage facilities. The directive also lays the groundwork for an eventual secondary market in storage facilities[78].

The prescriptions relating to retail markets have to do with customer freedom of choice and smart metering. The directive states that customers shall not be charged a fee for switching providers and details the breadth of provider information that should be made available to the customer. The directive identifies a smart electricity metering system as a direct contribution to increased customer information and dictates that all member states should conduct an economic feasibility assessment of smart metering by September 3, 2012. The member states in which the outcome of the economic assessment is positive should prepare a smart metering implementation scheme with a timeline of no longer than 10 years, under which at least 80% of customers are equipped with smart meters by 2020[79].

With regard to regulation, the third legislative package defines the responsibilities, authority, and duties of regulators much more explicitly and establishes, through Regulation 713/2009, the Agency for the Cooperation of Energy Regulators (ACER), which will become active on March 3, 2011. ACER will be tasked with

[78] European Commission, 2010b, "Interpretative Note…Third-Party Access to Storage Facilities", Brussels, Accessed 20/04/2010 at <http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/2010_01_21_third-party_access_to_storage_facilities.pdf>

[79] European Commission, 2010c, "Interpretative Note…Retail Markets", Brussels, Accessed 20/04/2010 at <http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/2010_01_21_retail_markets.pdf>

overseeing cross-border regulatory issues and molding an integrated European regulatory regimen for the internal market as a whole; it will also be tasked with monitoring energy efficiency and security of supply issues within the member states. The purpose of the establishment of ACER is to facilitate cooperation between the regulatory authorities of each member state in an effort to further integrate the European internal electricity market. The third directive also instructs member states to name just one regulatory authority to handle all regulatory issues pertaining to the electricity (and gas) market[80].

3.5.3 Improvements and implications of the third directive

The third legislative package was issued as a result of an inquiry into the EU's energy sector, wherein serious issues were identified with regard to market concentration, insufficient operator unbundling, lack of internal market integration, and opaque price formation. The third legislative package addresses these concerns – especially operator unbundling – and further harmonizes cross-border regulation with the introduction of ACER. The combination of stricter yet more diverse unbundling rules as well as increased EU-level regulatory cooperation should not only promote competition within the internal electricity market but also increase the EU's energy security.

The principle changes to electricity market liberalization policy implemented by the third directive are the establishment of a stronger set of unbundling schemes and the enforcement of stronger cooperation between member states[81]. The European Commission has exhibited a clear preference for ownership unbundling in the third directive (as well as in previous directives), but the ITO, and, to a lesser extent, the ISO model, were introduced as alternatives in markets where full ownership unbundling is not a political or economic reality. The ITO model specifically was introduced as a

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[80] European Commission, 2010d, "Interpretative Note…The Regulatory Authorities", Brussels, Accessed 20/04/2010 at <http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/2010_01_21_the_regulatory_authorities.pdf>

[81] Scholz, U. and Purps, S., 2010, "The Application of EC Competition Law in the Energy Sector", *Journal of European Competition Law & Practice*, Vol. 1, No. 1, pg. 37 - 51 (pg. 51)

compromise between the EC and eight member states that were willing to guarantee the independence of their transmission operators but unwilling or unable to alter the operator's ownership structure (Scholz and Purps 2010, pg. 39).

Meanwhile, the European Commission has empowered itself to enforce cross-border electricity market cooperation with the third directive by establishing ACER. ACER will allow the individual member states to coordinate their regulation efforts, strengthen cooperation between TSOs within the European Union, and enhance the EU's position as concerns security of supply and energy efficiency. These regulatory measures were implemented because of a recognized structural deficiency in the promotion of competition within the internal electricity market (Scholz and Purps 2010, pg. 38) and will be used in conjunction with increased enforcement of anti-trust regulations.

The third legislative package should result in a greater degree of operator unbundling – albeit not necessarily through the ownership unbundling process – than was achieved through the first and second directives. This will result in a higher degree of liberalization across the EU, although not to an absolute, abstract extent. For those countries in which complete ownership unbundling was originally infeasible or unrealistic or both, the third legislative package presents a practical means of implementing some unbundling without having to flaunt the ideal. By taking a step toward unbundling through one of the new models (ITO, ISO), these countries' electricity markets will take the critical, practical first step in the process toward achieving the ideal. When considering the alternative – inability to completely implement the proposed unbundling reforms because of their rigid structure and incompatibility with existing electricity market infrastructure in some member states – the third legislative package can be seen as more pragmatic than its predecessors and therefore more likely to institute real market reform. While not advocating the same high standard of liberalization as the first two legislative packages, the third package is likely to result in greater absolute results and more progress toward the common goal of liberalization.

3.6 Effects of EU legislation on Estonia's energy security

As they relate to the research question, '*What effect does electricity market liberalization have on a country's energy security?'*, the effects of the EU's electricity market directives on Estonia's energy security are unclear. Ownership unbundling is intended to promote competition, and further integration into the wider European electricity market will provide Estonia with an increased number of suppliers from which to draw electricity – most notably in the short term, the Nord Pool market. Ownership unbundling will likewise make Estonia a more attractive partner on energy initiatives than if it were to retain a state-owned, vertically-integrated monopoly electricity provider. Theoretically, these elements of liberalization should render Estonia more energy secure, diversifying its potential sources of electricity and driving prices down through increased competition.

But given historical trends following liberalization efforts, market concentration may actually increase within the Baltic electricity grid once liberalization is pursued in earnest. And rather than falling, electricity prices have tended to increase following liberalization implementations within the European markets. The increased internal regulation and pan-European regulator cooperation initiatives proposed by the third EU legislative package are intended to keep market power from concentrating, and their effectiveness has yet to be determined. It is therefore impossible to predict with any certainty the effect that EU legislation will have on Estonia's energy security.

4. THE NORD POOL ELECTRICITY MARKET

Nord Pool, the single electricity exchange between the Nordic countries of Sweden, Finland, Norway, Finland, Denmark, and Estonia, is the largest physical power market in the world[82]. Nord Pool began operating as a Norwegian power exchange in 1993 following the liberalization of the Norwegian electricity market. Sweden was integrated into the exchange in 1996, followed by Finland in 1998, Western Denmark in 1999, Eastern Denmark in 2000, and Estonia in 2010[83]. Nord Pool is considered one of the most stable power markets in the world[84]; in 2009, 287 TWh of electricity was transmitted through Nord Pool at a value of €10.8 billion, representing 72% of total electricity consumption in the Nordic countries (Nord Pool Spot-a).

Nord Pool is comprised of two separate functional entities: a physical electricity market, operated by Nord Pool Spot AS, and a financial market, operated by Nord Pool ASA[85]. Clearing services and derivative products are handled by NASDAQ OMX Commodities[86]. All participants who meet Nord Pool's requirements are given access to the markets and trade on equal terms, although participants must have a physical connection to the grid to either supply to or consume from it.

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[82] Nord Pool Spot-a, "About Us", Accessed 22/04/2010 at <http://www.nordpoolspot.com/about/>

[83] Nord Pool Spot-b, "History", Accessed 22/04/2010 at <http://www.nordpoolspot.com/about/History/>

[84] Weron, R., Simonsen, I., and Wilman, P., "Modeling highly volatile and seasonal markets: evidence from the Nord Pool electricity market", in H. Takayasu (ed.), The Application of Econophysics, Springer, Tokyo, 2004, pg. 182-191 (pg. 185)

[85] Lucia, J.J. and Schwartz, E.S., 2000, "Electricity prices and power derivatives: Evidence from the Nordic Power Exchange", Working paper #16-00, The Anderson School at UCLA (pg. 4)

[86] Nord Pool-a, Organization, Accessed 22/04/2010 at <http://www.nordpool.com/en/asa/General-information/Organisation/>

4.1 The Nord Pool physical market

The Nord Pool's physical market is comprised of *Elspot*, which is a "spot" market for day-ahead electricity contracts, and *Elbas*, which is a real-time "aftermarket" to the *Elspot* used for load balancing. On the Elspot, contracts are traded for physical delivery over each hour the following day. Each contract guarantees a *load*, denominated in MWh, at a *system price* (Lucia and Schwartz 2000, pg. 5). The system price is derived by finding a balance between bids and offers from the market participants through the intersection of the market's supply and demand curves. This trading method is called *equilibrium point trading*[87]. System prices are calculated within a window of 12-36 hours ahead for the next day: consumers submit bids before the auction window closes at 12:00 noon and the system price is calculated, per-hour, for all users within the network without consideration of bottlenecks within the transmission grid. The system price is therefore a theoretical price at which electricity contracts clear for all users within the Nordic electricity grid when bottlenecks do not constrain transmission. Because the system price is day-ahead, it can functionally be considered a one-day futures contract. Table 7[88] below outlines the timeline of operations for the day-ahead spot market on Nord Pool.

Table 7: Timeline of activities on the day-ahead Nord Pool spot market

Time	Activity
11:00	Deadline for submission of capacity allocation by TSOs
12:00	Deadline for submission of bids to the spot market for the next day
14:00	System price and area prices calculated and published
24:00	Contract period begins
Source:	*Futures and spot prices – an analysis of the Scandinavian electricity market*

Data: Botterud, Bhattacharyya, and Ilic 2002, Author: Eric Seufert

To deal with the reality of transmission bottlenecks, the Nord Pool market has been divided into "bidding areas" – geographic areas that connect to the Nord Pool grid.

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[87] Nord Pool Spot-c, "The Elspot Market", Accessed 23/04/2010 at <http://www.nordpoolspot.com/trading/The_Elspot_market/>

[88] Botterud, A., Bhattacharyya, A., Ilic, M., 2002, "Futures and spot prices – an analysis of the Scandinavian electricity market", Research Paper, Accessed online 21/05/2010 at <http://mit.edu/ilic/www/papers_pdf/futuresandspotprices.pdf>

Participants submit bids directly to their relevant bidding area, which is the area in which their production or consumption is physically connected to the network. A pricing mechanism within the Elspot market adjusts prices based on capacity limitations between bidding areas through additional area prices; thus, when transmission bottlenecks occur between any two bidding areas, the prices in those areas will not be equal to the system price. Intra-bidding area congestion falls under the purview of that region's TSOs.

Three types of bids can be made in the Elspot: an hourly bid, a block bid, and a flexible hourly bid[89]. Table 8 below illustrates the structure of a sample hourly bid form.

Table 8: A sample hourly bid form

Sample Elspot Bidding Form - 3am (MWh)								
		Price (NOK)						
		0	100	150	200	...	2000	2500
Hour	1							
	2							
	3	50	50	10	10		-30	-50
	4							
	...							
	24							

Data: Nord Pool Spot, Author: Eric Seufert

Hourly bids are submitted in *price steps*: at each price level, the bidder indicates the price for which it would be willing to buy electricity (positive number) or sell electricity (positive number). Prices are denominated in Norwegian Krowns (NOK) and loads are denominated in MWh. In the above example, this particular bidder is willing to buy 50 MWh of electricity for 100 NOK/MWh and is willing to sell 50 MWh of electricity for 2500 NOK/MWh at the specified hour. The minimum price change between price steps is 1 NOK or 0.1 EUR, and the maximum number of price steps a bidder may submit is 64, including bids at the lower and upper technical bid limits established by Nord Pool Spot AS. An hourly bid may also be *price independent*, meaning that, over the specified hour, the volume of electricity bid for does not change with price. For bidders who wish to buy electricity at low prices and sell electricity at

[89] Nord Pool Spot-d, Bid Types, Accessed 23/04/2010 at <http://www.nordpoolspot.com/trading/The_Elspot_market/Products/Bid-Types/>

high prices – such as the user depicted in Table 7 -- Nord Pool constructs a linear interpolation from the submitted bid/price pairs to determine that user's trade volumes.

4.2 The Nord Pool financial market

Nord Pool's financial market, used for price hedging and risk management, is comprised of *Eloption* and *Eltermin*[90]. The financial market facilitates the trading of "futures, swaps, options, electricity certificates, as well as emission allowance and certified emission reduction contracts"[91]. Futures and forward contracts are traded on Eltermin; European options, sometimes called "swaptions", are traded on Eloption, with quarterly and yearly forward contracts serving as the underlying security. Contracts on both markets are standardized to denominations of 1 MWh for the delivery period, and all contracts are settled in cash by the clearinghouse against the system price in the spot market – that is, they are not redeemed for physical delivery of electricity. Futures contracts are traded with daily and weekly time horizons and forward contracts are traded with monthly, quarterly, and yearly time horizons[92].

The contracts traded on Eltermin are written using the arithmetic average of the spot market's system price over a given time interval, deemed the *delivery period*. The delivery period is preceded by the *trading period*. Futures and forward contracts are settled differently during the trading period: market price fluctuations for futures are compensated for through participants' margin accounts, whereas forward contracts are not settled until the delivery period. None of the contracts traded on Nord Pool are traded during the delivery period (Koekebakker and Ollmar 2005, pg. 3-4). Futures contracts have shorter delivery periods than forward contracts; daily futures contracts with a delivery period of 24 hours are available to be traded within the next week, and weekly futures contracts with a delivery period of 168 hours are available to be traded within the next four to eight weeks. Both contracts are available for peak and base loads,

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[90] Koekebakker, S. and Ollmar, F., 2005, "Forward curve dynamics in the Nordic electricity market", *Managerial Finance*, Vol. 31, No. 6, pg. 74-95 (pg. 77)

[91] Fleten, S. and Wallace, S., 2009, "Delta-Hedging a Hydropower Plant Using Stochastic Programming", Published in Kallrath, J., Pardalos, P.M., Rebennack, S. and Scheidt, M. (eds), 2009, *Optimization in the Energy Industry*, p. 515–532, Springer

[92] Nord Pool-b, "Power Derivatives", Accessed 03/05/2010 at <http://www.nordpool.com/en/asa/Markets/Power-derivatives/>

although peak load futures contracts can only be bought with a one-week time horizon[93]. The maximum trading time horizon available on the Nord Pool financial market is six years.

Nord Pool acts as a clearinghouse for its financial market by serving as a legal counterparty in all contracts, obligating it to accept responsibility for settlement of the contract. This reduces counterparty risk and also decreases the settlement period for traded contracts[94].

4.3 Modeling Nord Pool Prices

Lucia and Schwartz characterize Nord Pool's system price as "highly erratic" from a study done of daily spot prices between January 1, 1993 and December 31, 1999 (Lucia and Schwartz 2000, pg. 7). Their sample period produced a high and low of 423.38 and 14.80 NOK (per MWh), with a median price of 142.57 NOK. The two highest prices from the period came on extremely cold days: the highest in 1994 around the time of the Lillehammer Olympic games, and the second highest in 1996. They found an annualized price volatility of 189% over the period, but they also observed a significant difference between cold and warm seasons. Their study measured warm seasons to be twice as volatile as cold seasons, with cold seasons experiencing significantly more stable prices but with a mean 22% higher than that of warm seasons.

Lucia and Schwartz's study also reveals that price extremes in the Elspot are frequent, with the price distribution being positively skewed, revealing that higher extreme prices have a greater probability of occurring than lower extreme prices. They found that the largest intra-day price jumps, positive and negative, occurred during winter, and that excess kurtosis was more than 4.5 higher in cold seasons than in warm seasons. They attribute this phenomenon to the shape of the supply curve, which they call the *supply stack*: in periods of high demand, marginal capacity introduced to the grid through added generation systems is generally less efficient than the previous

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[93] Nord Pool-c, "Product Sheet", Accessed 03/05/2010 at
<http://www.nordpool.com/Documents/Communications/Publications/Productsheets/FM.pdf>

[94] Nord Pool-d, Markets, Accessed 03/05/2010 at <http://www.nordpool.com/en/asa/Markets/>

capacity introduced (because the most efficient generators are used first). This leads to large "jumps" in prices where short-term demand shocks are experienced as a result of a sudden, significant change in temperature, with prices quickly normalizing (Lucia and Schwartz 2000, pg. 9).

Despite these characteristics, academic study has been undertaken to attempt to model both electricity prices and forward and futures curve dynamics from Nord Pool data. Lucia and Schwartz claim that Nord Pool system prices exhibits "some signs of predictability" (ibid.), noting that day-to-day, intra-week price increments can help predict price increments for that same period of consecutive days up to several weeks in the future. They base this phenomenon on demand consistency within the week. They also note consistency with intra-day and intra-week price levels, observing differences between the price curves and mean values for non-holiday weekdays and non-working days (including holidays). Finally, as mentioned earlier, seasonality is shown to affect price levels: cold seasons experience a mean system price of 28% higher than warm seasons in their survey. This can be explained by increased heating and lighting costs incurred as a result of colder weather and shorter days. Lucia and Schwartz determine that this seasonal component of electricity prices is taken into account by market participants, influencing the price curve for forward and futures contracts.

Lucia and Schwartz produce a set of one- and two-factor models for forecasting the Nord Pool system price. The models begin with the deterministic function $F = f(t)$, where t is a constant, time. They then add to the function two terms to capture the peculiarities of the Nord Pool market discussed above: D_t, a binary variable which describes whether or not the day in question is a weekend or holiday, and M_{it}, which is a binary variable determining the month to which the date belongs for purposes of seasonality. The one-factor model based on the spot price is represented through the sum of two components: this deterministic function, which is considered to be predictable, and a diffusion stochastic process, X_t. The model is expressed as:

Equation 1: one-factor electricity pricing model

$$P_{\mathrm{t}} = f(t) + X_t$$

The two-factor model based on the spot price adds a third component: a stochastic process describing the behavior of oil prices, ε_t. This process is understood to have a long-term equilibrium price level as well as a short-term mean reverting component. The model is expressed as:

Equation 2: two-factor electricity pricing model

$$P_{\mathrm{t}} = f(t) + X_t + \varepsilon_t$$

Koekebakker and Ollmar contend that electricity forward and futures price curves are more difficult to model than for other markets. Their study of six years (1995 – 2001) of price data for Nord Pool forward and futures contracts finds that a two-factor model explains only 75% of the variance in prices, compared to 95% in other markets. They also find that the correlation between short-term and long-term futures contracts is lower than in other markets. They determine that more than 10 factors are necessary for a model to explain 95% of the variance in the price data used. Koekebakker and Ollmar used two models in their analysis: one in which volatility was independent of the forward price level, and one in which volatility was proportional to the forward price level.

As mentioned, Koekebakker and Ollmar find that two factors are common across all forward and futures maturities. The first factor is positive for all maturities, shifting all forward prices in the same direction. The second factor, however, shifts forward prices for short-term and long-term maturities in opposite directions. They find that the causes of price uncertainty at the long end (toward the end-point of two years) of the price curve have little influence at the short end of the curve; they attribute this to the non-storability of electricity, which renders price prediction past the point of reasonable supply forecasting nearly futile. Since electricity cannot be stored, they argue, and long-term contracts are not correlated with short-term contracts, hedging long-term commitments using short-term contracts could produce unfortunate results. They determine that the characteristics of the Nord Pool's forward curve dynamics, as a proxy for all electricity markets, create a difficult and ineffectual environment for price hedging.

4.4 The effect of further integration into Nord Pool on Estonia's energy security

In addressing the research question, '*What effect does electricity market liberalization have on a country's energy security?',* the effect of Estonia's further integration into the Nord Pool electricity market will be guided by competing forces. Concerning the security of supply element, increasing the capacity of the connection between Estonian and Finland will do nothing but increase Estonia's energy security: by integrating into the Nord Pool market, Estonia will have a larger and more secure pool of electricity from it (and the integrated Baltic grid) may draw. But the stability of Estonia's electricity price may suffer as a result: given that it produces electricity sufficient to meet its own needs through the use of an internally-available resource (oil shale) by a state-owned monopoly, Estonia currently enjoys stable electricity prices. Additionally, spot prices on Nord Pool are generally higher than prices within the Estonian electricity market; Estonia will likewise experience a price increase by further integrating into Nord Pool. These opposing effects will have an inexact effect on Estonian energy security.

The Nord Pool market was chosen for this analysis for two reasons. The first is that Estonia became integrated into the Nord Pool market in 2010 and will expand that integration by enlarging the capacity of the Estlink connection with Finland. This renders an analysis of the Nord Pool market relevant. The second is that Lithuania, the first Baltic state to initiate electricity market liberalization, adopted the Nord Pool Spot's market model in 2009[95], powering its electricity market with the same systems utilized in Nord Pool. This non-physical integration will ease the process of integrating and harmonizing the Baltic and Nord Pool electricity grids.

[95] "Nord Pool Spot will deliver the technical solution for new Lithuanian market place", Lietuvos Energija AB, 28/08/2009, press release, Accessed 25/05/2010 at <http://www.lpc.lt/en/main/news/press?ID=991>

5. EMPIRICAL ANALYSIS OF THE NORD POOL ELECTRICITY MARKET

This chapter will introduce an empirical analysis of the Nord Pool electricity market for the time period of January 1st, 2008 to December 31st, 2009. This is the period preceding Estonia's inclusion in the Nord Pool electricity market; for this reason, it serves as a better indicator of the volatility and spot price environment into which Estonia will become further integrated as its electricity market liberalizes and the capacity link between Estonia and Finland is enlarged.

The characteristics of electricity markets which differentiate them from other financial markets have been explored at length in previous chapters (Chapter 1 and 4), but they will be identified again here[96]:

- *Seasonality*
  Electricity prices are highly seasonal, with weather conditions and seasonal social behavior influencing electricity demand;
- *Price spikes*
  Because electricity cannot be stored and supply must instantaneously meet demand, price spikes cannot be smoothed;
- *Mean-reversion*
  Electricity prices are susceptible to price shocks as a result of weather events, but prices generally revert back to their mean following spikes;
- *Volatility clustering*
  A common feature of financial markets wherein large changes in price are

[96] Koopman, S.J., Ooms, M., Carnero, M.A., 2007, "Periodic seasonal reg-ARFIMA-GARCH models for daily electricity spot prices", *Journal of the American Statistical Association*, Vol. 102, No. 477, pg. 16-27 (pg. 18)

followed by further large changes and small changes are followed by further small changes.

This thesis is primarily concerned with the volatility of electricity market spot prices; for this reason, the empirical model will focus on the volatility characteristics of the Nord Pool market. The main academic works used as references in constructing this model come from Koopman, Ooms, and Carnero (2007), Knittel and Roberts (2005), and Lucia and Schwartz (2000). Koopman, Ooms, and Carnero (2007) explore seasonality, price differentials across the different days of the week, and demand-side effects on Nord Pool spot prices using a GARCH process. Knittel and Roberts (2005) utilize hourly spot prices from the Californian electricity market and similarly use a GARCH process in their model. And Lucia and Schwartz (2000) use a two-factor stochastic model to forecast spot and futures prices on the Nord Pool exchange.

5.1 The data and descriptive statistics

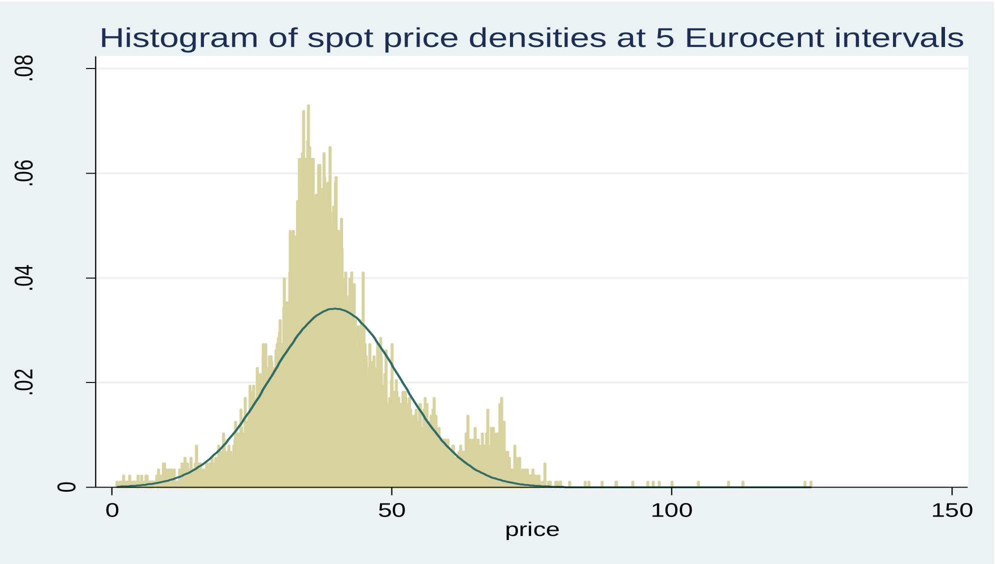
The spot price data for the Nord Pool market was retrieved from the historical data section of the Nord Spot website. The data is presented from January 1st, 2008 to December 31st, 2009 in one-hour increments. The spot price is priced in Euros. Variables attributed to the data are organized as follows:

- *Hour* – the hour of the day (on a 24-hour scale);
- *Lprice* – the log of the spot price;
- *Sqrtprice* – the first square root of the spot price;
- *DayofWeek* – the day of the week, from 1-7 (the week starts with Sunday);
- *isWeekday* – binary variable describing whether the day is a weekday (1) or not (0);
- *WarmSeason* – binary variable describing whether the date falls under the 'warm season' (i.e. May through September, inclusive) category (1) or not (2);
- *Mon – Sun* – seven binary variables, one each for the days of the week.

A first glance at the spot price data shows considerable skewness. The kurtosis value of 4.4 reveals that the data distribution is peaked, or leptokurtic. A positive skewness value of 0.7 reveals a fat right tail, indicating that the mean value of 39.8 is greater than the median. An initial analysis also reveals a considerable spot price discrepancy between warm and cold seasons, with warm season prices exhibiting a lower (and smaller) range, a lower mean, and a flatter distribution than cold season prices. Appendix Table 1 displays the descriptive statistics for the entire dataset as well as the specific Warm Seasons and Cold Seasons datasets. Graph 2 below displays a histogram of Nord Pool spot prices over the time period, with a normal distribution graph superimposed onto it.

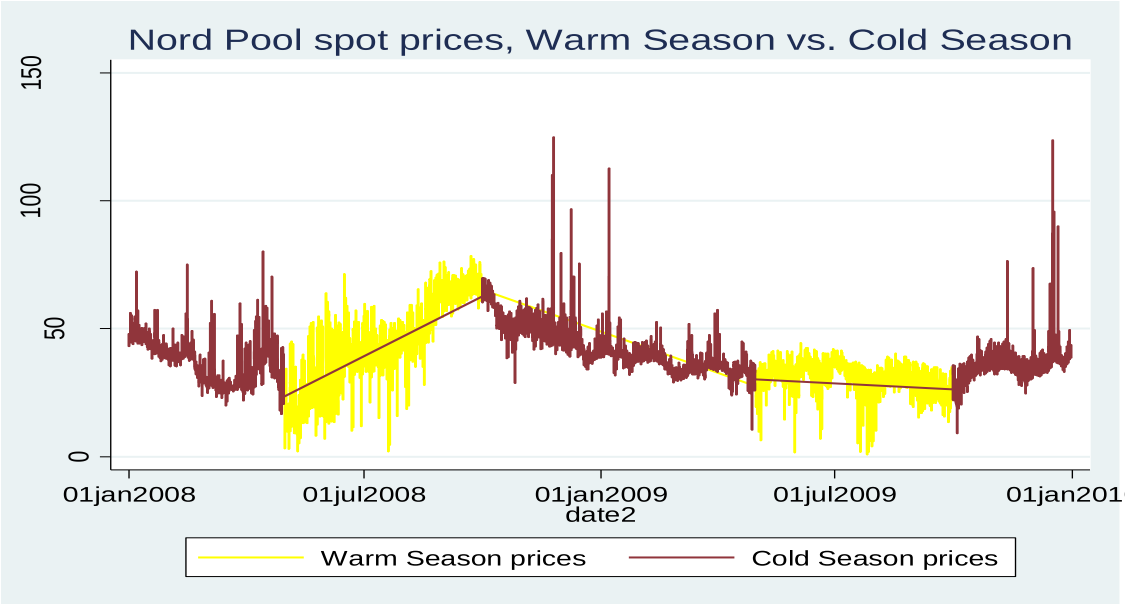
Graph 3 below plots the spot prices over the time period with a color separation between Warm Seasons and Cold Seasons. The Cold Seasons exhibit extreme upward price spikes whereas the Warm Seasons generally remain more stable.

Graph 2: Histogram of Nord Pool spot prices, 5 Eurocent intervals



Data: Nord Pool Spot, Author: Eric Seufert

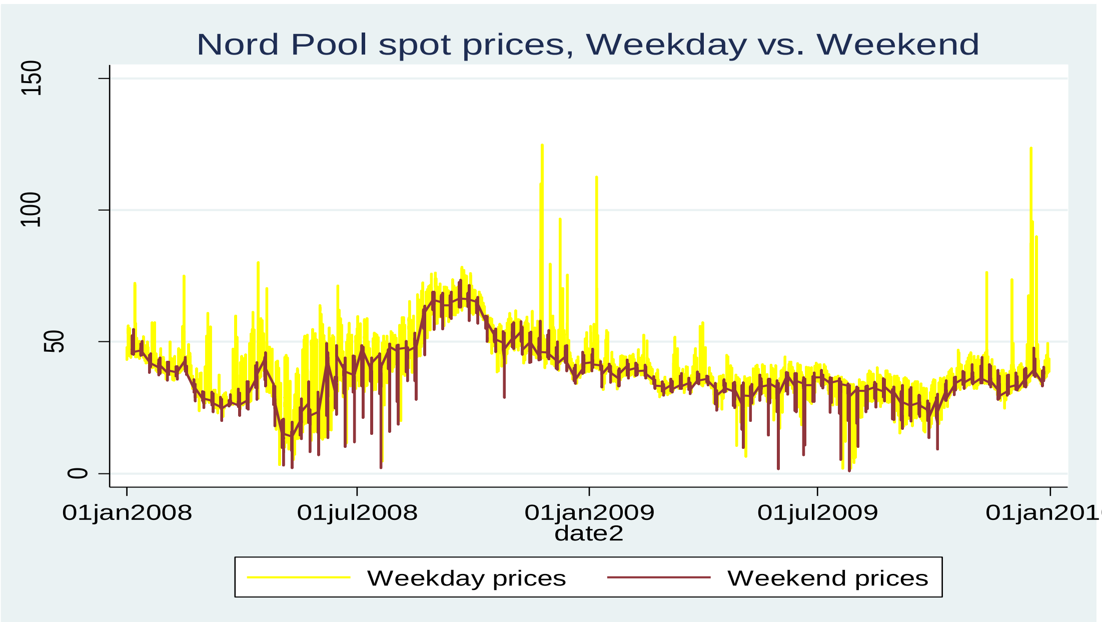
Graph 3: Nord pool spot prices, Warm Seasons vs. Cold Seasons



Data: Nord Pool Spot, Author: Eric Seufert

Graph 4 below compares Weekend and Weekday prices and reveals a similar trend: Weekday spot prices, when usage is higher, exhibit extreme price spikes, whereas Weekend spot prices remain more stable.

Graph 4: Nord pool spot prices, weekdays vs. weekend days

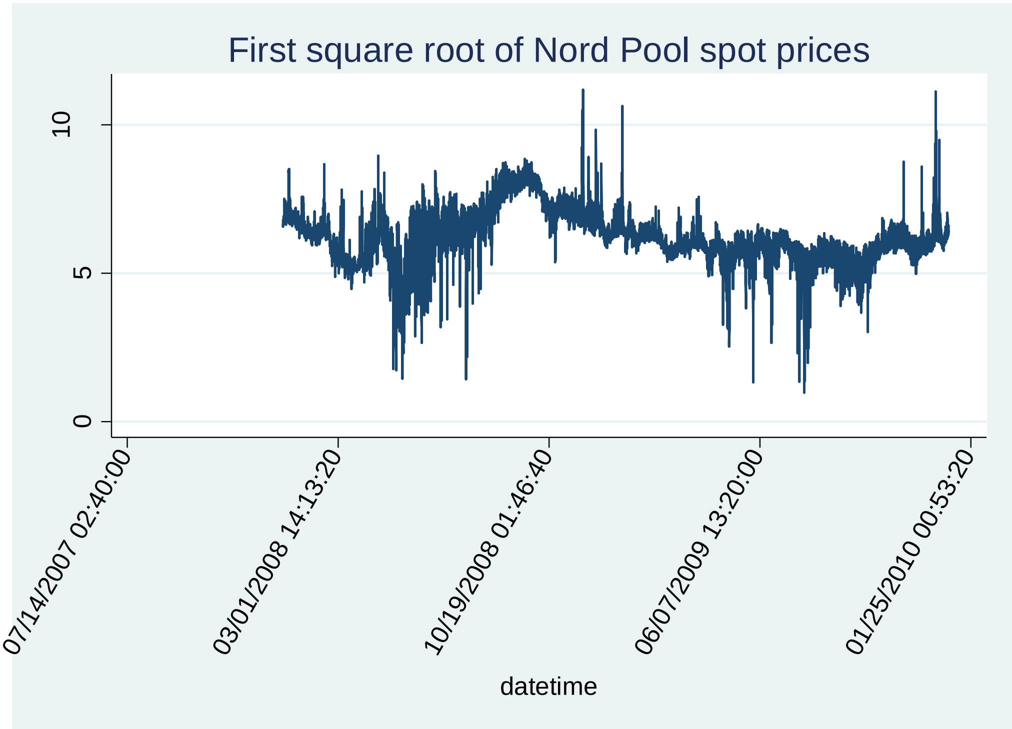


Data: Nord Pool Spot, Author: Eric Seufert

To get a better visual of directional volatility, the first square of the Nord Pool prices is pictured in Graph 5 below. The first square data reveals downward price volatility in the Warm Seasons and upward price volatility in the Cold Seasons, as was described by Lucia and Schwartz (2000). A histogram of the first square prices reveals a fat tail on the left side of the distribution but a spike in density at the right side (Graph 6). The first square data distribution remains leptokurtic.

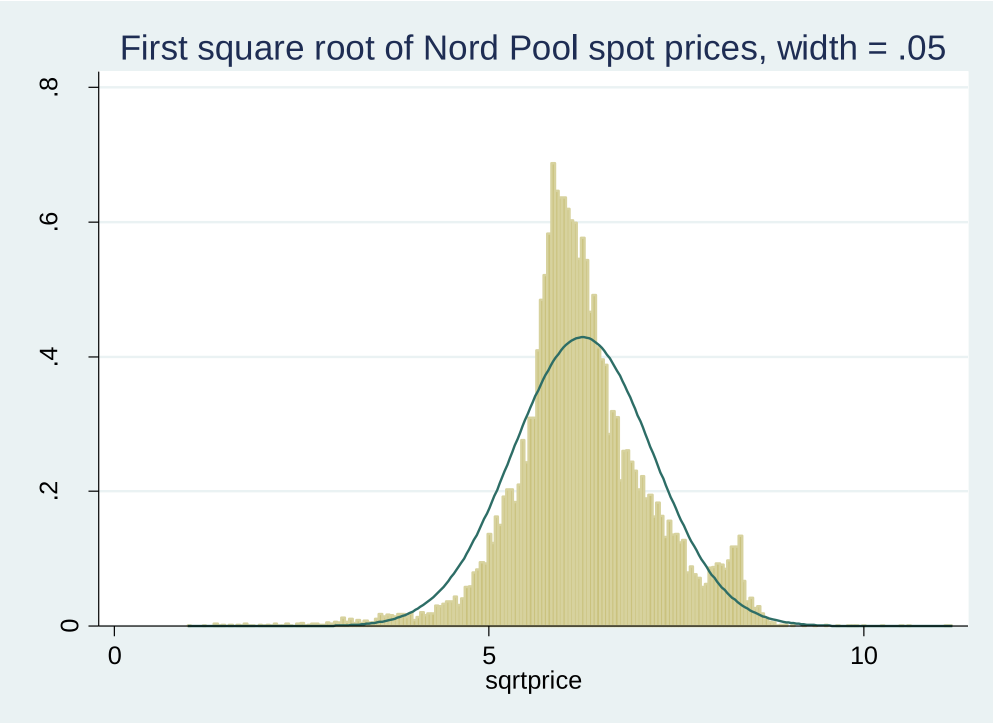
Graph 7 displays the squared price data broken down by day of the week. While the graph is difficult to read, it does showcase the fact that the most extreme upward price spikes generally occur during the week, whereas the downward price spikes generally occur during the weekend. This is also described by Lucia and Schwartz (2000). The summary statistics for the first square data by weekday can be found in Appendix Table 2.

Graph 5: First square Nord Pool spot prices



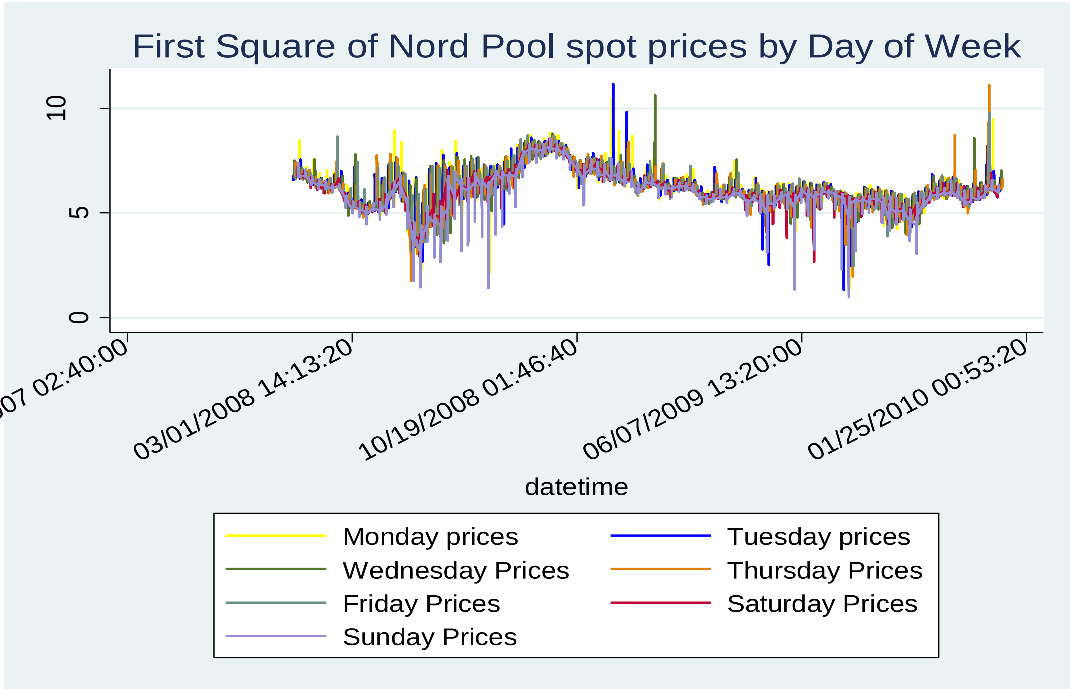
Data: Nord Pool Spot, Author: Eric Seufert

Graph 6: Histogram of first square Nord Pool Spot Prices



Data: Nord Pool Spot, Author: Eric Seufert

Graph 7: First square Nord Pool spot prices by day of the week



Data: Nord Pool Spot, Author: Eric Seufert

5.2 The GARCH(1,1) process

The Generalized Autoregressive Conditional Heteroscedasticity (GARCH) process takes into account excess kurtosis and volatility clustering to provide an accurate means of forecasting volatility (and, in financial time series, the covariance of returns)[97]. For this reason, it is an appropriate process to use when modeling electricity spot prices, which are heteroscedastic (i.e. their variance is not constant over time).

The GARCH(1,1) process is a derivative of the ARCH process, which was introduced by Engle[98]. Given an infinite number of parameters, the ARCH(p) process has been shown to approximate the GARCH(p, q) process (where p is the order of the GARCH variance term and q is the order of the ARCH error term), which itself is approximated by the simpler GARCH(1,1) process. The GARCH(1,1) process is fundamentally similar to the Exponentially Weighted Moving Average (EWMA) process, which it has essentially replaced. The EWMA process is described below:

Equation 3: The exponentially weighted moving average process

$$\sigma_n^2 = \lambda\sigma_{(n-1)}^2 + (1-\lambda)\mu_{(n-1)}^2$$

The first term, σ_n^2, is a measure of current-term variance, and it is a function of two lagged variables: the variance in the previous period ($\sigma_{(n-1)}^2$)and the squared return in the previous period ($\mu_{(n-1)}^2$). Each term is weighted – by λ and $(1-\lambda)$, respectively, with both weights necessarily summing to 1.

The GARCH(1,1) process adds another term to the EWMA process: a measure of the long-term mean variance (κV_L). This term allows the model to predict persistence of variance around the mean. The GARCH(1,1) process is comprised of two equations, which are described as such:

[97] Alexander, C., 2001, Market Models A guide to Financial Data Analysis, New York, Wiley.
[98] Engle, R.F., 1982, "Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation", *Econometrica*, Vol. 50, pg. 987-1007

Equation 4: The GARCH(1,1) process

$$\gamma_t = \mathrm{C} + \varepsilon_t$$

$$\sigma_n^2 = \kappa V_L + \alpha\sigma_{(n-1)}^2 + \beta\mu_{(n-1)}^2$$

The first equation represents an estimate of the conditional mean, with a constant (C) and an uncorrelated error term (ε_t). The second equation represents an estimation of conditional variance, with a constant (κV_L) and terms for variance and return. The weights for the second ($\alpha\sigma_{(n-1)}^2$) and third terms ($\beta\mu_{(n-1)}^2$), representing lagged variance and return, respectively, are notated with weights α and β.

5.3 Modeling Nord Pool spot prices using GARCH(1,1)

The hourly Nord Pool spot price data from January 1st, 2008 00:00:00 to December 31st, 2009 23:00:00 was defined as a time series with a delta of one hour and the GARCH(1,1) process was run. The results of the GARCH(1,1) process can be seen in Table 9 below (the entire process output can be seen in Appendix Table 3).

Table 9: GARCH(1,1) process results

```
ARCH family regression

Sample: 01/01/2008 00:00:00 - 12/31/2009 23:00:00, but with gaps
                                                Number of obs   =      17538
Distribution:  Gaussian                         Wald chi2(.)    =          .
Log likelihood =  -12751.81                     Prob > chi2     =          .
```

	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
sprice						
_cons	6.084063	.0016274	3738.53	0.000	6.080874	6.087253
ARCH						
arch						
L1.	.9414407	.0235599	39.96	0.000	.8952641	.9876172
garch						
L1.	.0814207	.0046515	17.50	0.000	.072304	.0905374
_cons	.013832	.0002533	54.62	0.000	.0133356	.0143284

Table 9 presents the estimated parameters as well as the estimates' standard errors and tests of significance. All parameters are significant at *p-values* less than 5%, including the constant. The process results indicate that the GARCH(1,1) model can be expressed as:

Equation 5: GARCH(1,1) results

$$C = 6.0841 \qquad \gamma_t = 6.0841 + \varepsilon_t$$

$$\alpha = .0814 \qquad \sigma_n^2 = 0.01383 + .0814\sigma_{(n-1)}^2 + .9414\mu_{(n-1)}^2$$

$$\beta = .9414$$

$$\kappa V_L = 0.01383$$

Because the three conditional variance coefficients do not sum to less than 1, which is required in a mean-reverting variance process, the model indicates two things[99]:

- Variance is persistent and slow to decay (sum of coefficients is close to 1);
- Variance is not mean-reverting (coefficients sum to more than 1).

The first revelation of the model is in line with the prevailing academic literature; the second is not. This exposes a market which experiences volatility clustering and a slow return to mean prices following spikes. The results of this analysis are most likely caused by the seasonality of the market and the fact that only two years (and five Warm/Cold seasons) worth of data are being investigated.

[99] Engle, R., 2001, "GARCH 101: The Use of ARCH/GARCH Models in Applied Econometrics", *The Journal of Economic Perspectives*, Vol. 15, No. 4, pg. 157-168 (pg. 163)

6. ANALYSIS

This thesis has presented a new theoretical framework for the academic study of energy security, examined the issues influencing Estonia's energy security by way of electricity market liberalization, and produced an empirical model of the Nord Pool electricity market, to which Estonia will become further integrated in the near term. Against the backdrop of its research question – '*What effect does electricity market liberalization have on a country's energy security?* – this thesis has attempted to determine if Estonia's consistent access to electricity supplies at a stable and affordable price will be affected by its liberalization program.

The factors identified as elements of a liberalization initiative in this thesis produce competing or indeterminable effects on Estonia's energy security. Furthermore, the historical discrepancy between the theoretical and empirical results of liberalization – that is, what *should* happen versus what *does* happen – render a resolute, unambiguous qualification of the research hypothesis impossible. Therefore, the conclusion of this thesis is that both positive and negative effects of liberalization will result in an indeterminate net effect on Estonia's energy security. The factors explored in this thesis are summarized below

6.1 Price point trends

As discussed in Chapter 3, electricity prices in Europe have generally risen after the implementation of liberalization programs. This runs counter to the theoretical expectations of liberalization programs: that increased competition would drive prices down. But, as also discussed in Chapter 3, liberalization efforts have precipitated intra-European electricity market concentration through mergers and acquisitions, decreasing competition not only at the national level but at the regional and European levels. The European Union has openly questioned whether liberalization efforts in Europe have truly facilitated competition, and their implementation of a stricter and broader regulatory framework may abate market concentration concerns going forward. That said, the effect of higher electricity prices on energy security is negative – but higher prices cannot be attributed solely to liberalization. On the conceptual level, liberalization *should* bring about competitive influences which drive market prices down – and this has happened in some electricity markets, as was discussed in the Introduction. But this has not been the historical case in Europe; post-liberalization price point trends therefore require further investigation before a determination can be made as to the effect of liberalization reforms on electricity prices.

It also remains to be seen whether the European Union can adequately enforce adherence to its electricity market directives, especially concerning ownership unbundling. Increased regulation may keep market concentration at bay, but if member countries are allowed to continue to postpone their ownership unbundling obligations, the competitive forces which the EU hopes to instantiate within the internal electricity market – and which, even in *theory,* have not been completely proved to decrease prices – may never truly develop. EU credibility will have a large impact on the success of inter-European electricity market integration, and the EU's endless steam of increasingly-equivocal and watered-down electricity market directives have yet to successfully implement the competitive forces which liberalization aims to catalyze.

6.2 Price stability

As discussed in Chapter 3, Many Western European countries experienced a period of high price stability immediately following liberalization reforms, but those periods eventually gave way to stable market prices. Many of these countries, however, already hosted a somewhat competitive electricity market, with independent generators competing for business. But this is more a symptom of spare capacity than a consequence of liberalization; as was discussed in Chapter 1, liberalization introduces price volatility as a result of the operational incentives at work in a competitive market.

The non-storability of electricity and need for supply to be immediately matched with demand in an electricity market presuppose price volatility within a competitive electricity market; price spikes are unavoidable, and forecasting models do not yet exist which can adequately hedge them away.

For countries such as Estonia, wherein a state-owned monopoly provider essentially operates the market, liberalization will almost certainly produce price instability. A state-owned monopoly can mandate price points and capacity and is not beholden to shareholders or investors in expanding or repairing infrastructure. This ensures a high level of price stability which a competitive market is unlikely to be able to match. And especially in Estonia's case, where integration into Nord Pool is the most relevant near-term expansion into the European internal electricity market, liberalization is almost sure to lead to price instability given the volatility of the Nord Pool Spot, which was investigated through the academic literature in Chapter 4 and empirically in Chapter 5. Chapter 5 exhibited empirically the volatile nature of the Nord Pool spot and econometrically described its volatility clustering and non-mean reverting character. These competing influences of the price stability effects of liberalization contribute to the inscrutability of the effect of liberalization on energy security.

6.3 Stability of supply

While liberalization can lead to diversity of supply by opening a market to external participants, it can also discourage infrastructure investment as was discussed in Chapter 1. Electricity infrastructure projects require large capital outlays, and in a competitive, volatile environment, generators are rewarded for providing electricity at the marginal price during periods of high demand but are punished for having to cover large operational costs during periods of low demand. Generators are therefore incentivized against infrastructure investment, which can lead to capacity constraints.

That said, a liberalized electricity market is more likely to attract external investment and participation than one which is not privatized or is manipulated by the government. Also, diversifying the sources of electricity supply can ensure consistent access. In the case of small countries in which former state monopolies once operated the electricity market, more leverage is available for the government to lure external investment by providing subsidies or establishing market mechanisms such as price floors. Again, these countervailing forces prevent a clear judgment from being made on liberalization’s effects on energy security.

CONCLUSION

The efficacy of this thesis' hypothesis, given the competing effects of liberalization on each of the components of the energy security model proposed in the theoretical framework in Chapter 1, cannot be evaluated. Each element of the energy security model is complex and diverges empirically from the predicted theoretical outcomes. And these factors are also highly-dependent on a country's pre-liberalization resource profile and market structure, further confusing the net effect of liberalization from an abstract, theoretical standpoint. While the effects of increased prices and increased price volatility following a liberalization program induce negative consequences on a country's energy security, the diversity and stability of supply provided by liberalization buttress it. These competing effects differ in magnitude and are difficult to quantify. For this reason, *the hypothesis can be neither confirmed nor denied*.

Estonia is likely to face increased prices and increased price volatility as a result of its liberalization program. As explored in Chapter 5, the Nord Pool Spot market exhibits volatility clustering but not mean reversion, with a high degree of volatility. This volatility, as surmised in the theoretical framework, is difficult to hedge against, leaving Estonia's economic infrastructure susceptible to a high degree of input price risk which could be disruptive to the continuity of operations for electricity-intensive industries. Liberalization will however inspire confidence in the Estonian electricity market by foreign investors and provide Estonia access to external sources of electricity, which it will need to utilize as it adapts to EU directives mandating its reduction of oil shale use. While these external sources of electricity will be more expensive than internally-produced electricity, they will also provide diversity and security of supply to

Estonia. The net effect of these changes on Estonia's energy security is impossible to predict.

Directions for further research

This thesis reveals two directions for further research. The first is of the effect of liberalization on market price volatility. Very little academic literature is dedicated to this topic; most liberalization studies explore the relationship between liberalization and prices. But as was proposed in the theoretical framework, price volatility is an important aspect of energy security and should be investigated as an effect of liberalization.

The second is a more thorough empirical study of the volatility of Nord Pool spot prices over an expanded time frame and the effect of new participant accession on market price volatility. While the empirical study in this thesis did not reveal a mean-reversion characteristic of Nord Pool spot prices, this is most likely due to the limited time frame in which the study was conducted. More data is required before the Nord Pool spot can be determined to not exhibit mean reversion, which contradicts the prevailing market literature. Also, given that Estonia began participating in the Nord Pool spot in 2010, it would be reckless to attempt to glean any insight into the effects of its integration into the Nord Pool spot on either price volatility within the Nord Pool market or on the price effects within the Baltic grid. Given more data, interesting analysis could be performed on both of these points.

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APPENDIX

Appendix Section 1: Worldwide energy dynamics

Oil and natural gas fields are not uniformly allocated across the globe: "proven reserves of oil and gas are rather unevenly distributed and only a few countries and regions will remain surplus exporting producers in the future"[100]. Among these countries, a select few control the vast majority of the world's oil supply, with "the Organization of Petroleum Exporting Countries (OPEC) members—Saudi Arabia, Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, United Arab Emirates, Angola, and Venezuela—[holding] 75.2% of world's oil reserves and [controlling] about 41.7% of oil production"[101]. The concentration of the bulk of the world's oil reserves in the hands of an organization like OPEC presents obvious energy security concerns, one of which is price fixing. But the diversity of the OPEC countries – located on three separate continents and representing multiple forms of government and ethnic and religious demographic compositions – calls into the question the ability of OPEC to effectively control prices. Indeed, Almoguera and Herrera find that, over the period between 1974-2004, "OPEC cannot be viewed as an effective cartel"[102]. The contend that, "as a cartel, OPEC has not been successful in controlling oil prices. Indeed, there appears to be no clear consensus in the empirical literature regarding OPEC's stability as a cartel or its ability to influence prices" (Almoguera and Herrera 2007, pg. 2).

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[100] Correlje, A., van der Linde, C., 2006, "Energy supply security and geopolitics: a European perspective", *Energy Policy* Vol. 34, pg. 532–543 (pg. 533)

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OPEC's ability to control prices may change in the future, as "the overall picture suggests that the supply of non-OPEC oil will decline more rapidly, resulting in an increasing call on OPEC oil" (Correlje and van der Linde 2006, pg. 533). And as OPEC becomes increasingly monolithic in terms of the countries supplying oil to the world, the geographic diversity of exporting countries may give way to resource hegemony in the Persian Gulf, as this region "contains about 60 per cent of the current proven reserves" (ibid.). Put another way, oil exporters in the Persian Gulf, with ownership of the majority of the world's oil reserves, may be able to exert more influence over oil prices as OPEC becomes increasingly important as an exporter. An increased level of influence over oil prices by the Persian Gulf is exacerbated in terms of energy security risk by the "high degree of political instability" (Gupta 2008, pg. 1195) plaguing the governments in this region. Also amplifying the risks of the world's increased dependence on oil from the Persian Gulf are the logistical realities associated with the region: "About 88% of the Persian Gulf oil bound to Asia, Western Europe and United States is transported through the Strait of Hormuz…[which is] extremely susceptible to shipping accidents and terrorist attacks" (Gupta 2008, pg. 1196).

Energy security risk will also be affected by increased demand for energy resources from emerging economies. In "non-OECD countries like China and India, demand for oil is rapidly increasing in association with economic growth and transport needs" (Correlje and van der Linde 2006, pg. 533). This increase in demand will be met with decreased future production and a paucity of spare capacity – the lack of spare capacity being a present reality: "over the past decade…spare capacity was increasingly concentrated in Saudi Arabia and recently it has been reduced to virtually zero" (Correlje and van der Linde 2006, pg. 534). Production decline is the result of two factors: dwindling resource availability and a lack of infrastructure investment (ibid.). Eight of the top oil producers in the world have already experienced a production peak – "the US peaked in 1971, Canada in 1973, Iran in 1974, Indonesia in 1977, Russia in 1987, UK in 1999, Norway in 2001, and Mexico in 2002" (Gupta 2008, pg. 1196). With the exception of Iran and Indonesia, these countries are all found within the most stable half of Gupta's index of political risk ratings of oil producing countries (ibid.). The implications of a lack of spare capacity and decreased production on energy security risk are universally bad: lack of production will drive prices up over the long term, and a lack of spare capacity will subject energy markets to price shocks. And the long-term result of production infrastructure neglect on the cost of energy (and thus energy security risk) to the developed world will manifest itself in the investment needed to maintain production levels : “The long-term security of oil supply to the EU and other consuming countries, thus, largely depends on the attractiveness and accessibility of producing areas like Russia, the Persian Gulf and Africa, to investments…via foreign direct investments (FDIs) by the international oil industry, and the ability of the companies to bring the oil and gas to the market” (Correlje and van der Linde 2006, pg. 534). Many countries, however, have exhibited a “reluctance…to allow FDIs in new oil and gas production facilities” (ibid.).

Two bright spots on the supply side of the energy equation create cause for measured optimism. The first is Iraq, where the “the share of oil and gas produced for the world market, in Iraq, by private international oil companies will increase considerably” (ibid.) should the political situation there stabilize. This is far from a given, however, and the “tens of billions of dollars required to bring the industry's output back up to its 1978 peak of 3.5 million barrels per day” have not been invested as a result (Yergin 2006, pg. 3). The second are technological innovations, which are allowing for production from previously-unexploited sources of hydrocarbons. This is evidenced in “nontraditional supplies, ranging from Canadian oil sands (also known as tar sands) to deposits in ultradeep water to a very high-quality diesel-like fuel derived from natural gas” (Yurgin 2006, pg. 4).

Appendix Table 1

```
. summarize price, detail

                            price
-------------------------------------------------------------
      Percentiles      Smallest
 1%        13.35            .96
 5%        23.93            1.4
10%        27.51           1.78       Obs               17538
25%         33.1           1.81       Sum of Wgt.       17538

50%         37.9                      Mean           39.88852
                        Largest       Std. Dev.      11.68938
75%        45.23         110.07
90%        56.02         112.73       Variance       136.6416
95%        64.56         123.71       Skewness       .7146433
99%        71.22         124.88       Kurtosis       4.430363

. summarize price if warmseason==1, detail

                            price
-------------------------------------------------------------
      Percentiles      Smallest
 1%         9.23            .96
 5%       18.665            1.4
10%        23.48           1.78       Obs                7340
25%        30.85           1.81       Sum of Wgt.        7340

50%       36.135                      Mean           39.44003
                        Largest       Std. Dev.      14.50016
75%       47.715             77
90%        63.91           77.3       Variance       210.2546
95%       68.895          77.94       Skewness       .5445633
99%        72.79          78.33       Kurtosis        2.97029

. summarize price if warmseason==0, detail

                            price
-------------------------------------------------------------
      Percentiles      Smallest
 1%        24.35           9.17
 5%        27.36           9.35
10%        30.23          10.13       Obs               10198
25%        34.32          10.42       Sum of Wgt.       10198

50%        38.84                      Mean           40.21133
                        Largest       Std. Dev.      9.133739
75%        44.47         110.07
90%        52.84         112.73       Variance       83.42518
95%        57.16         123.71       Skewness       1.169496
99%        67.13         124.88       Kurtosis       6.972143
```

Appendix Table 2

```
. summarize sqrtprice if mon

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
   sqrtprice |      2496    6.345991    .9647553   1.363818   10.49143

. summarize sqrtprice if tues

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
   sqrtprice |      2520    6.372001     .889819   1.345362   11.17497

. summarize sqrtprice if wed

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
   sqrtprice |      2520    6.383049     .858343   3.570714   10.61744
```

Appendix Table 3

```
. arch sprice, arch(1) garch(1)

Number of gaps in sample:    3
(note: conditioning reset at each gap)


(setting optimization to BHHH)
Iteration 0:   log likelihood =  -14854.361
Iteration 1:   log likelihood =  -13151.756
Iteration 2:   log likelihood =  -12953.463
Iteration 3:   log likelihood =  -12910.213
Iteration 4:   log likelihood =  -12878.935
(switching optimization to BFGS)
Iteration 5:   log likelihood =  -12861.484
Iteration 6:   log likelihood =  -12790.491
Iteration 7:   log likelihood =  -12778.471
Iteration 8:   log likelihood =  -12767.551
Iteration 9:   log likelihood =  -12752.807
Iteration 10:  log likelihood =  -12752.056
Iteration 11:  log likelihood =  -12751.906
Iteration 12:  log likelihood =  -12751.828
Iteration 13:  log likelihood =   -12751.81
Iteration 14:  log likelihood =   -12751.81
(switching optimization to BHHH)
Iteration 15:  log likelihood =   -12751.81
```