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Christopher Frey

World Trade Law and the Emergence of International Electricity Markets

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Meinen Eltern, Burckhard und Renelde

Preface

This book is based on my doctoral dissertation, which I defended in September 2020 at TU Dresden. I wish to express my profound gratitude to my supervisor, Professor Dr. Thilo Rensmann, for his constant support and encouragement and his shared curiosity for the topic. I also wish to thank Professor Karsten Nowrot for his support and immediate willingness to assume the role as second examiner.

With hindsight, it is not easy to recall my initial motivation to dedicate years of my professional life and countless lonely hours behind books and articles to the law of electricity trade. I ascribe it in part to early family narratives about ancestors who had helped to electrify their home valley in Western Germany. Professor Jürgen Grunwald at the Europa-Institut of Saarland University clearly contributed as well. His master's course on European energy and environmental law was special as it transcended the world of norms and paragraphs and connected law with physics and chemistry.

We are living in times of great transitions. There is a chance that a society based on renewable energy sources can be more peaceful and equitable than the past century which was largely powered by fossil fuels and the struggle for securing them. But that is not a given. The risk of cementing existing dependencies, power disparities and resource curses is real. I am deeply convinced that multilateral institutions and a rules-based system of equal partners—yet to be established—are the way forward.

Many people in different places have contributed in their own way to this work. In addition to the ones already mentioned, I am grateful to my former colleagues at the research project Global TranSAXion in Dresden, where many fruitful research ideas were born and where first pages of this study developed. Tilman Dralle deserves specific mentioning as I am deeply thankful for his companionship during long days at the library, his good humour and bright mind. At the TU Dresden, I also benefitted greatly from numerous discussions with students from the electrical engineering and energy economics departments. Some of them, like Maria Kosse, Caroline Wever and Andreas Leibenath, turned into friends. A research period at the Faculty of Law of the University of Canterbury on the beautiful South Island of New Zealand brought not only valuable insights but resulted in lasting friendships.

Above all, I wish to thank Christian and Emma Riffel for their hospitality and kindness and Abdul Hasib Suenu for proofreading parts of this work. I greatly appreciate the support of the TU Dresden Graduate Academy which made this unique and fruitful experience possible. Over the past couple of years, I expanded my horizon working alongside my numerous talented colleagues at ENERCON and Sunfire. I am especially grateful to Aram Sander for being an intellectual sparring partner and for critically reading some chapters of this book.

Finally, I want to thank my family for their enduring support and Lena for her companionship and constant encouragement. Without you, I would not have seen this through.

Berlin, Germany Christopher Frey
March 2022

Contents

Abbreviations

AB	Appellate Body
AC	Alternating current
ACER	Agency for the Cooperation of Energy Regulators
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of South-East Asian Nations
ATC	Available transfer capacity
B.C.	British Columbia
CETA	Comprehensive Economic and Trade Agreement between Canada and the European Union
CFE	Comisión Federal de Electricidad (Mexico)
CHP	Combined heat and power
CISG	United Nations Convention on Contracts for the International Sale of Goods
COM	European Commission
CPC	Provisional Central Product Classification of the United Nations
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
CRIE	Comisión Regional de Interconexión Electrica (Central America)
CUSFTA	Canada–United States Free Trade Agreement
CUSMA	Canada–United States–Mexico Agreement
CWE	Central Western European Electricity Market
DAM	Day-ahead market (Southern African Power Pool)
DC	Direct current
DSU	Dispute Settlement Understanding of the WTO
ECJ	European Court of Justice
ECOWAS	Economic Community of West African States
ECT	Energy Charter Treaty
EEA	European Economic Area
EFTA	European Free Trade Association
ENTSO-E	European Network of Transmission System Operators for Electricity
EOP	Ente Operador Regional (Central America)

EPA	Economic Partnership Agreement
EPCA	Enhanced Partnership and Cooperation Agreement
EPR	Empresa Proprietaria de la Red (Central America)
ERERA	ECOWAS Regional Electricity Regulatory Authority
EU	European Union
EURATOM	European Atomic Energy Community
FTA	Free trade agreement
FIT	Feed-in tariff
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
HVDC	High-voltage direct current
Hz	Hertz
IADB	Inter-American Development Bank
IEC	International Electrotechnical Commission
ILA	Agreement on Import Licensing Procedures
IPP	Independent power producer
ISO	Independent system operator
ITA	Information Technology Agreement
ITC	Inter-transmission system compensation
kV	Kilovolt
LNG	Liquefied natural gas
MER	Mercado eléctrico regional (Central America)
MFN	Most-favoured-nation
MW	Megawatt
MWh	Megawatt hour
NAFTA	North American Free Trade Agreement
NERC	North American Electric Reliability Council
NSOG	North Sea Offshore Grid
NT	National treatment
NTC	Net transfer capacity
OECD	Organisation for Economic Co-operation and Development
OJ	Official Journal of the European Union
OPEC	Organization of the Petroleum Exporting Countries
OTC	Over the counter
OU	Ownership unbundling
PPA	Power purchase agreement
PTA	Preferential trade agreement
PSO	Public service obligation
PUHCA	Public Utility Holding Company Act
PV	Photovoltaic
RCEP	Regional Comprehensive Economic Partnership
RES	Renewable energy sources

RERA	Regional Electricity Regulators Association (Southern African Power Pool)
RTO	Regional transmission operator
SACREEE	SADC Centre for Renewable Energy and Energy Efficiency
SADC	Southern African Development Community
SADCC	Southern African Development Coordination Conference
SAPP	Southern African Power Pool
SCMA	Agreement on Subsidies and Countervailing Measures
SGCC	State Grid Corporation of China
SIEPAC	Sistema de Interconexión Eléctrica de los Países de América Central
SPS	Agreement on Sanitary and Phytosanitary Measures
STE	State trading enterprise
STEM	Short-term day ahead market (Southern African Power Pool)
TBT	Agreement on Technical Barriers to Trade
TEC	Treaty establishing the European Community
TEN-E	Trans-European energy networks
TEP	Third Energy Package
TEU	Treaty on European Union
TFEU	Treaty on the Functioning of the European Union
TPA	Third party access
TRIMS	Agreement on Trade-Related Investment Measures
TSO	Transmission system operator
TWh	Terawatt hour
TYNDP	Ten-Year Network Development Plan
UCC	Uniform Commercial Code (United States)
UCPTE	Union pour la coordination de la production et du transport de l'électricité
UCTE	Union for the Co-ordination of Transmission of Electricity
UHV	Ultra-high voltage
UN	United Nations
U.S.	United States
UNCTAD	United Nations Conference on Trade and Development
VCLT	Vienna Convention on the Law of Treaties
WAPP	West African power pool
WBGU	German Advisory Council on Global Change
WCO	World Customs Organization
WERC	Western Electricity Coordinating Council
WPDR	Working Party on Domestic Regulation
WTO	World Trade Organization
WTOA	Agreement Establishing the World Trade Organization
W/120	Services Sectoral Classification List

Part I
The Technical and Regulatory Foundations of Electricity Trade and the Emergence of International Electricity Markets

Chapter 1
General Introduction

Electricity permeates modern life. It is an invisible force on which we are now so dependent that we notice it only when it is missing. Demand for electricity has been growing rapidly and an end is not in sight.[1] At the beginning of the twenty-first century, it is difficult to imagine any production process or service sector that does not rely on electricity to deliver the goods and services the society wants.[2]

The degree of access to electricity for private households is a measure of civilizational progress and achieving universal access has been identified as a policy priority by governments around the world.[3] Yet 13% of humanity still lacks access to modern electricity.[4] This equals 840 million people, two-thirds of which are located in Sub-Saharan Africa.[5] At the same time as policy-makers and entrepreneurs are

[1] According to the International Energy Agency (IEA), electricity demand has increased by around 70% since the year 2000. See Bouckert and Goodson (2019).

[2] A WTO dispute settlement panel has recognized the important role of electricity in an obiter dictum by stating: 'Electricity is the lifeblood of modern society. Yet it is invisible to the naked eye and often unnoticed in the day-to-day lives of billions of people. There is little doubt, however, that reliable systems of electricity are the engines that drive economies world-wide, bringing power to a host of consumers for a myriad of uses and applications including in homes, factories, offices, farms, transportation systems and telecommunications networks. Most goods depend upon electricity for their production, as do essential services ranging from healthcare to banking. Few discoveries can boast such wide-ranging impacts on the quality of human life as electricity.' WTO, *Canada – Measures Relating to the Feed-in Tariff Program*, Report of the Panel (19 December 2012) WT/DS426/R [7.10].

[3] United Nations (2021b), Sustainable Development Goals, SDG 7 ('Ensure access to affordable, reliable, sustainable and modern energy for all'). The main indicator for the sub-target of ensuring universal access to modern energy by 2030 (SDG 7.1) is the proportion of the population with access to electricity. https://sustainabledevelopment.un.org/sdg7.

[4] United Nations (2021a), Sustainable Development Goals https://www.un.org/sustainabledevelopment/energy/.

[5] International Energy Agency, SDG7: Data and Projections (November 2019) https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity.

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seeking to tackle this vital challenge, the existing energy landscape is undergoing a fundamental transformation. Having come to accept climate change as a major threat to permanent human existence on earth, governments around the world have started to phase out the use of fossil energy sources and to engage in a transition towards relying on renewable energy. Two trends can be observed in this respect: The first is a replacement of the use of fossil energy in transport, heating, cooling and industrial processes with electricity, a development that will undoubtedly drive further growth in the demand for electricity. The second is the replacement of electricity generated using fossil fuels with electricity generated from renewable sources. In parallel with this international energy transition, a less visible development is taking place: the interconnection of formerly isolated national electricity systems and the emergence of international electricity markets. With the rapid development of technology, visions of long-distance electricity transmission are turning into reality. The United Nations (UN) has committed to promoting investment in energy infrastructure and clean energy technology within the framework of the Sustainable Development Goals.[6] Addressing the global community of states, Chinese President Xi Jinping announced in 2015 that China would seek ways to create a 'global energy internet'.[7] The first concrete steps to realize a global energy interconnection based on long-distance electricity transmission have been taken since that announcement.[8] While the technology for the transportation of electricity over thousands of kilometres continues to advance rapidly and the necessary financial means would be available, the regulatory framework of an ever-more global electricity trade has so far been largely neglected. It is often simply assumed that the general trade rules which have been developed since the end of World War II will lend themselves to application to trade in electricity. This study seeks to critically scrutinize this claim and to examine whether the issues arising from cross-border electricity trade are adequately addressed by the existing normative framework of world trade law. Along the way in this analysis, possible regulatory gaps will be identified. Moving beyond this assessment, this study then suggests ways how to further develop and possibly expand on international trade law in its present state.

[6] United Nations (2021a).

[7] Xi Jinping, Remarks at the UN Sustainable Development Summit (26 September 2015), https://sustainabledevelopment.un.org/content/documents/20548china.pdf.

[8] One notable measure was the establishment of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) with headquarters in Beijing and regional offices on several continents. GEIDCO regularly convenes high-level stakeholders and advances research on interconnections and high-voltage transmission technology.

1.1 The Current State of Research

The frequency of publications on the energy-trade nexus and the application of world trade rules to the energy sector have intensified in recent years. Up until very recently, electricity as a separate subject of international trade law was hardly covered at all.[9] Rather, a constantly growing body of international economic law literature treated energy in a horizontal fashion by looking at issues of relevance for several or all energy sources.[10] Reflecting the economic realities of international trade in energy at the time, the focus was mostly on oil and gas and it was sometimes simply assumed that the findings were transposable to the electricity sector. Publications treating the electricity sector in its own right are still rather exceptional in the international economic law literature, although the picture is starting to change.[11] *Gudas* has explored the framework for the interconnection of electricity networks in EU and international economic law in his published dissertation.[12] His findings mainly relate to the phase of development of cross-border electricity transmission projects and the actual impediments to trade once infrastructure is established are touched upon only in relation to access and transit obligations.

Despite the increasing academic interest regarding the law of international electricity trade, many issues remain underexplored. The applicability of trade rules of general application to the characteristic features of electricity deserves more attention. This applies specifically when interconnectors have been constructed and electricity is traded internationally on a commercial basis, i.e. when trade 'actually happens'. Few authors have engaged in a thorough and critical examination of the notion that trade in electricity can be subsumed under the rules of the General Agreement on Tariffs and Trade (GATT), the General Agreement on Trade in Services (GATS) and trade agreements concluded outside the WTO. Suggestions on how to adapt these rules to contemporary and future challenges in electricity trade are even rarer.[13] Scholars commenting on electricity in international trade law usually pay little attention to the multitude of features that distinguish electricity from the goods, services and commodities international trade lawyers are more familiar with.[14] This thesis seeks to remedy this gap by analysing world trade law

[9] A first in-depth engagement with the specifics of electricity trade was published in 2004 with the edited volume by Bielecki and Desta (2004). Very few journal contributions treating the subject can be found even earlier. See especially Pierros and Nüesch (2000).

[10] See, e.g., the recent book by Marhold (2021), and the contributions in the volume edited by Selivanova (2012).

[11] Two notable exceptions are a book by Gudas (2018) and a volume edited by Cottier and Espa (2017).

[12] Gudas (2018).

[13] Some authors have pointed to the need for energy-specific rules within the WTO Framework. See, e.g., Cottier et al. (2011) and Poretti and Rios-Herran (2006).

[14] One notable exception is Espa (2017).

disciplines based on a solid understanding of the technical and economic features which make electricity a ‘special case’ in international economic law.

1.2 The Structure of This Book

The present study consists of four main parts. Part I aims to lay the foundations by examining the relevant physical features of electricity, the main technical aspects of electricity systems and the realities of contemporary electricity markets and their regulation. It also sketches the ongoing development towards more international trade in electric energy. Part II analyses the general applicability of the rules of world trade law to the electricity sector. Part III deals with actual barriers to trade in electricity and examines the relevant disciplines in the WTO Agreements, the Energy Charter Treaty (ECT) and some preferential trade agreements that are not sector-specific (PTAs). Based on the findings in Parts I–III, Part IV proposes a way forward concerning the multilateral regulation of electricity-specific trade challenges.

References

Bielecki J, Desta M (eds) (2004) Electricity trade in Europe: review of the economic and regulatory challenges. Kluwer Law International, Alphen aan den Rijn

Bouckert S, Goodson T (2019) The mysterious case of disappearing electricity demand. IEA Commentary, 14 February 2019. https://www.iea.org/newsroom/news/2019/february/the-mysterious-case-of-disappearing-electricity-demand.html

Cottier T, Espa I (eds) (2017) International Trade in sustainable electricity: regulatory challenges in International Economic Law. Cambridge University Press, Cambridge

Cottier T, Malumfashi G, Matteotti-Berkutova S, Nartova O, De Sepibus J, Bigdeli SZ (2011) Energy in WTO law and policy. In: Cottier T, Delimatsis P (eds) The prospects of international trade regulation: from fragmentation to coherence. Cambridge University Press, Cambridge

Espa I (2017) The treatment of restrictions and financial charges on imports and exports of electricity under EU and International Law. In: Cottier T, Espa I (eds) International Trade in sustainable electricity: regulatory challenges in International Economic Law. Cambridge University Press, Cambridge

Gudas K (2018) The law and policy of international trade in electricity. Europa Law Publishing, Waterstraat

International Energy Agency (2019) SDG7: Data and Projections. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity

Jinping X (2015) Remarks at the UN Sustainable Development Summit on 26 September 2015, https://sustainabledevelopment.un.org/content/documents/20548china.pdf

Marhold A (2021) Energy in International Trade Law. Cambridge University Press, Cambridge

Pierros P, Nüesch S (2000) Trade in electricity: spot on. J World Trade 34:95

Poretti P, Rios-Herran R (2006) A reference paper on energy services: the best way forward? Manch J Int Econ Law 3:2

Selivanova Y (ed) (2012) Regulation of energy in International Trade Law. WTO, NAFTA and Energy Charter. Kluwer Law International, Alphen aan den Rijn

United Nations (2021a) Sustainable Development Goals. https://www.un.org/sustainabledevelopment/energy/

United Nations (2021b) Sustainable Development Goals, SDG 7. https://sustainabledevelopment.un.org/sdg7

Chapter 2
Technical and Regulatory Foundations of Electricity Trade

The present chapter aims to set the stage for the subsequent legal discussions. The goal is to carve out the distinguishing features of electricity that make it special from a trade regulation perspective. Electricity possesses fundamentally distinct properties when compared with the goods and services that make up the majority of international commercial transactions and for which the rules and procedures of world trade law have been defined. These specific features of electricity have a multitude of consequences for the regulation of its production, trade, and consumption. Against this background, the present chapter aims to lay the foundations for the application of the rules of international economic law to international trade in electricity. It also introduces the terminology of trade-related electricity issues which will be used throughout this thesis.

The present part starts by explaining as briefly as possible the most important features that make electricity a unique phenomenon. In a second step, the evolution of electricity networks from the end of the nineteenth century until the present day is briefly sketched out, followed by a short overview of the state of the art of transmission technology and the electric grid. Ultimately, likely future developments of relevance for international electricity trade are discussed. The concept of an electricity system lies at the heart of this analysis. The term ‘electricity system’ as used here comprises the whole of the technical infrastructure within a certain regulatory area necessary to fulfil the tasks of production (‘generation’) of electricity, its transport (‘transmission’) and delivery to end-users (‘distribution’).[1]

[1] Schwab (2015), p. 30. It bears mentioning that the literature on electricity systems is as vast in volume as in disciplinary diversity, comprising such disciplines as engineering, economics, mathematics and IT, among others. The following discussion is strictly limited to what is considered relevant for the subsequent legal analysis presented herein.

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2.1 Technical Aspects of Electricity Systems

2.1.1 The Physical Properties of Electricity

Electricity is a form of energy. It appears as a natural phenomenon in lightning and magnetism, but also in biological systems for the transmission of nerve impulses. For the purposes of modern economic use, electricity is always the result of a conversion process. Primary energy sources like coal or natural gas are converted to electric energy by using devices called generators. The process of conversion using primary energy sources makes electricity a secondary energy source. Once generated, electricity is a process rather than a substance. From a physical point of view, electrons in a conductor (usually a metallic wire) are situated between metallic atom cores and the generator induces a directional motion of these electrons. When the generator sets the electrons in a directional motion, nothing of mass or substance is added or 'produced' in this process. The electrons are in the wire ab initio and their number remains constant throughout the entire process.[2] A wave of electrons moving back and forth in a wire is called 'alternating current' (AC). When the electrons in a wire are moving constantly in one direction the process is called 'direct current' (DC).[3] With respect to AC, the number of pendular movements of the electrons per second is referred to as 'frequency', which is usually denoted by the term 'Hertz' (Hz). Electricity systems operate on either one of two standards, 50 or 60 Hz. In the United States (US), Canada, Japan, Taiwan, the Caribbean and some parts of South America, the prescribed frequency is 60 Hz. In all other parts of the world including Europe, the standard is 50 Hz.[4] Direct current has a zero frequency as electrons do not oscillate back and forth.

The pattern in which electricity spreads over an electric grid is determined by laws of physics referred to as Kirchhoff's laws. In an electric grid consisting of several wires, the electric current will always take the path of least resistance. The properties of the flow of electric energy over wires have been likened to water flowing through a network of interconnected pipes. When one wire is 'full', i.e., running at maximum capacity, electricity will seek the wire not yet running at maximum capacity, if available.[5] An electric signal spreads through the wires at close to the speed of light. The term 'voltage' describes the amount of electrical pressure or tension, i.e., 'the force that causes current through an electrical conductor'.[6] As a rule of thumb, higher voltages mean more electricity can be transmitted

[2] Ferrey (2004), p. 1910.

[3] Brown and Sedano (2004), p. 37.

[4] Massachusetts Institute of Technology (2011), p. 244; Laloux and Rivier (2013), p. 5.

[5] Brown and Sedano (2004), p. 29.

[6] Graf (1999), p. 835.

via a given conductor. Electricity networks (so-called 'grids') operate at different levels of voltage ranging from less than 1 kV to more than 1000 kV.[7]

The character of electricity as a physical phenomenon as opposed to an object or tangible property has important consequences for its generation, transmission and consumption. The terms 'order and delivery' of electricity, while sensible from a commercial point of view, can be misleading when looking at the electricity network from a technical perspective. Kirchhoff's Laws prevent a targeted flow of electrons along a precise predetermined path in the network. To safeguard the stability of the electricity system, the fundamental characteristics voltage and frequency have to be maintained at the same level with only very minor deviations tolerated. Voltage and frequency are maintained by generators feeding electricity into the network and consumers withdrawing electricity (referred to as 'load') at different points of the network. The sum of generation and load within a network must be zero. Thus, rather than 'delivering' and 'receiving' electric power in a bilateral transaction, generators and consumers on different ends of an electricity network contribute to maintaining the stability of the system.[8]

Importantly, the consumer cannot be certain of the origin of the electricity unless there is only a single line directly connecting the generator and consumer. As consumers are usually connected to a grid structure with multiple entry points for generators, it will not be possible in most cases to ascertain where the electricity consumed at a certain point in time is coming from.

The contractual arrangements between the different market participants in the electricity sector in principle say little about the physical flows of electricity.[9] As electrons cannot be steered along a certain path in the grid, the only variables that can be influenced are generation and load. Therefore, the commercial electricity transactions must be notified to the operator of the transmission system for balancing supply and demand. In this way, the financial and physical sides of trade in electricity are brought together.

In some regions, most notably in Europe, the assignment in accounting terms of certain electricity consumption to amounts of production is realized via so-called 'balancing groups'. In a balancing group, a number of generators and consumers are pooled together purely for accounting purposes. When imbalances occur, a designated balancing responsible party is obliged to level these imbalances, e.g., through procuring additional amounts of electricity. This procedure seeks to ensure an overall system balance of supply and demand. Countries where electricity is traded over designated exchanges are usually divided into one or more 'bidding areas' for which electricity is traded at one identical spot price.

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[7] It is difficult to make generalized statements in this respect. Some Low-voltage local area networks for the supply of residential end-consumers operate at voltages as low as 0.4 kV.

[8] Cf. Buchmüller (2013), p. 60, who likens electricity available between generators and consumers to a lake, the water level of which always remains the same, the balance being achieved by a constant equilibrium between supply and demand.

[9] Brown and Sedano (2004), p. 33. See also Lakatos (2004), p. 123.

All electrons in the grid have the same physical properties.[10] Accordingly, electricity is not distinguishable anymore once it is fed into the grid.[11] In light of the preceding observations concerning the physical and contractual flows of electricity, it might intuitively be a surprise that electricity consumers are increasingly willing to pay a higher price for certain 'types' of electricity. Electricity suppliers have started to offer their customers special products, such as electricity marketed as 'green' (electricity from renewable sources), for which consumers are often ready to pay slightly higher tariffs. However, the decision of a consumer to enter into a contract with a supplier offering electricity from renewable sources does not instantaneously result in a delivery or 'flow' of renewable electricity to the consumer. It merely guarantees that the share of renewable electricity in the overall electricity mix rises. The consumer willing to pay more for 'green' power thus provides the supplier with additional capital to invest in more renewable generation capacity.[12] Some countries have established national or regional green certificate schemes to verify the desired quality of electricity generation labelled as renewable. Only when a given electricity system is fed entirely by renewable energy can the consumer be certain of receiving 'green' electricity. Until then, the electricity will always be a mix of different generation sources.

Another aspect that needs mentioning here is that in interconnected networks, the physical flows over transmission lines are not easily attributable to the owners of the networks. In interconnected networks, the fact that electricity does not take the shortest path over a network but the one with the least resistance can result in the unintended use of networks not owned by the network operators receiving compensation for their transmission services.[13] This phenomenon is referred to as 'loop flow' and will be discussed below in the context of import and export restrictions and transit.[14]

2.1.2 *Grid Dependency and Capacity Constraints*

One of the most important distinguishing features of electric energy is that its transport is only possible via immovable physical infrastructure. Once generated and fed into the grid, the electricity is transported via transmission lines operating under either DC or AC. Transmission infrastructure can be installed in the form of overhead lines or underground cables. When the connection crosses sea straits, special submarine cables are used for the transmission. At present, there is still no technically and economically viable alternative to these forms of fixed

[10] Hunt (2002), p. 35, refers to electricity as 'the most homogeneous product imaginable'.

[11] Lakatos (2004), p. 123.

[12] Schwab (2015), p. 37.

[13] Brown and Sedano (2004), p. 33.

[14] See below in Chap. 11, p. 170.

infrastructures. Thus, unlike primary energy sources like coal, oil or liquefied natural gas (LNG), electricity cannot be moved in larger quantities by mobile means of transport on roads or rails, through the air or on the sea.[15] This obvious fact deserves emphasis because it has several important consequences for the application of legal provisions.

Electricity lines are limited in capacity. It is not possible to increase the capacity of an existing line on short notice to respond to an increased demand at one end of the line. When the capacity limit of an existing power line is reached and the forecasted load will exceed this limit, there are in principle only two ways to further enhance the capacity: Improving the existing power line technically or building new power lines.[16] As the first option is limited by technological constraints and the second often makes no economic sense, the transmission of electricity is widely regarded as a natural monopoly. This natural monopoly character requires special procedures concerning capacity management and network access on non-discriminatory terms.[17]

Several types of constraints limit the capacity and length of transmission lines. Much like water flowing through pipes, electricity transmitted over long distances gradually loses pressure (i.e. voltage).[18] Furthermore, electricity is lost during transmission as it dissipates into the air in the form of heat.[19] These technical constraints have led commentators to characterize electricity as principally a 'local' form of energy.[20] At the same time, however, it must be noted that recent technological advances have allowed electricity transmission over ever-longer distances while reducing losses. These technological developments have also led to proposals for the interconnection of electricity networks on a global scale.[21]

The construction of new transmission lines requires large capital investments and involves planning and permitting procedures which will take several years in some jurisdictions. Rights-of-way must be established and a number of interested parties have to be consulted. While large-scale infrastructure projects regularly face public opposition, the resistance to new overhead power lines is often particularly fierce. Today, most jurisdictions also require mandatory environmental impact assessments before authorizing the construction of a power transmission line. As a result of the multitude of concerns and competing interests surrounding the construction of high-voltage transmission lines, it can take up to a decade or longer for new transmission

[15] It could be argued that the electricity stored in electric vehicle batteries constitutes a mobile means of transport, as the energy can be discharged from the car in a different location. It is indeed conceivable that in the not-too-distant future the sum of electric vehicle batteries will constitute an important means of flexibility for the electricity system.

[16] Massachusetts Institute of Technology (2011), p. 39.

[17] This issue is dealt with in more detail below in Sect. 2.2.2, pp. 27 et seq.

[18] Brown and Sedano (2004), p. 35.

[19] Ibid.

[20] Müller (2001), p. 27. See also Botchway (2001), p. 3, who argues that 'By necessity (. . .) electricity transactions primarily have to be regional.'

[21] See below in Sect. 3.2.7, pp. 74 et seq.

lines to be put into operation. In the European Union (EU), the planning and permitting stages of electricity infrastructure projects have frequently lasted for more than 10 years.[22] The European Commission has made repeated attempts to expedite this process.[23] The construction of new power lines, especially in the high-voltage range, also requires considerable capital investments. These are usually the responsibility of either the electricity generators, the transmission system operators as regulated utilities, or 'merchant' transmission companies that invest in new power lines between different price zones and generate revenue in the form of congestion rent.[24] The technical constraints described above in combination with the capital intensity and the administrative barriers limit the trading possibilities and, to a certain extent, the degree of competition on the electricity market.

2.1.3 Storage of Electricity

Considering the nature of electricity as the result of a physical process requiring the constant flow of electrons, it is not surprising that electric power as such is not storable except on a very limited scale. 'Storage' of electricity has traditionally meant the conversion of electric energy into other forms of energy, like heat or mechanical energy.[25] While the methods have increased in efficiency over time, energy is always lost in the process. The use of hydro storage is limited by geographical conditions and in addition, hydro storage facilities are controversial due to their impact on the surrounding landscape and ecosystems.[26] Batteries are advancing in capacity at an impressive pace but do not yet present an economical alternative to additional generating capacity (i.e. new power plants) in most places. The conversion of electricity to hydrogen for transportation via pipelines and mobile means of transport and reconversion of hydrogen to electricity is seen by some as a possible way forward.[27] The development and deployment of efficient storage options will be a fundamental pillar of the transition from a fossil fuel-based generation landscape to an energy supply largely made up of variable renewable sources, like wind and solar photovoltaics (PV).[28]

[22] European Commission, Commission Staff Working Paper: Energy Infrastructure Investment Needs and Financing Requirements, SEC (2011) 755 final, p. 5, citing the electricity interconnector between France and Spain, the commissioning of which took more than 40 years.

[23] Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 on guidelines for trans-European energy infrastructure [2013] OJ L 115/39.

[24] Brown and Sedano (2004), p. 22. On merchant transmission investments see Gerbaulet and Weber (2014); Joskow and Tirole (2005), p. 233; Brunekreeft (2005), p. 175.

[25] Buchmüller (2013), p. 59.

[26] Gatzen (2007), p. 2.

[27] See, e.g., Meyer and Thomas (2021).

[28] Casazza and Delea (2010), p. 132; For an overview of storage options and application strategies see Gatzen (2007), p. 4. See also below in Sect. 2.1.6.3, pp. 19 et seq.

The impracticality of storing large amounts of electricity in short term makes the matching of supply and demand the most critical factor in securing electricity supply. Generation must respond immediately to substantial changes in consumption. As electricity cannot be brought to the market from warehouses, silos or tanks, the generation capacity and the transmission and distribution infrastructure always have to be oriented towards maximum load to serve consumers in peak demand times.[29] Demand-side management methods are only slowly penetrating the electricity sector. This distinguishes electricity supply from services like telecommunications, where customers can be ‘put on hold’ if the requested party is busy.

The lack of storage options makes electricity systems dynamic and highly complex balancing mechanisms.[30] Disturbances at one end of the system will have (almost) instantaneous effects throughout the entire system.[31] A temporary disequilibrium between supply and demand frequently leads to serious problems for the whole system. It also distinguishes electricity transmission from the transport of consumer goods. The latter can be temporarily stuck in road traffic when the medium of traffic (roads) is congested without seriously endangering the entire system. The storage problem of electricity combined with the varying demand and occasional peaks also leads to considerable variations in the wholesale price of electricity.[32]

2.1.4 The Evolution of Electricity Systems

The history of electricity systems comprises developments from lighting an incandescent lightbulb to serving billions of people and involving a multitude of actors on the stages of generation, transmission and distribution. The emergence and widespread use of electrical energy in urbanized areas is closely associated with the ‘second industrial revolution’ which is deemed to have taken place during the last decades of the nineteenth century in the US and parts of Europe.[33] The electrification of cities spurred industrial development and subsequently revolutionized households and improved the lives of millions of people. Many names and places are associated with the evolution of the electric system around the end of the nineteenth and early twentieth centuries.[34]

Thomas Alva Edison deserves specific mention for his inventions, which paved the way for ensuing commercial developments in the electricity industry. Initially, Edison was looking for an alternative to gas lighting, which was the prevalent source of lighting in American and European cities. His answer was the incandescent

[29] Cf. Müller (2001), p. 26.

[30] Laloux and Rivier (2013), p. 2.

[31] Ibid.

[32] Hunt (2002), p. 32.

[33] Hughes (1983), p. 176.

[34] On the ‘early phase’ of this development see Passer (1953).