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„The Influence of Electricity on Socio-Economic Development“

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For the people who supported or inspired me; knowingly or not.

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1. INTRODUCTION

Life stops being simple the moment one flicks a switch and nothing happens. Electricity has enabled members of modern societies to delegate many unpleasant, tedious and strenuous tasks to machines which are powered by this versatile source of energy. We have managed to utilise electricity to carry out work for us in such a sophisticated way and to such an extent that would be difficult to substitute by any equivalent source known today, least of all by simple muscle power.

Getting to this point of utmost economic and personal dependence on a complex energy system, of which electricity is only one if yet a structurally fundamental part, has taken centuries and due to fluctuating natural resource availability (at least the availability of one specific kind at a certain amount, time and place) the question of how to cover the energy demand for an increasing population with energy-intensive living standards becomes ever more pressing.

Before the discovery and widespread utilisation of fossil fuels and electricity, muscle power was the prime mover of the economy. Estimates for today claim that in industrialised countries work done by muscle power only accounts for less than one percent.[1] Reverting back to pre-industrial times and giving up on all conveniences that came with an energy-intense lifestyle is undesirable for most people. If energy provision is intrinsically linked with economic development which in turn secures a more comfortable lifestyle, finding a solution to energy shortages or uneven distribution is of utmost interest for economists, policy makers and average citizens alike.

Energy is resource and currency at the same time. It is omnipresent, but being able to harness and use it appropriately to one's needs is a completely different story. Economic development and quite frankly any kind of development requires the availability of adequately usable energy. The betterment or upkeep of a standard of living, even just meeting subsistence, requires a certain amount

[1] Hinrichs and Kleinbach, *Energy*, 1-2.

and form of energy which is said to be one of the key elements of economic growth.

As Wrigley – amongst others – pointed out, presuming a connection between energy consumption and income per capita is plausible.[2] Actual proof instead of a series of circumstantial evidence has yet to be delivered in many cases. A correlation between energy consumption and economic growth is most likely if not evident; but the direct causality is difficult to prove. The research question can thus be summarised as such: what proof, if any, can be provided to determine a causal relationship between energy consumption – in particular electricity –, economic growth and better living conditions for a society?

The large disparities between those who use larger and those who use smaller amounts of energy – a fact that is visible just by opening the newspaper in the morning – ultimately lead to the philosophical question of equality. Who deserves a larger share of the energy available? What is considered to be a human right? Is there something like a right of access to energy? If so, does this right come with a corresponding obligation? Who is allowed to consume conserved energy of millennia – those who extract it or anyone who is willing (and able) to pay the market price for them? These and many more questions alike are worthy of being answered, yet doing so in this paper would overextend its purpose, scope and require extensive data from fields of study outside of history and global studies. Therefore, I will leave those questions unanswered, hoping for them to be kept in mind when looking at the bigger framework and focus on the search for sound arguments for effects of electricity on the economic and social spheres of a society.

2. METHOD, THEORY, SOURCES

Framing this topic appropriately is a challenge. The issue of energy, even if ‘only’ narrowed down to electricity, is vast and so radical choices were necessary to compose a coherent structure and content within the scope of this thesis.

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[2] Wrigley, *Continuity, Chance and Change*, 123-124.

The intention is to investigate which opportunities open up to a society if it makes use of a specific kind of energy, namely electricity, and to which extent academia has managed to prove a direct relationship between energy provision and scenarios presumably resulting from making use of that energy. The focus, hereby, lies on looking for effects of the associated technology and framework conditions on the economic, social and cultural spheres of a society.

Overall, a macrohistoric approach was chosen to accentuate the circumstances across different countries, time periods or groups of people. Therefore, this thesis will not concentrate on specific events but rather try to decipher a more general pattern of socio-economic change due to the usage of or lack of access to electricity. In this respect this work positions itself in the field of global history. Interregional or international connections, interaction and trans-border phenomena will be part of the discussion of the relevant topics.

Electricity as the prime energy with which this work is concerned was chosen for a series of reasons. Firstly, electricity is an indispensable part of our daily lives without which a lifestyle as we know it is simply impossible. Secondly, it has economically beneficial qualities in contrast to other kinds of energy such as fossil fuels, solar energy or muscle power, all of which will be outlined in more detail in the following chapters. Thirdly, as it is predominantly converted from other primary energy sources (water power, fossil fuels, solar power, etc.), it is not bound to a certain region and availability of a specific (possibly finite) raw material and therefore theoretically available in every corner of the world as long as the appropriate technology is provided. This makes it a truly global and fair energy source, at least in theory.

Western Europe, especially Great Britain in the 19th century, and the United States will serve as prime examples due to their proactive research efforts in the field of electricity and the application of electricity at an earlier stage than in many other regions of the world. They were able to make use of their political dominance over parts of the world and their networks at that time to spread the technology beyond national borders. Starting in the early 19th century, with a brief overview of the discovery of electricity and invention of all necessary devices for industrial and commercial utilisation, the focus will be on determining and evaluating reasons for and effects of large-scale implementation. By World War II most of (Western) Europe had gained access to electricity, if yet not generally on a household level. Nonetheless, the impacts on society were visible by then and further investigation after that point in time would exceed the scope and intention of this thesis and is thus largely omitted.

The aspect of energy used for military purposes (weapons, armour and ammunition) is generally excluded from this research. Even though credit has to be given to the incentives for innovation, the promotion of technology and sparking economic growth by employment and production, destruction and hindrance by waging war have been very extensive too.[3] All the data available is subject to interpretation and very difficult to incorporate in this analysis. Also, it did not prove to be of fundamental necessity for the concerns of the research question.

In order to being able to critically examine the research question, a list of topics was chosen to evaluate the influence of electricity as an energy source. Topics include economic growth, industrialisation processes, transport, telecommunication, science and technology after the age of enlightenment, demographic development, living standards and urbanisation, as well as political, social, cultural, economic and technological aspects. All must be taken into account when talking about the implementation of a novel energy source and should be critically evaluated when detecting the effects of that undertaking. Therefore, the major part of the research will consist of a study of works by economic, cultural and social historians, amongst them John McNeill, Vaclav Smil, Alfred Crosby, Rolf Peter Sieferle, Paul Warde, Crosbie Smith and Robert Millward, Vincent Lagendijk, Astrid Kander, Lennart Schön, Kerstin Enflo, Erik van der Vleuten, Robert U. Ayres and Benjamin Warr, who have done extensive research on the topic of the role of energy in economic and social history and will, naturally, also be cited. Their findings will be outlined and juxtaposed according to their relevance to the topic discussed and the overall theme of the research question. The ultimate aim is to come closer to separating

[3] Warde, *Energy consumption in England & Wales: 1560-2000*, 17.

substantiated arguments from merely plausible and probable chains of causation.

2.1. State of research

It is a well acknowledged commonplace that economic growth is caused by the usage of growing amounts of readily available energy and leads to better well-being and higher living standards for people. Finding suitable data or even choosing sound parameters for conducting primary research is an undertaking with countless obstacles. Many have tried and were at least partially successful in delivering explanations and data that states a clear correlation between energy usage and economic growth. The scholars mentioned above have all contributed to the debate by providing the most solid collection of data and arguments available today. Yet, the primary data is often problematic to analyse and therefore proving an immediate causal relationship between energy provision, economic growth and an improvement of living standards is a challenging enterprise.

Underlying to most of the research efforts is the impulse to find and explain driving mechanisms behind economic growth. This is itself is anything but a novelty. Reading through literature from the late 20th century has shown, though, that research in that field concentrated primarily on the development of the technology and the narration of events relating to technology and economic society rather than looking for structural energy-related mechanisms with commensurable triggering factors on an economy and society.

Research in the history of energy in relation to its effects might have passed its infancy, but there is still a long way to go before all basic questions have been critically investigated and scholarly satisfactory answers can be provided on a larger scale.

2.2. Data collection and reliability

Data reliability is, as often in the field of history, an issue. There is very little data on energy consumption as well as production before the dawn of the industrial revolution and even then the reliability remains questionable and rough estimates will have to suffice as references.[4] The use of statistics has been kept to what was considered to be the absolute minimum for clues or reference points and yet, it needs to be emphasised that all of the so-called evidence shall be scrutinised very carefully.

Just like the scholars whose works will be referenced in this thesis, my personal experience also showed that finding sound data is close to impossible at times. Even if figures of some kind are available, determining their bias and validity as well as applying a scheme for interpretation which would allow comparisons with data from other regions, times, institutions or the collections by other scholars can easily become a matter of arbitrariness. Every figure and every argument shall therefore be interpreted with this background in mind.

2.3. STRUCTURE

The structure of the thesis has started with an introduction of the research question and methodological remarks. A brief overview of the scientific background and the basic definitions of the realm of electricity as well as the different kinds of energy will be provided. The most important inventions and their implementation will be outlined briefly in chapter 5. A separate introductory chapter will describe the role of transport and its immediate relation to energy policies as it is too far-reaching and all-encompassing to be outlined along the way in other parts of this research. Each subchapter of the core sections 7 and 8 will be headed by an arbitrarily phrased statement which stands as a representative for a plausible and general assumption about the effects of electricity on economy and society and the circumstantial aspects of politics and culture which can be found similarly in the pertinent literature. The intention is to identify probabilities that either refute or reinforce the line of reasoning by juxtaposing arguments by scholars as well as my own. The hypothesis behind it states that in many cases the arguments collected are merely a reflection of assumptions, expectations and plausibility, but lack

[4] Warde, *Energy consumption in England & Wales: 1560-2000*, 11-12.

profound evidence. The conclusions drawn from the entirety of the research efforts will be summed up in the end. So let us start at the beginning.

3. DEFINITION OF TERMS, NATURAL SCIENTIFIC FUNDAMENTALS

Technology and science-related terms deserve clarification at this point. Whoever is familiar with the definition of physical units is welcome to skip directly to chapter 5. Yet, in regard to the core section everyone is invited to broaden and refresh their previous knowledge about the issue and discover relevant facts and figures which will aid in comprehending the relations between the natural sciences, technology and the economic and social spheres of the kind of energy discussed.[5]

3.1. ENERGY

Energy represents the capability to perform work. "It is needed for every economic sector and activity, and there is no substitute."[6] By conversion it can change its form and is separated in energy available and unavailable for useful work, which is reflected in the efficiency rate upon conversion.

Materials that contain energy, such as wood, coal, oil and so forth are referred to as energy carriers. So the body able to contain, absorb and release energy is of vital importance in terms of energy density. Energy as such is therefore not the only thing that matters; it is rather the package it comes with and its usability in that form that has value for human beings, especially as far as the economic side is concerned. In this sense, some forms of energy correspond with capital, which also needs a material component of some kind as the coin or paper note holds no value as long as it cannot be traded for something by someone else who agrees to the terms of trade and is available at the same time. The transferral of energy as well as capital requires two parties, one that gives and one that receives.

[5] For detailed references, please consult the works by: Ayres and Warr, The Economic Growth Engine; Gerthsen and Meschede, Gerthsen Physik.
[6] Ayres and Warr, *The Economic Growth Engine*, xxi.

An economy is driven by an influx of energy (labour, raw materials, etc.) and capital.[7] The total amount of energy does not de- or increase, it merely shifts within the system.[8]

Hinrichs and Kleinbach describe energy in a similar fashion. “We cannot “see” energy, only its effects; we cannot make it, only use it; and we cannot destroy it, only waste it (that is, use it inefficiently). Unlike food and housing, energy is not valued in itself but for what can be done with it.”[9]

3.2. ELECTRICITY

Electricity is a wide-ranging physical term which implies the existence and movement of charged particles. Energy is released upon the shift of the particles which either attract (positive and negative) or repel (positive and positive or negative and negative) each other. Only very little electricity is directly available in nature. Electricity is, in the vast majority of cases, a form of secondary energy as it is generally converted from another source of energy.

Electricity is bound to a conducting and, if available, an electricity-conserving medium.[10] Metals are good conductors and enable the electrons to move towards the positive pole once voltage is applied. Voltage stands for the potential difference between two electrically charged poles and the force that moves the particles between them. Ampere is the unit for the amount of charged particles passing a certain point in a certain time frame – the strength of the current. The higher the resistor in an electric circuit, the more voltage (potential difference) is necessary to move the current through the conductor.

Another relevant fact is that electricity has high energy density.[11] The density describes the amount of energy content per volume. Conclusively, three key features, which will be relevant for the arguments in the core section of this thesis, shall be pointed out at this stage and distinguish electricity from most

[7] Ayres and Warr, *The Economic Growth Engine*, xix.
[8] Smith, *The science of energy*, 291-293.
[9] Hinrichs and Kleinbach, *Energy*, 2.
[10] Meya and Sibum, *Das fünfte Element: Wirkungen und Deutungen der Elektrizität*, 79.
[11] Smith, *The science of energy*, 191-194.

other kinds of energy: it is invisible, has no odour and can as such not be touched as it has no physical body per se.

3.3. POWER

Power is the amount of work performed in a certain time period, which practically means the rate at which energy is converted (power equals the amount of work – joule – divided by time unit – e.g. seconds or hours). Its unit is Watt.

The common term 'horsepower'[12] is derived from James Watt's observation of strong brewery horses. He did not consider them average horses, due to the inability of a 'normal' horse to keep up high energy levels over longer periods of time and their less muscular physique than of those horses observed. Eventually they would only be able to uphold about half a horsepower.[13]

Between 70 and 100 Watt is the maximum power output a human being is able to maintain over a longer time span, whereas draught animals can sustain levels of 500 to 800 Watt.[14] It may be more energy efficient to get seven men to do they work of one animal, because in general their food-to-motion conversion rate is better, but it may not be possible to concentrate all their energy in a way that a draught animal is capable of. Logistics, hence, play a substantial part in the efficiency debate, too, which will be discussed in more detail in chapter 6 about transport. Multiplying forces, which simply refers to more energy available, and focusing energy in an applicable manner are not automatically corresponding processes.

3.4. WORK

In analogy to the definition of power, work is the amount of energy moved over a distance. It is measured in joule, with 1 joule being the work done by a force of one Newton acting over a distance of one metre. "Whenever a current flows through any circuit it performs work, or produces heat or chemical action

[12] 1 horsepower equals, depending on the specific definition, between 735 and 746 Watt.
[13] Nye, *Consuming Power*, 22.
[14] Biagioli, "Work and Environment in Mediterranean Europe," 34.

equivalent to work."[15] Electricity and mechanical work in general produce heat which in turn can be converted into mechanical energy. In economics, the term generally refers to labour which is work (as the transferral of energy) performed by human beings, animals or eventually machines to produce a good or provide a service.

3.5. EFFICIENCY

The term efficiency presupposes a definition of usefulness. Only when it is clear what is considered 'good' or 'useful' work, efficiency can be evaluated as it represents the part of useful work in relation to the energy available. Striving towards utmost efficiency is a core principle in natural and economic sciences. The counter-part is entropy, which reflects the amount of energy that is unavailable for conversion into useful forms of work. It practically means that entropy cannot be avoided whenever a conversion of energy takes place. All transformation processes of energy "must end up either as a useful product, a stock change or a waste", as stated in the First Law of Thermodynamics, which is also applicable for economic processes.[16] Efficiency is, naturally, particularly important in systems where energy of whichever nature is scarce and/or expensive, or at least limited for the purposes intended.

Human beings have an efficiency rate (of muscle power) of about 18 percent. This means that of 100 calories consumed only 18 are converted in mechanical energy, thus movement and muscle power. The rest is used for controlling body temperature, primarily heating the body, as well as all other bodily functions. Although on average eight to ten times as strong as a human being[17], horses have an even lower efficiency rate of only 10 percent.[18]

Efficiency marks one of the core principles of economics. It is the base of the concept to use a minimum of resources to gain a maximum of output, turnover or profit. The more efficient all input factors which equal the resources

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[15] Smith, *The science of energy*, 282-283.
[16] Ayres and Warr, *The Economic Growth Engine*, xx.
[17] Wrigley, *Continuity, Chance and Change*, 35; Wrigley, "Energy contraints and pre-industrial economies," 160.
[18] McNeill, *Something new under the sun*, 25.

necessary are, the higher the potential profitability (given that conditions such as prices and sales figures remain constant or on the rise). It is the simple concept of making the most of what you have. The crucial question for the agent involved is always if, how and to what extent efficiency can be improved by him or herself.

Waste of energy is in general unwanted. Yet, the cost for waste disposal is rarely included in cost calculations of neoclassical theories; neither is waste per se classified as economically harmful but rather disregarded and left out of the equation.[19]

3.6. FRICTION

Friction is part of the concept of motion. It is always opposing, meaning resisting the motion force, which represents an interaction of at least two objects (e.g. wheel and gravel on ground) within their environment (e.g. a dirt road). Friction is an inescapable natural phenomenon which is a prerequisite for the functioning of our world.[20] Simply touching an object with your finger requires friction. Friction is particularly relevant when it comes to efficiency as its force disturbs the energy flow and reduces the amount of energy at the end of the distance it has to cover. The kinetic energy 'lost' on the way is simply converted into heat at the point(s) of contact. Furthermore, friction wears out the touching materials which eventually can lead to malfunction or destruction of the components involved. If friction is a problematic issue depends on whether stiction of materials is desired or not.

3.7. CONVERSION

Contemporary science agrees that energy can neither be created nor destroyed. It is a constant which needs to be converted into a form which is (economically) useful for human beings or just distributed properly.[21]

Electricity is in the vast majority of cases a form of energy that has been converted many times before. For instance, the sun's energy is converted via

[19] Ayres and Warr, *The Economic Growth Engine*, 10.
[20] Hinrichs and Kleinbach, *Energy*, 41-42.
[21] Ibid, 3.

photosynthesis into plant matter which eventually was pressurised under immense heat into coal or oil over the course of millennia. This condensed form of energy is then extracted and used to heat water which changes to steam and powers a mechanical turbine. The turbine drives a generator and converts mechanical energy in electric energy by means of induction.

	To Chemical	To Electrical	To Heat	To Light	To Mechanical
From Chemical	food plants	battery fuel cell	fire food	candle phosphores-cence	rocket animal muscle
From Electrical	battery electrolysis electroplating	transistor transformer	toaster heat lamp Spark plug	fluorescent lamp light-emitting diode	electric motor relay
From Heat	gasification vaporization	thermo-couple	heat pump heat exchanger	fire	turbine gas engine steam engine
From Light	plant photosynthesis camera film	solar cell	heat lamp radiant solar	laser	photoelectric door opener
From Mechanical	heat cell (-crystal-lization)	generator alternator	friction brake	flint spark	flywheel pendulum water wheel

Table 1: "Energy Conversions"[22]

To look at the specifically economic aspects of conversion, the following graph, compiled by Kerstin Enflo, Astrid Kander and Lennart Schön tries to demonstrate the production process from an energy perspective.

[22] Hinrichs and Kleinbach, *Energy*, 39.

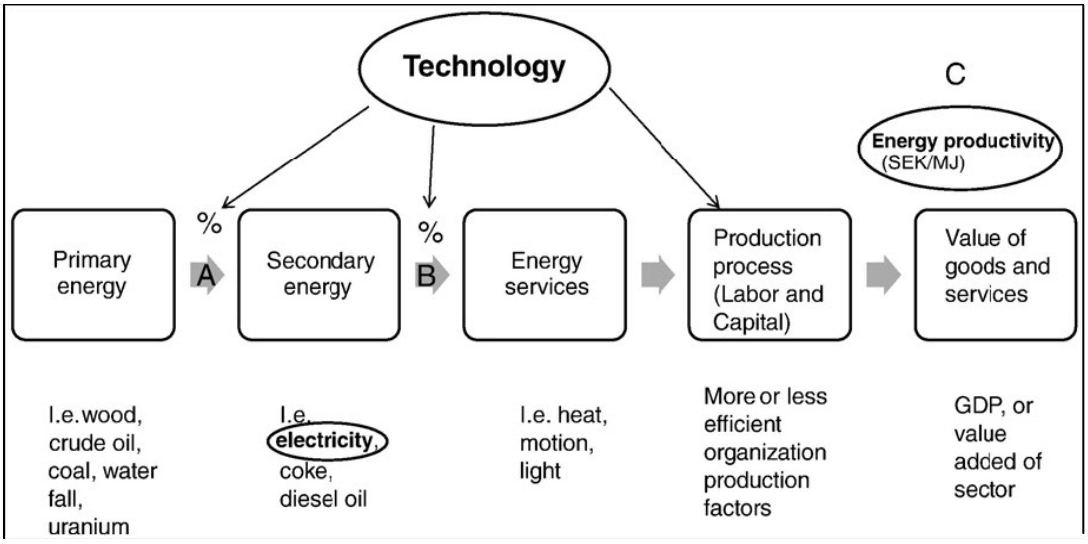

Table 2: "A conceptual model of the production process from an energy perspective"[23]

From one step to the next, energy losses occur and the remaining amount eventually gets integrated with labour and capital to complete the production process. Electricity is a very versatile form of energy and leaves room for innovation and thus improvements; however, as energy losses are unavoidable they are, according to Enflo et al., simply shifted to another part of the conversion process. Electricity's transcendence lies in its ability to complement production, organisation and working conditions in a way that makes it superior in productivity in contrast to alternative energies, even after checking for any artificial statistical gains due to the shift of conversion losses from the production site to the electricity generating plant. Further, the magnitude of its effect depends on how many aspects of an industry are transformed to best benefit from electricity. So the innovative and dynamic power stands out when looking at electricity as a power source. One needs to be careful, though, not to mistake the seemingly positive influence of electricity on productivity with an overall positive trend in economic development.[24]

3.8. CONSERVATION

Electricity comes with two major challenges for scientists and engineers. Firstly, the issue of transport without major losses, and secondly, conservation when

[23] Enflo, Kander, and Schön, "Electrification and energy productivity," 2809.
[24] Ibid., 2810, 2814.

the produced or delivered amount of energy exceeds the immediate demand.[25] Conservation means to preserve or save energy for usage at a later point. The amount of energy able to be conserved is the total energy available minus the energy consumed. The calculation of the total energy consumed is the product of "energy required for the activity (intensity) x frequency of activity". Conserving energy can happen either by using the energy available more efficiently and thus decrease the share of consumption, or by a change in lifestyle to consciously use less energy in the first place. Becoming more efficient is a matter of technology which is limited to physical laws whereas lifestyle changes depend on individual choices not necessarily attached to logic or rationality.[26]

With the development and advancements in electrometallurgy, the battery was able to solve one aspect of the conservation problem of electricity, even if it was not suitable for all appliances.[27] The advantages of conservation instead of increasing the amount of available useful energy are that more often than not it is cheaper to work on the expenditure side than gain new resources. Particularly the case of oil or coal make that clear: it would take millennia and many times more energy to reproduce fossil fuels than it takes to use them more efficiently or even find a substitute for them. Conserving the finite resources also buys scientists more time to work on the issue of substitution and it allows quicker responses to shortages as looking for new supplies is often very time-consuming. Fossil fuels occupy a central role in the making of pharmaceuticals and plastics, so finding a way to conserve as much as possible for as much time as needed to find viable and affordable alternatives is therefore not just a matter of convenience but also a matter of health and survival.[28]

After these introductory remarks, we will now focus on the different kinds of energy to which the above mentioned definitions apply.

[25] Zängl, *Deutschlands Strom*, 6.
[26] Hinrichs and Kleinbach, *Energy*, 24-25.
[27] Morus, *Frankenstein's children*, 167.
[28] Hinrichs and Kleinbach, *Energy*, 26-27.

4. KINDS OF ENERGY

Fundamental is the understanding that basically all energy on earth is a derivate from solar radiation. Speaking in economic terms, the sun's power is "the only possible source of surplus".[29] The sun's energy, next to regulating weather conditions, nourishes plants which in turn provide nutrients for animals and human beings that convert part of their energy into motion and heat. The higher the dependence on immediate solar radiation – meaning that there are few to no storage facilities such as fossil fuels – the more volatile and susceptible to fluctuation is an economy. The sun has always had one major advantage over any kind of fossil fuel or energy commodity: it is free of charge. This made the transition of a solar-powered, agricultural economy into a fossil-fuelled and electrified one especially challenging as the cost factor (albeit a distorted one, which will be explained later on) became even more relevant.

Before describing the sources of energy, we will differentiate between the principle types of energy, most importantly: kinetic and potential, which can be summarised under mechanical energy. Further we can classify also chemical, nuclear, (geo)thermal, light and electrical energy. Any energy that makes an object move or moves an object is regarded as kinetic. The position in relation to the gravitational force that an object is exposed to defines its potential energy.[30] In other words, the further away from the ground an object is located, the more potential energy it has (to fall).

Paul Warde defines seven energy carriers in his analysis, all of which come with a cost – not merely monetary – for human beings: "Food for human beings; Firewood; Fodder for working animals; Wind; Water; Fossil fuel sources; Primary electricity."[31]

Taking up this classification scheme as it proved the simplest and most suitable for structuring the issue, the following pages will go into depth describing each

[29] Beaudreau, "On the Creation and Distribution of Energy Rents," 76.
[30] Hinrichs and Kleinbach, *Energy*, 37.
[31] Warde, *Energy consumption in England & Wales: 1560-2000*, 17.

carrier of energy. Great Britain will serve as the prime reference and example for comparing figures of the different energy carriers within a political entity.

4.1. FOOD

The energy density of food is measured in joule or calories. Both are units that indicate the amount of energy content that can be burnt, meaning converted into thermal energy. One calorie is the amount of energy needed to heat one litre of water by one degree centigrade. The caloric value of a food item is, apart from joule, generally given in kilo calories (kcal) which are colloquially also referred to as calories. The energy content is dissected and burned by the body in the process of digestion to keep up the body's comfort temperature (which means to move particles to create friction and thus heat) and perform work of muscles, organs and build new cells. Food intake and work intensity are therefore related. Thus, also a portion of economic growth can be attributed to greater calorie consumption. Not to forget, children and elderly people often enough did not work or at least not as intensively, but they facilitated the process. Regardless, they must consume food and energy in any case. Calorie intake depends on various factors such as demographic structures of society, occupation, availability and composition of the food (e.g. cereal, vegetables, meat, dairy products, etc.). To measure this correctly is however highly complex and the data available only allows rough estimates. Calculations on how many kilo calories were consumed per day and which share alcoholic beverages hold also differ considerably.[32]

Food, therefore is the body's fuel. The difference, when comparing bodies with machines, is that machines can be idle and then restarted, whereas human and animal bodies have to be kept going at least at a subsistence rate.[33]

It order to understand the complexity of the role food play in the energy equation of a society it is important to note that the energy density of different kinds of foodstuffs (vegetables, meat, cereals, oat, maize, rice, sugar, etc.) varies considerably. If more energy can be provided by food intake, more energy is per

[32] Warde, *Energy consumption in England & Wales: 1560-2000*, 23-31.
[33] Wrigley, "Energy contraints and pre-industrial economies," 155.

se available for physical labour. This means that in theory those societies with access to more calories for manual work could be expected to have a more successful economic performance (given that the structure, demographic, overall efficiency and size of the economies compared are similar). Sugar, maize, potatoes and rice are mostly non-indigenous plant species in Europe. Their energy density is higher in comparison to vegetables and cereals which provide less caloric value as the staples of pre-industrial Europeans. Repeatedly one can read about the economic advantage gained from the import of energy-dense staples from the Americas as Europeans with access to colonial markets had more physical muscle power per individual at their disposal simply because of an improved diet.[34]

It can easily be agreed upon that a betterment of diet is definitely advantageous in terms of health and wellbeing. However, whether it was measurable by any scientific standard which share of economic growth can be attributed to dietary conditions remains unresolved.

Food as fuel is particularly economically relevant, as we need to focus on the level above subsistence. An average human being needs an intake of about 1500 kcal to keep up body functions. If a worker takes in 2500 kcal it leaves him with roughly 1000 kcal to spare for labour. Cutting down food rations only by a fifth to 2000 kcal reduces work performance by 50 percent.[35]

With different preparation techniques one needs to invest different amounts of energy. Food needs to be carried from its place of production to the place of consumption; it might need to be ground, chopped or heated. For example, it takes about three calories of fuel to cook one food calorie.[36]

In order to measure how much food a region was able to produce and thus to see how many people the land could live off of it, one needs to look at the maximum average crop yield per hectare and calculate the limits of capacity.

[34] Crosby, *The Columbian Exchange*; Smil, *Energy in world history*, 78-80; Malanima, *Economia Preindustriale*.
[35] Wrigley, "Energy contraints and pre-industrial economies," 159.
[36] Wrigley, *Continuity, Chance and Change*, 45-55.

Given a strictly solar-based pre-industrial economy and excluding areas unsuitable for agriculture or pasture, Britain's land could account for an average of 50 gigajoule[37] per hectare. This equals roughly the figure of Austria's energy output per hectare in pre-industrial times. Agricultural stability benefited from Europe's little exposure to climatic extremes.[38] Only by reduction of per capita calorie intake or intensification of work efforts marginal output rises could be accomplished. Eventually, though, stagnation or reductions in living standard were unavoidable. With the introduction of fossil fuels in the economic system, Britain's virtual acreage surpassed the entire size of the island already in 1840.[39]

Essential to evaluate is if an increase in productivity corresponds to an actual increase in production and if work processes could be relocated to formerly unproductive or service sectors in order to measure long-term success of agricultural innovations.[40] As livestock was a rival for crop yields (both need land resources), the most energy-intensive tasks were assigned to draught animals. Great Britain had the largest proportion of animals for agricultural labour in Europe in 1800, while at the same time having the least amount of labour force working for food production. Population figures rose by over 100 percent since the late 16th century but the number of people employed in agriculture only increased by a margin. This means that more and more people were engaged in something other than food production and therefore able to transform the socio-economic structure of the country. Still, Great Britain was mostly capable to cater for its own food which indicates higher output levels per farm worker.[41]

Another aspect is that animals come with side-benefits. Not only does an hour's work of an ox add up to four hours for a human being. As ruminants they are less care-intensive than horses, which need oats and thus reduce the space for

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[37] 1 gigajoule equals 10^9 joule; 1 joule equals 0,239 calories
[38] Sieferle, "Transport und wirtschaftliche Entwicklung," 15.
[39] Sieferle, *Das Ende der Fläche*, 290-294.
[40] Sieferle, "Transport und wirtschaftliche Entwicklung," 27.
[41] Wrigley, "Energy contraints and pre-industrial economies," 160; Wrigley, *Continuity, Chance and Change*, 35.

cultivation of cereals. Horses, though, can be used for faster transport and substitute eight hours of human labour by only one.[42]

Plus, all animals produce manure which can be used to fertilise the fields. Grass for the animals might grow well in years with bad crop yields. If needs be, they can also be slaughtered during extreme food shortages.[43]

4.2. FODDER

As mentioned earlier, the efficiency of a working animal must not necessarily be higher than that of a human being. Concentrating energy however cannot always be achieved by the multiplication of individual forces. For example, several labourers could combine their efforts and plough a field by hand; but most draught animals can concentrate their energy levels much better as they can exert more force on one spot and are thus more effective at times than the joined forces of field workers who can only deliver a certain amount of power individually. So, higher energy input via fodder might still result in more productivity even if the direct correlation between fodder intake and power output might suggest otherwise. More efficient breeds aided the development of using animals instead of human labour. Animals have been domesticated for labour over centuries. After 1870 England and Wales carried out yearly animal censuses, but no data was collected over the concrete use of these animals. Horses, for instance, were increasingly employed outside agriculture during the 19th century. Around two thirds of the 2.85 million horses, the peak number counted in 1901, were used for carrying commercial goods, pulling trams, riding and leisure. With the introduction of the motor vehicle, horses were pushed back to the farms again.[44]

But fodder must grow somewhere, too. Just as food and firewood, it competes for (arable) land which then cannot be used differently. Draught animals have a much higher de facto calorie intake than humans and might require a special diet. Horses, for instance, need oats. Adding to that, animals usually need a

[42] Biagioli, "Work and Environment in Mediterranean Europe," 34.
[43] Wrigley, *Continuity, Chance and Change*, 42.
[44] Warde, *Energy consumption in England & Wales: 1560-2000*, 40-44.

pasture which again cuts off land for other purposes. Generally speaking, the more land is expendable for draught animal the less human labour force needs to be deployed and the more energy is left for a worker for other (value adding) activities.[45]

4.3. FIREWOOD

Only very rudimentary research has been done in regard to firewood. Deforestation figures and estimates about the use of wood for building, packaging and heating are difficult to measure, but it is being estimated that up to 90% of woodland in England and Wales was being used as fuel. Overall, estimates peak at 3.6 million cubic metres of firewood per annum in 1750.[46] The energy released upon burning equals the amount the tree amassed during its lifespan via photosynthesis.[47]

Firewood was not only needed to keep rooms temperate, but was also required for many manufacturing and industrial processes such as "brickmaking, glass refining, pottery manufacture, the smelting and handling of non-ferrous metals, salt boiling, brewing, dying, baking and many more."[48] Glass in particular is a product that requires large amounts of thermal energy and was considered a luxury until inexpensive and abundant heating material was available.[49]

With the advent of coal (which is practically concentrated firewood) and later gas and electricity as the main heating sources, firewood steadily lost its predominant role in that field and almost stopped to compete with Malthus'[50] other three necessities of life. This also left more wood for construction purposes while more heat from other sources meant cheaper brick-making and more funds for insulation which again reduced the need for heating.[51]

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[45] Wrigley, *Continuity, Chance and Change*, 38.
[46] Warde, *Energy consumption in England & Wales: 1560-2000*, 32-38.
[47] Wrigley, "Energy contraints and pre-industrial economies," 162.
[48] Ibid.
[49] Wrigley, *Continuity, Chance and Change*, 125.
[50] Malthus, *An Essay on Population*.
[51] Wrigley, *Continuity, Chance and Change*, 55.

4.4. WIND

Wind was predominantly used for sailing ships and mills. England and Wales had a geographical advantage due to their constant exposure to strong winds and proximity to seaways. A prominent role was acquired during the exploratory ages of the British sailing ships, when a combination of an efficient rudder with a decent sail allowed improvements in long-distance travelling at sea.[52] In early modern times Britain's large merchant marine reflected its status as a trading nation, only to become even more dominant with the introduction of steam powered vessels in the late 19th century.[53]

Wind mills, on the other hand, were a strictly local way of exploiting this energy source. They were mostly used for drainage or grinding. A major disadvantage was that they were not workable all year round or controllable to run at a certain or even constant pace. Also, there are no records of their work lifespan or other reliable statistics, except for sightings.[54]

The last decades have seen a renaissance of windmills but now they are used for decentralised electricity generation. The advantage of today's windmills is predominantly that now energy can be stored and transported to wherever it is needed from wherever the most favourable wind conditions are.

4.5. WATER

Apart from water being absolutely essential for all forms of life on our planet, water next to wind has also a strong commercial potential as it can perform work when in motion (i.e. a stream powering a mill, steam powering a turbine, etc.).

Before the invention of hydroelectric power plants, water as a source of energy was concentrated in industrial mills for mining and agricultural mills to fulfil the same task as windmills. Their efficiency rose considerably during the course of the 19th century, starting at around 15 percent or lower in the early phase and

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[52] Wrigley, "Energy constraints and pre-industrial economies," 161.
[53] Warde, *Energy consumption in England & Wales: 1560-2000*, 45.
[54] Warde, *Energy consumption in England & Wales: 1560-2000*, 48; Smil, *Energy in world history*, 103-115.

peaking at up to 85 percent by the turn of the century. With the wide scale construction of railway networks – who were the largest user of water power – and further industrialisation, water power gained increasing importance. Workshops, metal production, textile and paper industry needed water power to function. Wherever feasible, water was substituted or rather converted to steam to drive a steam engine. Calculating the efficiency of water mills comes with similar difficulties as wind mills do and the technology itself imposes similar disadvantages, too. Figures vary from as little as 25 percent to up to 60 percent in a time span between 1750 and 1900. Both wind and water heavily rely on geographical and meteorological factors and can be regulated only to a very limited extent, thus limiting their application possibilities.[55]

The usage of water power often enough implied some severe alterations to the landscape like dams, dikes, water ditches, power plants, etc. To create or increase a level difference in order to drive the turbines with forceful streams of water, dams had to be constructed which flooded arid land and vulnerable ecological and cultural areas. Fish were trapped on either side of the dam which disrupted also other micro-ecosystems. Attempts to challenge such projects have been taken at times, but they were usually met by powerful entrepreneurs and politicians who successfully lobbied in favour of power plant projects.[56]

Positive effects of dams or reservoirs were potential protection from natural floods and the securing of central supply of drinking and process water.[57]

4.6. FOSSIL FUELS

Fossil fuels are energy reservoirs that have developed over millennia by means of pressure and heat, and contain the condensed photosynthesized solar energy of plant matter. Coal had been known and used for centuries, but only after technical innovation brought it to the forefront of industrialisation it acquired a central and prominent role.

[55] Warde, *Energy consumption in England & Wales (1560-2000)*, 50-57.
[56] Nye, *Consuming Power*, 23.
[57] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.

The earliest usage of fossil fuels was for heating, whether it was regulating room temperature or heat for simple production processes. Special furnaces and treatment techniques had to be developed. By the mid-17th century most (proto) industrial business in Great Britain, with the exception of iron smelting, were principally able to work with coal and later on gas as thermal energy source rather than firewood which burned at far lower temperatures. Between 1650 and 1700 consumption of coal multiplied from 0.2 to 2.9 million tons per annum. 1816 already marked 17 million tons of coal consumption of which 9.3 were used for household heating, almost 5 for industrial purposes, 1.9 for energy conversion and still roughly 1 million for mining purposes.[58]

Coke, a refined coal product, was a key element in the early 18th century to enable iron smelting, but it took until the 1760s to the 1790s to largely substitute wood as construction material with iron and steel.[59]

In early industrialising Britain, a worker mining an estimated 500 pounds of coal in one day would have collected the amount of energy of over 500 days worth of food for himself.[60] Clearly, coal cannot be eaten, but this example indicates the ratio of thermal value of ‘fresh’ plant material and the condensed versions in coal, coke or even oil, which is by far more energy-dense than the former.

Another downside, apart from being inedible, is that digging and drilling for the source is arduous, dangerous and a technical challenge as British coal mines were prone to flooding. Even with animal aid effective drainage was almost impossible once a critical depth was reached. Once the steam engine provided a viable solution (in spite of all its problems like risk of explosion, little initial efficiency rates, etc.), it allowed workers and animals to be used for other purposes in the mining realm.[61]

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[58] Sieferle, *Das Ende der Fläche*, 171, 173.
[59] Ibid., 173.
[60] This does not refer to the amount of energy above subsistence that is available to perform physical work; Wrigley, “Energy constraints and pre-industrial economies,” 166.
[61] Ibid., 167.

At an efficiency rate of 0.5 to 1.5 percent the steam engine in the early 18th century (in 1712 the first economic steam engine was used in a mine in Wolverhampton for drainage) demanded massive amounts of coal itself; yet that was of rather little importance in that respect as new fuel was literally right at hand and also rectifiable rejects of coal could be used to fire the machine.[62] A cycle developed in which coal was used to mine coal.

The issue of scale was also important as the output grew proportionally to the cube of capacity (volume = m^3) of the machine. Small steam engines were therefore even less efficient than large ones that could take advantage of economies of scale.[63]

A fundamental problem of using fossil fuels is that the usual price mechanism does not work. In theory, the price of a good or service is supposed to reflect the combination of production and labour cost plus the (perceived) value added. This also includes the cost for extraction and reproduction of the raw materials in most cases. With fossil fuels, it is impossible to reproduce them in any foreseeable future, or more correctly wait for them to reproduce. Effects and reproduction costs are far too abstract for the rather pragmatic pricing methods. Hence, their arbitrary price does not correlate with the actual – and probably incalculable on an objective basis – cost of the resource extraction and (re)production. Consumption and reproduction in this are two completely detached procedures for economic considerations.[64] Particularly in the beginning detrimental effects on the environment have not been included in the equation. The intensification of mechanical agriculture and fertilisation exhaust the soil and monoculture leads to higher crop yields but also a decrease in biodiversity.[65] Awareness together with finding applicable methods of resolution have only started to sink in recently and slowly in contemporary debates. Both the extraction of the source as well as global warming and the immediate dependence on raw materials have led to a change in perception, however, not yet to an actual change in behaviour or pricing.

[62] Sieferle, *Das Ende der Fläche*, 172-173.
[63] Ibid., 317-323.
[64] Ibid., 334.
[65] Ibid.

Altogether each advantage of fossil fuels comes at a price to pay which often enough seems to be too far-flung to be integrated into business calculations.

4.7. ELECTRICITY

Electricity[66] "is always a secondary form of energy. ... Both thermal electricity – produced, that is, by means of coal or oil – or other forms of power such as hydro-, geo-, or nuclear electricity" are therefore mere conversions of one form of energy into another, just to be then converted into various other forms such as movement, light or heat.[67]

In the course of history, and particularly after the two World Wars, the larger part of fossil fuels were used indirectly to convert to electricity in large thermal power stations.[68] Between 1900 and 1935 worldwide electricity supply rose over 10 percent per annum.[69]

Which kind of energy is going to be harnessed and used in the end depends on a series of factors. The natural or geographic condition, for example mountains and hills, as well as the soil quality and other environmental aspects affect whether or not mechanised agriculture is a viable option. Economic and demographic elements, like the proximity of a city with need for food and raw materials, and the population density and labour price levels, further influence the choice of energy.[70]

The final conversion of energy happens generally to serve one (or more) of the four sectors industry, transport, residential and commercial.[71]

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[66] Warde initially uses the term primary electricity, defined as "source that has become useful for human beings, and is harnessed at a cost, to be converted into heat or mechanical work". (Warde, *Energy consumption in England & Wales: 1560-2000*,17-18.) Sieferle restricts his definition to a derivate of conversion of nuclear and hydropower. (Sieferle, *Das Ende der Fläche*, 176.)

[67] Warde, *Energy consumption in England & Wales: 1560-2000*, 62.

[68] Sieferle, *Das Ende der Fläche*, 275.

[69] Smil, *Energy in world history*, 187.

[70] Biagioli, "Work and Environment in Mediterranean Europe," 31.

[71] Hinrichs and Kleinbach, *Energy*, 12.

The focus of this thesis will be dedicated to electricity, its characteristics, advantages and possibilities it has to offer. The physical aspects have been dealt with in the previous chapter. The following ones will concentrate on the technological development and the effects of the implementation of this kind of energy.

5. Chronology of Use and Inventions

Before proceeding to the core chapters, this section intends to outline the most relevant inventions which deserve special mentioning in regard to this research as well as the development of use of energy in different eras.

Scientific developments usually follow a certain pattern by undergoing a series of stages. First is the discovery of a phenomenon which has already existed but not yet been examined by means of conscious observation and accumulating knowledge about it. In the process of invention, knowledge is applied to create a new skill or tool regarding the phenomenon. Innovation (note: or rather implementation as a less potentially misleading term) is the process of successful application of invented tools or methods. Diffusion, ultimately, is the spread of the abovementioned in a community.[72]

As indicated in the previous chapters, humans have always been inventive and innovative. Major driving forces for innovations are a scarcity of resources in the economic sphere and threats to power relations that often manifested themselves in military conflict.[73] Enflo et al. point out the dynamism and importance of innovations for the economy as "[i]nnovations in energy technologies are principal drivers of economic growth."[74] This statement relates back to a supposed direct relation between energy consumption and economic development.

[72] Niele, *Energy*, 107.
[73] Ayres and Warr, *The Economic Growth Engine*, 26.
[74] Enflo, Kander, and Schön, "Electrification and energy productivity," 2809.

As reciting the entire history of science is not the intention of this research, I would like to cut directly to the relevant parts for the chapters to follow. A brief overview of the rise of fossil fuels, as a major stepping stone towards electrification, will initiate this brief chronology of use and inventions.

The structure of the use of energy changed during the process of industrialisation and the increasing reliance on non-traditional energy sources such as fossil fuels and electricity. The pre-industrial world was characterised by the concentration of diffused energy, whereas the industrial revolution initiated a system of diffusion of concentrated energy.[75] Generally speaking, one could identify phases of dominant energies such as muscle and water power until the 1880s, fossil fuel-induced steam power until the 1920s and from then on electricity. None have existed solely or indeed ever ceased to exist.[76]

By 1900 fossil fuels were used by most people indirectly; directly, biomass was the most common deliverer of energy for everyday life.[77] Engineers had mastered the challenge of converting heat into motion, which allowed all kinds of machines to be constructed that did not need an increase of muscular power in order to increase speed or intensity. Plus, it was a vital step towards opening up the transport bottlenecks.[78]

Steam engines enabled production of mechanical energy practically anywhere, which was the first step towards liberty of energy use wherever needed.[79] Internal combustion engines were the next decisive technological advancement, followed by electro engines. Both engine types represented the full potential of exploitation of energy source at that time. Each generation was easier and safer to handle than the previous one and provided easier transport and storage capacities at a cheaper rate than their predecessors. The big commercial breakthrough came with the combustion of diesel and gasoline in engines in

[75] McNeill, *Something new under the sun*, 13; Smil, *Energy in world history*, 161-165.
[76] Nye, *Consuming Power*, 7.
[77] McNeill, *Something new under the sun*, 14.
[78] Wrigley, "Energy contraints and pre-industrial economies," 167.
[79] Smil, *Energy in world history*, 161-165; McNeill, *Something new under the sun*, 13.

combination with Karl Benz' electrical ignition. Essentially, these inventions provided the basis for mass transportation as we know it.[80]

Whereas finding out when electricity was first used for mass transportation is a matter of consulting an encyclopaedia or textbook, determining a distinct starting point of electrification is much more complex and depends on the respective definition of the term (e.g. first experiments, breakthroughs, implementation, scientific or commercial recognition of the technology, etc.). It was a long transitory process with overlaps, periods of stagnation and gradual adaptation. Essential cornerstones of development were definitely the telegraph and the light bulb as well as the electromotor. The most significant developments took place in the middle of the 19th century. This does not mean that the entire population was involved directly in the process. Traditional craftsmen were still outnumbering industrial factory workers to a large extent, but the trend had been set.[81]

One very important aspect when pointing out the competitive advantage of electricity is its application in communication. The most prominent inventions of the early days of electrification, the telegraph and the telephone, shall now briefly be outlined.

5.1. THE TELEGRAPH

A breakthrough in communication came with the invention of the telegraph by Samuel F. B. Morse, who transmitted the message "What hath God wrought?" from Baltimore to Washington D.C. on 28th May 1844. Before that, the most sophisticated system for long-distance messaging were large semaphores sending only the simplest signals from one tower or elevation to another in sight. With the fall of night and bad weather conditions this kind of communication was usually halted. By causing deliberate long or short interruptions in the electricity circuit connecting two telegraph posts Morse and his assistant developed the Morse code. His journey was long and arduous to

[80] Felber, ""La fée électricité": Visionen einer Technik," 105-121; Smil, *Energy in world history*, 167-169.
[81] Crosby, *Children of the sun*, 110; Smil, *Energy in world history*, 192.

start up the project and it took the trained artist years to find enough financiers. Even once the project had been launched it took several decades to expand substantially. 1856 saw the first connection between New York and Washington D.C., another five years later a line between New York and San Francisco was established and after three failed attempts to lay a transoceanic cable from Newfoundland to Ireland, the efforts of engineers prevailed in 1866. Engineers and companies from Britain were highly influential in the underwater cable market and not only worked towards economic profit but also towards political and military unification of the British Empire. Their success came with impacts on the economy, diplomacy, intellectuals, literature and journalism.[82]

In Britain, where private telegraph companies were the main initiators in the network build-up process, the governing bodies issued rights of way alongside roads and railway tracks which fostered competition. The industry was nationalised, though, in 1868 and – like in most other European countries – integrated with national postal services. Tariffs were regulated after competition came under pressure by the UK Telegraph Co. and once the government recognised the military and civil potential by being able to control the flow of information via this medium. Being able to monitor the spread of information is a major advantage and support in administration of countries and companies. Faster news transmission also enables quicker reaction to a problem. Granting rights of way from that point on became obsolete but administration costs kept eating up profits, even after the merger with postal services. Still, the political and military element seems to have overruled the lack of economic efficiency and led to more and more state takeovers of private telegraph and transportation companies in the 1860s and 1870s all over Europe. Immediate military concern on the British island itself may have been lesser than in Continental Europe, but Britain's concern about controlling Irish communication was of utmost strategic importance. Austrian's chancellor Metternich was much more aware of the military potential of the technology and sceptical towards its use for civil purposes, which made him convince the emperor to monopolise all kinds of electrical communication tools already in 1847. The German railway company for instance, got integrated in the

[82] Crosby, *Children of the sun*, 105-106; Smith, *The science of energy*, 269.

administrative state system and was headed by army officials as a sort of civil section of the military.[83]

5.2. THE TELEPHONE

The Morse code, however, took communication only so far. With the patent of the telephone in 1876, applied for by the American Alexander Graham Bell with the aid of Thomas A. Watson, newer and way more sophisticated levels of exchanging ideas and information were in reach.[84]

Years before Bell, a German schoolmaster named Philipp Reis invented a 'telephone' in the 1860s but received little attention by his fellow scholars or the public. Unlike Bell, he had failed to link his invention with a proper application and commercial potential. He demonstrated it only to a scientific audience, which unlike the American or also British one, was not connected to the business community. With the war between Austria-Hungary and Prussia and the following unification efforts, the state was occupied with other concerns. Telegraph systems were controlled by the state, either Prussia or Austria-Hungary and the market for new electrical devices was limited and largely occupied by Siemens.[85]

Bell managed to enthral his audiences because he could convince them his invention was auxiliary for political and social development. An asset Reis definitely lacked was Bell's principal banker and soon-to-become father in law. Originally, Bell had experimented with the visible speech system his father had invented to enable the deaf to speak by having them associate symbols with sounds. Having a hearing impaired daughter, the Boston lawyer and telegraph enthusiast Gardiner Hubbard approached Bell in 1872 and called him as a professor to the University of Boston. He realised the potential of Bell's experiments with sounds over a wire which would try to find a way for transmitting multiple messages simultaneously in both directions of the telegraph connection line. Bell failed at inventing a harmonic telegraph, but in

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[83] Millward, *Private and public enterprise in Europe*, 64-65, 72.
[84] Crosby, *Children of the sun*, 106.
[85] Carlson, "Electrical Inventions and Cultural Traumas: The Telephone in Germany and America, 1860 - 1880," 143-147.

1876 he succeeded in transmitting voice. His version of the telephone was presented to the public at the Philadelphia Centennial Exhibition that year. Hubbard lobbied for Bell's telephone and suggested to extend telegraph posts from only railway stations – the stronghold of Western Union – to post offices to enhance service and accessibility for citizens. Wealthy businessmen were approached to sell them patents and licenses to and form a telephone company.[86]

"Since the telephone was literally in the hands of the user, controlled and manipulated by him, Hubbard felt that the telephone eliminated the evils of the intermediary [telegraph operator Western Union]", which made the network "more personal and democratic." Hubbard hoped the telephone would create a virtual community of a rising middle class.[87]

Simultaneously, communication was disembodied and the telephone facilitated the growth of anonymity.[88]

5.3. LIGHTING

The most prominent appliance of electricity is probably for lighting. Lighting underwent serious efficiency improvements between the year 1800 and 2000, much of it due to the introduction of gas lighting and electricity. For the same amount of money as in 1800 (note: provided figures have been adjusted to inflation levels), four times as much light could be bought only 50 years later. In 1900 the amount rose to 14 times, in 1950 340 times and finally in the year 2000 one thousand times as much light as in 1800. This list simply indicates that gas light became cheaper very quickly. It is mirrored in the consumption statistics of these years, which is measured in lumen seconds (lms) and indicated here in lumen hours (lmh).[89] With a drop in prices, consumption shot up: an amount of 0,0057 million lmh on average were consumed in Great Britain per person in the year 1800. In 1850 this figure had risen to 0,039

[86] Carlson, "Electrical Inventions and Cultural Traumas: The Telephone in Germany and America, 1860 - 1880," 148-149.
[87] Ibid., 151.
[88] Nye, *Consuming Power*, 173.
[89] A lumen second is the unit to measure the amount of energy. It is the product of the luminours flux and time.

million lmh, 1900 already 1,23 million lmh, 1950 saw a jump to 28,6 million lmh and the year 2000 showed a staggering amount of 189,89 million lmh per person.[90]

The gas market came under distress when in the late 1870s the London stock exchange was rocketed by the announcement of the inventions by Thomas Alva Edison. Manufacturers of coal gas feared for their profits and market shares, which soon became a valid concern.[91]

Experiments with electricity that produced bright sparks and glows had been known from the 18th century. After many different attempts and constructions, Thomas Edison's light bulb proved the most successful and was patented in 1880. Competitors with similar constructions of lighting devices (as well as electricity generators) in the end lacked Edison's determination, networking and organisational skills to assert themselves in the scientific contest.[92]

Gas was the main competitor of electric light. The grant of a patent to the light bulb by Thomas Edison was one of the milestones in the process of electrification in 1880. It was remarkable because up until then electric power was not yet a common, solid commodity and it needed a large number of small consumers to boost profitability. The installation of electric light bulbs actually created the initial necessity to install electricity supply in most instances. This, however, was only feasible if the price of electricity was able to compete with that of gas. Marketers of electric lighting systems found it challenging to make consumers spend their income on a variant – if yet superior in many respects – of light energy.[93] Zängl argues that the tariffs for power supply were arbitrary from the very beginning, both because of the competition with gas and other energy supply channels, and the interrelated interests of politicians and entrepreneurs in the electricity business. An example for arbitrary pricing was an agreement between Siemens and AEG which fixed the price of light bulbs.

[90] Sieferle, *Das Ende der Fläche*, 189.
[91] Hellrigel, "The Quest to Be Modern: The Evolutionary Adoption of Electricity in the United States, 1880s - 1920s," 67.
[92] Crosby, *Children of the sun*, 108-109; Smil, *Energy in world history*, 170.
[93] Hellrigel, "The Quest to Be Modern: The Evolutionary Adoption of Electricity in the United States, 1880s - 1920s," 86.

They were one of the few short-term wearing parts and their price had a decisive role in the consideration to switch to the electric lighting system.[94]

Edison knew how to encourage the councils to substitute of gas lamps with his electric light bulbs by modelling them into the same sockets as the gas installations and adding in 1881 an electricity meter, or to be more precise electrolyte meter.[95]

Major assets of Edison's invention were that the light did not dazzle or glare and did not impose a fire threat as it eradicated the open flame problem and was generally cooler than the gas counterpart. Its white light shone about ten times as bright as yellow gas originated light and up to a hundred times brighter than candle light. The electric wires could be bent and laid out at will instead of the more static construction of gas pipes. With the lack of gas the problem of potential explosion was solved, too. Left was the risk of electric shocks and electrocution, but that affected individuals instead of all immediate surroundings (as would have been the case with gas for instance). Another convincing asset of the technology was its convenient transportability. The primary energy source, be it coal, hydropower or suchlike, was converted at the generator site which could be kilometres away from the point of electricity consumption where it was dispatched to through wires and cables. This was the solution to a massive logistic challenge as all fossil fuels had to be physically transported to the consumer. He or she then converted the energy 'themselves' in their gas lamps, coal stoves, etc. Whether it was via train, wagon or pipe, overall it was time-consuming, costly and a sometimes strenuous effort which was substituted by flicking a switch instead. An electric lamp was always ready, constant and demanded no effort once installed.[96]

[94] Zängl, *Deutschlands Strom*, 23-25.
[95] Ibid., 16-17.
[96] Crosby, *Children of the sun*, 108-109; Smil, *Energy in world history*, 170; Nye, *Consuming Power*, 95-96; Hellrigel, "The Quest to Be Modern: The Evolutionary Adoption of Electricity in the United States, 1880s - 1920s," 68.

5.4. SCIENCE, ENTREPRENEURSHIP AND POLITICS

Not only Edison used his entrepreneurial skills and political contacts to promote his scientific achievements. The relationship between politics and technology remains ambiguous and both influence each other to a great extent and in some cases even blend. To a far larger degree than Edison had managed the Germans Werner von Siemens and Johann Georg Halske were active in the political sphere. Together they founded the Telegraphen-Bauanstalt von Siemens & Halske in 1847.[97] Their essential contribution to electrical engineering is the discovery of the dynamo-electric principle in 1866, which, however, had also been claimed by the Englishmen Wheatstone and Varley, and the Hungarian Jedlik at the same time or even earlier. Siemens described the principle of converting electric power into motion without the use of permanent magnets, which is the core principle of a dynamo, thus an electric motor/generator.[98]

Werner von Siemens was not merely an entrepreneur and scientist but also a state agency representative in his position as telegraph officer and project supervisor. Thus, he was able to commission the construction of telegraph lines to a cable producing company that Siemens & Halske held shares of, putting him in a very powerful and profitable position. His company was the official supplier of the German state, therefore also the main supplier to the military, and it was at the core of constructing Germany's telecommunication system. Siemens & Halske also built the first German electric railway and mine railroad in 1879 and 1882.[99]

This marriage of politics and entrepreneurship can be both to the advantage and disadvantage for the public. Construction could happen in a fast and relatively unbureaucratic way, but due to their solitary and powerful position pricing was an arbitrary matter. In such a situation concerns of the population can be largely discarded or ignored.

As much as his political involvement was beneficial for Siemens, on official side he faced some challenges. One of the biggest opponents of electric railroad

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[97] Zängl, *Deutschlands Strom*.
[98] Ibid., 16-17.
[99] Ibid.

construction was the military, which feared total fallout of the railway system in case of disruption of the central electricity supply. In general one could say that European administrators reacted more hesitant towards technological developments than their US American counterparts.[100]

A countless number of mind-boggling statistics about the amount of energy, particularly oil, industrialised nations consume have been compiled. Some figures, though, deserve repetition at this point to set the stage for the complex nature of the energy issues discussed in this paper. For instance, from 1920 to 1940 the production of electric power in Great Britain per person per year doubled from one to two gigajoule.[101] This figure seems small in comparison to one of the most prominent examples of the late 20th and early 21st century: the United States. While being home to only less than 5 percent of the global population in 1998, about 25 percent of the world's energy resources at that time were consumed in the US. An equivalent of 70 pounds of coal is used by one US citizen on average per day; the ordinary world citizen uses – or is able to use – only 20 percent of that sum. Given that the United States relied on 90 percent of that energy to come from fossil fuels, the question of sustainability becomes even more pressing.[102]

What is striking is that between 1978 and 1998 the GDP in the United States increased by 67 percent while energy consumption 'only' grew 17 percent. This could indicate a more efficient usage of resources. That being said, it is crucial to understand that the economy was built on comparably low and also steady energy (and in particular oil) prices which gave it, combined with an encouraging cultural climate towards innovation, a comparative advantage to start with. Problems became more immanent when the point of peak oil was reached in the United States in the early 1970s.[103]

The global oil crisis in the 1973 and 1979 and arbitrary price mechanisms demonstrated which importance energy provision at a supposedly cheap and

[100] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
[101] Sieferle, *Das Ende der Fläche*, 274.
[102] Hinrichs and Kleinbach, *Energy*, 3.
[103] Ibid., 7, 15, 21.

predictable price could have for a system built on reliable and affordable transportation. Proper transportation is an integral part of any functioning economy. One prerequisite for the widespread success of the car and the revolutionary effect it had on transportation was a combination of fossil fuel combustion and electric ignition. Once the car had become a means of mass transportation, the (industrialised) world had become quite a different place. The following section will outline why the advancement of technologies in the transportation sector were of such influence on the economy and society as a whole.

6. Transportation

Electricity played, at first, an indirect role in transportation matters. Before the coming of motorised vehicles, which contained an internal combustion engine with an electric ignition, as well as the electricity powered conveyor belt, electricity-aided transportation can be primarily understood as the transmission of messages via telegraph and telephone. Transportation is an interplay of various kinds of energy (with electricity only being one part) that are all used to facilitate movement. Most of the remarks made about transportation in this chapter relate to energy in the broader sense.

To cover the basics, a transport network presupposes a certain degree of sedentariness of a society and consisted first and foremost of transport within the premises. In agricultural societies, transport was limited to the conditions of a solar energy system, which means using muscle power (walking, animals), gravity (slopes, rivers), wind or water. Factors like "velocity, safety, reliability, flexibility"[104] and others are important next to cost.[105]

Transport is an essential part of the production line of any product. More precisely, it creates a line by connecting the stationary parts of the production process. It depends on several circumstances and conditions such as friction,

[104] Sieferle, "Transport und wirtschaftliche Entwicklung," 30; German original: "... Geschwindigkeit, Sicherheit, Verläßlichkeit, Flexibilität, ...".
[105] Ibid., 2-3, 30.

weather, roads, distance and load, which all influence the cost of transportation. The easier, faster and safer the delivery of any part of the production line can be managed, the lower the cost, which leaves new margins for price leverage, investment or even the incentive to start up producing or servicing in the first place. Transport has a crucial and versatile role, which offers solutions, e.g. being able to sell goods and services outside the home market, and creates new problems at the same time, such as increasing competition from other regions that used to be too remote to participate in the respective market.

For instance, without carrying any goods, a person can cover about 40 kilometres per day when walking. Several relay runners in ancient Greece could accumulate about five times as many kilometres. The same applies to travelling by horse, where long distances are rather covered by several horses in relay or one fast horse for a short distance.[106]

Transport of goods is somewhat more complicated. Cereal transportation was only profitable on short distances because the longer the way the more was needed as food (equalling fuel) for the carrier, be it a human being or an animal, both for the trip itself and the return. Estimates by Sieferle state that over the distance of 50 kilometres 16 percent of a load of 40 kilograms of cereal were needed for the carrier's own consumption; at 100 kilometres that amount increased to 25 percent. The cost also largely depends on the pathway. On average, cereal transportation over land cost 4 kilograms per tonne-kilometre (tkm), on waterways only 1 kilogram and at sea just about 0,4 kilograms. Bulky wood increased those cost levels over land by 40 percent, on waterways by 10 percent and at sea still by 4 percent.[107]

Without draft animals, the construction of proper streets was seldom lucrative. Streets were needed to keep friction of wheels on the ground minimal.[108] More friction meant more energy necessary to cover ground. More energy meant higher costs. The lighter and more valuable a good was and the more urgent the request for delivery was, the more willing were the recipients to pay the extra

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[106] Sieferle, "Transport und wirtschaftliche Entwicklung," 5.
[107] Ibid., 5-9.
[108] Ibid., 5.

cost for overland transport. The extension of the network also enhanced postal and communication services, which in turn were a driving force for improvements.[109]

Once European markets were accessible for extensive food imports from overseas, the Baltic areas and Russian steppes via large and fast steam vessels, food prices worldwide dropped and food provision rose.[110] Friction is less of an issue on water than it is on solid ground, so transportation cost is lower on waterways; however, the logistical problems might outweigh the saved cost on fuel. The major 'disadvantage' of waterways in general is that they can only be complementary to land transportation. Before railroads were a realistic alternative, the transportation of bulk goods was only profitable via water.[111]

After their initial establishment, water ways, streets or postal networks could then be used and extended for electricity-aided transport of messages (telegraph and telephone in the 19th century, radio, computers, etc. in the 20th century), goods and people (cars, trams, metros and other vehicles, most of which were only equipped with electric drives decades after their initial introduction).

The precondition to modern transport was to find a way to convert first heat (i.e. from the steam engine) and later electricity into motion. At unprecedented speed people and goods could be transported where simultaneously reliability and predictability in terms of timing were vastly improved. Compared to traditional ways of transport and travelling like horse-drawn coaches, rafts or sailing ships[112], steam ships and trains were far less sensitive to weather conditions and were more rationally operable. Better transport allowed for regional specialisation and made food import a viable alternative to domestic production.[113]

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[109] Möser, "Prinzipielles zur Transportgeschichte," 81, 86.
[110] Millward, *Private and public enterprise in Europe*, 71.
[111] Popplow, "Europa auf Achse: Innovationen des Landtransports im Vorfeld der Industrialisierung," 81.
[112] A vessel's draught or width ratio became more problematic with heavier and bulkier shiploads and decisions about manoeuvrability and mooring possibilities had to be made in favour of either the former or the latter; Möser, "Prinzipielles zur Transportgeschichte," 49.
[113] Wrigley, "Energy constraints and pre-industrial economies," 167; Wrigley, *Continuity, Chance and Change*, 70-71.

6.1. VIRTUAL SURFACES AND IMPORT SUBSTITUTION

Virtual surface, in regard to transportation, is a term used to describe the amount of land that would have been necessary to 'produce' energy (fodder, food, plant matter, etc.) for animals or humans in order to being able to cover the same distance with an equivalent load. Britain's virtual surface for railway transportation is estimated at 80 000 km^2 in 1890. Qualitative aspects such as speed and infrastructure are being left out of this equation. So in order to substitute the railway, which was primarily powered by means of fossil fuels until well into the 20th century, Britain would have needed over 30 percent of the entire land mass; a figure that exceeded its expendable capacities (note: provided that there are any) in the agricultural sector. Between 1890 and 1912 the rise in transportation of goods is calculated at about 75 percent, from 308 million tons to 520 million tons; that of passengers at roughly 50 percent, from 796 million tons to 1.3 billion tons. This means that just before World War I roughly 120 000 km^2, equalling over 50 percent of the surface of Great Britain, would have been needed as substitution acreage.[114]

As striking as these figures might appear, they gain particular relevance to our prime interest in electricity when considering that as a secondary source of energy which is in many cases generated from fossil fuels. Virtual surface can be acquired either from using concentrated energy of previous times – fossil fuels – or by using other people's land – import substitution.

The example of sailing ship construction demonstrates a case of industrial import substitution. When old, tall, strong trees became scarcer in Britain after extensive deforestation over decades and centuries, constructors of sailing ships from about 1850 onwards turned to Russia and Scandinavia for special construction materials as Britain's forests transformed into young, fast growing monocultures for firewood and building timber.[115]

However, once steel was affordable, which surpassed even the strongest wooden mast in durability, as well as with the advent of other metals of construction

[114] Sieferle, "Transport und wirtschaftliche Entwicklung," 30-31.
[115] Sieferle, *Das Ende der Fläche*, 169.

material, Britain could avoid the issue of timber import for this branch and outperform others with its industrial edge. Particularly during the industrial revolution, developments in transport were closely linked to iron and steel processing which was enabled on a large scale by making use of electricity.[116]

The ships arriving in harbours full of people and goods could be loaded and unloaded with heavy electrical machinery like a crane which considerably speeded up cargo transition to continue the journey for instance via railway. Electricity was an essential part of the development of industrial metallurgy and enabled cost effective ways of energy-intensive metal possessing.

6.2. ADMINISTRATION, TIMING AND COMMUNICATION

Efficient transport is also a necessary precondition to successfully administer countries on a large scale over a long period of time. This entails faster and higher-volume transportation of goods, services and people – particularly the military – as well as information via the telegraph and the telephone.[117]

Transport and communication were relevant tools for governments to promote unity on a social and political basis, so together with the military also the civilian parts of administration were interested in aligning routes and establishing the most efficient and effective network possible to reach and control even the most remote parts of the country. Timing was a central issue that could decide about failure or success of a military operation, so being able to transport messages and people quickly to the people in charge was a decisive element.[118]

By extending the operation radius of the transportation network, further incentives for mass production were provided by multiple consumer potential and access to resource depots, while at the same time overall transportation

[116] Möser, "Prinzipielles zur Transportgeschichte," 121.
[117] Sieferle, "Transport und wirtschaftliche Entwicklung," 34.
[118] Millward, *Private and public enterprise in Europe*, 62.

costs dropped proportionally. As division of labour became easier and more profitable, competition became fiercer in terms of resources and location.[119]

Significant is that improvements in transport apparently worked better or easier in countries with little immediate state intervention, like Great Britain as opposed to France. Britain's railway companies competed for routes and customers, whereas France's lines were in parts nationalised and less flexible to economic demand as their British private counterparts. This does not mean that in Great Britain extension of the network was discouraged by the administration. To the contrary, Britain's officials hoped to gain from desired enhancing effects on the economy and additional state revenue via tariffs and taxes without having to be directly involved and taking on risks.[120]

Transportation played a vital part in terms of colonisation. The colonial endeavours of several (not only European) countries leave little doubt. The conquering of new territories and the logistics behind them are only one small fraction as the real importance of transport lies in the transfer costs of the materials extracted from the colonies. Only when transport was efficient, reliable and affordable, the whole endeavour could become lucrative. The question whether or not the benefit of colonies actually outweighed the cost to establish and uphold them, as well as the definition of cost and benefit has yet to be agreed upon by scholars of that field.[121]

Rationalisation has remained a central point in the sophistication of networks and technology. The aim of rationalisation is practically always to use the smallest amount of energy possible for the functioning of the system. Already in pre-industrial times there were efforts to rationalise transportation by making the means available more professionally, implementing clock frequencies, exploiting economies of scale and providing calculability and reliability as far as possible. Fossil fuel-driven and electrified vehicles, though, surpassed the hardly elastic load limits and marginal utility of a solar-powered system.[122]

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[119] Sieferle, "Transport und wirtschaftliche Entwicklung," 33-34.
[120] Möser, "Prinzipielles zur Transportgeschichte," 59, 126-127.
[121] Ibid., 43-48.
[122] Ibid.

One essential problem with energy and transport in general in pre-industrial economies is that biomass has to be transported from not only far distances at times, but that it occurs scattered in uncountable locations. Immense transportation, both qualitative and quantitative, is necessary to condense the biomass's energy in the one place where it is needed. This also explains part of the very high costs involved. With the advent of the harnessing of fossil fuels which have concentrated biomass within themselves already, it is wise to construct special transportation techniques for these very valuable and energy-dense commodities because a commercial break-even point could be reached far quicker than with any other kind of (bulky) raw material in the strictly solar-powered economy. The transportation ways, once established, could in many cases also be used for transporting other agricultural goods and people. In general, demand for products of the solar energy sector grew alongside the transition towards a fossil fuel economy. They were needed to close gaps in the system the fossil fuel industry could not yet bridge. This related to human labour being indispensable in the production process as well as transportation from a train station to the end consumer per horse or foot which would not have happened before because the good or service would have been out of reach to start with.[123]

When talking about transportation of electricity itself, we are faced again, as discussed in chapter 3, with the issue of entropy and the difficulty of storing it. Getting the right amount of energy from A to B has been a major challenge for engineers, particularly under consideration of economic sustainability. Proper transport facilities enable faster delivery of more goods and services and the construction of more sophisticated buildings. Transport incorporates also the transmission of messages; communication is practically the transport of information. Once you know about a product you can look for ways to get access to it and decide if you would like to buy it – with the cost factor being influenced by the transport system. Transport of people and information about the place you consider visiting, is an essential part of tourism, cultural exchange and social mingling. The whole world becomes somehow accessible. What we now

[123] Sieferle, *Das Ende der Fläche*, 323-324.

term globalisation and urbanisation can start to change the fibre of entire societies.

Transport is an essential but complex system that is indispensable for the functioning of society as a whole. As it penetrates all parts of the economy it is not only a significant cost factor but also an incentive or barrier for trade and communication. The presence and efficiency of the 'right' kind of transportation network is therefore significant and shall be kept in mind and referred to for the discussion section later on.

Following the introductory chapters about the concept of energy, it is now time to investigate the effects it may or may not have on society and the economy. The following chapters will deal with arguments in favour or against claims about the possible influences of electricity in particular as a source of energy.

7. EFFECTS OF ELECTRICITY

In order to come closer to answering the research question the effects that a technology has or can have on the surrounding economy and society need to be investigated more closely. As briefly mentioned in chapter 2, the statements heading the following sub-chapters have been compiled in an effort to identify the common opinions and (mis-) conceptions about the advantages and disadvantages of electricity as a kind of energy in respect to its (potential) effects on economy, society and culture in a broader sense. Granted, the selection is somewhat arbitrary. The criteria for selection were first of all based on the most frequent arguments found in pertinent literature[124] and more general works about the topic, often enough without traceable or reviewable explanation. Secondly, they were targeted towards the issues economy and society in particular. Thirdly, they all are phrased from a positive and affirmative position on the overall question about the causal relationship between energy consumption, economic growth and the betterment of living conditions. The arguments discussed in that subchapter will then be used in the attempt to

[124] see bibliography

either further confirm or raise doubts about the statement in question. It is acknowledged that some of these statements or claims could also be used more generally with the broader term 'energy' or other kinds of energy such as fossil fuels; however, each section intends to explain how electricity is specifically involved in the arguments for or against the statements in question. Beginning with the issue of access to electricity and living standards we will move towards efficiency and influence on production output, manual labour, urbanisation, communication. Economic development and societal change will receive special attention throughout the line of reasoning.

This upcoming section will be particularly concerned with the technologically-induced effects of electricity and its influence on economy and society.

7.1. "ACCESS TO ELECTRICITY CAN RAISE LIVING STANDARDS"

Many scholars as well as common sense have claimed that energy, economic growth and living standards build a causal chain. Presupposing that energy and economic development are intrinsically linked, energy and in this case electricity play a vital role for economic growth. Energy can be seen as an indispensable commodity for which a certain price has to be paid, which makes it an influential part of the economic system. This does not necessarily refer to a defined priced market value but for instance also to the muscle power that has to be invested to harness energy.[125]

According to Enflo et al., who attempted to evaluate this correlation taking the example of Sweden, "electricity consumption and energy productivity are non-stationary[126] variables in all industries". They detected the largest long-term statistical connections in sectors where electricity was used in manifold ways – production of machinery and chemicals. Electricity seems to have a driving characteristic for productivity as opposed to merely reacting to the challenges in the production process. It proved to be more powerful and dynamic according

[125] Smil, *Energy in world history*; Crosby, *Children of the sun*.
[126] "non-stationary" refers to variables that react to shocks permanently and have a time independent statistic mean, variance and covariance; Enflo, Kander, and Schön, "Identifying Development Blocks - A New Methodology," 62.

to the statistic than its fossil fuel competitors when looking at productivity figures and it apparently leads to a restructuring and rationalisation process.[127]

Enflo et al. have thus tried to isolate electricity as a special source of energy and its potential influence on the productivity in different sectors of an economy. They found it to be of great significance which supports the more general statement about energy in a broader sense by Beaudreau who outlined the positive influence on economic growth: "[E]nergy is the source of all rents[128] (surplus). One could define these rents as the difference between total potential energy as represented by the available food in any given year, and the energy required to sustain life in that year. Any surplus could then be used to generate more wealth, say via better nutrition, and the resulting increased physical (muscular) effort."[129] This essentially means that whatever amount of (useful) energy is left in one year after all basic needs have been covered counts as surplus which can be invested to create prosperity.

"By netting out the cost of energy (extraction, transportation, distribution, etc.), one obtains aggregate gross domestic product (gross national product). It follows that to increase income (material wealth) a society must generate additional energy rents, which ... implies increased levels of energy and organization (as factor inputs)."[130] In other words, any kind of (economic) surplus, which is necessary to create wealth, is only available via the increase of energy influx. Today, the Global Footprint Network is trying to calculate how much biomass nature is able to produce in one year and confronts that figure with all the energy used up in the same period to see when we exhaust our resources. Earth Overshoot Day, being 21st August in 2010, marks that day after which humanity reverts to other sources of energy than biomass to cover its demand.[131]

Before we proceed, the term wealth which is intrinsically linked with an improvement of living conditions deserves clarification.

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[127] Enflo, Kander, and Schön, "Electrification and energy productivity," 2813-2814.
[128] In this case, the term "rent" refers to added value and profit.
[129] Beaudreau, "On the Creation and Distribution of Energy Rents," 73.
[130] Ibid., 74.
[131] Global Footprint Network, "Earth Overshoot Day."

7.1.1. MATERIAL WEALTH

That leads us to the question of the definition of wealth. Money itself is just a trading certificate that allows the possessor to accumulate goods and make use of services. Both will be summarised under the term material wealth which has a cultural and social character.

Material wealth is by Beaudreau referred to as "the aggregate value of all material transformations."[132] When material wealth is socially connoted with happiness and success, and it is connected with the amounts of energy available, one could easily assume an increase in energy consumption will lead to an increase in material wealth and thus the level of contentment. The complexity is that the definition of what is considered a basic necessity for happiness is subject to change in a society and the availability of the 'right' kind and amount of energy it is not equally distributed for varied reasons.

Over the course of time, society's parameters of what one needs to be wealthy (and by this also successful and happy) changed. Luxuries became every-day commodities and to keep up your status and to keep up life quality in comparison to others, more and more energy was needed to satisfy the increased demand. Those who were in charge of energy access and distribution thus held a powerful position within society.[133]

Electricity boosted demand and use of energy in many cases instead of just satisfying needs. Standards of satisfaction change over the course of time and are raised to higher levels if wealth (presuming it is generated by higher energy consumption) is more widely spread. Thus, it is not possible to revert to a previous level without failing to meet these higher standard demands. On top, population growth intensified demand either way as more people simple require more energy. The power-relations in energy politics will be dealt with in more detail in chapter 7.7.

[132] Beaudreau, "On the Creation and Distribution of Energy Rents," 74.
[133] Nye, *Consuming Power*, 183.

It remains an unresolved question if wealth is intrinsically limited in this world or if it can keep growing indefinitely. This question shall be dealt with primarily in philosophical debates, but yet it is good to keep it in mind when talking about how to increase wealth and improve living standards as different methods would be needed in both scenarios. Is there something like a fixed amount of wealth (equalling a fixed amount of energy) of which everyone tries to get a bigger piece at the expense of the weaker members of society or can wealth simply be increased to satisfy a growing population with more material wants and equality is thus only a matter of fair distribution? The latter presupposes that energy as such is an infinite resource, which contradicts today's scientific stand of having an overall constant amount of energy available for conversion (see definition of 'conversion' in chapter 3).

When defending the former, you would need to discover ways to make do with the resources given, find technical solutions to exploit energy sources to the maximum (granted, every economist eventually strives towards highest possible efficiency) and rely on politicians or the markets – depending on your ideological stance – to allocate wealth. This would basically mean making use of the available energy sources in the most efficient way possible. The focus would eventually be on improvement of services instead of accumulation of material goods to acquire higher living standards.[134]

Ideologically, electricity could be regarded as a utopia which by technical means had the potential to overcome the divide between rich and poor the (factory-) industrialisation process had partially created and made visible. Electricity was supposed to help level out the social disparities and hygiene issues of an industrialised mass economy by being a more just, versatile, clean, user-friendly and accessible source of energy.[135]

A race not only for survival but also status had been triggered by the dynamic gap between the poor and the rich. Yet, this struggle for betterment in comparison to others can be fruitful only when social mobility is possible in

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[134] Melosi, "Energy Transitions in Historical Perspective," 12.
[135] Schott, "Elektrizität und die mentale Produktion von Stadt um die Jahrhundertwende," 225.

principal, as opposed to life in a caste system, and differences can be overcome by own initiatives.[136]

7.1.2. Location of settlements

Wealth is not only a matter of 'what' but also of 'where'. Resources have always played a fundamental role in the location of settlements. Depending on the energy mix needed for subsistence, whether it is an industrial plant or a residential town, those areas with the most resources with the comparably smallest extraction costs were at an advantage.[137]

In traditional societies this regards first of all land fertility, availability of water for drinking, energy generation and transport, and woodland for heating, cooking and constructing. Hence, geographical aspects matter, particularly when pressure on all these land-based resources grows with an increase in population. A convenient example for geography as potential facilitating factor for economic development is Britain's usage of waterways. "In effect, with energy demands increasing and the availability of water power being in inverse proportion to its cost, English entrepreneurs had three alternatives: they could move to areas where there was less competition for water, stay where they were but pay more for their water rights or decide to switch to steam power."[138] The historic impact of Britain's decision to change the energy structure and bank on new technologies does not need to and will not be covered in detail here, but it is vital to understand the circumstances that led up to that point in order to investigate its potential effects on economic, societal and political development.

Furthermore, the perceptions of distance and time were subject to change in an industrialised setting. The day became scheduled along different time lines than those of sunrise and sunset. Automated clocks divided the day in precisely separable time frames, standardised social time and turned work days into work shifts. Trains followed an ever more rigid schedule and crossed distances at unprecedented speed and predictability of duration. Electrified trams also

[136] Sieferle, "Transport und wirtschaftliche Entwicklung," 24.
[137] Ciriacono, "Hydraulic Energy, Society and Economic Growth," 20-27.
[138] Ibid., 27.

accelerated local public transport. The same applies to communication via telegraphs and telephones. The concentration and professionalisation of municipal power plants and water supply systems made delivery of electricity, gas and water more reliable and enabled predictable production and consumption opportunities. At the same time electric motors granted small producers and craftsmen certain flexibility. Time delays between centralised electricity generation and decentralised consumption was practically inexistent, which in itself was a characteristic of that kind of energy and imposed the problem of storage in case of differences between higher supply than demand.[139]

Even though industrialisation processes enabled to explore a wider range for gathering resources, location still mattered. The connection to marketplaces, information and transport networks became even more important with the shift from subsistence farming towards wage labour – an issue that will be tackled in the following sections.

7.1.3. THE INDUSTRIAL REVOLUTION AND BEYOND

The industrial revolution and the structural change of economy it sparked deserve special mentioning at this stage as its role for a (potential) change in living standards is crucial. At the wake of industrialisation, energy sources of several millennia were at hand for customers. This means that they had access to more energy than the amount of total production (primarily deriving from direct solar power) of one year which also meant that now more resources or material wealth could be distributed. It was up to society to divide up the potential wealth amongst its members. In general, all groups could profit from the provision of an overall vastly increased amount of energy, either directly or indirectly. Some more proactive and influential pressure groups managed to seize a bigger share than more passive ones. As the increase of energy was so much larger than before (we are talking thousands and millions of years in comparison to one year's crop yields; no matter how good the harvest was and how efficient the land was worked, it would just not come even close to

[139] Gugerli, "Modernität - Elektrotechnik - Fortschritt: Zur soziotechnischen Semantik moderner Erwartungshorizonte in der Schweiz," 54-55.

matching this energy potential), inequalities appear on a much larger scale and social problems materialise.[140]

An important development that started to transform entire economies was the shift from subsistence farming towards wage labour. Increased specialisation changed the energy input and labour output ration. Electricity as a very energy dense production factor has, together with fossil fuels, one of the highest output ratios if efficiently and effectively applied in the production process. “Energy deepening, defined as an increase in the energy/labor and energy/capital ratio increased the overall level of energy rents [referring to surplus], over which the owners of labor and capital (organizational inputs) bargained. The result was higher real wages and real profits, as organizational inputs (labor and capital) appropriated the resulting energy rents.”[141] Only when high per capita output levels result in real income rises throughout the economy, they will have a transformational and lasting impact.[142] This paradigm refers to energy influx on a larger scale and not only electricity, yet considering electricity’s particular characteristics in terms of energy density and versatility, an increase in surplus and profit for the enterprise itself and potentially also the individual labourer becomes more likely. It was not only an increase in energy itself but its output levels per labourer or per capital investment (machines, organisation, etc.). If machines had better quantitative output ratios and qualitatively could perform the same or equivalent task as well as tasks which a human being is incapable of, they became preferable work forces – which does not automatically mean that labourers were replaced at once with machines or reassigned different tasks.

In spite of beneficial effects for some labourer groups, unemployment rates particularly in the early stages of wide-scale electrification in Western Europe and North America in the mid- and late 19th century rose and thus household income was reduced considerably for the ones affected by layoffs.[143] Adjustment to the changed setup of the economy took its time and toll on the people not

[140] Wrigley, “Energy contraints and pre-industrial economies,” 168.
[141] Beaudreau, “On the Creation and Distribution of Energy Rents,” 80-81.
[142] Wrigley, *Continuity, Chance and Change*, 82.
[143] Zängl, *Deutschlands Strom*, 77.

able to adapt quickly. During times of economic depression, the existence of a mass consumption culture and energy-intensive standards of living was difficult to grasp.[144] By the early 20th century, living standards had changed and poverty was thus redefined. Thousands of labourers were made redundant by substituting their labour force for mechanised electricity, which correlates with the increase of electricity consumption during the Great Depression when production surpassed consumption capacity.[145] For the post-World War II-era, Beaudreau detected a close connection between energy consumption and income growth per person, particularly in relation to electricity consumption.[146] Chapter 7.3 will examine the effects of technology on the human workforce in more detail.

One must not forget that the traditional economy was not simply replaced by an industrial economy; rather, both were overlapping and evolving structures of society.[147] Neither was there such thing as an absolutely liberal market economy with all consumers equally informed and technologies fairly accessible.[148] The white-collar power domination within the energy structure excluded those unable to fill high-ranking positions for whichever reasons and promoted societal segregation as well as geographical isolation.[149] For the poor, electricity remained a luxury. Most Americans were unable to afford electricity for their households well into the 1940s.[150] However, initiatives were taken to not exclude them from the technological advancements. This happened probably less out of purely altruistic reasons and rather to keep a broad base of customers. One of the German models was an electricity meter which operated by upfront payment with coins, which provided a risk-free alternative to an invoice at the end of the month for both the customer, who could not control exactly how much electricity he or she was consuming, as well as for the provider, who could be sure to have the bill covered.[151]

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144 Nye, *Consuming Power*, 183.
145 Ibid.
146 Beaudreau, "On the Creation and Distribution of Energy Rents," 75.
147 Wrigley, *Continuity, Chance and Change*, 28-29.
148 Nye, *Consuming Power*, 10.
149 Ibid., 209-210.
150 Rose, "Getting the Idea Out: Agents of Diffustion and Popularization of Electric Services in the American City, 1900 - 1990," 227.
151 Zängl, *Deutschlands Strom*, 96-97.

What was so distinctive about the legacy of the industrial revolution altogether was its transformative dynamic which resulted in a continuous increase of real income per capita in the long run. This was the precondition for wealth accumulation because it kept lowering expenditure for food and the need to work in agriculture, provided population growth did not exceed profit levels. The fundamental issues, that sparked social, political and economic controversies was what people actually used the extra money for and what was supposed to be defined as 'useful' or 'appropriate'.[152]

A couple of examples will now outline how different regions carried out the process of industrialisation in order to see which specific energy-related challenges they had to cope with.

7.1.4. REGIONAL EXAMPLES

Taking a step back and looking more closely at the circumstances in different industrialising regions in the 19th and early 20th century might paint a clearer picture of the energy structures available that ultimately led to the adaptation of electricity at a certain point in time.

Looking at the bigger picture of industrialisation, other countries than Great Britain took quite different paths towards industrialisation. A simple imitation of the British way was mostly neither feasible nor necessary, depending on the structure of the political economy or the prevalence of industrially useful natural resources. Steam was a problematic driving force for engines in arid areas with unsteady or little access to water.[153] Britain concentrated on the textile industry, while Belgium's focus lied more on metallurgy; France used its hydro-energy potential for instance by constructing hydroelectricity plants along its streams; America and Russia at first exploited their extensive woodlands for more energy supply and Japan made up for its lack of coal fields with industrious work ethic and distinct craftsmanship. Sweden lacked fossil fuels, but could use its water power to generate electricity alternatively.[154] Steam

[152] Wrigley, *Continuity, Chance and Change*, 9-11, 33-34.
[153] Nye, *Consuming Power*, 252.
[154] Enflo, Kander, and Schön, "Electrification and energy productivity," 2809.

and coal as such were neither new nor particularly uncommon in other areas than Great Britain and even there they were utilized to generate heat and motion at an ever growing rate only slowly. Each step forward in technological development was one towards greater reliability and efficiency, allowing manufacturers to broaden and accelerate the industrialisation process at the same time. In order to keep up this progression, the domination of fossil fuels was ever more unavoidable. This does not mean that without fossil fuels a country could not have industrialised, it rather refers to the speed of the process that could not have been kept up otherwise.[155]

For example, the United States saw a decline in proportional expenditure on food stuffs from 67 percent of income to 43 percent between 1860 and 1900. Obviously, not all of it can be attributed to energy-related economic changes, but the quick and drastic change is significant and it leaves us with the question what the new difference was spent on. Among the growing choices were improvements in lodging, transport, apparel, entertainment and luxurious goods.[156]

Concerning lodging, living in a house with electric wiring, light and appliances as well as connecting it with sewer services meant spending about 25 to 40 percent more on rent or purchasing in the late 19th century United States city. Eventually, tenants had little choice as not only owners sought to raise market value of their property but official regulations and public notion of health and safety hazards of old-fashioned housing made upgrades mandatory. This facilitated and accelerated the expansion of city limits towards consolidation of suburban areas with the centre in order to profit from modern conveniences. Furthermore, this added to the competitive advantage of technology service providers as cities became more compact and population figures and density were on the rise. Simultaneously, it created a widening gap between the population in more remote areas and city dwellers as service provision in the

[155] Smil, *Energy in world history*, 193.
[156] Nye, *Consuming Power*, 96.

countryside was rarely economically feasible and so incentives had to be provided to suppliers in order to make services available.[157]

Another example for early industrialisation are the Netherlands. The Dutch used their geographical position in combination with technological, organisational and economic skill to their best advantage particularly from the 17th century onwards. Passenger canals lowered transportation costs considerably and especially in the 17th and 18th century they made up for their lack of coal by using peat as a thermal energy source. In terms of energy density and burn temperature, peat is positioned inbetween firewood and coal. All this led to industrial and economic growth, but this path was not sustainable in order to keep up the front runner position once the British coal mines were commercially exploited on a large scale.[158]

Again, what has this do with electricity? The prime example is the use of turbines, generators and eventually electro motors. Electricity offers the unique option of being able to convert to another kind of energy, kinetic energy, but also back again into its 'original' form, so to speak. Granted, depending on the sophistication of the process, a certain amount of entropy will always occur due to conversion losses. All of the devices to produce or convert electricity rely on a primary energy influx to function. Whether it was a waterfall powering a turbine or coal burning at high temperatures to heat water for steam to move it as well as other examples, all energy sources need to be readily available, at best in abundance and cheaply to be converted into electricity at a competitive price before extensive electrification and change of a production process makes economic sense.

Nye points out that electricity did not inevitably lead to mass production.[159] Just like him, I fully agree with the facilitating characteristic of electricity in the production process. Yet I definitely do not defend a deterministic stance where electricity is looked upon as a central cause for the changeover in the mode of production and the trend towards standardised bulk production and

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[157] Nye, *Consuming Power*, 92, 98.
[158] Wrigley, *Continuity, Chance and Change*, 113-114.
[159] Nye, *Consuming Power*, 139.

(corresponding) mass consumption. Going a different path relying only on biomass and fossil fuels was possible, but it was simply more difficult. If a producer relying on traditional energy supply faced a competitor who used electrically driven tool, machines or devices, economic survival was, in the long run, a matter of intense effort. From all evidence collected, the likelihood of electricity having a major influence on standardisation processes and efficiency enhancement is affirmed. It created a more predictable work environment. The technological developments that emerged with electricity as a source of energy changed whole branches of industry and the structure of economic interaction.
By the increase in output numbers and productivity via automation and acceleration of work processes, standardisation and improvements of efficiency, the production surplus could be increased, traded and the (potential) revenues reinvested for further enhancements. The higher output reduced unit costs but also sales prices due to increased competition, which in turn left the consumer with a bigger share of his or her income at the end of the month.
Electricity enabled a change in the mode of production and the organisational setup of an enterprise.

Worth mentioning is the fact that being connected to the electric system does not necessarily mean using it for many different purposes. The starting point for wide-spread electrification was definitely the substitution of gas light facilities in the late 19th and early 20th century with electric light bulbs. The real breakthrough for electrical appliances came only after the First and Second World War with all kinds of affordable household devices driven by electric power. Electricity providers combined production with the creation of new wants.[160] The companies who had managed to not only produce electricity but also develop electricity consuming equipment, be it a refrigerator, a radio, an electric stove, telephones and so forth, had huge incentives to increase consumption once an industrial saturation level was coming closer. For example, 90 percent of Austrian households in 1950 were equipped with an electric power connection, but they accounted only for 9 percent of entire consumption. Thirty years later this figure had climbed to 23 percent and

[160] Tetzlaff, “Vernetztes Denken?,” 21-23.

altogether total consumption of private households saw an increase from only 2 petajoule[161] to 33 petajoule.[162]

Household appliances were generally used to alleviate the daily chores such as heating, illuminating and preparing or storing food; but also before the introduction of the electric stove significant improvements in the production of foodstuffs had been driven by electrification.

7.1.5. FOOD INDUSTRY

The coming of electricity driven industries had a lasting impact on the food industry, which is a term inseparably connected with the achievements of industrialisation. The mass production of cheap cans due to advancements in metallurgy enabled by electric power made canned food widely available.[163] This brought an aspect of diversity to the diet as food could be preserved and transported more easily.

At first cans were crafted by hand from other alloys, on average 200 to 400 a day, but the manufacturing could easily be mechanised with the introduction of aluminium in the industrial process. In 1883 30 000 cans could be produced in a single day by a machine that was operated by twelve unskilled workers. A precondition was standardisation of the can itself as well as its content and advertisement along its distribution lines.[164]

Soon, though, canned foods faced competition from the development of electrically driven cooling techniques. Even though it took several decades for household size refrigerators to become widely affordable, commercial operations started in the 1870s in the United States.[165] This was a major contribution to the improvement of living standards. Perishables could be stored over several days, improve diet composition and food quality, and

[161] 1 petajoule equals 10^{15} joule
[162] Sieferle, *Das Ende der Fläche*, 279.
[163] See chapter 7.2.3 for further reference
[164] Nye, *Consuming Power*, 117-118.
[165] Ibid., 118.

reduced the time and money that had to be spent on food shopping as bulk purchases were made feasible and lucrative.

Because decent food storage and transportation became possible and affordable for the individual, new impulses were given to agriculture to enhance diversification of produce and further spoilage reduction. Agriculture and use of biomass thus changed their character.[166] Imports – facilitated by faster, mostly fossil-fuel driven transport – secured provision of staples in case of crop failure. This did not fully prevent famines but definitely lowered the risk. Simultaneously, people tended to need fewer calories in general as the hardship of physical labour was gradually taken over by machines and the improved heating facilities aided the body to keep up its comfort temperature.[167]

Noteworthy is, that all these developments led to improvements in urban households primarily. Prices for farm products declined with agricultural overproduction and food preservation that led to the elimination of local reliable markets and enabled the middle-men to take the largest margin of the profits.[168]

The advancements in the food industry which have been aided by technological achievements in electricity had overall beneficial effects on living conditions as the possibility for more variety of diet and a more steady and generally higher provision of foodstuffs influenced the health of individuals positively.

7.1.6. HEALTH AND SAFETY ASPECTS ON HOUSEHOLD AND INDUSTRIAL LEVEL

Electricity has characteristics that have different impacts on nature and the people around it than more tangible kinds of energy like fossil fuels. For example, electrical light was not only brighter than gas light, it also lacked the unhealthy fumes and reduced the fire hazard as there was no open flame. The

[166] Sieferle, “Transport und wirtschaftliche Entwicklung,” 26.
[167] Nye, *Consuming Power*, 120.
[168] Ibid.

same also applies to cooking with electric heat. Soot, smoke, dust, the carrying of coal and wood were all substituted for a small regulating button.[169]

New problems were potential electric shocks or electrocution and short circuits with cables or wires catching fire. Yet, the alternatives were gas pipes that could either explode or just leak and poison the resident like a broken coal furnace could, too, and steam or water lines that bore the risk of bursting. Each technology came with its own challenges and the more sophisticated and user friendly the system, the more consumers relied on specialists for installation, maintenance and repair work.[170]

Health is related to wealth and with better health a population rise could be expected. The government became increasingly responsible for the health and safety of its citizens.[171] Successes in combating diseases, additionally, lead to higher life expectancy and a better health status which generally is reflected in an increase in population.[172] However, the energy-induced sources of wealth did not spark a tremendous increase in population figures. People still got married, but had fewer children which left them again with more income to spare.[173]

Particularly health and convenience aspects seem to have been positively influenced by the implementation of electricity as a source of energy. Heavy and repetitive labour could be eased and/or taken over by machinery which relieved the physical exertion of workers. It was an accelerating input factor that boosted competition amongst workers and machinery which left some labourers in better economic and physical shape and sidelined others in redundancy. The following subchapter will take a closer look at the effects technology had on population development on a larger scale.

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[169] Zängl, *Deutschlands Strom*, 69, 71; Plitzner, "The Amazing Magic that Lives in a Wire," 88-89.
[170] Nye, *Consuming Power*, 96.
[171] Ayres and Warr, *The Economic Growth Engine*, 43.
[172] Sieferle, *Das Ende der Fläche*, 334.
[173] Wrigley, *Continuity, Chance and Change*, 89.

7.1.7. EFFECTS ON POPULATION DEVELOPMENT

In pre-industrial times, agricultural success and population figures were closely linked. If, by whichever means, output could be increased, eventually population would quite literally eat up those profits, meaning that more people would match the increased food availability. With the new gains and the restructuring of the economy towards industrial labour and service provision, employment in towns and professions outside agriculture in the countryside were on the rise. This furthered the ongoing economic restructuring process. Precondition was that the revenues from intensified and mechanised agriculture would not simply be divided amongst the agricultural population, but that profits were preserved and reinvested to create ever more profit. The cultural background must agree to this unusual process in order not to relapse into the traditional system.[174]

By making use of fossil fuels and electricity, for the first time and over a long period of time "production could outpace population."[175] The new technologies and energy sources enabled an (at least temporal) escape from Malthus' land restrictions, allowed for widening social disparities, and now that poverty was a fate one was able to avoid, it developed into an actual problem.[176]

Population growth develops (also) through economic expansion. Provided there is a limited amount of energy available, energy shortages are unavoidable. The only means to combat this shortage is, according to McNeill, by exploitation of people (slavery) and environmental degradation.[177] Sieferle repeatedly refers to the usage of borrowed time and land when he explains the escape from land restrictions by turning to fossil fuels as energy source to meet demands.[178] Pomeranz is strongly convinced that coal and colonies were the answer to energy shortages by the British that eventually gave them a (temporal) advantage for economic expansion in comparison to other parts of the world, in particular China.[179]

[174] Wrigley, *Continuity, Chance and Change*, 36-37.
[175] Ibid., 90.
[176] Wrigley, "Energy contraints and pre-industrial economies," 167.
[177] McNeill, *Something new under the sun*, 7-12.
[178] Sieferle, *Der unterirdische Wald*.
[179] Pomeranz, *The Great Divergence*.

Opinions are manifold and debate is far from over. A tendency by scholars[180] of that field towards problem solution outside the national boundaries (import, colonisation) and the usage of fossil fuels and eventually (their conversion to) electricity can be detected, if yet they are often just one part of the arguments provided for economic growth next to cultural and structural reasons.

In terms of electricity's more direct effects on population development the arguments collected are applied in more general terms of energy as a holistic concept that incorporates all kinds of (useful and accessible) energy. Therefore, no substantiated clues can be provided thus far.

"The move along the spectrum from traditional to modern may also be pictured in other terms as from *Gemeinschaft* to *Gesellschaft*, or from feudal to capitalist."[181] A sense of individualism can also be attributed to the change in economic structure. Life away from family-run land and business implied less immediate dependence on kinship. Men and ever more women were to fend for themselves in factories and service enterprises. Until the state was willing and able to take over certain tasks of the extended families and the church in case of severe economic deprivation, the burden on the individual was sometimes even increased. So the system-induced 'independence' came with chances and risks alike.[182]

The utilisation of electricity on a macro level, as one aspect of the use of non-traditional energy sources, offered members of a society at the least the potential of a betterment of livelihood. Once access to electricity was provided, its manifold application opportunities could alleviate certain chores of daily life that could be automated. It contributed to the change of structure of energy economics towards further rationalisation and enhancement of efficiency – a topic that will be examined in more detail in the following chapter.

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[180] See works by K. Pomeranz, R.P. Sieferle, J. McNeill, I. Wallerstein or A.W. Crosby
[181] Wrigley, *Continuity, Chance and Change*, 101.
[182] Ibid., 119-120.

7.2. "ELECTRICITY INPUT LEADS TO HIGHER EFFICIENCY AND PRODUCTION OUTPUT BY BEING ADVANTAGEOUS OVER OTHER KINDS OF ENERGY AND OPENS UP NEW MODES OF PRODUCTION WHICH ENABLE AND ACCELERATE STANDARDISATION AS A PRECONDITION FOR ECONOMIES OF SCALE"

For demonstrating the general advantages of this distinct source of power, I can do no better than quote Vaclav Smil's description: „Only electricity offers the following combination: instant, effortless consumer access; ability to step into every consuming niche and be converted into motion, heat, light and chemical potential with unmatchable control, precision, and speed; silent, clean (at the point of final conversion), and extremely reliable individualized delivery; and capacity for easy accommodation of growing or changing uses. And this energy can be produced from a wide variety of (often inferior) fuels. Its conversion to heat can be accomplished with nearly perfect efficiency, it can provide temperatures higher than combustion of any fossil fuel, and its utilization requires no inventory."[183] Electric heat wears out material slower and to a lesser extent and can be regulated more easily, just as electricity as such is a more predictable and reliable source which allows for a steadier work flow.[184]

Concerning inventory, electricity obviously needs appliances and power outlets but the original conversion of the primary fuel into electricity happens by and large not in the facility where it is consumed and therefore limits the converting devices to the ones transforming electricity into its final form for usage.

Zängl speaks of further economically relevant attributes as electricity represents the "ideal homogenous product". The product is identical anywhere in the world and thus not subject to quality fluctuation. At the same time, it can be easily regulated and monitored, and offers instant transportability along clearly determined routes which became increasingly monopolised with the spread of the technology.[185] Last, but not least, electricity has a high energy density and is silent and clean at point of consumption.[186]

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[183] Smil, *Energy in world history*, 201.
[184] Nye, *Consuming Power*, 142.
[185] Zängl, *Deutschlands Strom*, 42.
[186] Smil, *Energy in world history*, 169-171, 191.

Electricity granted a certain freedom of location and movement of machinery with such high precision other power sources were unable to provide. It made better lighting and ventilation available. Nye estimates that it could account for a 20 to 30 percent output increase while amounting to just about 1 to 3 percent of overall budget.[187]

Ventilation by means of electric fans was far more efficient at ensuring purer air for both workers and machinery. Malfunction due to dust congestion was a serious problem in particular with electric machines as their accuracy and general functionality allowed for less tolerance in this respect.[188] Having a solution at hand that was driven via the same power grid made initial concerns disappear quickly.

Simply having a seemingly abundant energy source initially is not as valuable as one might be led to believe. Coal, for example, had been known for centuries before, but it could 'only' provide thermal energy, however at much better rates than alternative sources. Usage was limited to a small, regional radius around the mine. The relevance of an energy source lies not in its mere presence; it is evaluated by whether or not it triggers an effect.[189] Even though coal was already a significant step in terms of energy conversion efficiency from all kinds of wood, hydrocarbons and electricity are yet more efficient.[190] It was the invention of a technique to convert its potential to mechanical energy that set off the fundamental changes in the economic structure. The same applies to electricity. Experiments with electrical currents have long predated the actual implementation of economically feasible devices.[191]

Additionally, the development of technological systems requires a certain intention behind it by the promoting agents. Gaining a competitive advantage can be identified as a major incentive for innovative energy systems.[192] Once

[187] Nye, *Consuming Power*, 141.
[188] Ibid.
[189] Ibid., 171.
[190] Smil, *Energy in world history*, 187.
[191] Wrigley, *Continuity, Chance and Change*, 90.
[192] Nye, *Consuming Power*, 9.

practical conversion techniques and appliances had been initiated, electricity's full potential could materialise.

Distribution of the technology grew in particular with refinements of the devices and the system itself, as well as with increased pressure on limited alternative sources such as fossil fuels. This also involves a certain time lag between the implementation and statistical results because of circumstantial factors such as stabilising energy supply and according reorganisation of the production process.[193]

7.2.1. EFFORTS TOWARDS EFFICIENCY

The pursuit of more efficiency itself was nothing unusual or revolutionary. Already in the times of agricultural intensification leaps in efficiency were accomplished, however, all efforts were eventually bound to reach an equilibrium status with diminishing returns that restricted them to the amount of land available and the time and energy expendable to work the land. Each new step forward made the next one even more difficult, in contrast to a fossil-fuelled and electrified economy.[194] By maximum optimisation, standardisation and reorganisation of labour input, often at the expense of accelerated work paces and higher demands on each individual, productivity was increased along with reducing unnecessary power expenditure also to the benefit of the worker. This method, nevertheless, eventually reached a ceiling that could only be lifted by a power influx outside the muscular capacity of human beings and animals. Even with the addition of wind and water power, which was merely an exchange of one mechanical force with another, the actual problem was simply lifted to a higher level allowing the traditional mode of production to remain for a longer period of time. The transmission of mechanical energy (e.g. via carrying half-finished products or overhead shafts) was still the same such as the setup of the factory. In spite of high frictional losses and difficulty to regulate the intensity of

[193] Enflo, Kander, and Schön, "Electrification and energy productivity," 2809.
[194] Wrigley, "Energy contraints and pre-industrial economies," 158; Wrigley, *Continuity, Chance and Change*, 29-30.

the power, if one transmitter was defect the entire production line came to a halt.[195]

Electricity was able to change that. It was the amplifier in a world that longed for better gradation, easier distribution and more intensity of prime mover power. Unit drives were built to be driven electrically, which allowed more manoeuvring space in case of failure of single machine groups.[196]

New and improved materials brought about constant price reductions and machine efficiency enhancements. Particularly improved electro-conductive alloys are worth mentioning in this regard. Also, the connection between power plants, smelting works, waste incineration plants and the usage of exhaust steam brought efficiency enhancing effects.[197]

Efficiency is a particularly pressing issue if the resources or production factors such as energy provision are very scarce and/or expensive. Given that electricity counts as secondary energy, the question of which primary energy source is used for being converted into electricity is of major importance when talking about sustainability. In general, electricity has the advantage of being practically infinite and reproducible, but the characteristic of the primary source might be contrary. Becoming ever more dependent on fossil fuels to be converted to electricity imposes major threats to sustainability of modes of production and entire economic processes.

Resources may be unstable, inefficient, scarce or limited in use or conversion, which gives electricity per se a certain advantage.[198] That being said, the advantage is given that electricity could be produced from various primary forms of energy, depending on availability in the respective regions and their technological possibilities concerning conversion. It can be converted from fossil fuels, like in Britain in the 19th century, or water in Scandinavia where coal was in short supply. France in particular made use of nuclear power to meet its

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195 Smil, *Energy in world history*, 194.
196 Crosby, *Children of the sun*, 102; Smil, *Energy in world history*, 194.
197 Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
198 Smil, *Energy in world history*, 206-211.

electricity need in the 20th century and has continued to do so until today. Considering, though, that electricity is converted – always with a loss – from another source first, the efficiency equation might look different. The difference is that once electricity is produced primarily outside the factory in a centralised plant, the losses are counted in the electricity plant but not at the factory or the consumer directly, thus painting a more efficient picture at its final point of conversion in addition to its other advantages mentioned at the beginning of the chapter. Enflo et al.[199] refer to this phenomenon as book-keeping effects. Especially in the beginning of the 20th century a trend towards centralised electricity generation became more evident.

Whichever primary fuel was eventually used, Millward found that even in 1898 80 percent of electrical installations were estimated to be used for self-consumption of the electricity manufacturer and not by the purely consuming part of society.[200]

Energy itself is always an investment. The investment of energy is needed to extract, harness and convert more energy. The process of energy 'production' practically feeds itself. This makes energy a viable cost factor as it is resource and profit at the same time, regardless of its shape, composition or direct usability. So going back to the initial question of efficiency and comparable advantage of electricity, one has to consider that efficiency figures will be comparably better than those of biomass or even fossil fuels if taken after the initial conversion of a primary energy source into electricity. Taken the entire economic cycle into account, efficiency has to fall by definition as entropy is an unavoidable physical process. What electricity does is provide the consumer with opportunities to use production components in a more efficient way by delivering a standardised quality energy resource with possibilities for fine regulation and easier handling. This means electricity comes with economically favourable spin-off effects for various production processes and setups, within and outside its respective area.

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[199] Enflo, Kander, and Schön, "Electrification and energy productivity."
[200] Millward, *Private and public enterprise in Europe*, 77.

Ayres and Warr point out that technological innovations which drive economic development do not necessarily have effects on other sectors and are searched for and implemented along clear intentions rather than coincidence. Furthermore, every energy concept is embedded in a framework that changes with social innovations like new laws, taxation and insurance policies, the military, education facilities, the role of religious institutions, governmental structures.[201]

All of the abovementioned frameworks are formed alongside organisational patterns and structures which (gradually) underwent changes with the introduction of new technologies.

7.2.2. ORGANISATION AND STRUCTURAL CHANGES

Electricity's characteristics allowed new organisational patterns for labourers and machines and therefore enabled further change in the production process that was initiated in the early days of the industrial revolution. The productivity of labour and capital were enhanced by reaching unprecedented low levels of entropy when transmitting power, overall gradually improving working conditions and utilising opportunities for economies of scale.[202] Adding to this is the circle of expansion of the economy and the equivalent need for more energy, which might pose unforeseen problems regarding the availability or efficiency rates of one particular resource.[203] "Changes in scale can lead to changes in condition" and crossing a threshold can provoke non-linear effects.[204]

As Morus pointedly puts it, "Machines could be celebrated as the sources of the new wealth that was already in the process of transforming the nation [note: Great Britain] into the nineteenth century's greatest imperial and industrial power. Equally they could be condemned as the source of poverty visible in the metropolis's and many provincial cities' growing slums. They could be

[201] Ayres and Warr, *The Economic Growth Engine*, 11, 15-16.
[202] Enflo, Kander, and Schön, "Electrification and energy productivity," 2808.
[203] Smil, *Energy in world history*, 206-212.
[204] McNeill, *Something new under the sun*, 4.

metaphors for progress as much as for spiritual decay. Electricity had an important role to play in this machine culture."[205]

Industrial workers' identity was, in the early days, influenced by several factors such as the traditions of the particular craft or by the people in charge to dictate the pace of work. Competition or a division of labour was not customary and generally discouraged within the trade. The craftsmen reacted to the masters' requirements only within the limits of cultural custom of their trade and thus came into conflict with their superiors when the introduction of machines brought about new kinds of discipline. The firm control of the workplace was one of the biggest assets machines could contribute to the restructuring of the economy and provided masters with striking arguments to reorganise their enterprise. If workers were to compete with technology, they were compelled to comply with rationalisation, regardless of their traditional stance. "Machinery was a physical embodiment of the division of labour, a means of internalizing its drive toward specialized efficiency. … Machinery enforced uniformity of work and uniformity of product."[206]

As skilled labourers were mostly substituted with machines and unskilled, cheaper operators, skill-demanding craftsmanship got increasingly sidelined and had to look for niche markets or try to gain a supervising position on management level.

The less established the branch of industry (meaning the less traditional), the easier it was for electricity to compete with existing energy structures. Particularly up-and-coming sectors were the most promising adopters of electricity as a means of power.[207]

During the 1830s and 1840s electricity was slowly introduced in the British factory system.[208] Along with the adaptation of a new kind of energy came a change in the entire manufacturing structure. The implementation of the unit

[205] Morus, *Frankenstein's children*, 155-156.
[206] Ibid., 157.
[207] Nye, *Consuming Power*, 140.
[208] Morus, *Frankenstein's children*, 159.

drive first of all meant the end of the overhead shaft drive system, which intricately conveyed mechanical energy over long stretches with many frictional losses, a lot of background noise and the danger of loose parts falling from the ceilings. Now the space was literally cleared for installing new electric lamps and ventilation for the workers' comfort and allowed easier reallocation of work units within the factory layout.[209]

The units were aligned to build an assembly line with distinct specialisations in each unit. Ford's conveyor belt manufacturing system, first used in 1913, marked one of the most radical approaches towards rationalisation during the industrialisation process, however with big success at the time.[210]

Electricity furthermore enabled transportable machines which could easily be plugged in elsewhere.[211] Before, the most efficient operating overhead shaft systems demanded that the consumer of the largest amount of energy was to be put as close as possible to the energy source as frictional losses increased further down the transmission line. Therefore, assembly lines which were arranged along different logistic parameters would have increased energy expenditure and therefore cut into profit margins. "The combination of .. five practices – subdivision of labour, interchangeable parts, single-function machines, sequential ordering of machines, and the moving belt – defines the assembly line."[212]

All mechanical production components were drawn under one roof wherever possible to enable the maximum output of mechanical energy, both the workers' and the machines', with minimal transmission losses. Large-scale operations with short distances between each unit amounted to higher production output levels.[213]

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[209] Smil, *Energy in world history*, 194.
[210] Ibid., 195.
[211] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
[212] Nye, *Consuming Power*, 143.
[213] Wrigley, *Continuity, Chance and Change*, 78.

Apart from rationalising the production process in terms of time and logistics, assembly lines reduced bottlenecks, minimized inventory and left leverage for dividend payments and reinvestment. Important to understand in this regard is, that profit margins per se were not massively increased by mere standardisation; the difference was usually made in turnover and multiplication of small margins. [214]

Not all branches were suitable for assembly line production. Canning and bread baking, for instance, were examples of easy changeover in the United States, whereas laundry work and preparation of other foodstuffs remained traditional for decades to come.[215]

7.2.3. Electrometallurgy and electrochemistry

The aspect of electrometallurgy and electrochemistry is often neglected when shedding light on the transformation process from a solar to a fossil fuelled and electric society. Iron smelting already demanded very large amounts of thermal energy in comparison to other industries.[216] Copper and other valuable metals could now be refined by means of electricity.[217] The importance of high-quality steel and metals for the fabrication and composition of engines, wires and parts of machinery might be overlooked, such as the immense amount of energy that is needed to manufacture those items. The smelting of steel requires a temperature of roughly 1500°C and reaching that temperature was extremely challenging and expensive until about 1850 and just about impossible for the smelting of refractory metals (nickel, cobalt, chromium, etc.) until the availability of extensive amounts of electricity[218] Additionally, the costs and logistical efforts for the extraction, importation and transportation of the raw materials, which did not necessarily exist within the national borders, have to be taken into account in order to being able to calculate the effective energy input/output-ratio. The process of electrolyzing aluminium oxide, for instance, requires six times more energy than smelting iron. In 1886, 62 years after the

[214] Nye, *Consuming Power*, 144, 148.
[215] Ibid., 152.
[216] Wrigley, "Energy contraints and pre-industrial economies," 162.
[217] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
[218] Ayres and Warr, *The Economic Growth Engine*, 37.

initial isolation of the element, the American C.M. Hall and the Frenchman P.L.T. Heroult discovered an economically feasible method for aluminium smelting, if yet it remained a luxury item in industrial production for many decades. Over 50 000 kWh were necessary to smelt one tonne of aluminium during the 1880s. A hundred years later this required 'only' around 15 000 kWh. The connection with the chemical and metal industry with the electricity business thus involves two-directional spin-off factors as one feeds on the other for its advancement.[219]

This is one of the undeniable effects of (for whichever reason cheap) electricity. By making new and energy intensive material more widely available and affordable, other innovations became feasible and spill-over effects, if yet unevenly distributed and incidental at times, into other sectors occurred. For example, the production of steel or aluminium transformed the construction industry and aviation. An initial byproduct, chlorine, could be used to decontaminate water and provide sanitation for a countless number of people. Cheap glass production changed architectural designs and light concepts.[220]

The new organisational patterns and structures of economy followed, as can be seen from the specialisation and rationalisation efforts described so far, a general trend towards division of labour that had been initiated in the early days of industrialisation. The specialisation of tasks in different economic sectors intensified with the promotion of industrialisation.

7.2.4. DIVISION OF LABOUR

Agriculture was affected by the (ever more trans-national) division of labour as domestic arable land owners in industrialising countries were allocated the task of intensified food production instead of provision of a variety of raw materials. Import substitution from other (specialised) regions would make up for the difference in commodity composition. More and more industries developed in whose production process agricultural products played no other role than for

[219] Smil, *Energy in world history*, 178-181.
[220] Ayres and Warr, *The Economic Growth Engine*, 25.

the labourers' food, most notably metallurgy, transport industry, producers of chemicals and of course electrical goods.[221]

Specialisation and the division of labour were facilitated by the developments in the energy sectors. Manufacturers started to specialise in the production of light bulbs or wires, others fabricated dynamos and after 1890 water and steam turbines. Hence, a whole branch of industry was established to satisfy the demands it was creating at the same time.[222]

Decisions about initiating specialisations have to be taken very carefully as revoking large-scale technological implementations, particularly relating to specialisation, is a very challenging and expensive undertaking.[223] The larger and more thorough the structural change, the more difficult the reversion or remodelling.

Energy is an obvious input factor in the modern production process. Labour is reduced to a minimal source of (physical) energy. Capital, on the other hand, is by definition not physically productive. Together with information and management, both capital and human labour are regarded now as "organization related factor inputs", which play into the overall energy balance. Energy in a broader sense remains the sole physically productive part, whereas the organization related factor inputs ensure that the energy is used sensibly (meaning efficiently) according to the (economic) intentions of the undertaking. If now the cost for energy as the 'material' input of the process rises, or is expected to rise, production costs go up accordingly and growth rates of energy use, which equal growth rates of output, are expected to drop.[224]

As electricity in particular requires very little physical force but lots of organisational skills and is capital intensive, the latter two contribute to a large extent to the energetic outcome of the process. In other words, even if electricity is comparably cheaper to 'produce', all other factors around it still heavily

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[221] Wrigley, *Continuity, Chance and Change*, 70-71, 81.
[222] Smil, *Energy in world history*, 194.
[223] Nye, *Consuming Power*, 3.
[224] Beaudreau, "On the Creation and Distribution of Energy Rents," 73-74.

influence cost and the production processes as a whole. This problem is reduced by economies of scale as the costs are dropping proportionally to the increase of output. The fixed costs are simply very high in comparison to biomass alternatives.

The larger the enterprise, the better its chance of long-term survival with electricity provision. This means that because of the high demand for start up capital and a high level of expertise, both technically and organisationally, large structures held a competitive advantage over small family businesses. This applies not only to the energy industry itself, but also to other energy-intensive industries with demand for high capital investments, such as the automobile industry.[225]

7.3. "The use of electricity shifts labour input from manual to mental"

Electricity can not only be seen as a facilitator of the increasing division of labour, it actually became part of it because it took over specific tasks in the production process. It was able to support workers in some cases and replace them in others. Electricity marks the „socio-political crossroads of human labour".[226] It facilitates the decline of craftsmanship when work processes are changed to assembly lines and unit production in automated sequences. The term electrical work can be taken literally in this sense as instead of muscle power electricity is now used to operate machinery, which leads to an increase in unemployment figures. Furthermore, energy-intensive, artificial products such as aluminium and chemical products, as well as mass and disposable products are in increasing demand, many of which require lots of (automated) energy and little skill or muscle power.[227]

[225] Nye, *Consuming Power*, 125.
[226] Zängl, *Deutschlands Strom*, 6.
[227] Ibid., 6-7.

7.3.1. INVESTMENT DELIBERATIONS ABOUT THE USE OF MACHINES INSTEAD OF HUMAN LABOUR FORCE

When machines are available that could replace human work force in one or more parts of the production process, a decision can first of all be made between continuing to pay for physical labour by a person on a regular basis or investing in a machine with a generally different structure for operation costs. These deliberations are not only influenced by cost factors but also by performance and organisational aspects. A simple example can outline which energy dimensions we are talking about in terms of industrial factory labour. If a conveyor belt were to lift 100 tons of coal 100 feet straight up, it would require the energy of about 10 horsepower, which equals roughly 8 kilowatts. Having the same task fulfilled in the most savvy and efficient way by labourers was definitely doable, but not even one hundred of them could compete with a low-maintenance employee like electricity. Furthermore, electricity could perform tasks that humans were either less or simply not capable of. Amplifying and recording people's voices, aligning and projecting pictures so fast the eye lost track and perceived them as motion on screen, scanning, welding and automated control mechanism shall name just a few.[228]

Obviously, it can be argued that there was merely a shift towards monitoring the new machinery and the job losses are a transitory effect of this shift. Yet, this is only true for the skilled labourer, who was capable of supervising and controlling the process. By producing large volumes of standardised goods, economies of scale come into effect which in turn lead to lower consumer prices and lessen the burden on the individual's income, in particular of those in the low-wage sector. However, if low wage turns to no wage this effect is of little help to the individual concerned.

The steam engine in particular advanced to become the symbol of high-performance industrialisation and represented the main competitive advantage the small trades lacked: concentration of abundant energy for high-volume turnouts. Whoever wanted to incorporate such a machine and all it entailed into

[228] Nye, *Consuming Power*, 138-139.

their business needed to cover high investment costs which would only amortize at a certain scale of output.[229]

The cost was not merely the machine itself but also the training of the operators but most of all the servicemen and supervisors needed. The role of professional education changed in the restructuring process of the economy during industrialisation.

7.3.2. EDUCATION AND TRAINING

The restructuring of the economic process demanded different levels of education and training for the workers, depending on their position within the production line. Apprenticeships were of little need because they lost their relevance. Both operators of machinery who could be poorly qualified in terms of craftsmanship and people involved in the management and organisational part needed a different form and level of training.[230] White collar workers needed skills that could not be gained from a standard apprenticeship while traditional craftsmen were overqualified and eventually too expensive. A clash with traditional guilds and trade groups was practically inevitable, but in the long run the industrial form of production had consumers on their side as traditional ways of production were outperformed and undercut.

The more sophisticated machines became, the more tuition in electrical matters was necessary to being able to sell appliances and repair them.[231] This increased the pressure on both the unskilled who got more and more sidelined as well as the skilled workers who needed to educate themselves repeatedly as soon as new developments in that field occurred.

[229] Lackner, "Der Elektromotor als Retter des Handwerks: Mythos oder Realiät?," 158.
[230] Nye, *Consuming Power*, 134-135.
[231] Rose, "Getting the Idea Out: Agents of Diffustion and Popularization of Electric Services in the American City, 1900 - 1990," 230.

7.3.3. Machines as support and competitors to human labour force

Labourers found it increasingly hard to compete, especially wherever simple work processes could be automated and where high volumes where produced. The new technology was far from perfect, but its advantages became more and more convincing, making thousands of workers redundant. Fossil-fuelled steam engines, though, were just the beginning.

From about 1900 onwards, electric motors started to dominate the scene.[232] The electromotor was a tool to merge craftsmanship with industry, which had many positive effects for labourers, too.[233] The combustion engine and electro motor together formed the precondition for wide-spread mechanisation in the industrial sector wherever physical force could be substituted in a routine process and thus reducing the chores for workers in many cases.[234] They produced neither odour nor dust because they lacked tangible fuels such as coal, gas or oil, and compared to other combustion engines they were remarkably quiet. One kind of electromotor however was made fit for the sewing machine, which brought the big breakthrough also in small businesses and the textile industry. Electric motors for crushing, cutting, pressing and lathes in the food industry, repair and service sectors were amongst the most successful.[235]

Demand for such products rose as prices fell due to reduced costs and prices by standardisation and automation which in turn gave incentives to actually increase labour force in order to being able to meet demands.

The electro motors in production machinery multiplied the energy at hand for workers and had the potential to further efficiency in terms of organisation, economies of scale and specialisation whereas the electro motors in vehicles of all kinds ensured growing market integration as the improved transport facilities brought goods and services closer to people – or the other way around.[236] Opposing the positive aspect of this statement to a certain extent, one

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[232] Lackner, "Der Elektromotor als Retter des Handwerks: Mythos oder Realiät?," 159.
[233] Zängl, *Deutschlands Strom*, 29.
[234] Sieferle, *Das Ende der Fläche*, 280-281.
[235] Lackner, "Der Elektromotor als Retter des Handwerks: Mythos oder Realiät?," 160-163.
[236] Goldin and Katz, "The Origins of Technology-Skill Complementarity*."

can also argue that the shift occurs from skilled to unskilled labour. A Viennese magazine stated that in the 1890s „the proportion of highly qualified labourers declined, ever more unqualified labourers were recruited, in particular women; the piecework pressure rises.“[237]

One fundamental difference between pre-industrial times and life after the introduction of high-potential energy sources in general is that in modern days the consumer is largely detached from the notion of how much energy, be it muscle or electricity, went into the production of a good or service.[238] The process has become too abstract for most people to grasp, especially when considering the vast range of ready-to-use products available. Workers got more and more estranged from the labour process itself.[239] So did customers who bought a standardised good from a certain brand instead of an artisan. Also share holders and investors had to become familiar with a more abstract way of production with physically invisible factors such as electricity, capital, management and organisation.

Wherever (standardised) labour force was in need, electricity driven machines could ease the situation and also counteract the influx of foreign labourers or substitution by animals, which needed a certain amount of care.[240] This was not only the case in industrial settings, but also in agriculture as the shift towards labour substitution with machinery intensified with the coming of cheaper electric motors and other appliances. On a farm there was a big incentive to reduce the labour force, particularly that of seasonal workers, as the owner needed to make sure that the net product of the extra workforce exceeds the level of subsistence for himself and his family and leave him with a profit on the working capital. Simultaneously, the worker must retain an income high enough to provide for his dependents in order to take up the position. As the same principal applies to industrial settings and as high yielding agriculture is mandatory in order for this division of labour to function, the close connection between those two realms cannot be sidelined in the argumentation. This

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[237] Zängl, *Deutschlands Strom*, 29.
[238] Nye, *Consuming Power*, 262-263.
[239] Ibid., 133.
[240] Zängl, *Deutschlands Strom*, 72-73.

entanglement shall also demonstrate that agricultural performance, in spite of industrial and technological advancements, still played a decisive role in the overall economy. In terms of convenience electrical lighting simply faced no long-term competition.[241]

7.3.4. NEW EMPLOYEE STRUCTURES

The new production system mostly looked like this: Higher-ranking white-collar employees were – and are – administering labourers or farm workers who had turned into employees. Machines were able to replace many blue-collar workers in a high-energy society. The establishment of management-intensive corporations called for teamwork, flexibility and less individualism in the manifestation of standardised processes and mass products as opposed to skilful and distinctly unique handicraft.[242]

Human labour input was limited to a minimal role in the production process, in charge of supervision, controlling and support as human muscles were replaced with machines, automated tools and more (mostly fossil fuel or electric) energy input.[243] Talking solely about the replacement of muscle power with machines and a shift towards supervision tasks is only half of the story, though.

Canny management techniques and the acquisition of patents secured the growing enterprises the revenues of their invention or product. A strive towards stringent efficiency, cost effectiveness and benefiting from economies of scale eventually paid off as successful companies were then both able to out- and undersell competitors and still have budgetary leeway for advertisement and forward integration into retail sales. The more excess was produced and the more competitors arose, the more important the position of advertising became which practically created a new professional field.[244]

Noteworthy is the fact that the owners of railway, telephone or electric light companies did not just or exclusively advertise their individual brand but rather

[241] Wrigley, *Continuity, Chance and Change*, 45, 60.
[242] Nye, *Consuming Power*, 208.
[243] Smil, *Energy in world history*, 193.
[244] Nye, *Consuming Power*, 125, 164.

the system as a whole.[245] Many of them were mostly monopolised anyway in many countries, so the task was more to convince potential costumers to participate in the respective technology system than decide between different providers.

Communication was promoted also by the electricity providers themselves, apart from telephones and telegraphs. For their customers the companies issued leaflets and news as well as simplified versions of relevant laws and regulations.[246]

When looking at the entire transformation process of labour during that time period, one could detect overall patterns. The tasks for the masses of labourers who could not (yet) be replaced by machinery became easier but also more repetitive and dull (e.g. a worker at the conveyor belt repeat the same motion over and over again for hours per day), while those of the few managers, salesmen, scientists and researches became more and more complex and sophisticated. The main difference of these researchers compared to their predecessors was that they were increasingly not employed by scientific societies, by royals or universities. More and more found themselves working for companies undertaking systematic experimentation for a distinct economic purpose for a single brand product, product line or branch of industry. This shift or rather linkage could only take place because the enlightened common sense policy of the time, particularly in Western Europe and the Anglo-Saxon world, allowed for this crossover of science and business and fostered the inquisitive nature of scientists by providing them with the necessary equipment for a conducted problem solution. Problems were of practical and technical nature, and so should be the solutions for them. Companies that did not want to or simply did not compete in the race for new inventions, apply for patents and constantly optimise and rationalise their operations would eventually find themselves under distress to stay in business.[247]

[245] Nye, *Consuming Power*, 131.
[246] Gugerli, "Modernität - Elektrotechnik - Fortschritt: Zur soziotechnischen Semantik moderner Erwartungshorizonte in der Schweiz," 55.
[247] Nye, *Consuming Power*, 126, 134.

As can be seen in the previous paragraphs, the issue of whether the energy intensive economy, particularly with the adaptation of electricity, had a positive influence on labourers' job satisfaction is debatable. So is if the effects triggered merely shifted large parts of the workforce to fulfil new, less strenuous and more mentally challenging tasks. Personally, I support the notion that both the layoff of human work force and the creation of new jobs and professional fields are part of the legacy of the industrial revolution. Electricity in particular enabled production processes simply outside the human capabilities and was complementing the processes in beneficial ways that outweigh the dismissals of workforce in the long run. Granted, it is easy to suggest that from an outside and merely economic perspective as the implications for the concerned individual would have been serious. Still, looking at the competitive advantage of the technology itself, the arguments were strikingly convincing. Those workers who were willing and able to adapt to the changed circumstances found themselves generally at better health as the physical labour was taken over by machine wherever possible. Supervision, management and advertising – all tasks where the mental input is more relevant than the physical one – gained importance. For those redundant or unfit for these kinds of profession, work became even more repetitive and on top difficult to hold on to as one could easily be replaced by either any other human being or a machine, eventually.

In order to look at one of the specifically advantageous characteristics of electricity, the following chapter will focus on the role of light in the process of economic and social development.

7.4. "Electricity, in particular electrical lighting, has a crucial influence on economic and social development as well as urbanisation"

For millennia the day was the time between sunrise and sunset. Depending on season and location, this time was subject to gradual and constant change. Time was a completely different concept that was used to measure natural and festive seasons rather than minutes and hours. As human vision is not sufficient for seeing in the dark, plus considering that humans are highly dependent on their vision, daylight was an essential precondition for work and productivity. Being able to domesticate fire, make candles and oil or gas lamps enabled people to brighten interiors and extend the day, even though it involved considerable effort at times and the intensity of light was often enough extremely poor in particular in contrast to today's standards.

7.4.1. Gas light as the primary rival

The 19th century was dominated by gas as light source. Its light was brighter than that of candles or other light sources and the transportation through pipes was comparably practical. Major disadvantages were the hot and open flame which made sultry summers even less pleasant and quickly burned up all the oxygen in closed rooms, leaving you with the decision between a headache or freezing with the windows open in winter. If nothing else, a substantial fire hazard always remained as gas also kept flowing when the flame was extinguished by a breeze and the entire complex could catch fire with the next spark.[248]

The characteristics of gas lighting called for small rooms that could be aired out individually and with minimal draft to potentially extinguish the flame as the best option to make maximum use of the light source. The soot eventually altered the colour of wall and furnishings, so the darker the foundation the less tainted it looked. Electricity, in contrast, provided plenty of possibilities for spacious and light coloured rooms and thus allowed new architectural layouts of industrial, business and living space.[249]

Gas lamps in public places were first installed in London in 1814, followed by places like Brussels 1819, Rotterdam and Berlin 1826, Amsterdam 1833, Lyons 1834, Barcelona 1841, Vienna 1842, Gothenburg 1845, Oslo 1846 and Odense 1853, which had all been set up by a British company.[250]

The price developments of gas were of great relevance to the long-term successful implementation of the lighting devices. Millward found that between

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[248] Crosby, *Children of the sun*, 108.
[249] Nye, *Consuming Power*, 195.
[250] Millward, *Private and public enterprise in Europe*, 36.

1882 and 1914 British coal prices, in relation to other retail price developments, rose by 30 percent, whereas that of gas dropped 12 percent. The price for electricity declined yet more quickly, however years and years passed by before gas was substantially sidelined in price competition. It took until approximately World War I before electricity could emerge as the economic winner of the competition with gas as a lighting source.[251]

Important to note is that, in spite of the low-entropy rates of electricity upon consumption and the generally high conversion rates, inefficiencies still occurred and were merely relocated to the site of generation and transmission.[252]

Factory owners were amongst the first to be convinced of the superiority of the light bulb and were quicker to understand its economic potential for their enterprises. The architecture of a factory building obviously had to comply with production necessities, but also with light provision. Windows were expensive but necessary to air out the premises from gas fumes, dust and heat. Plus, they let in daylight to save expenditure on gas lights. Electric light enabled the construction of spacious, windowless (or at least fewer and smaller and therefore cheaper windows) interiors.[253] The psychological effect and health aspect of this is definitely debatable, but savings potential can be a very convincing argument.

With the ceilings cleared from overhead shaft drives that used to pass on mechanical energy, there was ample room for lighting devices and electrical overhead crane facilities to transport materials.[254] Not least, prevention of accidents, which again saved costs, by electric drives for lifting devices and other means of transportation was another asset of installing electricity in the work environment.[255]

[251] Millward, *Private and public enterprise in Europe*, 36, 76.
[252] Enflo, Kander, and Schön, "Electrification and energy productivity," 2809.
[253] Nye, *Consuming Power*, 139.
[254] Ibid.
[255] Lackner, "Der Elektromotor als Retter des Handwerks: Mythos oder Realiät?," 165.

Without efficient and affordable lighting a full transition to the factory system was not realizable, so price and quality of light do have a lasting impact on industrialisation efforts.[256] Electric light was brighter and enabled longer working hours and thus more (potential) economic output during shift-work. The working day could be turned into work shifts that were standardised and independent from seasonal and natural circumstances. Times was assigned a new meaning in the industrial process and was able to be exploited far more freely than before.

7.4.2. LIGHT IN PUBLIC PLACES

In Germany, electrical light was used first for building purposes at construction sites and for military test purposes in 1868. In the 1880s boulevards and several public institutions were equipped with electric lighting. Only by 1914 the light bulb started to prevail in households and thus the wide-spread implementation of an electrical system itself[257]

Modern lamps in the early 20th century did not bring about a reduction in electricity consumption, but more and brighter light. Brighter light meant also brighter cities and more communication as social life was not hampered by the fall of darkness anymore. Advertisement was brought to a new level of sophistication with ample options of lighting that put competitors on the spot to act. Customers are not likely to spend their money on an unknown product, so using electricity not only to promote a product itself but also equip the means of advertisement with electrical light was part of the campaign. Brightly illuminated theatres in Europe and the United States were some of the flagships of advertisement of electricity firms and reinforced the idea of electric light being an affordable and modern luxury good.[258] Public places, buildings or stairwells brightly illuminated furthered this development and slowly incorporated the technology into everyday life, if yet starting out as a luxury.[259]

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[256] Sieferle, *Das Ende der Fläche*, 189.
[257] Zängl, *Deutschlands Strom*, 15, 66.
[258] Felber, “"La fée électricité": Visionen einer Technik,” 116; Binder, “Visionen der elektrifizierten Stadt: Stadtvorstellungen im Diskurs um die Elektrifizierung,” 195.
[259] Zängl, *Deutschlands Strom*, 67, 90-95.

Once the implementation of electric light systems had taken place, the larger amount of electricity in economical terms was used for lighting. In other words, a large share of total electricity consumption was used for lighting. Only after consumers had become accustomed to this application of the technology, a shift towards more electrical power transmission for other uses and appliances occurred.[260]

With the installation of electric lighting systems the end of simple and detached electric units had come. The diffusion of the light bulb demanded the construction of a complex and wide-spread system and corresponded with the trend towards mass production of standardised and system-conform items.[261] Together with the communication devices telephone and telegraph, lighting sparked extensive network building which brought about the biggest noticeable changes for the individual. This was particularly noticeable in urban areas that could benefit most from the possibilities electricity came with as will be explained in the following section.

7.4.3. URBANISATION

An electrically illuminated city centre created an image of modernity and positioned electricity as an especially urban and progressive source of energy. Horse-drawn trams had been substituted by electrical ones in large towns throughout Europe by 1890.[262] Electrified trams could cover longer distances in shorter time than horse-drawn ones and facilitated the outward growth of the city as well as the suburbanisation which mirrored the increasing separation between work and living place. Later, automobiles increased the process of suburbanisation which was well in place since the end of the 19th century.[263] Sanitation improvements were advertised by the local councils as horse manure could be reduced or eliminated completely from the streets. Last but not least, installing lights, tramways and electric systems in the public sector guaranteed

[260] Luxbacher, “Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945,” 47.
[261] Ibid., 48.
[262] Millward, *Private and public enterprise in Europe*, 82.
[263] Nye, *Consuming Power*, 177.

the providers, increasingly co-owned and co-managed by the municipalities themselves, a large and reliable customer.[264]

In terms of architecture and construction, the skyscraper is worth mentioning. The more people are competing for less and less space available, the more expensive becomes the ground to build on. Without the aid of electric lifts and escalators as well as solid and affordable steel and heating facilities, these very tall buildings would not have been a functional and sensible solution for saving space in urban areas.

Electricity allowed entrepreneurs as well as individuals more freedom of location also away from urban areas than would have been possible if only the car had prevailed. Buildings and factories could be constructed wherever in reach of the electrical grid which was considerably easy and cheap to extend if needed. Trams and trains could substitute the automobile in terms of transport and vice versa.[265]

Urbanisation implies a smaller proportion of the population employed in agriculture and a shift to provision of services in an urban setting with a smaller degree of self-sufficiency. Therefore, peasants or farmers are required to produce additional amounts of food for the urban market. The notion of the self-sufficient farmer detached from market mechanisms is somewhat exaggerated also in regard to earlier periods as regional centres had long played an important role as trading places for the farmers' labour products.[266] The speed and scope of urbanisation is however significant and unprecedented with the advent of industrialisation. Money as the predominant means of exchange facilitated that process of increasing interdependence of the urban and rural areas.

Which source of lighting was used might seem trivial at first sight, as long as there was light in the end. Taking a closer look though shows that lighting

[264] Binder, "Visionen der elektrifizierten Stadt: Stadtvorstellungen im Diskurs um die Elektrifizierung," 197-199.
[265] Nye, *Consuming Power*, 194.
[266] Ibid., 25.

methods had considerable influence on architecture, the notion of time, production opportunities, health and safety as well as municipality politics, advertisement and lastly the networking and spin-off effects for the entire technology sector. I strongly support the notion of electrical light as a driving force for the entire electricity sector due to its ample advantages for businesses and individuals alike. The arguments discussed are generally in favour of the claim that electricity, in particular electric light, had an important influence on economic development. Furthermore, the predominant finding is that it transformed the economy for the better. Electric light changed the perceptions of space and time especially in urban areas and therefore had influence on the social structure of a community.

The impetus for advancing the technology needed determination by savvy people who used not only their scientific but also marketing and networking skills to overcome the initial obstacles. If it had not been for convinced politicians, pressure groups and financiers, the likelihood of the success of the technology, in spite of competitive advantages, would have been far slimmer. The following chapters will be dedicated to this very topic and tries to portray the interrelations between scientists, engineers, lobbyists, financiers and governing bodies and their means of electricity-aided communication.

7.5. "ELECTRICITY IS THE PRECONDITION FOR COMPLEX AND INSTANT COMMUNICATION"

Electricity revolutionised the way of people's interaction. It can act as an instant intermediary by allowing the immediate transmission of code, sound and images that was simply without competition if communicating face to face was not an option. The examples of the telegraph and telephone in particular were chosen to demonstrate how electricity was a vital component of the predecessors of our well-established communication tools. Other sources of energy or methods of communicating were simply incapable of delivering a similar service.

"Access to electricity revolutionized communication, but would do so across the whole range of human activity – city lighting, industry, transportation, entertainment – only if massive voltages became available."[267] Improved transport facilities provided governments with an incentive to conquer new territories which then could be administered, governed and exploited more easily by means of faster and more convenient communication tools.

The networking effect of electricity was, again, one of the most striking arguments that prevailed in the debated about the adaptation of the new technology. Being able to instantly communicate at a very sophisticated level with other parties without the need to be physically present does not only save the transport fare, it also provides an incentive for increased communication in the first place as the threshold to get in contact is reduced. Information can travel far distances without the need of a human being as the messenger and without or with very little time lag. This simplified business relations as well as the administration duties.

Electricity enabled instant communication at unprecedented levels. When connection and communication with other parts of the world becomes possible, if not unavoidable in some cases, new political, social, cultural and economical challenges arise which have to be attended to eventually by all members of society. Cultural discrepancies between peoples can be fuelled by increased interaction and competition as well as alleviated by better communication opportunities. Politicians need functioning communication tools to gain and remain in governing positions. They have to be sensitive to cultural peculiarities and able to act accordingly and within the critical time frame in order to fulfil their duties of guidance and representation. This brings us to the last focus area of this research: culture, politics and the structure of society.

8. POLITICAL AND CULTURAL ASPECTS

After having dealt with primarily the technological and economic side of the spectrum, it is now time to look at the influencing factors surrounding these

[267] Crosby, *Children of the sun*, 10.

realms. Political choices and cultural identity can have significant value in the development of a region's economy and its social fabric. Both will be looked upon in a structurally similar fashion than the previous chapters and will lead us towards the conclusive remarks about the answering of the overall research question.

8.1. "POLITICAL WILL TO BOOST TECHNOLOGY IS ESSENTIAL"

The role of politics can be looked upon as a very crucial, ambiguous, difficult and thankless. It is supposed to provide a legal framework for businesses to operate, for individuals to participate in the market, for scientists to pursue 'useful' (however defined) research and for society to function. Change of this framework is difficult, expensive and time-consuming and many regulating institutions are very hesitant to embrace changes and innovations as they complicate planning procedures.[268] As some of the demands of pressure groups are counteracting, compromise is the most common solution which practically means: nobody gets what they actually want and some will be even less content than others. So in order to keep frustration to a minimum, skill, tactic and – depending on your belief system – a bit of luck is necessary to succeed, regardless of the opposing parties' arguments. Political forces can be very complex and are based on personal, tactical, economic, moral and many other agendas, all of which are embedded in a distinct cultural background that had developed over centuries. As decisions about energy systems influence a multitude of spheres of life, politics appear to be unavoidable.

The sort of energy consumed is not always a matter of technological superiority; rather it can be ground on political power, prestige and hegemony, and the choices further depend on "lifestyle, worldview and social organization."[269] Those are reflected in the political structure of a country or region. Every government is restricted in its choices of energy by local natural resources, the structure of their economy, their expertise, level of technology and their political will and/or necessity to act.

[268] Ayres and Warr, *The Economic Growth Engine*, 40.
[269] Dooley, "Introduction," xvi.

Political concerns are as potent as economic prospects, technological improvements and environmental considerations when a new kind of energy is debated to be implemented.[270] They are supposed to represent the conglomerate of a society's choices and intentions which act as a regulating force and trajectory of a people's present and future.

Zängl is very straightforward about the relation between politics and technology when he states that "technology penetrates the entire industrial society; it structures political, social and societal action. Technology is always political; it incorporates violence, war and power."[271] Morus agrees when he says that "[e]lectricity was easily seen as the universal power of both nature and industry. It was a progressive force that dominated the natural and could be harnessed to dominate the social world as well."[272]

The potential of electricity as a source of energy needed to be discovered, tested and promoted to the respective clientele. In order to reach these stages scientists, engineers, businesspeople and the authorities needed to agree at one point on the investigation of the technology's capabilities and further development and application opportunities. This means that these exploratory processes had to be legitimised specifically, which will be the topic of the following subchapter.

8.1.1. LEGITIMISATION OF SCIENCE

Far-reaching consequences can result from being able to outline what is considered to be a legitimate science. Thus, politics played a crucial part already early on in the scientific development process. Most scientists financially depended – and still depend – on grants and support from sponsors for their research. If a potential result was to benefit the political agenda, or could work against it, it was in the interest of officials to act accordingly. As particularly in a still largely traditional society wealth and success were directly and closely

[270] Dooley, "Introduction," xvii.
[271] Zängl, *Deutschlands Strom*, 3.
[272] Morus, *Frankenstein's children*, 184.

linked with natural resources and how they were used, the involvement in science could have immediate or indirect effects on political economy as well.[273]

Research in physics was explicitly legitimised in Great Britain due to its alleged value for the nation.[274] Physicists took on the role engineers who were to construct mechanical machines to perform industrial processes. The scientific approach was generally very pragmatic. London, with its large number of workshops and manufacturers strewn all over, presented the ideal location for finding appropriately skilled workers, engineers and material resources to perform the natural-scientific experiments.[275]

Mechanics was considered the ideal of physics, to which a 'comon-sense'-philosophy of the age of enlightenment and industrialisation could be applied. A clear distinction between science and technology had yet to be established. Energy was a measure for work being done or potential work, demonstrating a direct link to matter and mechanical processes.[276]

For many decades, if not centuries, mechanics served as prime discipline within physics, especially during pre-industrial times and the early stages of the industrial revolution. Mechanical tasks were undertaken in agriculture and manufacturing, so the incentive to understand and improve performance to raise efficiency was a given.

The founding fathers of the Royal Institution of Great Britain, established in 1799, were land-owning aristocrats. Their aim was to develop better strategies to cultivate the land. Not only should this raise output and generate a more detailed understanding of natural phenomena, it also was to reduce the hardship of daily life of the rural population in order to prevent social unrests and uprisings.[277]

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[273] Morus, *Frankenstein's children*, 4-12.
[274] Meya and Sibum, *Das fünfte Element: Wirkungen und Deutungen der Elektrizität*, 211-212.
[275] Ibid., 156, 213.
[276] Morus, *Frankenstein's children*, 156; Meya and Sibum, *Das fünfte Element: Wirkungen und Deutungen der Elektrizität*, 211-212; Smith, *The science of energy*, 289.
[277] Morus, *Frankenstein's children*, 13-14.

It was a time in which reciprocal action of education institutions and industry was encouraged.[278] The changes in attitude towards progress and the power of the individual had come with the spread of enlightenment philosophy.

8.1.2. Patents

What started out with technological experiments materialised in the 1840s into a commercial and financial force. Patents were increasingly applied for to secure economic gains the electrical apparatuses were able to produce. The catch was, however, that patent rights were difficult to exercise and their acquisition was an expensive and tedious undertaking. Further, issuing a patent counteracted to a certain degree the greater idea behind the technology of wanting for it to spread, bring fame to the scientists responsible and also the propagation of the product itself. The other option was to go for popularity rather than pure profit and marketing the technology via exhibitions and articles in magazines and journals.[279]

Knowledge is generally considered a non-rival good (also by lack of enforcement possibilities in case of attempts of monopolisation), whereas a physical product – resulting from knowledge application – is up for competition for profit.[280] Patents are insufficient to provide substantial insight in the connection of electricity and economics as they were often undermined and eventually became redundant as the technology was considered general knowledge. Another, also contemporary, problem with patents is that on the one hand they discourage competition as they exclude potential rivals at least for some time from the market. On the other hand, without patents the incentive for investment in research is sometimes lacking because the risk of losing revenues by copying technology through others before amortisation of the investment can be considered too high. This can have detrimental effects due to a lack of innovation. A satisfactory solution has yet to be discovered and then sensibly implemented and exercised by the regulating official bodies.

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[278] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
[279] Morus, *Frankenstein's children*, 159, 165-166.
[280] Ayres and Warr, *The Economic Growth Engine*, 46.

8.1.3. FINANCING AND OWNERSHIP

Also the banks, often enough subjects to political agency as some of them were state-run or closely linked to public financing projects, had their say in the electricity business. The need for extensive and expensive infrastructure makes it very capital intensive and the uncertainty of success meant that creditors, investors and share holders had to be lured with high interest income, making money lending and financing yet more costly. Exactly because of the risk of these enterprises, the state remained hesitant for a long time (in Germany roughly until World War I) and left the initial implementation of electricity to private companies entirely or preferred to issue concessions. The officials' hesitance, however, and the high demand for capital established a very close link between plant operators, bankers and financiers as (co-)owners and shareholders from very early on. This also shows that building the technological infrastructures is highly arbitrary and depends on ideological and political stance as well as economic prospects.[281]

Eventually, several forms of ownership of public and private ownerships of power plants and networks were established across Europe. Energy suppliers usually were not competing for unused land. Someone else owned this land, whether it was a local landlord or a governmental body who needed to agree to network installations running across their premises. In general one could say that a private concessionaire had to comply with a set of conditions before being allowed to start up the project. In order to be granted "rights of way", as Millward terms it, the finances and the engineering capabilities were checked by officials, which opened up bribery possibilities. Their liabilities were defined and in some cases politicians were included in the board of directors. Secondly, attempts were taken to control the company's profits, like capping prices to secure (however defined) affordable provision of energy. In return, multiple bidding and duplication of infrastructure was discouraged or even prohibited by law. Regulations for electricity and trams were stricter than those previously for (non-electric) railways, gas and water. "Effectively, as a quid pro quo for rights of way, bidding for franchise was encouraged, while the fares, rates and tariffs of

[281] Zängl, *Deutschlands Strom*, 42-43; Langendijk, *Electrifying Europe*, 23, 49; Nye, *Consuming Power*; Ayres and Warr, *The Economic Growth Engine*, 10.

the enterprises were usually regulated; and this was the case whether or not an enterprise was in public ownership."[282] The more rights of way were granted and the more companies started to bid for customers, the more governments got involved in the alignment of routes and the construction of plants.[283]

8.1.4. NETWORKS

Without suitable network structures politicians, policy makers and business people would lack the tools to govern, communicate or trade. Networks, both technological and social, are essential for the functioning of a political economy. The value of technological infrastructures lies not only in the transmission of energy from producer to consumer, but in their networking effect. This means that electricity systems, once integrated in public, private and commercial venues, can be beneficial on multiple scales that exceed the effects of pure multiplication of electric lines. Therefore, the combined value of individual lines is amplified by their socio-economic spin-off effects in society via the network feature. As electricity can be used for manifold purposes, some of which have not been known until decades after the initial implementation (i.e. computers, sound amplification, film, kitchen appliances), the network keeps perpetuating itself by adding ever more appliances and excluding those from so-called progress or modernization that do not have access to the electrical system. The term 'power system' can thus be understood in both the political and the energetic sense of the word.

Electricity in particular demands complex and sophisticated technological infrastructures. They serve as the material grid of transmission, but also stand figuratively for regional or trans-regional integration. The usage rate indicates the economic efficiency of the system which is ever more important for electric lines because they cannot be used for transmitting alternative kinds of energy. As electricity was extremely difficult to store, one of the biggest challenges was the difference between peak hours and nadir. The conservation aspect sets electricity apart from potentially rivalry sources coal and gas. As long as there was no feasible way to conserve electricity, producers aimed at constant capacity

[282] Millward, *Private and public enterprise in Europe*, 63-64.
[283] Ibid., 25-29, 81.

utilisation of the power plants. Given the different ways of generation of electricity, this may lead to different levels of dependences. If, for example, the supply of the primary energy source for electricity generation is reduced (e.g. slower water current due to drought, shortage of coal, lull, etc.) and consumption demands cannot be met by production outcome, the choices are either to fall short of delivering and so cause a power outage or buy electricity from other producers into your network, if possible. Simultaneously, in order not to be found in this position in the first place, efforts are considerably increased to ensure stable supply of the primary energy resources needed for production. When integrating power lines with different peaks and a different clientele (private customers, large industries with steady electricity consumption, municipality venues, etc.) those costly imbalances could be levelled and prices stabilised. Additionally, if one plant fell short of production another one could temporarily take over. The extra cost for organization and infrastructure could usually only be covered by large corporate or state entities and in accordance with local officials entangled in the electricity sector.[284]

8.1.5. REGIONAL DIFFERENCES AND CHALLENGES

Due to limited transportation capacity, particularly in the early days, and orientation alongside peak demand as storage was a major issue, networks started out locally and grew only slowly into regional, national or even trans-national ones, mostly aided by the proliferation of (publicly available) electricity supplies in the 1880s and 1890s that sparked consumption. Municipalities were most likely to take over operation and ownership in areas where the technology suited the local structure the best (meaning, short range for transportation of electricity) and local government was powerful enough within the political framework of the state. France, for instance, due to its centralised structure, held on to the concession system much longer than other countries. In Britain municipal ownership of electricity companies inclined from 39 on 1895 to 164 only five years later. In the early 1900s 72 percent of all electricity supply

[284] Langendijk, *Electrifying Europe*, 19-21, 47; Zängl, *Deutschlands Strom*, 6.

enterprises and 56 percent of all tramway networks were under municipal control.[285]

Another factor in deliberations about implementing and connecting electrical systems was that politicians already had energy allegiances to maintain. Local governments were often enough involved in gasworks and advocating for the competitor was neither in their own nor in the interest of the gasworks operator. Middle ground could be reached by issuing concessions to private entrepreneurs who were willing to take the risk of starting an electricity plant and who eventually dominated the particularly precarious markets. In case of failure, the responsibility had been rolled off; in case of success, negotiations about governmental participations still remained optional.[286]

Another possibility was to combine efforts to provide gas and electricity under central management and thus increase profit-earning capacity. One company could then – with or without the direct involvement of a public body – build and operate the facilities and cater to a variety of energy needs such as water, gas and electricity.[287]

Building power plants and network structures, nationally or internationally, was as stated above, a risky business. Once it got started, measures had to be taken to keep competitors as weak as possible. The high implementation costs of the system juxtaposed with a small customer base in the early days made it necessary to find ways to uphold a rather monopolistic position of providers to remain profitable. Doubling the structures, meaning simply building two or more parallel transmission lines, not only put the existing provider in a predicament but was also believed to be ruinous for the challenger. Both would risk failure and with the increased involvement of public bodies legal action was taken against the duplication of networks and thus against competition.[288]

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[285] Millward, *Private and public enterprise in Europe*, 76-77.
[286] Langendijk, *Electrifying Europe*, 45; Millward, *Private and public enterprise in Europe*, 40-41.
[287] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 47.
[288] Nye, *Consuming Power*, 124.

The discussions about trans-national or even trans-regional power lines were therefore also a debate about both technology and politics. Electricity has the ability to figuratively connect people and transmit messages via the networks of communication and transport it powers, thus, providing a viable and spurring option for cooperation.[289] Interconnection was one of the best prospects to level out the vastly different geographical disposability of natural resources like water power, coal or oil, but also bore the risk of sharing the problem as power failure occurring in one country affected also others connected to the grid.[290] Scientists and engineers started an increasingly international discourse and a more global community, but also competition. Once the technological obstacles could be overcome (for instance long-distance transmission without overly high voltage losses, lack of standardisation of frequency and voltage), the political and legislative context came to the foreground.[291]

8.1.6. DEALING WITH CONFLICT

Disputes arose in the late 19th and early 20th century not only between entrepreneurs and officials about finances and regulations, but also amongst physicists and engineers frequently arose also about the determination of standards. Werner von Siemens opposed the idea that engineers should have any say in this matter and made use of his political privileges to advocate his position. The British Association for the Advancement of Science (BAAS, nowadays the British Science Association) together with other pressure groups decided upon the definition of physical units during meetings, where the BAAS made sure their elite physicists and engineers remained powerful and underlined British scientific credibility on an international stage.[292]

On the one hand, ongoing cultural and political conflicts between regions were part of deliberations. Was it wise to connect two latently rival regions and risk interference or dependence for the benefit of potential synergy factors and savings opportunities? Would factual interconnectedness be a better chance to

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[289] Langendijk, *Electrifying Europe*, 74.
[290] van der Vleuten, "Electrifying Infrastructures," 316.
[291] Langendijk, *Electrifying Europe*, 30, 41-43, 57.
[292] Smith, *The science of energy*, 277-287.

secure peace than political treaties were capable of?[293] Could pressure groups such as (trans-national) engineering communities or international organisations prevail over political disparities?[294] On the other hand, the network would only increase its profitability by either extending it to new markets or encouraging higher consumption of the existing customer base, which implied higher expenditure levels on electricity that was only available by higher household income. Finding answers to these questions which satisfied all parties involved in spite of different interests and priorities caused tension and power struggles which influenced the development of a network.

Ideological affiliation as well as military, economic and political alliances to prevent further armed conflict were driving forces in the construction of intensified networking efforts.[295] Europe's prestigious and potent position in world politics before the World Wars was not to be regained in the latter part of the 20th century, but unification of the political economic forces of individual countries aided the reestablishment process of the continents power.[296] Unification of their electrical system and trans-border cooperation was a logic consequence of that process towards synergy strategies.

The reluctance, with which the electric system was initially met, can be demonstrated by looking at the early consolidation of the market, where the largest market shares were split among a few large soon-to-become corporations. Markets were increasingly integrated and homogenised.[297] As indicated previously, the network effect is crucial for electric power generation and sales, as well as the high capital demand of the industry. Thus, small-scale plants on average were far riskier than large ones, particularly in the early days of the technology. Small family business structures were unapt for the characteristics of this market which thrived on network building and large scale generation of power, both favouring the establishment of corporations.[298]

[293] van der Vleuten, "Electrifying Infrastructures," 316-318.
[294] Langendijk, *Electrifying Europe*, 30.
[295] Ibid., 154.
[296] Ibid., 71.
[297] Sieferle, "Transport und wirtschaftliche Entwicklung," 34.
[298] Nye, *Consuming Power*, 111.

Once the public – or partially public – electricity plants operated and delivered "cheaper" electricity than the industrial site could have produced itself to remain self-sufficient, it enhanced dependences between the local generator and the industrial consumer. Simultaneously, to reduce the dependence of providers on such industrial large-scale consumers, public electricity plant operators in joint operation with political agents promoted and provided incentives for the electrification of households.[299]

8.1.7. CHANGEOVER AND ADAPTATION TO THE ELECTRIC SYSTEM

Towards the end of the 19th century towns started to come closer to a saturation level as far as simple electrification infrastructure was concerned. The electrification of rural areas in Germany was tackled with the provision of electricity for mills and sawmills, which had spin-off effects for the village. It was supported by authorities as an effort of 'modernisation' of the hinterland, as a technology with distinctively urban connotations was made available.[300] Electricity cooperatives, where each member was both producer and consumer, were more personal and easier to put through than an anonymous electricity company. In the long term, their output was not always able to cater for the increasing demands and so the larger companies could step in with new regulations and tariffs. Decisive was not the success or failure of these cooperatives itself, but the initial implementation of a system which could then be retained and utilised by other (commercial) providers.[301]

For over 60 years, starting in the 1880s, the market for electricity was dominated by only four firms, General Electrics and Westinghouse from the United States, and Siemens & Halske and AEG (Allgemeine Elektrizitäts-Gesellschaft) from Germany. All four engaged in production and distribution of electricity as well as all devices and appliances until the very end of the supply chain within and sometimes also outside national boarders, which guaranteed a decent economic mix to stabilise profitability. Their close relations with officials

[299] Zängl, *Deutschlands Strom*, 50.
[300] Langendijk, *Electrifying Europe*, 74.
[301] Zängl, *Deutschlands Strom*, 56-58.

at any given time played to their advantage against mushrooming smaller companies.[302]

One aspect was the construction of very large power plants, which both AEG and Siemens & Halske urged German officials to build. As they were the only ones capable of fulfilling the requirements of this undertaking and governmental support was needed to revoke zoning provisions and expropriate residents to clear the appropriate land for construction, the combination of entrepreneurs and politicians again was a crucial stepping stone in the electrification process in Germany.[303]

The United States saw the first electrical power station built for private customers in 1882, located in New York City and initiated by Thomas Edison.[304] In comparison to the United States, European corporations faced greater difficulties to gain the upper hand. Millward states that the Americans exceeded per capita electricity output of Europeans considerably well into the 1920s and suspects the reason behind it in the possibly challenges entrepreneurs faced in Europe upon implementation as well as good gas supply as a major competitor. European craftsman labour structure, the reliance on muscle power and the reluctance towards rigid subdivision of labour was stronger than across the Atlantic. Also, European workers were more united and fought against loss of control in the work process. The United States as a nation were more heterogeneous both culturally and in terms of religion than the majority of European nations. [305]

Probably the most official political commitment to electricity as the forthcoming energy source came from Vladimir Ilich Lenin in 1920, who announced to his comrades of the All-Russia Congress of Soviets that “Communism is Soviet power plus electrification of the whole country.”[306]

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[302] Langendijk, *Electrifying Europe*, 46-47.
[303] Zängl, *Deutschlands Strom*, 65.
[304] Crosby, *Children of the sun*, 110.
[305] Nye, *Consuming Power*, 128; Millward, *Private and public enterprise in Europe*, 82.
[306] Crosby, *Children of the sun*, 113.

Overall, the government first and foremost took a regulatory position in order to prioritise according to national needs for industry and services, ensure provision of electricity also in less profitable regions (countryside), replace less efficient energy sources and keep track of pricing. This went hand in hand with rationalisation and interconnection of electricity providers, which became subject to ever more extensive national legislation.[307]

Also on a smaller scale electricity was promoted. In the beginning of the 20th century, real estate owners were urged to lay electric conduits, especially when reconstructing or building new houses, to raise the rental value of the property.[308]

Once the public as well as administrators were convinced of the beneficial socio-political and economic characteristics of electricity as a whole, they became incorporated in the scheme for services of general interest of municipalities and other administrative bodies. The measures of electrification showed that the councillors were able and willing to react to altered societal situations and were supporting modernisation and dynamism.[309]

8.1.8. PRICING

As indicated earlier, price was not the sole argument when trying to sell electricity instead of other kinds of energy, but it was a tool to boost its distribution. Low tariffs were encouraged to enhance consumption and ensure adequate turnover, intensify dependence on electricity, increase sales of the manufacturing industries and electrical appliances, enable expansion of power plants, push back rival energies and conquer new districts. Not least, it was in the interest of the big electricity providers to deter manufacturers from building generators for self-supply by keeping prices low.[310]

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[307] Langendijk, *Electrifying Europe*, 53, 66.
[308] Zängl, *Deutschlands Strom*, 72.
[309] Binder, "Visionen der elektrifizierten Stadt: Stadtvorstellungen im Diskurs um die Elektrifizierung," 196.
[310] Zängl, *Deutschlands Strom*, 59-60.

Nevertheless, prices did matter. The emergence of the new economy with a supposedly 'free', competitive market mechanism banked on the provision of cheap energy. The price levels were expected not to fluctuate drastically and stay within a certain range by either custom or legal regulation if needed. Furthermore, an ample and steady provision of electricity was always presumed regardless of its priced market value. In case of shortages or surpluses, which influenced the energy price as a 'free market'-commodity, tensions were practically inevitable. "To be poor was to lack strategic control over entry and withdrawal from the market. … To be well-off was to create a system that could sustain itself for short periods if that proved necessary."[311]

Taxation is one of several governmental means to rearrange excesses and lacks of energy rents in order to reach a more even allocation of wealth among citizens.[312]

8.1.9. INFLUENCE OF WARFARE ON GOVERNMENTAL DECISIONS

Discussions in Europe at the end of the 19th and beginning of the 20th century about the development of monopolies of electricity supply came to a halt with the outbreak of World War I. Electricity production and consumption rose by its utilisation in the war industry as well as via the general consolidation of the market in the course of governmental undertakings.[313]

The USA faced, like other countries as well, a shortage of coal towards the end of the First World War. Journal articles promoted the change to electric heating and cooking as an act of "patriotic duty" to save the fossil resource.[314] War efforts made larger power plants necessary and existing ones were equipped with energy saving insulation and encouraged the usage of exhaust heat.[315] Overall the political watershed of the War was barely noticeable in technological developments because coal and energy shortages speeded up the construction of

[311] Nye, *Consuming Power*, 33-34.
[312] Beaudreau, "On the Creation and Distribution of Energy Rents," 75-76.
[313] Zängl, *Deutschlands Strom*, 81-82.
[314] Plitzner, "The Amazing Magic that Lives in a Wire," 95.
[315] Gilson, "Rationale Kalkulation oder prophetische Vision?," 131, 134.

(more hydroelectric) power plants and the implementation of electricity in every day life.[316] This, however, only makes sense granted that electricity is produced either with a smaller proportion of fossil fuels than needed in the household or from other sources, such as hydroelectricity.

Before 1914 and particularly in the very early phases of electrification the state, too, was a crucial customer and promoter of electricity via the military and navy. Because of the need for discretion and reliance in military operations, which was more important to officials than competition and low prices, a tendency developed to contract the same company over and over again. This was the case, for instance, in Germany, where Siemens & Halske repeatedly received orders from high ranking military officials, even if they were sceptical of the technological characteristics at first. On the one hand this happened to guarantee compatibility of all systems and on the other because of Siemens' early involvement in the political sphere as outlined earlier.[317]

With World War I in full swing, more and more factories were equipped with electricity to speed up production. Electricity became synonymous with rationalisation and the governments, wherever appropriate, stepped in as financiers and encouraged interconnection of power plants to increase and secure power supply. The military, thus, played a decisive role in securing electricity's position as a dominant fuel and changed the initially hesitant governmental attitude towards the technology. In addition, there was a large incentive towards electrification, especially hydroelectricity, as coal became scarcer and more expensive.[318]

Electricity in many respects had a rough start. In order to realise its full potential it needs to be readily accessible and incorporated in a strong and reliable network – something that can only be facilitated with governmental support. Standardisation was a necessity for the functionality of networks which also needed to be regulated and enforced from an official body in case of rouge operations threatening its stability. If, eventually, politicians could be convinced

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[316] Felber, “"La fée électricité": Visionen einer Technik,” 119.
[317] Zängl, *Deutschlands Strom*, 45.
[318] Langendijk, *Electrifying Europe*, 51, 54.

of the advantages of the new but in the beginning comparably expensive technology, the beneficial effects could materialise and be multiplied by the addition of more appliances, customers and production incentives in the economic realm which eventually showed positive results also for society as a whole. This supports the idea that the success of an energy system is inseparably linked with its compliance with a political agenda in the long run. Therefore, the relevance of policy makers shall not be underestimated or sidelined by merely looking at technological and direct economic superiority or inferiority of a source of energy.

Political systems have grown and changed alongside and within the cultural spectrum they are embedded in. Therefore, the following pages will take a closer look at how the mechanisms of cultural identity differ from those in technology and economics as such in order to point out some of the challenges that (political and non-political) advocates for electricity are faced with.

8.2. "CULTURAL IDENTITY INFLUENCED THE ASSERTION AND IMPLEMENTATION OF THE TECHNOLOGY"

Culture is the base of social interaction, of perception of moral and interpretation of actions, symbols, gestures and language. It creates the backdrop and framework for human interaction. Predominantly, it is not consciously articulated, defined or enforced, but it is rather the essence of (once intentional and conscious) decisions and choices of our predecessors which in contemporary circumstances often enough cannot be explained by concepts of logic or reason.

The terms good and bad, right and wrong, positive and negative, are by definition linked with judgement which demands a cultural context. Thus, all choices regarding energy must be interpreted and positioned within this cultural framework.

"Culture influences the way people weigh potential benefits and evaluate certain risks, as well as the way they react to the same perceived risks. Differences in risk perception, connected with certain behaviours, appear to be culturally based; and these differences have a strong impact on the position people take regarding the energy problem."[319] The perception of risks is subject to change as well as cultural and social differences. Moreover, the objective and subjective assessment of a risk do not necessarily coincide, making it difficult for sceptics to be convinced by allegedly objective data and expert statements. This is partially also reflected in the way that peoples' risk perception of economic and energy developments has not been evolving at a corresponding pace, meaning that the adaptation of a rationally 'better' source of energy did not happen the moment it was possible to be implemented, as can be seen when looking at the example of the lightning rod later on.[320]

8.2.1. CULTURALLY SHAPED PERCEPTIONS

Technology does not act detached from human agenda or emotional and cultural connotation. "[M]aterial goods are not incidental. They are building blocks of identity."[321] Machines are attributed certain characteristics that evolve and manifest themselves with intention, invention, investment, marketing and implementation over years and sometimes even generations. "The hegemony of large systems is culturally shaped"[322] and influences a people's perceptions of their world. New devices and energy systems do not automatically fit into cultural contexts but rather have to be made to fit with considerable efforts and ingenuity.[323] If this aspect is ignored or the efforts fail, the successful implementation of any innovation or invention becomes rather unlikely. "Energy choices are social constructions that often appear to be inevitable once they acquire technological momentum."[324] Yet, the process of change is generally scattered, slow and arduous as the line of reasoning within a social and cultural sphere follows different rules than those of science or economics.

Companies influence the way a technology is culturally perceived by its success or failure to address also societal problems by promoting virtues such as work,

[319] Dooley, "Introduction," xvii.
[320] Ibid.
[321] Nye, *Consuming Power*, 167.
[322] Ibid., 4-5.
[323] Carlson, "Electrical Inventions and Cultural Traumas: The Telephone in Germany and America, 1860 - 1880," 153.
[324] Nye, *Consuming Power*, 176.

organisation and discipline.[325] The assertiveness of a new energy source corresponds with the success of marketing efforts and how well it competes with – or complements – the dominant energy sources. Both the factual usefulness and the promotional techniques chosen to market the new energy source were scrutinised by potential customers and met by a series of positive as well as negative responses.[326] For example, the overhead cables of the electric tramway were often perceived as not aesthetical and as damaging to the look of the urban landscape.[327] A simple economic competitive advantage would not suffice as a convincing argument to adopt e.g. electricity or oil. Crucial in this respect is, if the new system of harnessing, converting, transporting and final utilization is challenging the existing one. One would presume that when looking at the new energies as competitors, for instance, the technological superiority of electricity in terms of versatility or reliable and cheap transportation in comparison to coal or wood imposed a threat to the established energy supply chain. Mine owners and related industrialists feared for their revenues and opposed the transition. On the other hand, if they engaged oil and electricity as supplementary to the traditional fuels, the persons in charge were keen to get involved in the restructuring of facilities and infrastructure on political, economic and social level. Their economic base could thus be broadened and allowed for customers to choose amongst traditional fuels, fossil fuels and electricity the most adequate for their purpose. The most successful fuel, in the end, is always the one that can adapt best to the changing needs of a society at a given place and time in history. The advantage of fossil fuels and electricity (often generated by means of fossil fuels) is their ability to keep up with the miscellaneous demands of an increasingly urbanised, industrialised and educated society.[328]

This did not only concern male part of the population, even though they were the main actors in the economic and political sphere in terms of decision making and wage labour. The role of women in the respective society, which will be looked at in more detail in the following sub-chapter, was redefined as well during the process of economic structural change.

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[325] Tetzlaff, "Vernetztes Denken?," 21.
[326] Nye, *Consuming Power*, 9-10.
[327] Luxbacher, "Die Geschichte der Elektrotechnik in der deutschsprachigen Technikhistoriographie vor 1945," 48.
[328] Melosi, "Energy Transitions in Historical Perspective," 5-7.

8.2.2. ROLE OF WOMEN

In spite of all the social predicaments for affected skilled workers and the setbacks unions had to suffer, the lack of expertise necessary to operate many machines had also an emancipating effect, as far as this adjective is appropriate in this regard. Women were in some cases preferred to be hired as they were thought to be less likely to join or form a union. Even if they did, the unionists were seldom concerned with their problems although officially they were committed to the cause. Factory work brought – or sometimes pressured by the economic deprivation of their families – women into the wage labour sector, but many patriarchal union leaders would have rather seen them back at home. Possibly this was not only out of a conservative world view but rather out of fear of more job losses for men. The most convincing argument, presumably, to hire women instead of men for simple tasks was that companies paid them little over half of a man's salary.[329]

Women were to protect their family from goods of little quality and seek for improvement of life at home.[330] A Swiss magazine called "Gartenlaube"[331], whose main readership were women, did not only directly advertise electricity in the kitchen but portrayed it as a "refining" effect on "spirit and body of humankind" and that it had the potential to improve "civilized behaviour, education and sanitation".[332] With women being able to dedicate more time "to sewing", a traditional task that "too little time" was spent on due to the heavy workload, women could now reduce their "guilt feelings" by letting electricity take over some of their duties.[333] As children stayed at home for longer and needed more attention, household work did not actually get less, also because the standards of cleanliness rose (more frequent repetition of chores) and new duties, formerly done by the husband or a maid such a beating rugs, were put on the housewives' agenda. This expansion of workload, which presumably was the case for both women with and without access to electrical appliances, was most

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[329] Nye, *Consuming Power*, 136-137.
[330] Ibid., 153.
[331] English translation: "arbour"
[332] Plitzner, "The Amazing Magic that Lives in a Wire," 91.
[333] Ibid., 96.

likely connected with an unvoiced assumption that household work was of little value and expendable at will.[334]

Both men and women were encouraged to believe in a certain emancipatory character of the new technology. Given the fact that most gadgets were bought by men, they had to be convinced of the advantages as well and were told that "even the unskilled husband" could handle an electric stove because it was largely automated.[335] Supposedly the extra expense for electrical appliances and installation was a good and cheap investment as opposed to the gains in emancipation (depending on the definition of the term), efficiency and time available for other activities. Needing to attend to household duties yourself meant social decline, but combining being a savvy housewife and a lady by 'hiring' electricity became perfectly acceptable and desirable. An advertisement of 1926 claimed the advantage of an electrified kitchen as enabling the woman to spend more time on her appearance to keep her husband and her surroundings happy and content. Health improvement and relaxation opportunities due to the reduction of time and effort involved when using electrical appliances were also advertised. There was one thing, though, that could spoil the housewarming party for electricity providers, and that was the gas stove.[336]

Having access to electric light and appliances in the household was considered basic after about 1930 in western Europe, while only 40 years earlier it was considered a luxury.[337] Electricity could be used to replace a helping hand in the household, a maid for instance.[338] This meant that not only qualified, generally male factory or farm workers were let go during the shift automated and mechanised towards factory work, but female servants as well. The technology itself was neither gender-biased nor discriminating against specific groups of society, but for those unapt for the system change it most likely created more problems than it solved.

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334 Nye, *Consuming Power*, 153-154.
335 Plitzner, "The Amazing Magic that Lives in a Wire," 102.
336 Ibid., 96-101.
337 Nye, *Consuming Power*, 171.
338 Plitzner, "The Amazing Magic that Lives in a Wire," 92.

Entrepreneurs in the field of electricity needed to assess the wants of the population, both male and female, and the level of convenience potential customers were able to afford in order to deliver products and services successfully. The acceptance of an invention depends on usability as well as the approval by public opinion. A few examples of cultural idiosyncrasies concerning electric innovations intend to demonstrate their influence on economic success of a technology.

8.2.3. REGIONAL EXAMPLES

World exhibitions were a suitable forum for assessing and shaping the cultural perceptions of technological devices that depended on economical, technical and social aspects and expectations. The attitude of Europeans (note: after enlightenment had spread and manifested itself) towards innovation was a rather positive one.[339] Especially the bourgeois belief in progress at the end of the 19th century was mirrored and tried to be incorporated in the campaigns. For instance, the Viennese Electricity Exhibition in 1883 demonstrated sound transmission by broadcasting two shows from the State Opera and the Varieté Ronacher, making music a good for the masses. The public was quickly convinced of the societal benefit of telegraphs and electric railways, which were amongst the first to be presented. Electric lighting and energy itself had a rockier start in Europe and remained controversial well into the 1880s. A decade later utopian ideas flourished in which electricity was an infinite and arbitrarily dividable source of energy. The spark for industrial progress became more and more directly connected to the availability of electric energy, but sceptics did not grow tired of pointing out the perceived detrimental effects on social fibre and the environment.[340]

Sceptics were not only home to the Old Continent. Also in the United States criticism occurred, but with the statesman and scientist Benjamin Franklin (1706 – 1790) they had a prominent and keen supporter of the enlightened and economic culture of thinking of natural sciences and he supported the view that nature holds a constant amount of what he called “fluidum”. This implied that

339 Sieferle, “Transport und wirtschaftliche Entwicklung,” 24.
340 Felber, “"La fée électricité": Visionen einer Technik,” 106-112.

humans were only able to reach three static states: excess, shortage or equilibrium.[341]

Franklin's stance towards electricity triggered different reactions. In France, for instance, his ideas were generally openly welcomed as his person was admired for being a freedom fighter against the British. This can be demonstrated taking the example of the lightning rod. Franklin had proposed to install his invention on rooftops of ammunition depots and arsenals to prevent instant explosions by lightning stroke. The British deemed the lightning rod itself too dangerous, but their French opponents not only embraced the device for military purposes but also for trading companies' premises.[342]

During the 1880s electricity came into discussion in the USA for its use in executions. As "anything cruel and unusual punishment" was prohibited in the U.S. constitution, it was debated whether or not electrocution was a more merciful and less painful death. Although it was primarily a legal issue, Edison was consulted and stated, or rather presumed, that electricity could perform the task and fulfil the requirements.[343]

In Italy, things were slightly different. The two physicists Luigi Galvani and Alessandro Volta were rivals over the origins of electricity, with Galvani defending his theory of all electricity being caused by organic, chemical reactions. Apart from their scientific disagreement, Volta made use of changing political circumstances to his favour. When in 1796 Napoleon invaded northern Italy and founded the Cisalpine Republic, Galvani was banned from his profession and died the following year. Volta decided to become a pro-Napoleon politician so he was able to keep his laboratory. In the two years until Austria conquered the region in 1799 Volta was able to scientifically prove Galvani wrong and substantiate his claims for electromotive force. He also used his good contacts with London and presented his apparatus for controlled handling with

[341] Meya and Sibum, *Das fünfte Element: Wirkungen und Deutungen der Elektrizität*, 75-79.
[342] Ibid., 82-94.
[343] Crosby, *Children of the sun*, 116.

the electric current at the Royal Society, which in turn again sparked interest in France.[344]

Galvani managed to make use of the scientifically liberal European institutions to continue his research while at the same time not alienating himself from important but potentially problematic pressure groups by playing along until he had secured himself and his research in a favourable position. He was able to convince the different authorities in charge of the relevance of his research while not getting in the midst of political conflict surrounding him.

8.2.4. CHURCH

Churches had to be brought on the side of engineers because they represented a central point in societal life, particularly in the countryside. The centre of an average village was the church building, which was usually also the highest construction and thus most prone to be struck by lightning. The church took a sceptical stand against the new technology, thinking it was interfering with God's will.[345] The church was also less than happy about the comparison of electric light with a "God-like force"[346].

The transformation to a machinery operated industry was criticised for its "soulless quality that threatened to spread and infect the nation's body politic."[347] What engineers and politicians in favour of electrification needed were for the church to demonstrate a public symbol of the positive effects of the new technology. Church clocks were driven by electric motors and hereby became the predecessors of electrical timing. This corresponded with the trend towards standardisation of time and its separation into equal units. The risk of fires due to lightning was reduced dramatically by the implementation of a lightning rod – something that needed decades of convincing in the late 18th and early 19th century, with its most prominent advocate being Benjamin Franklin. Significant, however, for the electricity providers was nevertheless, that with the

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[344] Meya and Sibum, *Das fünfte Element: Wirkungen und Deutungen der Elektrizität*, 137-138.
[345] Ibid., 89-94.
[346] Felber, ""La fée électricité": Visionen einer Technik," 112.
[347] Morus, *Frankenstein's children*, 159.

church they had not only found an important supporter or promoter, but also an additional large-scale consumer.[348]

With the introduction of electricity the fibre of a village was changed. The focal point shifted to the factory, which was surrounded by accommodation purely constructed for the workers of that factory. Especially in the earlier days and in case of in-house generation of electricity, these facilities were often geographically bound to regions with water streams or coal mines in order to keep entropy low by covering only short distances from generator to the consuming machines.[349]

In-house electricity generation, however, was mostly a matter of available fossil fuels.[350] Few locations proved practical enough to ensure constant and sufficient energy provision by means of hydropower or wind and therefore had to rely on outside energy supply, whether it was electricity itself or delivery of fossil fuels for conversion on site. So, entire villages and towns grew around factories in arbitrary and economically feasible locations.

8.2.5. PROMOTION OF ELECTRICITY

Technology can and is not only used to solve problems but also to create them. In order to increase sales and consumption and venture into new markets, electricity providers and their marketing specialists, just like every other producer in a competitive position, tried to find ways to make people want what they offer. To secure economic survival, companies took a proactive position instead of merely reacting to existing needs.[351]

As an example of a new strategy to reach potential customers, vending machines deserve brief mentioning. The first vending machines appeared in the late 1890s and sold chewing gum. The lack of personal interaction and the human eye to overlook the process implied the complete standardization of the product, the

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[348] Zängl, *Deutschlands Strom*, 37-38.
[349] Nye, *Consuming Power*.
[350] Enflo, Kander, and Schön, "Electrification and energy productivity," 2811.
[351] Tetzlaff, "Vernetztes Denken?," 23.

process and reliability of the mechanism. Brand names replaced the expertise of the shop assistant to assure or at least indicate quality.[352]

Vending machines were at first purely mechanical, but with electricity the process could become more sophisticated and cooling devices and light could be integrated. The computer would revolutionise this form of selling in the latter half of the 20th century. This indicates that machines were not only able to replace human labour but also that with the addition of promotion and the creation of a completely standardised and branded product the process of selling underwent change.

Furthermore, the coming of department stores created an almost theatrical consumption experience and added an entertaining element to the shopping experience.[353]

8.2.6. ENTERTAINMENT

It was not only mass production but also mass experiences that electricity facilitated via inventions such as the motion picture, the radio, the phonograph, loudspeakers and such like. These were not mere simplifications of elite culture phenomena but rather reactions to demand for popular culture by blue-collar as well as the growing community of white-collar workers. On the one hand, real income had grown which enabled more and more people to spend their money on more than just basic needs and saving for harsher times; on the other hand between 1850 and 1920 the average amount of working hours per week fell from 66 to 48, leaving more time for leisure opportunities. Film, radio and other media made entertainment, a traditionally local and domestic pastime, a regional and sometimes even trans-national commodity. Artists became famous in absentia and tours were means to present the audience with established entertainers rather than introducing them to new ones. Electricity was the intensifying part of the process, creating its own demand.[354]

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[352] Nye, *Consuming Power*, 168.
[353] Ibid., 172.
[354] Ibid., 157, 160-167.

Even courtship underwent change. Increased mobility, particular with the advent of the automobile, and entertainment opportunities out of house enabled socialising without constant parental supervision.[355]

Electricity is indispensable for popular culture of today's world for similar reason as described at the end of chapter 7.6. The entertainment industry, as such only developed after the large-scale implementation of electricity, made use of the communication tools that used vision and audio for getting attention from the audience.

8.2.7. CULTURAL EVOLUTION

"The series of smaller, albeit significant, changes in patterns of use occurred for many reasons, including consumer preference, availability, relative cost, technical innovation, and geographic determinants … [W]hile the causes of the transition produced evolutionary change, the results were indeed revolutionary."[356] This means that slow and gradual change occurred which eventually led to a fundamental change of the entire structure of society.

Considering the terms revolution versus evolution in the sentence above, it is important to understand that in this respect we are not talking about evolution in a strictly Darwinistic sense. Darwin's evolutionary mechanisms are not per se intentional and work via selection processes that do not create elements of a determined order. Rather, they adapt to circumstances by omitting the ones least capable of adjustment. Cultural evolution is, however, capable of consciously deciding to move in a certain direction and to deliberately seek new educational experiences.[357] This tends towards the logic of orthogenesis in which a human being intrinsically strives towards improvement of his or her economic standing and tries to develop techniques to master nature. This materialises as technological progress, education, modernisation and economic growth. Opposing both ideologies are defenders of the theory that humans have

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[355] Nye, *Consuming Power*, 180.
[356] Melosi, "Energy Transitions in Historical Perspective," 7.
[357] Sieferle, *Das Ende der Fläche*, 301.

to simply cope with unlikely or unpredictable situations and contingent breakthroughs in problem solution attempts.[358]

Regardless of the terminology used, not being connected to electricity supply meant being excluded from certain parts of the economy and societal life, for example information flow, or at least disadvantaged and left behind in industrial development.[359] Electricity represented modernity and progress and stood at the root of the so-called second industrial revolution, which started roughly in the late 19th century and gained momentum during the early 20th. It changed – or at least had the capacity to do so – the social fibre of a community. The term 'modern' was redefined and everyone not participating in the transition, for whatever reason, would eventually be regarded as an antiquated member of society. The more normal 'modernity' became, the bigger the perceived gap between the modern and 'un-modern' people. Electricity was promoted as a means to lead a comfortable life.[360]

What used to be a luxury slowly turned into a necessity, which was only possible because of the profusion of affordable mass products.[361] Scientists and engineers achieved their personal peak not merely by solving a problem but by creating a solution system for the benefit of society.[362]

8.2.8. Conclusive remarks about culture and society

Social practice is neither directly reasonable or consequential, nor can it be consciously learned. Habits have developed from causes which might not have any relevance to today's life but are part of common memory and so-called tradition, which is hard to combat even with sensible arguments. Breaking these habits touches sensitive ground as it involves change on a very personal level as well as collectively on (at least) a community basis. Furthermore, being

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358 Sieferle, *Das Ende der Fläche*, 302.
359 Smil, *Energy in world history*, 200-???
360 Hellrigel, "The Quest to Be Modern: The Evolutionary Adoption of Electricity in the United States, 1880s - 1920s," 72-74.
361 Wrigley, *Continuity, Chance and Change*, 80.
362 Nye, *Consuming Power*, 131.

knowledgeable and cognitively aware of a problem does not necessary mean willingness or capability to act upon it.

If a technological system does not correspond with cultural idiosyncrasies, the likelihood for its success are slim as popular opinion and habit eventually matter in spite of their sensibility. The agents can try to make use of the manifold communication opportunities electricity enables to penetrate and manipulate the collective opinion to promote itself and its applications.

9. CONCLUSION

Overall, a series of socio-economic effects could be collected from consulting the sources. Taking into account that 'positive' and 'negative' are culturally shaped terms, economic growth and a rise in food production due to economies of scale and rationalisation facilitated by electrification, a rise of living standards simply by an ease of individual manual work load and more sophisticated and affordable (mass) transportation with worldwide network(s) that also encompass telecommunication, are overall considered positive effects of electricity. The influence of electricity on telecommunication and lighting changed the pace and dimension of people's interaction as they were no longer forced to rely on communicating face to face or via mail nor did they depend on daylight, dim candle light or hazardous gas lamps. Communication could happen faster and far easier. Better lighting enabled, amongst other conveniences, the introduction or extension of shift work. The same applies to electricity-aided urbanisation which shifted workforce first towards factory labour and service provision in a system with ever more refined division of labour that had been initiated by the advent of the industrial revolution. In a second step electrically driven machines induced structural changes towards supervision and management instead of physical labour. Electricity eventually proved to be a (comparably) cheap and reliable source of energy which enabled more efficient machines, better designs, more specialisation, more sophistication and acceleration. Reliance on muscle power decreased with the usage of electric machines and appliances.

Energy-dense components such as electricity and fossil fuels are most likely a significant contributing factor to a change in the mode of production during the process of industrialisation. Important to keep in mind is the fact that as a secondary source of energy electricity relies on a primary which might be scarce, finite (fossil fuels) or subject to fluctuation (water, wind, etc.). The surplus generated from the additional amounts of energy could then be allocated amongst the human workforce. The entire concept of perception of wealth changed gradually as an escape from life for subsistence became a realistic option, at least for some. The access to energy sources is unevenly distributed across society and with increased possibility to gain wealth by accumulating energy rents the risk increases to fall behind and become stigmatised as poor in relation to others which sparks social tension and unrest. This in turn calls policy makers to the forefront to implement regulations to enable accessibility to energy rents also for the disadvantaged.

Enflo et al. provided the most convincing arguments with references about a causal relationship between the usage of electricity in the production process and the rise in production output, although stressing that the effects shall not be mistaken with general trends in economic development that might be unrelated to the technology used. Electricity appears to have a dynamic character predominantly in sectors that use electricity in various parts of the production process, for example the construction of machinery or electrometallurgy.

The technology and the production process itself become very abstract and detach the user from the perception of how much energy is actually needed for production or provision of a service. Urbanisation and increased migration are difficult to control and unwanted settlement, overcrowding and desertion of communities are practically unavoidable to a certain degree in the bargaining for energy rents. Along with the good comes the bad, so to speak. Yet, being able to have machines perform strenuous or tedious work left the majority of individuals affected with fewer chores on their tasks list, less work-related physical health issues and more time for leisure and consumption of convenience products and services.

Altogether, the majority of arguments compiled in this research have underlined the presupposition that energy provision – in particular that of electricity – economic growth and a betterment of living conditions are linked. There is little doubt that in the long run the positive effects for a society outweigh the negative. That being said, the long-term consequences of overexertion of resources have yet to be fully understood, but given the choice between electricity and an equivalent amount of energy of a different kind most people, presumably, would chose the former. The key word in this sentence and practically also in all the above is 'presumably'.

Actual proof for a causal relationship between energy provision (in this case electricity in particular), the development of the economy and its effects on living conditions is very difficult to detect. The authors of the works consulted have also been very cautious with definite statements about a direct causal link. A clear tendency towards an overall correlation of the three realms can be understood and small steps in the right direction have been taken to accumulate more data, but much more primary research would be needed in order to fully understand the complex relations between all influential factors to come to a sound conclusion with factual evidence. So much for what the literature has told us.

What can be said for certain is that electricity was able to overcome technological barriers that had not been able to be breached previously. Be it precise measurements of time, transmission of voice and images or concentration of power for fulfilling manual tasks. Cheap and abundant electricity undeniably enabled the production of a set of new materials which had beneficial but unforeseen consequences for a multitude of industry branches. These spill-over effects occurred on several occasions, yet remain unpredictable for the future but still relevant for long-term economic growth.[363] Electricity, just as any other kind of energy, has had an influence on our way of

[363] Ayres and Warr, *The Economic Growth Engine*, 44.

life and influences historical trajectories, whereas it is important to note that it does not per se determine historical outcome.

10. Outlook

Due to the limited time frame and research material available, pragmatic choices had to be made to focus on looking for arguments in support of or opposing a causal relationship between the usage of electricity, economic development and a change in living conditions. Several related issues would deserve more attention in follow-up research projects, such as covering examples from other regions with a different economic background or focusing in more detail on economic, political and/or social factors in relation to energy consumption. Agricultural advancements of the time period have been paid very little attention to but would in themselves hold enough questions for investigation in several research projects.

As indicated earlier, a more thorough study regarding potential causal relationships between energy provision, economic development and living standards is desirable and will definitely be tackled in a PhD-thesis to come.

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12. Annex

12.1. Abstract – English Version

The intention of this research was to investigate to which extent there is proof for a direct causal relationship between the use of a specific kind of energy, in this case electricity, economic development and as a presumed result a change in living conditions. The issue was tackled from three different perspectives: first, the technological side by explaining the characteristics of electricity and its economically most relevant applications. Second, the effects the implementation of a novel energy source had on the economy in the industrialisation process. Third, the effects on society – in particular the political and cultural sphere – were looked at in more detail. This investigation was carried out from a global history perspective by juxtaposing arguments by renowned scholars in the fields of economic history and social history in support or opposing statements about the distinct presupposed relationship between energy and socio-economic change. Furthermore, the research is particularly concerned with Western Europe and North America in the 19th and early 20th century. The results reveal that the likelihood of a causal relationship between the implementation of electricity in an economic system and positive effects on growth and the betterment of living conditions for the society affected is very high. However, factual proof is still scarce and more primary research is desirable in order to fully substantiate the claim of the presence of a causal chain of the three realms investigated.

12.2. ABSTRACT – DEUTSCHE VERSION

Die Intention dieser Forschungsarbeit war es, herauszufinden inwieweit eine direkte kausale Verbindung zwischen dem Gebrauch einer bestimmten Energieart, in diesem Fall Elektrizität, Wirtschaftswachstum und erwarteten Auswirkungen auf die Lebensumstände Einzelner bewiesen werden kann. An das Thema wurde von drei verschiedenen Perspektiven herangegangen. Zum Ersten wurde die technologische Seite beleuchtet indem an die Eigenschaften von Elektrizität und ihre wirtschaftlich relevantesten Anwendungsbereiche herangeführt wurde. Zweitens wurden die Auswirkungen der Einführung einer neuartigen Energiequelle auf die Wirtschaft während des Industrialisierungsprozesses beschrieben. Drittens wurden die Effekte auf die Gesellschaft – im Speziellen auf die politischen und kulturellen Bereiche – eingehender betrachtet. Diese Untersuchung wurde aus einer globalgeschichtlichen Perspektive anhand von Gegenüberstellungen verschiedener Argumentationen namhafter Wissenschafter aus den Bereichen Wirtschafts- und Sozialgeschichte durchgeführt, welche entweder zugunsten oder zuungunsten von Behauptungen über ein klares, vermutetes Verhältnis zwischen Energie und sozioökonomischem Wandel verliefen. Des Weiteren beschäftigt sich diese Forschungsarbeit vordergründig mit Westeuropa und Nordamerika im 19. und frühen 20. Jahrhundert. Die Ergebnisse zeigen, dass die Wahrscheinlichkeit eines Kausalzusammenhangs zwischen der Anwendung von Elektrizität in einem Wirtschaftssystem und positiven Auswirkungen auf das Wirtschaftswachstum und auf die Verbesserung von Lebensstandards innerhalb einer Gesellschaft sehr groß ist. Nichtsdestotrotz gibt es wenige effektive Beweise und die Durchführung von weiterer primärer Forschung auf diesem Gebiet um die Behauptungen über das Vorhandensein einer Kausalkette der drei untersuchten Bereiche faktisch zu belegen ist wünschenswert.

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2003 – 2007:	Diplomstudium Sport-, Kultur- und Veranstaltungsmanagement an der Fachhochschule Kufstein Tirol; Abschluss mit Auszeichnung Diplomarbeit: „Museum geht zur Schule; Bildung und musikästhetische Bildung in Österreich – Die Rolle der Museen am Beispiel des ‚Haus der Musik'“ – publiziert 2010: ISBN-13: 978-3639258769
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