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ÚSTAV JAZYKŮ

ENERGY TRANSITION

PŘECHOD NA JINÉ ZDROJE ENERGIE

BACHELOR'S THESIS

BAKALÁŘSKÁ PRÁCE

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Abstract

This thesis deals with energy transition and its environmental, economic, social, and political impacts. The objective was to present the current state of the energy system and examine the reasons for its ongoing change. The thesis is divided into four parts - Types and Uses of Energy, Energy and the Environment, Economic Aspects of Energy Transition and Energy Politics. The first chapter classifies energy source types and renewable energy. The second chapter stresses environmental problems arising from energy production. The third chapter focuses on the economic and socio-economic aspects of the energy transition and the last part analyzes important energy markets and describes their cooperation. Each chapter is based on the review of diverse scientific and popular scientific literature.

Keywords

Energy transition, renewable energy, environment, sustainability

Abstrakt

Bakalářská práce se zabývá přechodem na jiné zdroje energie a zkoumá jeho environmentální, ekonomické a sociální dopady. Tato práce popisuje aktuální výrobu energie z obnovitelných zdrojů a nastiňuje jejich využití v budoucnosti. Práce je rozdělena na čtyři kapitoly. První kapitola pojednává o aktuálních zdrojích energie a obnovitelných zdrojích. Druhá kapitola je zaměřena na vliv výroby energie na životní prostředí. Třetí kapitola zkoumá ekonomické a sociální aspekty přechodu na jiné zdroje. Poslední kapitola se zabývá analýzou důležitých energetických trhů a jejich spoluprací. Každá kapitola je podložena rešerší vybrané literatury.

Klíčová slova

Přechod na jiné zdroje, obnovitelná energie, životní prostředí, udržitelnost

Rozšířený abstrakt

Energetický průmysl se transformuje podobně jako ostatní technologická odvětví. Tento trend je posílen řadou událostí, především neustálým vývojem nových technologií, environmentálními změnami, rostoucí poptávkou po energii, touhou po nižších cenách energií a úsilím o lepší kvalitu života. Vzhledem k tomu, že energetický průmysl je jedním z největších původců skleníkových plynů, je nutné přejít na obnovitelné zdroje, aby se tyto emise snížily.

Vezme-li se v potaz změna klimatu, která ovlivňuje život ve všech zemích, je nutné zkoumat energetický sektor a jeho přeměnu. Tato práce se zabývá přechodem na jiné zdroje energie a sleduje jeho environmentální, ekonomické a sociální dopady. Zaměřuje se na aktuální výrobu energie z obnovitelných zdrojů a nastiňuje způsoby jejich využití v budoucnosti. Práce je rozdělena na čtyři kapitoly, které jsou podloženy rešerší vybrané literatury. Hlavní metodou byla analýza s cílem porozumět tématu komplexně.

První kapitola s názvem „Types and Uses of Energy“ (Typy a využití energie) pojednává o aktuálních zdrojích energie a o obnovitelných zdrojích. Na začátku kapitoly je uveden rozdíl mezi neobnovitelnými a obnovitelnými zdroji a poté je vysvětleno, ve kterých sektorech je energie využívána. V podkapitole „Renewable Energy“ (Obnovitelná energie) jsou popsány základní druhy obnovitelných zdrojů energie, například energie vody, větru, slunečního záření, biomasy, a jejich využití. Následně jsou kromě příkladů tradiční výroby energie zmíněny i některé nové startupy, které se zabývají vývojem inovovaných zařízení.

Druhá kapitola „Energy and the Environment“ (Energie a životní prostředí) se zabývá vlivem výroby energie na životní prostředí. V této části je popsána akcelerace globálního oteplování, která je primárně důsledkem technologické činnosti obyvatelstva na Zemi. V podkapitole nazvané „Impacts of Climate Change“ (Dopady změny klimatu) jsou analyzovány důsledky klimatických změn, jako například zvyšování hladiny oceánů nebo extrémní sucha. V podkapitole „Mining and Waste“ (Těžba a odpad) je popsáno odpadové hospodářství obnovitelných elektráren a zároveň je zdůrazněna nutnost vyvíjet strategie pro nakládání s odpadem. Dále jsou sledovány negativní dopady přechodu na obnovitelné zdroje na životní prostředí, jež jsou spojené s těžbou lithia a kobaltu, kovů nezbytných k výrobě obnovitelných elektráren, a vzácných zemin jako je neodymium a selenium. Kromě negativního vlivu na životní prostředí dochází i k vykořisťování obyvatelstva zemí, v nichž se tyto suroviny těží.

Třetí kapitola „Economic Aspects of Energy Transition" (Ekonomické aspekty přechodu na jiné zdroje energie) zkoumá ekonomické a sociální aspekty přechodu na jiné zdroje. V úvodu jsou vyčísleny očekávané náklady na přechod k obnovitelným zdrojům. Zajímavé je zjištění, že náklady kapitálu obnovitelné energie jsou stabilnější než u fosilních paliv. V podkapitole s názvem „Transition Effects in EU" (Důsledky přechodu na jiné zdroje v Evropské Unii) je popsán aktuální stav přechodu na obnovitelné zdroje v Evropské unii a jsou uvedeny hlavní problémy, rozdílný domácí produkt jednotlivých zemí a vzrůstající energetická chudoba. Závěr se věnuje úsporám energie a dopravě v Evropské unii v souvislosti s projektem „Green Deal" (Zelená dohoda pro Evropu).

Poslední kapitola „Energy Politics" (Energetická politika) se zabývá analýzou důležitých energetických trhů a jejich spoluprací. Na začátku je zmíněno, že přechod na jiné zdroje představuje pro některé země možnost vybudování energetické nezávislosti a naopak je hrozbou pro země, které jsou na exportu svých energií ekonomicky závislé. V podkapitole „Energy Markets" (Energetické trhy) jsou charakterizovány energeticky významné země z různých světových regionů (Asie a Oceánie, Severní Amerika, Latinská Amerika, Eurasie, Evropa, Blízký východ a Afrika). U každé země jsou uvedeny základní informace o exportu a importu energetických surovin, je nastíněn stav energetického sektoru a jsou představeny iniciativy, které napomáhají k přechodu na obnovitelné zdroje. Dále jsou uvedeny příklady aktuálně probíhajících projektů spolupráce v oblasti přechodu na jiné zdroje energie. Jedním z projektů, který se zaměřuje na vývoj obnovitelné energie, je program EU4Energy, který podporuje země východní Evropy a regionu Střední Asie. Energeticky nejvýraznější zemí je Čína, která má největší světovou spotřebu energie a současně produkuje největší množství energie z obnovitelných zdrojů. Čína je také velkým investorem do obnovitelných energií a největším producentem vzácných zemin. Poslední podkapitola s názvem „Conference of the Parties" (Konference OSN o změně klimatu) je věnována světově nejvýznamnější iniciativě, která bojuje proti klimatickým změnám.

Závěr bakalářské práce shrnuje nejdůležitější problémy jednotlivých kapitol. Zdůrazňuje kladné stránky obnovitelných energií, ale zároveň poukazuje na nedostatky, které by měly být odstraněny, aby byl přechod na obnovitelné zdroje skutečně udržitelný. Mnohé vědecké modely varují před dlouhotrvajícím suchem, potopami a jinými hrozbami pro život na Zemi. Nové technologie proto musí být rozumně využity, aby se zabránilo nejen enviromentálním katastrofám, ale také aby se předešlo různým energetickým krizím.

Přechod na jiné zdroje musí zohledňovat celou společnost. Energetická chudoba by měla být eliminována, aby lidé měli k dispozici základní zabezpečení. Společnost by měla kontrolovat instituce, které mají na zmíněné zabezpečení vliv, aby se energetické chudobě předcházelo. Obnovitelné zdroje by měly být implementovány do energetického systému na základě vědeckých studií, pomocí ekonomických nástrojů, s využitím dostupných výrobních kapacit a v souladu s mezinárodním právem.

Výroba energie bude nejpravděpodobněji vždy přesahovat finální spotřebu, nicméně je důležité zvyšovat efektivitu jejího využití. Státy by měly využívat ty druhy obnovitelné energie, které mají k dispozici, a případně je doplnit nukleární energií, alespoň do doby, dokud nebude vyvinuta lepší alternativa. Není možné najednou upustit od fosilních paliv. Nejvyspělejší země by měly s přechodem na obnovitelné zdroje pomáhat slabším zemím. Ačkoliv je zemní plyn fosilní palivo, které produkuje nejméně emisí, je nezbytné, aby země na něm závislé diverzifikovaly jeho dodavatele. Lidé žijící v demokratických zemích by měli zvážit, zda jim nevadí neetický původ prostředků využívaných k výrobě obnovitelné energie. Je zásadní, aby se obnovitelná energie, dnes tolik propagovaná, stala celkově udržitelnou.

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Author’s Declaration

Author:	*Jan Svatoš*
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Paper type:	*Bachelor’s Thesis*
Academic year:	*2021/22*
Topic:	*Energy Transition*

I declare that I have written this paper independently, under the guidance of the advisor and using exclusively the technical references and other sources of information cited in the project and listed in the comprehensive bibliography at the end of the project.

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Brno, May 26, 2022 Jan Svatoš

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List of Abbreviations

CEF – Connecting Europe Facility

CIS – Commonwealth of Independent States

COP – Conference of the Parties

EC – European Commission

EEA – European Environment Agency

EIA – U.S. Energy Information Administration

EU – European Union

GHG – Greenhouse gas

IEA – International Energy Agency

IRENA – International Renewable Energy Agency

NDCs – Nationally Determined Contributions

OEC – Observatory of Economic Complexity

TES – Total Energy Supply

UN – United Nations

UNEP – United Nations Environment Programme

1. INTRODUCTION

Just as other industries, the energy industry is undergoing significant changes. This trend is boosted by a series of events, particularly the unceasing evolution in technology, environmental challenges, energy demand growth, desire for lower prices of energy, and aspiration for a better quality of life. Since the energy industry is one of the largest contributors to greenhouse gas emissions, the energy transition represents an essential step to reduce this type of pollution. Moreover, dependence on imported fossil fuels coupled with other difficulties causes delivery shortages generating price spikes which motivate countries to alter their investments into renewable sources of energy.

Considering the detrimental impact of climate change in many countries, it is vital to investigate the ways of reforming the present energy system. The thesis deals with the transition to renewable sources of energy, its causes, and consequences. At the same time, it aims to describe the related technical and economic impacts on society. The research was based on a review of relevant scientific and technical literature. Taking into account the complex nature of the topic at hand and the limited space of the thesis, an analytical approach was selected to inform about the ongoing change in the most comprehensive way possible. At the same time, the thesis also offers a critical synthesis of the issues analyzed.

The thesis is divided into four chapters. The first chapter entitled *Types and Uses of Energy*, is dedicated to the classification of energy source types. Emphasis is put on introducing individual types of renewable energy and their properties. In the second chapter *Energy and Environment*, environmental reasons for the energy transition and the transition's potential downsides are presented. The third chapter, *Economic Aspects of Energy Transition* is concerned with economic and socio-economic aspects that affect the energy reform, particularly in the EU member states. The last chapter, *Energy Politics* analyzes some of the significant energy markets and indicates their progress in energy transition.

2. TYPES AND USES OF ENERGY

When it comes to energy types classification, the world currently depends mostly on non-renewable resources, such as petroleum, hydrocarbon gas liquids, natural gas, coal, and nuclear energy. Their extraction from the earth and then subsequent conversion to energy through burning causes a massive environmental burden. U.S. Energy Information Administration states (EIA) that these sources of energy might be efficient, however, at some point, mankind will run out of these supplies since most of them were formed thousands of years ago [1].

Nuclear power by fission is non-renewable because it creates radioactive waste, however this source of energy is currently the most efficient source of electricity in the world, and the amount of waste it produces is minimal compared to other non-renewables. What is more, nuclear power is emission-free. According to International Atomic Energy Agency [2], fission reactors should be replaced by fusion plants in the upcoming decades. Fusion works differently, instead of splitting atomic nuclei the reaction employs combining of atomic nuclei. Not to mention, fusion does not create any long-living nuclear waste [2]. Nuclear power is frequently left out of the clean energy mix, nonetheless, countries that are not fully capable of generating energy from renewable resources due to their geographic location or other limitations should consider maintaining at least some share of energy production by nuclear reactors.

According to Taylor [3], in October 2021, a group of 10 European countries (Czechia, Finland, France, Bulgaria, Croatia, Hungary, Poland, Romania, Slovakia, and Slovenia) requested European Commission (EC) to classify nuclear plants as 'green' sources of energy. Other states such as Denmark, Austria, or Luxembourg spoke against the inclusion of nuclear energy in the so-called EU taxonomy, claiming that nuclear reactors are not cheap and secure [3]. According to Reuters [4], on February the 2^{nd} 2022 EC has published final rules for natural gas and nuclear energy power plants, so they can be marked as green. Therefore, gas plants must run with low carbon emissions by 2035 and new nuclear plants must obtain construction permits before 2045 [4].

Figure 2.1 shows the evolution of electricity generation between 1971 – 2019.

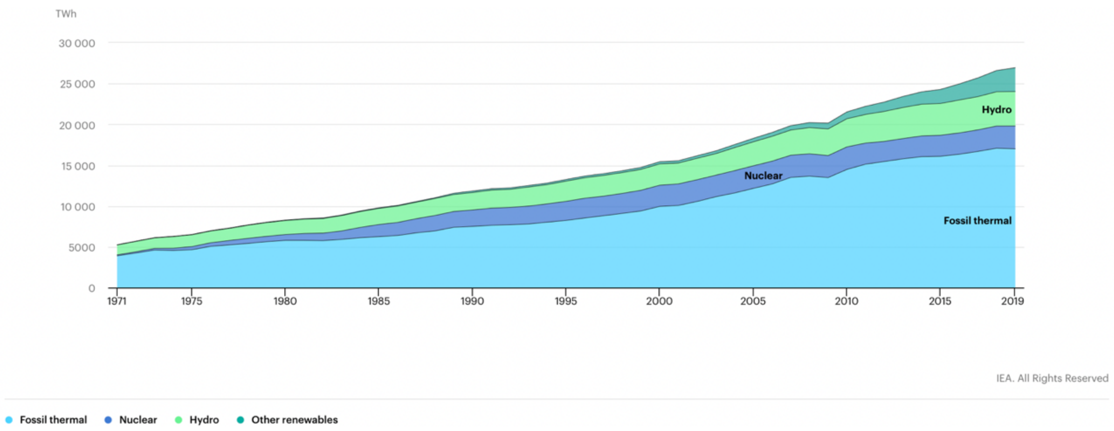

Fig. 2.1: World electricity generation by fuel (IEA, 1971 – 2019) [5]

Energy is used among different sectors, the main is transportation, followed by manufacturing, residential applications (heating), services, and other industries. Statistics of the largest end-users are shown in the figure 2.2.

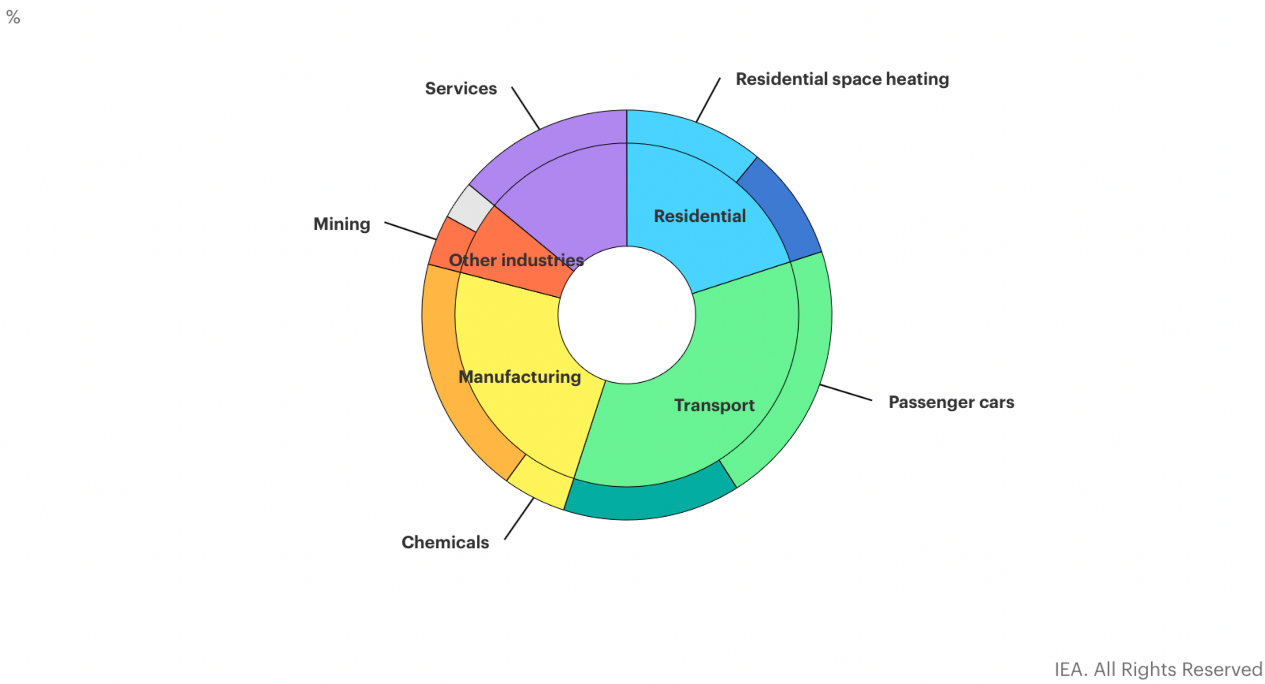

Fig. 2.2: Largest end-uses of energy by sector in selected IEA countries (IEA, 2018) [6]

2.1 Renewable Energy

It is clear, that fossil fuels meet our energy demands much more conveniently than renewable alternatives, mainly because fossil-fuel deposits are concentrated sources of energy, however, the results of the long-term use of non-renewable energy cause irreversible environmental and climate changes. For that reason, renewable energy should become the largest source of energy.

Considering that fossil fuels have finite reserves, and the Earth is facing accelerated global warming, countries all over the world are agreeing on different strategies and initiatives such as the Paris Agreement or the European Green Deal to reduce and eventually eliminate the use of non-renewable energy replacing it with renewable energy.

The main types of renewable energy sources include hydropower, wind energy, solar energy, and biomass energy. These sources of energy are renewable because they are replenished by natural phenomena. Production by renewables is increasing thanks to newly installed power plants and advancements in technology. Current production is dominated by hydro power and wind power followed by solar energy and bioenergy (fig. 2.3).

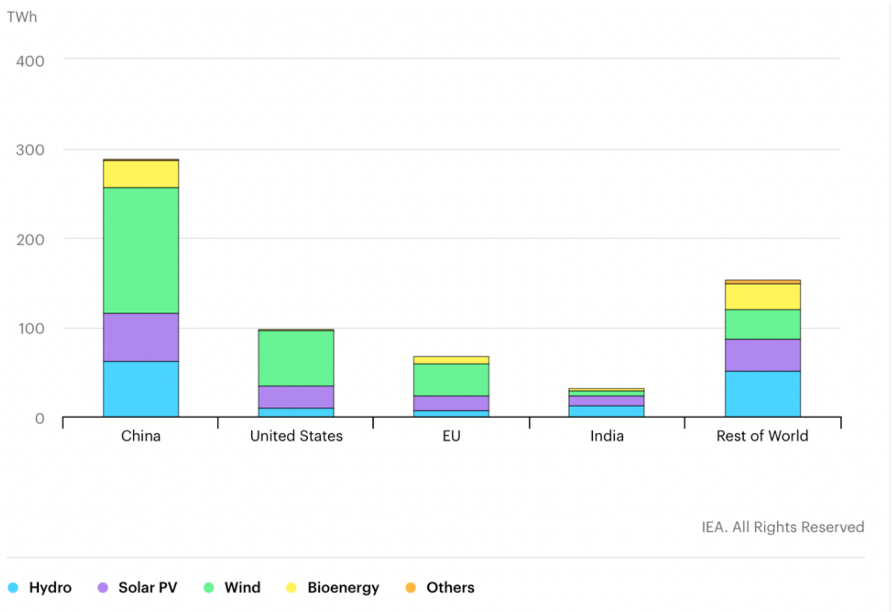

Fig. 2.3: IEA, Renewable electricity generation increase by technology, country and region (IEA, 2020-2021) [7]

Long-term storing of energy and building infrastructure for electric vehicles constitute the main technological challenges of the energy transition. The renewable energy possibilities are broad. It should be noted that distinct geographical locations have diverse possibilities of energy conversion at different efficiencies.

2.1.1 Hydropower Energy

Hydropower currently represents the primary source of renewable energy (fig. 2.1). In fact, the water has been providing mankind with mechanical energy for over two millennia. In the beginning, water's potential energy was converted into useful energy by rotating wheels and later turbines. Grinding wheat, cutting wood or other use of multifunctional tools was followed by generating electricity with dynamos and generators. According to Památkový katalog one of the early hydroelectric power plants was built in 1887 in Písek in the Czech Republic by the inventor František Křižík. The plant used two Francis turbines that drove a dynamo. Turbines he used are still the most common turbines today and can achieve over 95% efficiency [8]. Křižík demonstrated the functionality of his plant on the city lightning consisting of arc lamps that were invented by him as well. Direct current later replaced alternative current and new possibilities arose.

There are multiple ways of generating electricity from water flow. International Hydropower Association [9] identifies the following types of hydropower, which will be further characterized below: Storage hydropower, Pumped storage hydropower, Run of river hydropower, and Dynamic Tidal Power [9]. In general, most types of hydropower plants share a common ground regarding the essential parts of the plants (fig. 2.4).

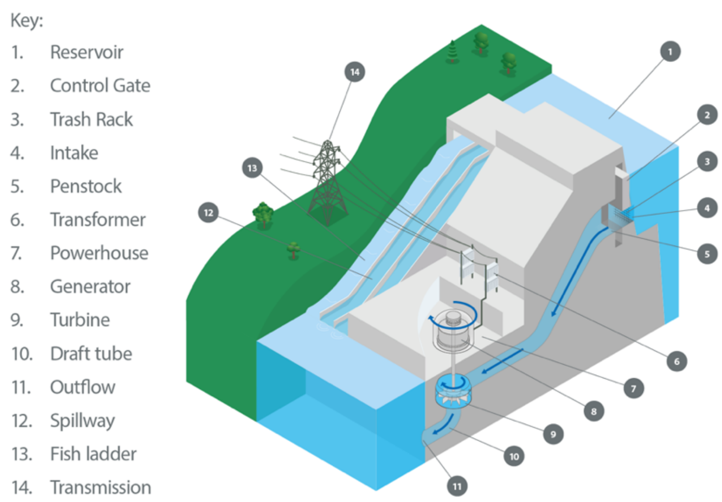

Fig. 2.4: Main components of hydropower plant (International Hydropower Association) [9]

Storage Hydropower

Water is stored using a dam or embankment and then released from the reservoir over a turbine that spins a generator shaft, generating electricity. The plant facility has control over water flow, which emits daily fluctuations and offers a continuous supply of electricity.

Pumped Storage Hydropower

Water is pumped into the upper storage using excess energy during low demand periods and if the demand increases, the water gets released through turbines to the lower reservoir and produces electricity.

Run of River Hydropower

Water flowing in the river is routed into a penstock to rotate a turbine. These plants require less space because they have relatively small storage facilities making them easier and cheaper to build.

Dynamic Tidal Power

Electricity can be generated using the natural rise and fall of tides caused by the Earth's gravitational interaction. Building a powerplant underwater is quite challenging, yet it is expected to see more tidal plants in the future with evolving technology.

When a hydropower plant is constructed, there are numerous factors to be considered, such as what type and size of the power plant can be built at a certain location. Any project requires elaborated studies examining all kinds of groundwork that have an environmental impact.

International Energy Agency (IEA) [10] states, that the maintenance of aging hydropower plants requires serious effort. Almost 40% of global hydro plants are at least 40 years old. North America has the oldest ones and China the youngest. Plants that are over 45 years old require major modernization refurbishments, so their performance is improved. This refurbishment can increase their efficiency usually by 5-10% [10].

2.1.2 Solar Energy

The Sun emits electromagnetic energy called solar radiation. The amount of energy reaching the earth is much lower than the sun creates but could provide the energy sufficiency of the whole planet. According to Mehmet, Çengel and Cibala [11], electromagnetic waves are expressed by the formula $\lambda = c/v$, where λ is a wavelength, v is a frequency, and c is the speed of light propagating in a medium. The Sun continuously emits radiation at a rate of $E_{sun} \approx 3.8 \times \_1026\ W$. The total solar irradiance $G_s = 1373\ W/m2$ is a value of the solar energy reaching the atmosphere of the Earth [11].

The main goal of utilizing solar energy collection is to make the technology more efficient and cost-effective. Solar energy has a relatively low rate of solar radiation on a unit surface, therefore greater surface area collectors must be installed. Despite that, solar energy can still help in locations where no energy infrastructure is available. There are multiple useful forms of solar energy conversion. The main methods are direct conversion to electricity through photovoltaics, conversion to usable heat via thermal collectors, and conversion through photosynthesis to biomass and fossil fuel (fig. 2.5).

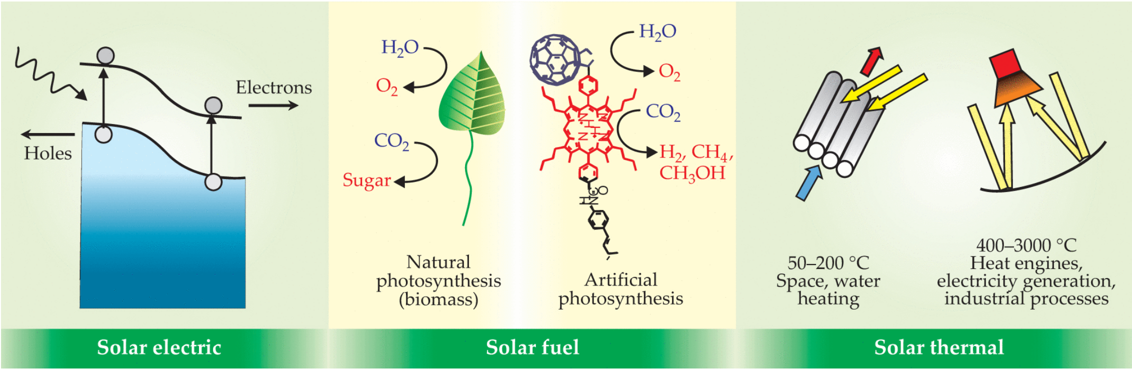

Fig. 2.5: Solar energy conversion (Crabtree, Lewis, 2007) [12]

Photovoltaics (PV)

A photovoltaic system converts solar radiation into electricity using different semiconductors. This system consists of an array of solar cells. Based on the Department of Energy [13], a single cell usually produces 1 to 2 watts of power. Solar cells produce direct current, so the produced electricity must be converted into alternating current for the following transmission [13].

According to the Department of Renewable Energy [13], the most cost-effective solar cells are currently Crystalline silicon cells. These cells are made of silicon atoms connected to form a crystal lattice. These cells represent about 95% of the market share, have an approximate lifespan of 25 years, and remain 80% efficient after expiry [13]. In Plante [14] states that crystalline silicon cells are additionally classified as monocrystalline cells and polycrystalline. Monocrystalline have higher efficiency of 13-19% but are more costly. Polycrystalline are less efficient 9-14% but easier to fabricate and cost less [14].

IEA [15] reported that solar photovoltaic generation increased by 156 TWh (23%) in 2020. This growth is a result of new policies in the United States, China, and Vietnam. Figure 2.6 shows annual PV growth between 2018-2020. Despite that energy generation improved by this quantity, the annual energy production growth of photovoltaics should be on average 24% to meet the “Net Zero Emissions by 2050 Scenario (NZE)”.

This normative scenario was developed by IEA, to show a challenging, thus achievable pathway of net-zero CO_2 emissions by 2050 [15].

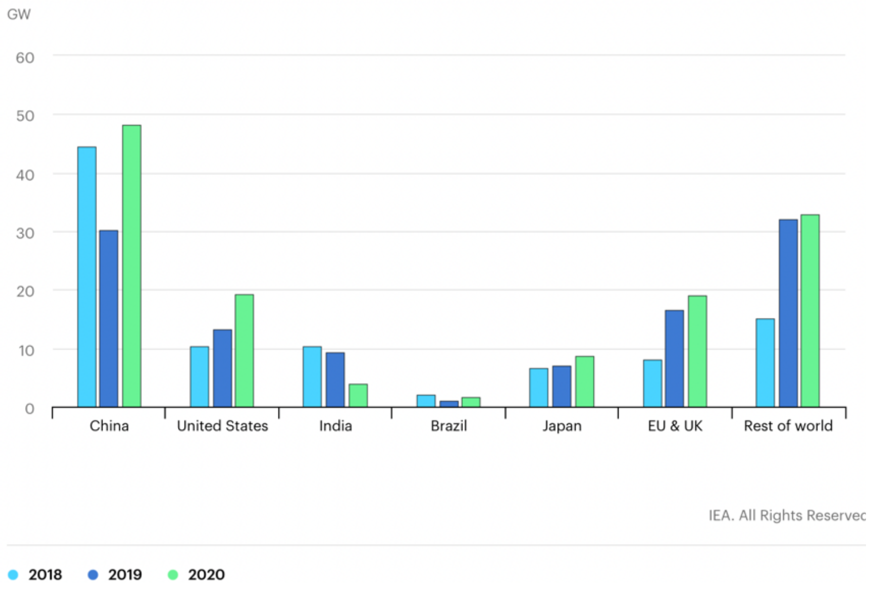

Fig. 2.6: Net solar PV capacity additions (IEA, 2018-2020) [15]

Solar thermal energy

Solar thermal collectors convert solar radiation into useable heat using uniquely designed lenses, mirrors, and heat absorbers. In most cases, heat is transferred by circulating fluid inside the collectors which can then heat water through a heat exchanger or can be converted into electricity via a heat engine. Eicker [16] classifies the following types of thermal collectors by their working temperature, which will be further characterized below.

Low-temperature collectors

These collectors work up to 100°C and are mostly used to heat homes and swimming pools. The fluid circulating inside the collectors is heated by an absorber plate and is anti-freeze to ensure it does not freeze in case of temperatures below 0°C.

Medium-temperature collectors

Such collectors work at higher temperatures reaching 300°C. This temperature provides higher efficiency and is used mostly for residential water heating.

High-temperature collectors

High-temperature collectors work up to 600°C. This allows them to create steam, which then spins a turbine and produces electricity. The heat generated by collectors is stored in molten salt which allows the plant to generate electricity 24 hours a day.

Solar fuel

Solar fuels are produced from solar energy through photochemical, photobiological and thermochemical processes. Common solar fuels are hydrogen, ammonia, or hydrazine. These fuels are made from ordinary substances such as carbon dioxide or water. Solar fuels have advantage of long-term power storage. According to DOE Office of Science, such fuels are promising, however, to enable commercial production, challenging problems dealing with efficient production or chemical reaction control must be settled down [17].

2.1.3 Wind Energy

Just as water or sun, wind energy has been used for many centuries. This energy was used for sailing, agriculture and recently for generating electricity. Windmills are used for mechanical power generation and wind turbines for generation of electricity (fig. 2.7). The wind originates with the sun because of solar energy absorption difference along the Earth's surface. Wind turbine performance is affected by the speed and density of wind. Wind energy is fast growing industry. There are various proven types of turbines that are used that remain to be produced. What is more, new innovative kinds of wind energy generators are emerging.

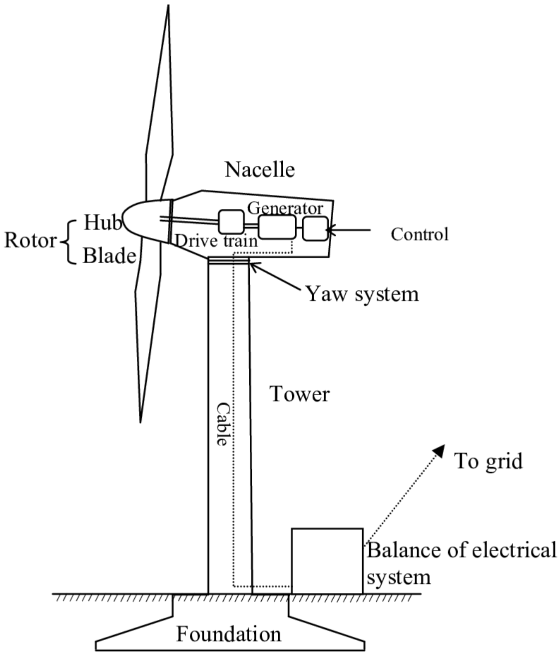

Fig. 2.7: Main components of a horizontal axis wind turbine (Albadi, 2010) [18]

When building a wind power plant, the area of future installation must be mapped to ensure consistent wind flow. Department of Energy states that a hub of a newly built wind turbine is usually 90 meters high, because the wind speeds are faster at higher altitudes [19].

Horizontal axis wind turbines

Horizontal axis wind turbines are usually the most noticeable turbine designs. They are efficient; however, they need stable winds. According to American Geoscience Institute [20], the wind speeds are higher above the sea, so it is more effective to install a wind turbine offshore rather than onshore. That is why more and more offshore windfarms are developing. Added value to this type of turbines is the fact that they do not take up more land and do not interrupt people with noise. Nonetheless, installing such technology with firm foundation at sea can be challenging and naturally not all countries have access to sea [20].

As presented by Smith [21], Denmark generated 80% of electricity from renewable resources in 2020. About half of its energy production derives from wind energy. Denmark has already built many offshore wind farms and plans to add more in the upcoming decades [21].

Vertical axis wind turbines

According to Windpower Engineering & Development [22], vertical axis turbines are convenient in places with unstable wind conditions. Their design is rotated by wind coming from all sides around the axis and in some cases from top and bottom of the axis. Because of low noise production these turbines are suitable for residential applications [22].

Innovative wind turbine designs

With the energy transition, new turbine designs are being developed. Some of the new designs are bladeless or with hidden rotary parts. Wind energy generators with hidden, slow spinning, or no rotary parts are as well safer for flying animal species contrary to typical horizontal axis wind turbines.

Vortex Tacoma is a bladeless energy generator made by a Spanish tech startup Vortex Blades [23]. The energy is generated when a cylindrical shaped alternator attached to a stator with coils and magnets oscillates (fig. 2.8). This specific oscillatory effect was defined by Von Karman as a Vortex effect. The main advantages of this bladeless generator are cost effectiveness and higher efficiency compared the swept area of a wind turbine. This project is funded by the European Union’s Horizon 2020 research and innovation [23].

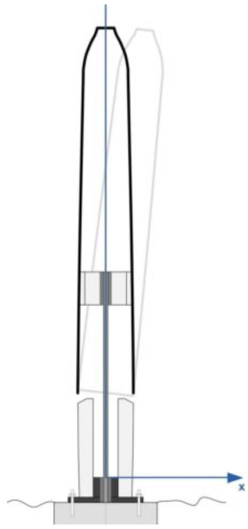

Fig. 2.8: Model of a Vortex Bladeless (Vortex Tacoma, 2021) [23]

PowerPod is a prototype small-scale wind turbine with hidden internal blade system made by Halcium Energy Inc., Salt Lake City, UT USA [24]. The system can collect incoming air from 360 degrees. The startup claims, that the alternator inside will output up to 1kW of power. This turbine does not sell yet and is expected to be available on the market by the end of 2022. The *PowerPod* is shown on figure 2.9. [24].

Fig. 2.9: PowerPod (Halcium Energy Inc.) [24]

2.1.4 Bioenergy

Bioenergy is a sustainable source of energy which is obtained from biomass. Biomass is made from organic materials such as forest residues, crop wastes, grasses, algae, food waste and urban wood waste. These materials can be burned, decomposed, or converted through technological processes into liquid or gas fuels. Biofuels are used solely or added in regular fuels.

Most common liquid biofuels are ethanol and biodiesel. Typical gaseous biofuels are biogas and syngas. Biofuels are increasingly incorporated into aviation and sea transport since these transportation sectors are the most pollutant ones. Figure 2.10 shows biofuel growth in key markets.

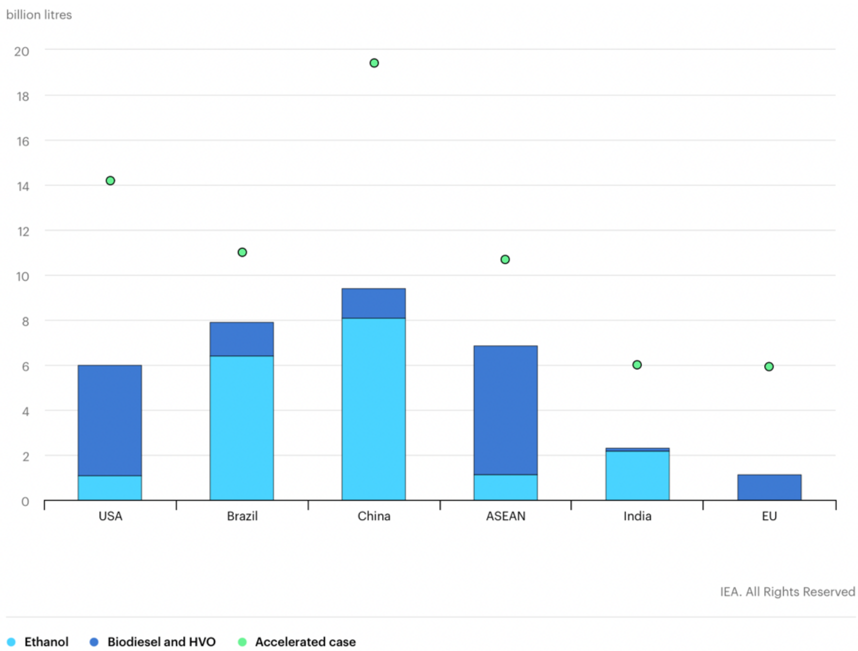

Fig. 2.10: Production of biofuel in key markets (IEA, 2019-2024) [25]

Every change is usually in some ways difficult, nonetheless, production capabilities of renewable powerhouses keep on developing, as shown in many examples (new powerplants, new alternative startups). Old plants should be also renovated to remain sustainable, and governments should support new startups to allow them offer new alternatives.

3. ENERGY AND THE ENVIRONMENT

One of the main reasons of energy transition is the need to limit the emissions of greenhouse gases (GHG), thus prevent the acceleration of global warming. NASA [26] declares that the climate change is a natural process, the Earth heats and cools itself in periods, nonetheless gradually. Humans have increased the amount of GHG since the industrial revolution [26]. Generating electricity, industry, transportation, building infrastructure and agriculture are the main emitters.

According to NOAA Mauna Loa Observatory in Hawaii, the volume of atmospheric carbon dioxide concentration constantly increases (fig. 3.1) [27].

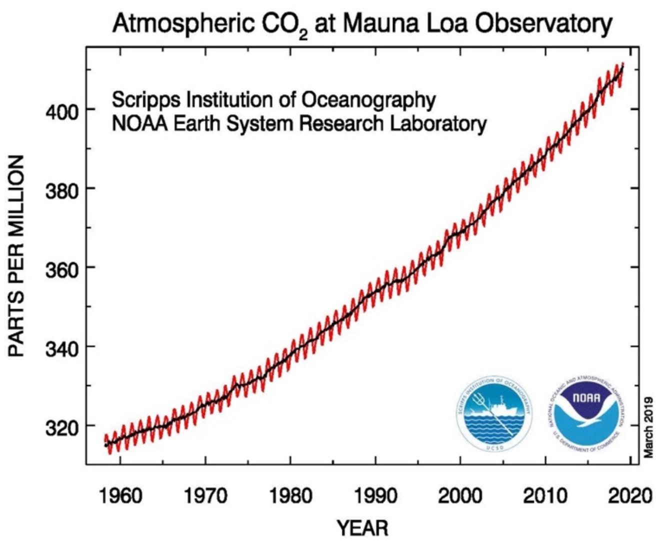

Fig. 3.1: Atmospheric CO_2 at Mauna Loa Observatory (NOAA, 1958 – 2021) [27]

This increase of carbon dioxide and other GHG is a major threat to the environment. Global warming leads to the increase in temperature which has impact on natural processes on the Earth. Higher temperatures negatively affect flowering stages of plants, shrubs, and trees, and put all humans, animals, and organisms in danger. NASA states that the temperature is currently increasing by 0.2 degrees Celsius per decade (fig. 3.2) [28]. This increase is these days more and more noticeable, even in locations that had proper living climate conditions for a long time. What is also noticeable is the decrease in air quality. It is challenging and harmful to live in some areas due to air pollution.

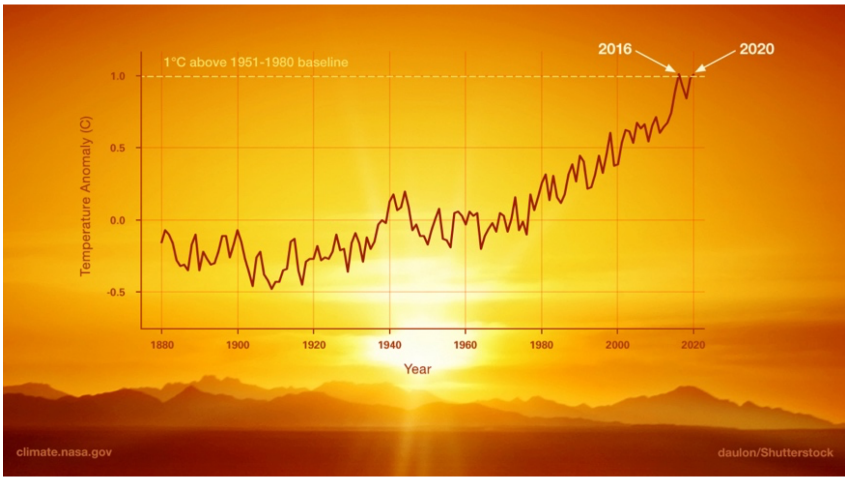

Fig. 3.2: Global warming (NASA's Goddard Institute for Space Studies, 2020) [28]

International Renewable Energy Agency (IRENA) [29] claims, that renewable energy can likely reduce 90% of carbon dioxide emissions. The Earth's atmosphere mainly consists of nitrogen (N_2), oxygen (O_2), argon (Ar) and carbon dioxide (CO_2) which is fractionally present alike other gases (neon - Ne, helium - He, methane - CH_4, krypton - Kr, hydrogen - H_2, nitrous oxide - N_2O). The amounts of gases in the Earth's atmosphere are displayed in fig. 3.3.

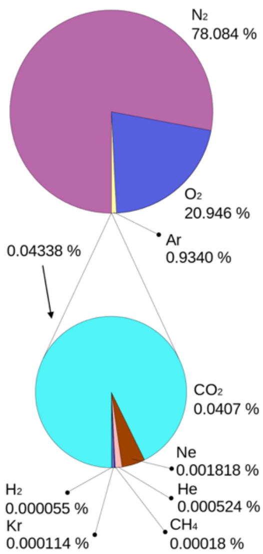

Fig. 3.3: Composition of Earth's atmosphere (NASA, 1987 – 2019) [30]

3.1 Impacts of Climate Change

The climate change, which is sped up by GHG brings a major threat to all living on the Earth. One of the most alarming regions on Earth which goes through apparent heating process is the Arctic region. Glaciers are melting faster than previously, and sea levels are rising. NOAA Mauna Loa Observatory [31] affirms that the sea level has risen across most of the world by 15-20 centimeters [31]. For that reason, countries with low elevation must build special coastal protection structures to protect themselves from floods. Even though building coastal protection was in the past a common part of infrastructure in some countries, for example in the Netherlands, yet many more coastal countries are expected to be affected by sea level rise in the future. Farrington [32] emphasizes that the Florida State, USA will have to spend up to $100 million every year to prevent coastal flooding which endangers millions of people [32]. Floods caused by intense rainfall represent another danger even in landlocked countries. Droughts are another threat that can lower the harvest of crop which is essential for feeding the increasing world's population. NASA [33] projected a drought scenario in the United States Southwest using a high future emission scenario (RCP 8.5) and claims that continuous production of GHG will cause severe long-lasting droughts in certain regions. Droughts are as well associated with risks of wildfires. The fire seasons are alike drought seasons becoming longer. Hurricanes, cyclones, typhoons, tornadoes can happen more frequently due to climate change [33]. These violent storms usually occur in the New Zealand, U.S., or Asia. Tornadoes were not as common in Europe, but they are starting to appear more frequently. In 2021 a few dangerous tornadoes were seen in the Czech Republic, in Belgium or in Italy.

3.2 Mining and Waste

When running a power plant, waste management plays an important role. Materials have a certain lifespan, so when photovoltaic panels, wind turbines, or lithium-ion batteries considerably decrease in efficiency or are uncapable of providing energy, they need to be recycled. If renewable energy powerplants lack a strategy to recycle decommissioned parts they will create comparable ecological burden as non-renewable power plants. Many materials within these newly developed renewable technologies are hard to recycle and new pathways for recycling processes must be prepared. European Environment

Agency (EEA) [34] stresses that fast energy transition to renewables will produce complicated waste streams of valuable elements and materials. To face these challenges, new policies ensuring the responsibility of waste producers must be implemented and issues dealing with high-capacity transport and specific recycling processes must be resolved [34].

Crownhart [35] states that 8 million metric tons of non-functioning solar panels could gather by the year 2030. Discarding used photovoltaic panels is currently much cheaper than recycling them. In the U.S. about tenth of panels is being recycled. A French startup called ROSI aims to reobtain valuable materials from panels that comprise 60% of its cost. There are as well companies that refurbish used panels and resell them for about half of the original price [35]. Wind power is another large contributor of waste. According to Martin [36], about 85-90% of wind turbines can be recycled except the fiber glass blades. These blades are nowadays mostly heading to landfills (fig. 3.4) or being burned which is not safe for the environment. With their durability it is hard to crush them, however a startup Global Fiberglass Solution claims to have developed a method to recycle these blades and turn them into fiber boards and pellets that can be used in the building industry [36].

Fig. 3.4: Disposal of wind turbine blades at the Casper Regional Landfill in Wyoming (Rasmussen, 2020) [36]

Electric components and electronic batteries are essential for most of the renewable energy projects. For example, most solar panels without battery storage would be able to generate electricity only when the sun is emitting solar radiation. Various types of batteries are used in most transportable electric devices and the automotive industry is raising battery demand for electric vehicle production. Statista [37] estimates that the global demand for batteries will increase from 185 GWh in 2020 to more than 2000 GWh by 2030. Such a rise of demand will require a rise in valuable metals mining such as [38] lithium, copper, cobalt, nickel, and rare earth elements [REEs] like neodymium, selenium, dysprosium, gallium, or indium. Mining these elements represents environmental as well as humanitarian threat, coupled with the fact that mining is by no means 'green'.

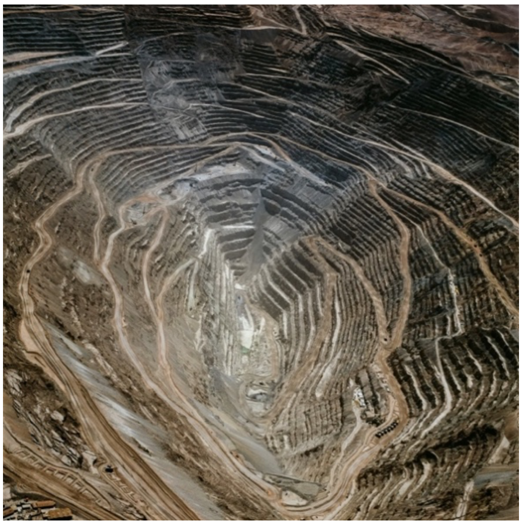

Fig. 3.5: The devastating environmental impact of technological progress (Maisel, 2019) [39]

According to SAMCO [40] there are two major lithium sources - underground brine deposits and mineral ore deposits. Before a raw material is good for use in further technologic manufacturing it needs to go through a long procedure which usually takes couple months up to few years before it is good for further use. Figure 3.5 displays scarred surface from lithium mining. World's biggest lithium deposits are South America, Australia, and China. The whole process employs variety of filtration methods and chemical treatments [40]. Katwala [41] states that for a tone of lithium, 2,273,045 liters of water are required. Mining already consumed about 2/3 of water in the Chile's Salar de Atacama region, which forced farmers to obtain water elsewhere.

Other rather controversial material is chemical element cobalt. According to Stone [43], the Democratic Republic of the Congo is the biggest cobalt supplier in the world, which represents about 70% of the market share. Most metal mining companies in this region are Chinese owned while one is based in Luxembourg [43]. RAD [44] exposed extensive exploitation of Congolese miners. Interviewed workers complained about the working environment in which long working hours, violence, low pay, unsafe working conditions occur daily [44]. McKie [45] claims many unregulated mines employ children that are even 7 years old. Figure 3.6 shows child working in a cobalt mine.

Fig. 3.6: Congo, child labour and your electric car (Sanderson, 2019) [46]

According to Nayar [47], China became the world leader in REEs mining. Mainly, because of the absence of environmental regulations. This results in the ability to mine cheaper and to dictate the price. Due to the exposure to radioactive materials like thorium or uranium, people developed lung, pancreatic, and other cancers in mining areas. Similarly, as in DR Congo, violation of human rights has been reported [47].

Environmental impacts represent a great threat to the whole of mankind. That is why every country should focus on emission production decrease to slow down the accelerated global warming. The other issue that should be stressed is that transitioning to renewable resources requires specific materials that employ unsafe mining processes. Companies and governments should be closely monitored to support reasonable mining procedures, since most of the mining methods use toxic chemicals that endanger waterways and cause health issues. Governments should also prevent exploitation and child labor, support fair trading and safe working environment. Streams of waste from new powerplants need waste management strategies to ensure proper recycling of old parts.

4. ECONOMIC ASPECTS OF ENERGY TRANSITION

It is evident that energy transition will have great impact not only on the infrastructure, but it will also bring economic and social changes. The initial costs of renewable energy transition are high; however, they should pay back in the future. These days, it is relatively uncertain what jobs will be available on the labor market with upcoming technology, yet the new energy sector will provide millions of job opportunities.

IRENA [48] reports that the investments put into the transition between 2021 and 2050 are 131 trillion US Dollar, while the expected cumulative payback will be at least 61 trillion US Dollar. Also, in 2050 the new energy sector will have 122 million jobs. To reach the net zero by 2050, all countries must remain committed to transition and proceed according to global policies [48].

Quinson [49] points out that the renewable power is becoming the most invested energy area, as the market of energy resources diversifies. The two main reasons are that renewables are already cheaper than fossil fuels and their costs are more stable. Oil companies are struggling because the investors are hesitant whether to invest in fossil fuels [49]. Eventually, companies and society will have to readjust to new conditions and eliminate fossil fuel subsidies. Figure 4.1 shows the capital cost decrease of renewable energy.

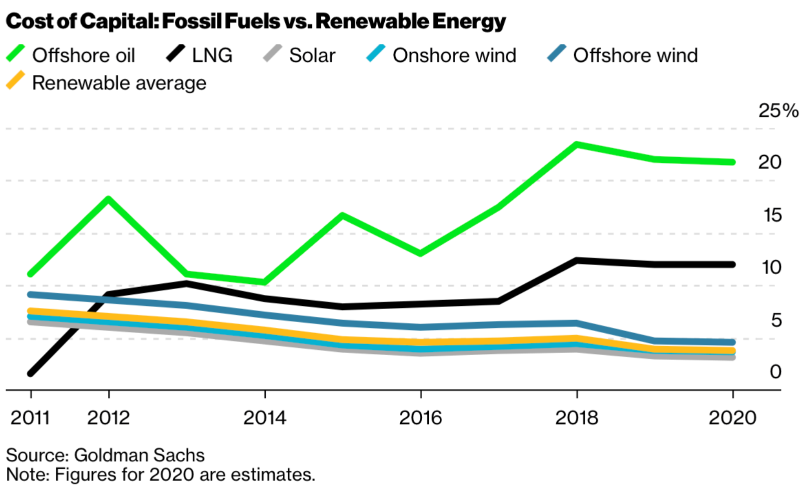

Fig. 4.1: Cost of Capital: Fossil Fuels vs. Renewable Energy (Goldman Sachs, 2020) [49]

Energy demand growth is another significant reason for energy transition. The Global Energy Statistical Yearbook [50] states that the trend of Global energy consumption over 1990 to 2020 kept on rising until 2019 and fell by 3.5% in 2020, due to Covid-19 lockdowns and other restrictions after steady growth 2.4% per year. Nonetheless, the demand for energy remains high [50]. The total energy consumption between 1990 to 2020 is displayed on figure 4.2.

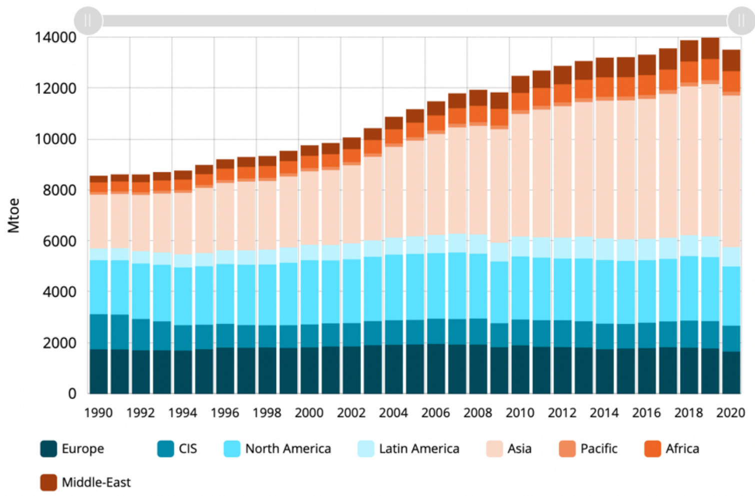

Fig. 4.2: Total energy consumption, 1990 – 2020 (The Global Energy Statistical Yearbook, 2021) [50]

4.1 Transition Effects in EU

Economic power of individual countries differs across the world as well in EU. Figure 4.3 shows economic forecast of GDP in EU. Inequality in gross domestic product, debt to GDP, employment and income rate is different in each member state, that is why not all countries have the same preconditions in the energy transition under a European Green Deal. Coupled with Europe's energy crises in 2021 and 2022 which arose due to COVID-19 restrictions and Russian invasion of Ukraine.

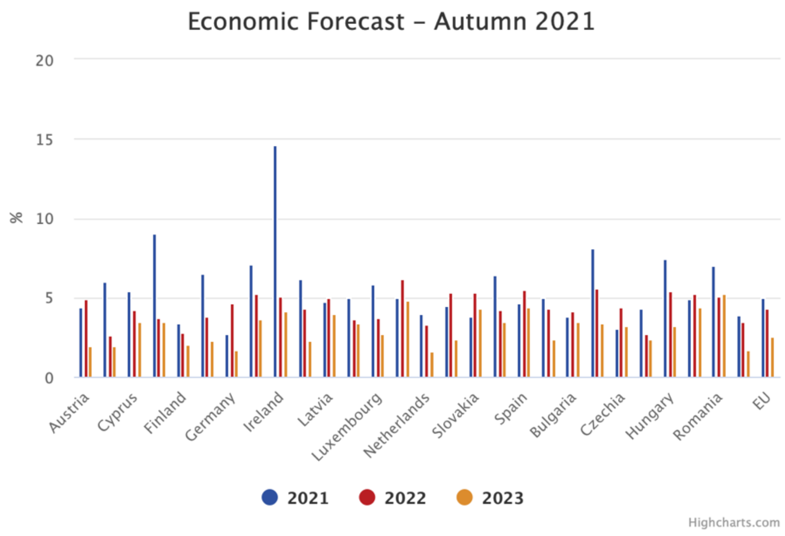

Fig. 4.3: Economic forecast of GDP in EU (European Commission, 2021) [51]

The Energy Poverty Advisory Hub (EPAH) [52] highlights that about 34 million people in the EU experience variety degrees of energy poverty in the form of inadequate heating, cooling, lightning, and lack of energy to power essential appliances. This impacts their physical and mental health [52]. More people are likely to suffer from some form of energy poverty with the current energy crisis and job losses due to COVID-19 pandemic. In [53] a public opinion survey commissioned by the European Parliament, 27% people say that Coronavirus had impact on their personal income.

4.1.1 Energy saving

With growing population, expanding trade and infrastructure, energy consumption substantially soars. Aside from essential human needs, the society yearns for commodities and resources that make its live more enjoyable. The pressure of consumer culture compels buyers to change and purchase goods frequently. A good example is consumer electronics. Statista displays a chart (fig. 4.4) of consumer electronic devices sold between the years 2013 and 2022, as well as estimation until the year 2026. The chart shows increase in production which results in higher energy demand and waste production.

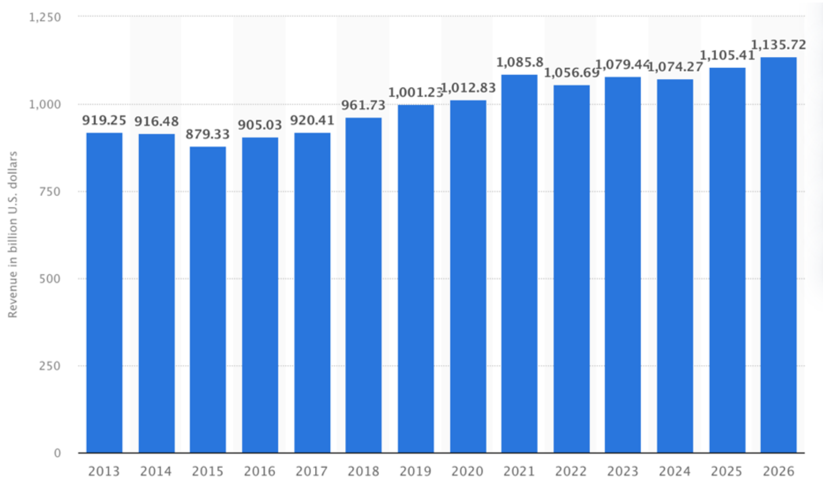

Fig. 4.4: Revenue of the global consumer electronics market from 2013 to 2026 (Statista Research Department, 2022) [54]

UN Environment Programme (UNEP) [55] states that electronic waste produced annually is worth $62.5 billion from which only 20% is properly recycled and the rest ends in the landfills. Electronics carry valuable materials; therefore, many initiatives aim to repair, re-use and recycle old commodities and materials because it would result in lower energy consumption [55]. The main issue is that the recent products have much shorter lifespan than before due to so called planned obsolescence. According to Malinauskaite and Erdem [56], such strategy was mainly adopted by businesses in the USA and both in Europe. Manufactures design their commodities to last less to make buyers purchase more often to increase their profits [56]. The EU [57] aims to switch to circular economy by changing its legislation to achieve sustainable consumption and to make sure that all resources are used adequately. The circular economy action plan supports the European Green Deal and is important in the process of achieving EU's climate neutrality by 2050 [57].

According to EC [58], EU implemented energy saving legislation to ensure that electronic products on the EU market have eco design and are energy labelled. Apart from the savings on energy, the consumers spend less on energy bills and companies have higher earnings. Figure 4.5 depicts current energy labels used in EU.

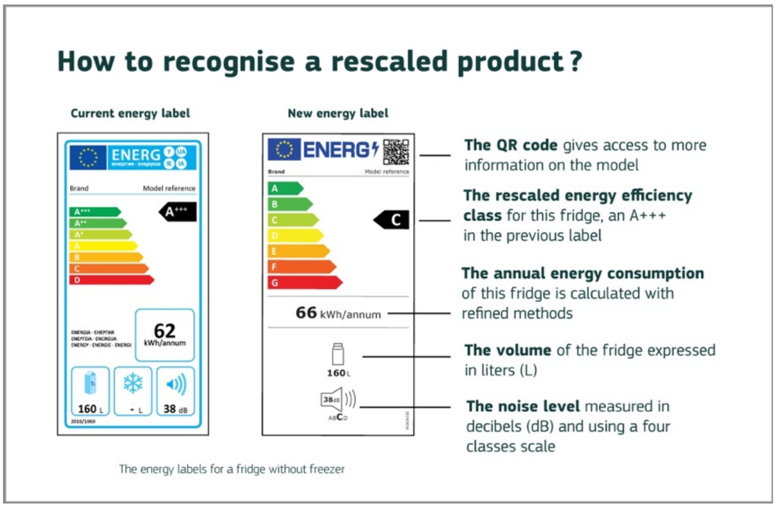

Fig. 4.5: A new generation of labels (European Commission) [58]

EC [59] states that buildings are responsible for 40% of EU energy consumption and 36% energy related to GHG emissions. That is why the Commission announced a strategy "A renovation wave for Europe". This strategy is addressing public building renovation, decarbonizing heating and cooling and dealing with energy poverty. The strategy is carried out by direct and private investments, research, and innovation [59]. To illustrate the shift to building energy efficiency, Centrum pasivního domu [60] states that houses in Europe built between 1970 and 1980 consumed over 200 kWh/m^2 of heat per year, while newly built houses in the Czech Republic must fulfill the energy consumption of 80 – 140 kWh/m^2 of heat per year and passive houses must be energy efficient 15 kWh/m^2 per year. EU member states can support the citizens through various funds if they decide to renovate a building or build energy efficient houses. For example in the Czech Republic, the New Green Savings Programme [61] offers wide range of funds focusing on house insulation, PV and solar systems, passive buildings, boilers, heat pumps and more. The funding can cover up to 50% of the eligible expenses. The average subsidy is about 207 000 CZK ≈ 8 420 EUR [61].

4.1.2 Transportation

Transportation as the biggest consumer of energy worldwide (fig. 2.2) is a substantial GHG emitter, therefore, has an impact on energy transition and economics. Since passenger cars produce the most GHG emissions in the transportation energy sector (fig. 2.2) and EU wants to become a carbon neutral economy, electro mobiles are highly promoted. Nonetheless, before any country can start using electric vehicles massively, energy generation capacity needs to increase, and proper charging infrastructure must be built. The EEA [62] claims that until 2030 the electro mobile energy demand will be limited and by 2050 the EU electrical capacity will need additional 150GWh of power. To spur the charging infrastructure development, the EU provides financial support through the Connecting Europe Facility (CEF) [62]. According to European Court of Auditors [63] the Commission was able to promote common EU charging plug, however the CEF investments were made on inoperable charging stations, mainly due to insufficient infrastructure analysis. Between 2014 and 2020, about 698 million Euros from CEF grants were spent on alternative fuels in road transport and around 343 million euros went for electrical charging stations [63].

Rokicki, Bórawski, Bórawska, Żak, Kosczela [64] observe that even though the electromobility share is rather small on the European continent, the demand has risen in recent years. The electric vehicle growth depends on the economic situation, standard of living and a set of motivators. Figure 4.6 shows newly registered electric vehicles in EU.

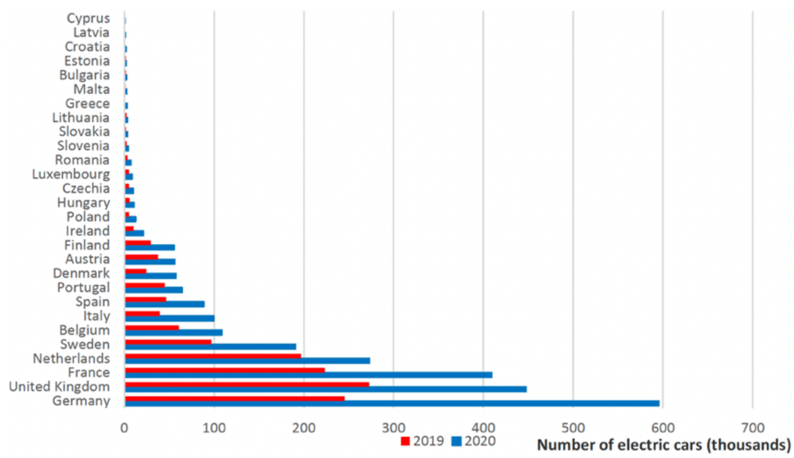

Fig. 4.6: Share of newly registered electric vehicles in EU (Rokicki, et al., 2021) [64]

Transportation in terms of poverty should be taken into consideration by governments as well. Many inhabitants may find commuting complicated with current high prices of electro mobiles and hydrogen cars. Alternatives for certain groups should be proposed. The 2019 Clean energy for all Europeans package [65] is an energy policy framework which addresses energy poverty. This package aims to bring new rules for consumers, the environment, and the economy.

Energy poverty should be supervised with transforming energy system to make sure that the energy transition strategy includes everyone, proceeds smoothly, and does not widen the socio-economic gap. Regulation of energy use would present a simple solution to a rather complex problem, yet it would be challenging to implement and to be accepted by everyone.

5. ENERGY POLITICS

As every country depends on energy supply, energy sector plays an important role in safety, security, and geopolitics. If a country experiences energy supply shortage it highly influences the lives of its citizens, security, industry, and state's economics. Countries that rely on foreign natural resources can be at risk since the energy supply is affected by the foreign country's political stability or sudden deviations on the energy market. Some countries are resource-rich mainly focusing on export while other countries are predetermined to import. On one hand energy transition brings an opportunity for states that are dependent on import and on the other hand it also brings a threat to countries that function mainly thanks to the natural resources export. That is why it is important to mention and analyze some of the most significant energy markets, realize their energy and transition related supplies and inspect how they cope with the ongoing path towards carbon neutrality.

5.1 Energy Markets

5.1.1 Asia and Oceania

China

China is one of the leading economies according to the World [66] the country had in 2020 the second strongest economy and its GDP was 14.72 trillion USD). China is a large exporter as well as importer of natural resources and diverse commodities. Figure 5.1 displays China as the global leader of REE production in 2021 and figure 5.2 shows that in 2021 China produced the most coal worldwide.

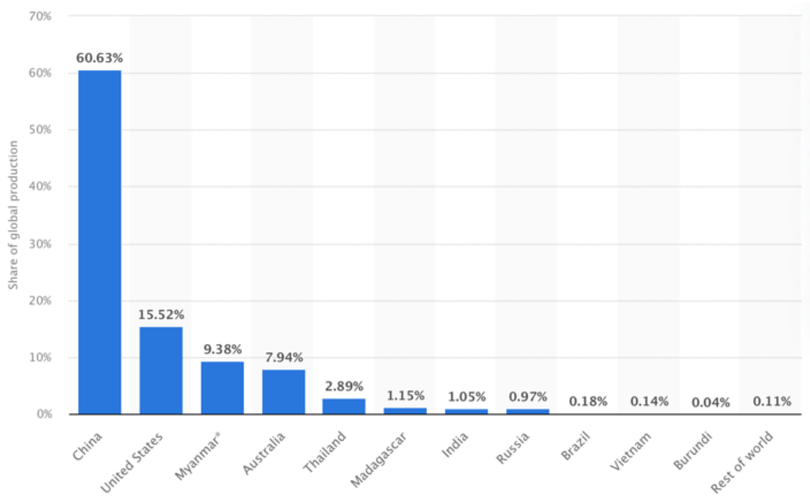

Fig. 5.1: Distribution of rare earths production worldwide as of 2021, by country (Garside, 2022) [67]

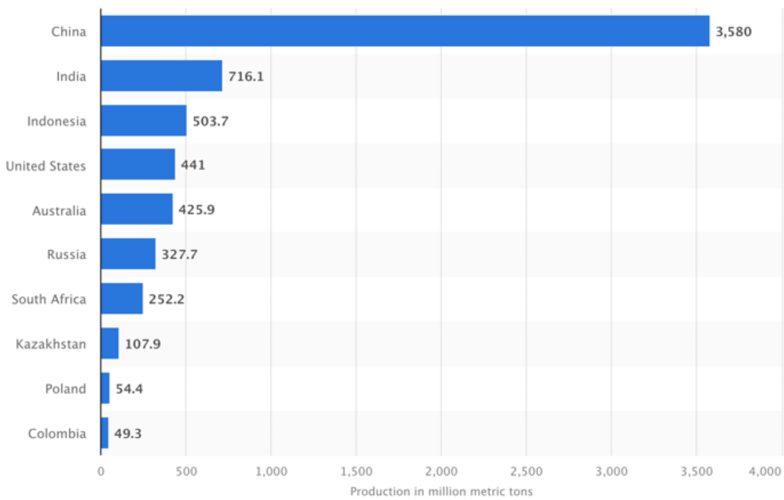

Fig. 5.2: Leading hard coal producing countries worldwide in 2020 (Garside, 2022) [68]

According to the Observatory of Economic Complexity (OEC) [69], in 2020 China imported $150 billion in crude petroleum (mostly from Saudi Arabia, Russia, Iraq, Angola and Brazil). According to ChinaPower [70], China is 67.3% dependent on these states and its dependency is likely to rise due to the exponentially growing oil demand. The political instability in the Middle East and Russia represents an energy security threat for China as well as other countries energy security threat, as a result China started investing in Africa. ChinaPower [70] states that the country offered development loans to African states to get access to their oil reserves. Other top imports according to OEC [71] involved petroleum gas, liquified natural gas, iron ore and copper ore worth $227.3 billion. In 2020, China exported the most broadcasting equipment, computers, office machine parts and telephones in the world worth $577.5 billion [71]. According to CompaniesMarketCap [72], renewable energy company with largest market cap ($61.80 billion) is LONGi Green Energy Technology. The company has headquarters in China and specializes on PV modules and solar energy solutions [72].

Such developed industry and production on which the rest of the world highly relies requires large energy supply. Since China is reasonably dependent on natural resources supply from foreign countries, its focus on energy transition intensifies. Figure 5.3 displays that China was the biggest investor in energy transition in 2020.

	Country	Investment (Billions of US$)	% of Global Total
1	China	266	35
2	United States	114	15
3	Germany	47	6
4	United Kingdom	31	4
5	France	27	4
6	Japan	26	3
7	India	14	2
8	South Korea	13	2
9	Brazil	12	2
10	Spain	11	2

Source: CSIS China Power Project; BloombergNEF

Fig. 5.3: Top Global Investors in Energy Transition (2021) (ChinaPower, 2022) [70]

China already produces the most energy from renewable power plants in the world (fig. 2.3), however its demand for coal and oil remains high. Huld [73] states that China included a set of goals that stress energy transition in its “Five-Year Plans”. Until 2025 the country intends to reduce energy consumption per unit of GDP by 13.5% and reduce CO2 emissions by 18% from 2020 levels also to have energy consumption share 20% of non-fossil fuels. By 2030 it aims to decrease CO2 emissions per unit of GDP by 65% compared to 2005 values and to have energy consumption share 25% of non-fossil fuels. In year 2060, China wants to consume 80% of energy from non-fossil fuels and become carbon neutral [73].

India

According to the World bank [66], India had in 2020 sixth strongest economy and its GDP was 2.66 trillion USD. With the second largest population, the demand for energy is on rise (3rd biggest consumer of energy worldwide). India is the second biggest producer of coal (fig. 5.2).

According to OEC [74], some of the top imported natural resources in 2020 India were crude petroleum, coal briquettes, petroleum gas and gold worth $115.6 billion, mainly from Iraq, Saudi Arabia, United Arab Emirates, Australia, and Switzerland. IEA states, that India depends by 75% on imported oil. If this trend continues the dependence can rise over 90% by 2040. Despite imports, India exported refined petroleum worth $25.3 billion [74].

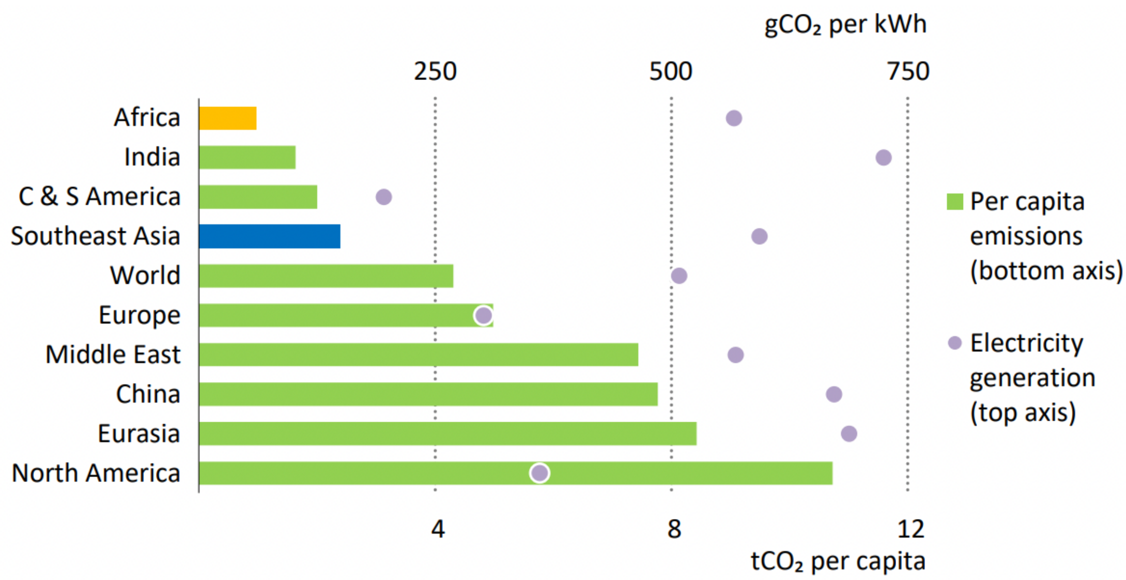

Fig. 5.4: CO2 emissions per capita and emissions intensity of electricity generation by region, 2020 (IEA, 2021) [75]

India is according to IEA [75] 3rd biggest CO_2 emitter and the world's biggest CO_2 producer from electricity generation. Figure 5.4 depicts CO_2 production by regions or country. The primary sources of energy are currently coal, oil, and solid biomass. India is alike China investing in energy transition. India has not yet been able to compete with China in PV panel, wind turbine or lithium-ion battery production, however new policies with goals to increase domestic production are being implemented. In 2021 India agreed to become Strategic Partner of IEA [75].

Japan

In 2020 Japan had third strongest economy and its GDP was 5.05 trillion USD according to the World bank [66]. Some of the top Japan imports in 2020 were according to OEC [76] crude petroleum, petroleum gas and LNG worth $96.6 billion.

Even though Japan is highly dependent on oil and natural gas import, it has managed to maximize its energy conservation and decrease overall supply. The overall decrease of energy supply is displayed on figure 5.5.

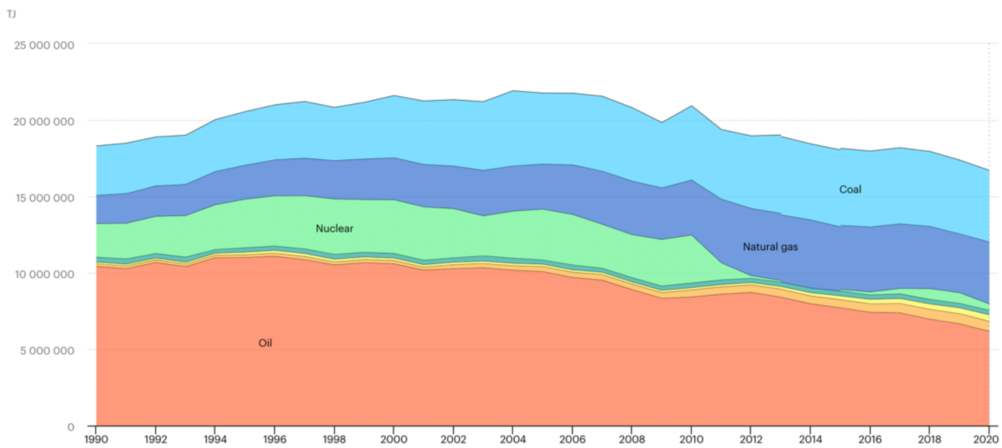

Fig. 5.5: Total energy supply (TES) by source, Japan 1990-2020 (IEA, 2021) [77]

Nagata [78] states, that Japan has accomplished high energy conservation through various policies such as “Top Runner Program” (mandatory efficiency targets for manufacturers to the next 3 – 10 years) or Energy Labelling System. According to METI [79], Japan strategy is to diversify its energy sector, start using nuclear energy more and maximize the supply from each energy source. Some of the goals to be met by 2030 are to increase energy self-sufficiency from 11% (in 2020) to ≈ 25%, reduce energy cost by increasing the economic efficiency, decrease GHG by 26% compared to 2013 levels [79].

Australia

IEA [80] states that Australia was in 2020 energy self-sufficient by 346%; (IEA computed energy self-sufficiency based on total energy supply, GDP, population, and other factors). According to OEC [81], some of the top Australian exports in 2020 were iron ore (world's biggest exporter), LNG (world's biggest exporter), coal briquettes and aluminum oxide worth $145.29 billion, mainly sent to China, Japan, South Korea, USA, and India. According to World Nuclear Association [82], Australia has almost 1/3 of Uranium deposits in the world. Most country's uranium deposits are exported since it has no nuclear reactors. Apart uranium, Australia is the biggest lithium producer (top exporters are displayed on figure 5.6). However, it should be stated that according to Barrera [84], the two biggest lithium companies are Chinese-owned - Jiangxi Ganfeng Lithium and Tianqi Lithium. Both companies have interests in lithium mines in multiple countries, but mainly in Australia, Chile, and China [84].

Country	2020 Lithium Production* (tonnes)	% of World Total
Australia 🇦🇺	40,000	46.3%
Chile 🇨🇱	20,600	23.9%
China 🇨🇳	14,000	16.2%
Argentina 🇦🇷	6,200	7.2%
Brazil 🇧🇷	1,900	2.2%
Zimbabwe 🇿🇼	1,200	1.4%
U.S. 🇺🇸	900	1.0%
Portugal 🇵🇹	900	1.0%
Rest of the World 🌍	500	0.6%
Total	**86,300**	**100%**

Fig. 5.6: Lithium Production by Country (1995-2020) (Visual Capitalist, 2022) [83]

IEA [85] states that Australia's energy sector is transforming towards renewable energy under Australia's Technology Investment Roadmap. The use of coal is still dominant, so the country is now planning to build new natural gas pipelines across the country, since the natural gas is more carbon free. Australia is facing some of the most extreme weather conditions and the energy security is one of the most important factors in any energy project [85].

5.1.2 North America

<u>USA</u>

In 2020 the USA had world's strongest economy and its GDP was 20.95 trillion USD according to the World bank [66]. IEA [80] states that USA was 106% self-sufficient in 2020. Some of the top exports according to OEC [86] in 2020 were refined petroleum (world's biggest exporter), crude petroleum, petroleum gas, and LNG worth $158.6 billion. The country exported mostly to Canada, Mexico, China, Japan, and Germany. The USA also imported crude petroleum worth $75.1 billion, mostly from Canada, Mexico, and Saudi Arabia [86].

While the USA was the second biggest investor in energy transition in 2020 under Donald Trump's administration 5.3, the energy transition in USA became more stressed when Joe Biden was elected president. According to the White House [87] in July 2021, the president and the bipartisan group agreed on a large $550 billion investment. The deal includes investments in clean transportation and in EV infrastructure, clean energy generation and power grid modernization. This investment should create new well-paying jobs, improve economy, and address the climate crisis [87]. According to EIA [88] in the following years the USA is expecting a large growth in LNG production and export. This is caused due to the increasing demand for natural gas and newly established capacities.

<u>Canada</u>

According to IEA [89], Canada is one of the most energy self-sufficient countries – 179%, similarly like Norway or Australia. In 2020 the country had the world's number 9 GDP – $1.64 billion. Some of the top exported natural resources were crude petroleum and gold worth $61.6 billion (mostly exported to USA, China, UK and. Japan) [89]. Venkatachalam and Milke [90] claim that Canada has a great potential on the LNG market. Even though Canada has massive natural gas reserves, there is only one export station under construction and several planned. It is expected that Canada with its great potential might become a significant exporter, since the distance between Asia and British Columbia is favorable. Venkatachalam and Milke [90] estimated that LNG export from British Columbia could add ≈ $5.9 billion annually to Canadian economy while raising employment rate in the following three decades.

Ener data [91] reports that in 2020 Canada was already producing 67.7% of electricity from renewables. According to IEA [89], most of the energy is generated by hydroelectric powerplants given by the geographical advantage. Also, in total energy-supply (TES), coal is used less, and natural gas is being used more. Canada is planning by 2030 to refurbish nuclear powerplants, cut CO2 emissions by 30% compared to 2005 levels and become carbon neutral in 2050 [89].

5.1.3 Latin America

Brazil

According to the World bank [66], in 2020 Brazil had 12th highest GDP. OEC [92] states that some of its top exports were iron ore or crude petroleum worth $46.3 billion. Brazil exported mostly to China, USA, and Argentina. IEA claims that Brazil was in 2020 energy self-sufficient by 112%.

Ener data [91] reports that Brazil generated 84.1% of its electricity from renewable resources. According to IEA [93], Brazil accounts for low carbon intensity. The dominant source of renewable energy is from hydroelectric powerplants, and new ones are being developed. Brazil is rich in oil and natural gas and in 2017 became net oil exporter.

Chile

Chile was in 2020 according to OEC [94] the biggest copper ore and refined copper exporter $35.9 billion. Chile was also the second biggest lithium exporter (fig. 5.6). IEA [95] states Chile became a big developer of wind and solar energy.

5.1.4 Eurasia

Russian Federation

As the biggest country in the world, Russia plays an important role on the global energy market. IEA [80] states that Russia was 191% energy self-sufficient in 2020. Due to the abundant amount of natural resources Russia has, its primary economic driver is gas and oil. According to OEC [96], the top exports in 2020 were crude petroleum, refined petroleum, petroleum gas, coal briquettes and natural gas worth $168.3 billion, exported mainly to China, UK, Netherlands, Belarus, and Germany.

There is a large network of pipelines between Russia and Europe, which is displayed on figure 5.7. As mentioned before in [97], EU has 43.3% dependence on Russian natural gas. This is given by fact that Germany policy makers have created excessive ties with Russia throughout the years. According to Sullivan [98], the first oil pipeline "Friendship Pipeline" that connected West Germany and Russia started operating in 1964. Later, other oil and gas pipelines developed. In 2012, a gas pipeline between Russia and Germany, Nord stream 1 opened. The pipeline was built, even though the Baltic states and Poland were against. Also, USA strongly opposed throughout the years and disagreed with the European dependence on Russia. New Nord stream 2 gas pipeline was supposed to open in 2022, however the certification was suspended because of Russian invasion of Ukraine [98].

Fig. 5.7: Natural gas pipelines from Russia to Europe (Sullivan, 2022) [98]

After the Russia invaded Ukraine on February 24th, 2022, and started a large-scale armed conflict, the rest of the world began to realize the Economic impacts apart from the human tragedy. The states buying natural gas and oil from Russia have been thus financing ordnance for many years. The countries respecting democracy, sovereignty and international law had to respond at least by applying severe sanctions that would maximally isolate the Russian economy and its military financing. Such sanctions however did not only harm Russian economy but also showed the extent of Europe's energy dependency. According to IEA [99], Russia generates most of its electricity from natural gas, nuclear power, hydroelectric powerplants and coal. The future of Russia's collaboration in terms of energy transition with other countries are uncertain.

Kazakhstan

Kazakhstan is a big energy exporter. According to OEC [100], some of the top exports in 2020 were crude petroleum, petroleum gas or refined copper worth $30.7 billion, mainly exported to China, Italy, and Russia. According to World Nuclear Association [101], in 2020 Kazakhstan was the biggest Uranium Producer and accounted for 41% of the world supply.

IEA [102] states, that Kazakhstan is focusing on natural gas pipeline expansion. Even though there is a small share of renewables, they are being slowly implemented. According to IEA [103], the country is a part of policymaking EU4Energy program along with Armenia, Azerbaijan, Belarus, Georgia, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. The member countries are displayed on 5.8. The program aims to develop sustainable energy (in Easter Europe and Central Asia) in collaboration with EU, IEA, Energy Community (collaboration third countries from Southeast Europe and EU), Energy Charter (multilateral framework in trade, transit, investments, and energy efficiency) [103].

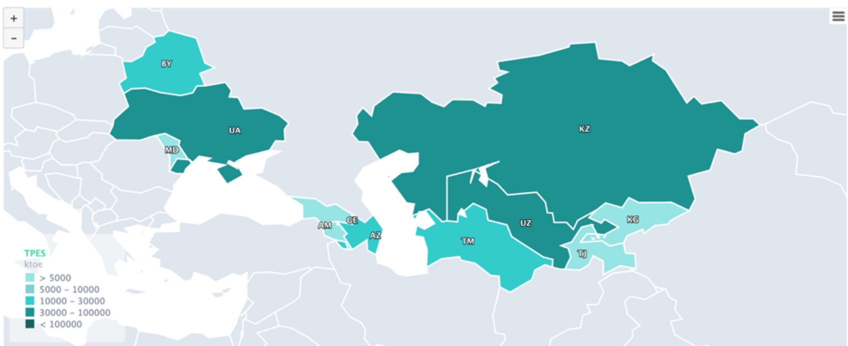

Fig. 5.8: Map of EU4Energy members (IEA) [103]

5.1.5 Europe

Countries in the European Union

The strongest economies in EU are according to World bank [66] Germany ($3.84 billion), France ($2.63 billion) and Italy ($1.88 billion). According to EC [104], the biggest energy supply imports come from Russia. EU imports from Russia 45% of natural gas, 25% of oil and 45% of coal. Other major suppliers were Norway, USA, Australia, or Iraq. Figure 5.9 shows energy dependency of individual EU member states.

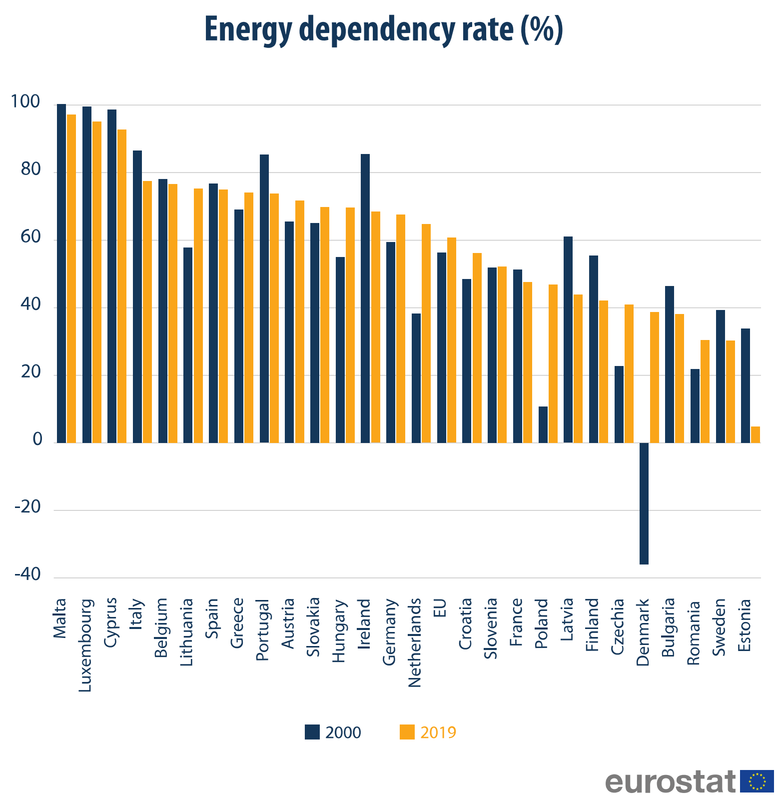

Fig. 5.9: Energy dependency rate in EU (Eurostat) [105]

Some EU member countries can produce big a portion of their electricity from renewable energy. According to Ener data [91], the countries with high share of renewables in electricity production are Sweden 68.4%, Portugal 59.7%, and Germany 44.5%. The biggest sources of energy in these countries are hydroelectric power plants and wind energy. As IEA [106] states, the original scenario for energy transition in EU was to slowly decrease dependence on Russian gas while building renewable energy infrastructure, however, due to war in Ukraine, the EU must alter the original outlooks.

EC [104] proposed a plan called "REPowerEU". The plan is focusing on large wind energy application and natural gas supply diversification especially LNG. EU is collaborating with numerous countries, has different strategies and research programs associated with renewable energy and energy efficiency. The most known strategy is the European Green Deal [107]. According to the Norton Rose Fulbright [108], Green Deal is a set of policies and proposals to achieve net zero GHG emissions and improve economic growth in EU by 2050. The cost of the strategy is €1 trillion, and the financing sources are the EU budget, the EU Emissions Trading System and the InvestEU program. The main goals are climate protection, pollution elimination, energy production from renewable resources, sustainable industry, efficient buildings and renovations, sustainable mobility, a Farm to Fork strategy, protecting biodiversity and carbon leakage prevention. The EU has already achieved 23% GHG emissions reduction from 1990 to 2018 [108].

Norway

Norway is very important energy supplier and in 2020 was according to IEA [80] energy self-sufficient by 727%. Norsk petroleum [109] reports that Norway exported in 2020 crude petroleum, LNG, and natural gas worth 333 billion NOK ≈ \$38.19 billion. The revenues from exported fossil fuels account for 40% of country's all exported goods.

Ener data [91] states that Norway produced 98.4% of its electricity from renewable energy, mostly from hydropower. According to EC [110], Norway has a close relationship with EU and collaborates via EU Emissions Trading Scheme (ETS) or European Economic Area. EU as well as Norway agree on 55% GHG emissions reduction by 2030 [110]. DNV [111] states, that Norway will not be probably capable of meeting the 2030 climate targets and the constant decrease in oil and gas exports associated with the energy transition will result in lower revenues. Norway has however a great potential on the eco industry market [111]. According to Statista [112], Norway has the highest share of the newly registered electric vehicles.

5.1.6 Middle East

The Middle East countries are key fossil fuel producers and exporters. The worldwide share of Middle Eastern crude oil exporters can be observed on figure 5.10 and the top exporter in 2020 was Saudi Arabia. The third biggest liquified natural gas producer was according to figure 5.11 Qatar.

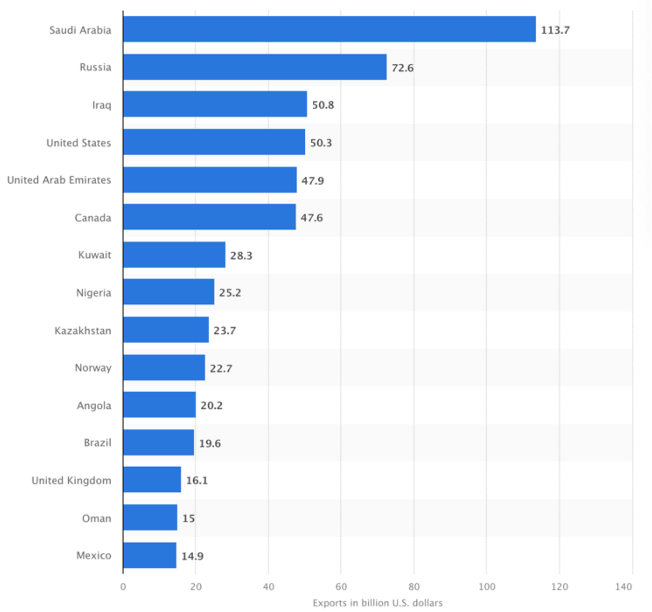

Fig. 5.10: Countries with highest value of crude oil exports worldwide in 2020 (Sönnichsen, 2021) [113]

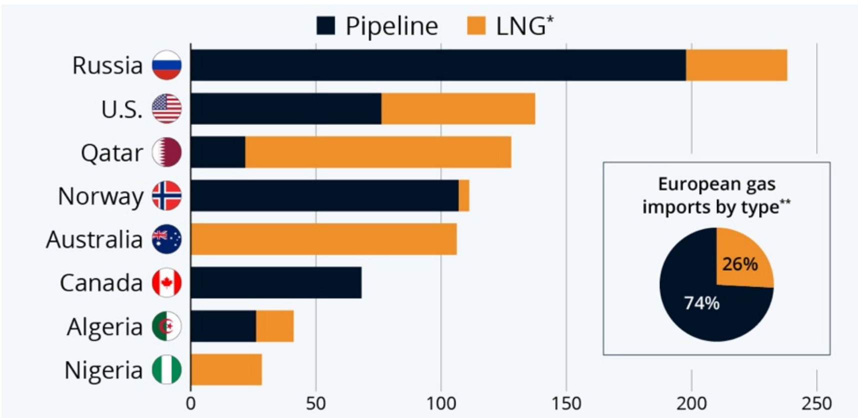

Fig. 5.11: Countries with highest value of LNG exports worldwide in 2020 (Buchholz, 2022) [114]

The share of renewable energy in the Middle East is miniscule compared to the share of fossil fuels and the TES of the Middle East is displayed on figure 5.12.

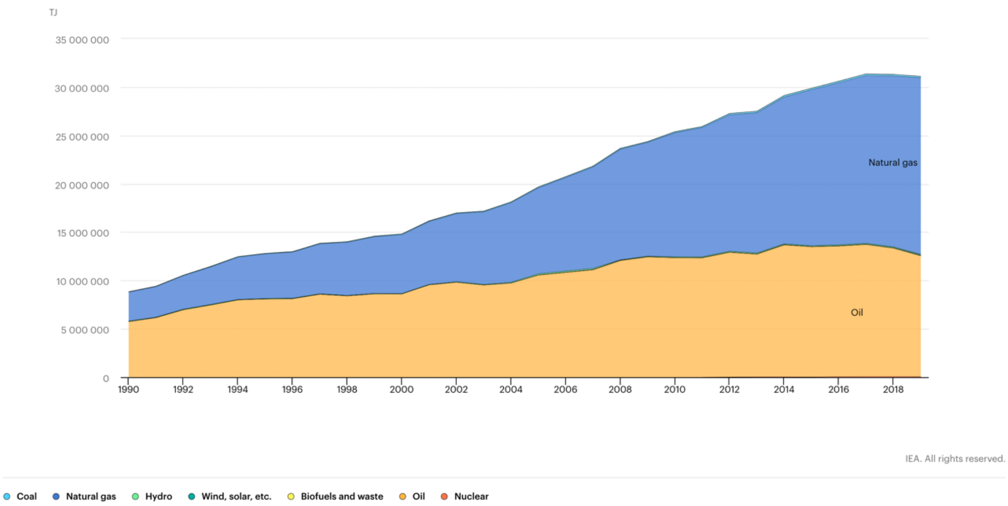

Fig. 5.12: Total energy supply (TES) by source (IEA, 2022) [115]

IEA [115] states that the revenues from oil export in this region will likely decrease in the future. Also, extreme climate changes in the Middle East motivate some countries to invest in renewable energy [115]. According to IRENA [116], there is an initiative called “Pan-Arab Clean Energy Initiative” on which the League of Arab States (LAS) based renewable energy cooperation. The goal is to increase the share of renewable energy from 12GW in 2013 to 80GW in 2030.

5.1.7 Africa

Nigeria

According to IEA [117], Nigeria is the largest economy and the biggest oil producer on the African continent. OEC [118] states that in 2020, the top exports were crude petroleum and petroleum gas worth $35.89 billion.

IEA [117] states that Nigeria is producing most of its electricity from natural gas, however there is low electricity and clean cooking access. The use of biomass in Nigeria represents an issue because it leads to deforestation and air pollution. The country has a large natural gas and solar potential [117].

South Africa

IEA [119] states that the energy mix in South Africa is dominated by coal. The energy supply has increased throughout the years as well as the production of GHG. IRENA [120] reports that the target in the Republic of South Africa is to have 8% share of renewable energy in 2030.

5.2 Conference of the Parties – COP

According to UN [121], the Conference of the Parties is a supreme governing body of the United Nations Climate Change Framework Convention (UNFCCC). COP meets every year since 1995. The main role of the COP is to review the implementation of legal instruments that address the climate change and ultimately achieving the Convention [121].

UN [122] reports that first significant action against the climate change was the adoption of "Kyoto Protocol". The Protocol was adopted on COP 3 in Kyoto, Japan in 1997, however came into force in 2005. The Protocol addressed 37 countries that were the biggest GHG emitters. The legislation target was to reduce emissions by 5% compared to 1990 levels. Some of the mechanisms the Kyoto Protocol employed were emission permits. Also, a proper transparent verification, monitoring and review system was developed to ensure the legislation was adhered to [122].

UN [123] states that another significant progress was made in 2015 when 196 Parties adopted the Paris Agreement on COP21. The agreement is unique because for the first time, all the countries unified to fight the climate change by limiting the global warming below 2°C (ideally 1.5°C) comparted to pre-industrial levels [123]. In [124], every five years the parties are required to submit Nationally determined contributions (NDCs). These contributions are steps that battle national emissions of each country. There are also long-term goals that are not mandatory. The emphasis is put on technology development and capacity-building in developing countries. The process is tracked via enhanced transparency framework (ETF). From 2024 the countries are required to report progress and actions they have taken [124].

According to UN [125], the latest COP26 meeting in 2021 in Glasgow, Scotland accelerated the urgency for action and the member countries must present NDCs in 2022 instead of 2025 as planned originally. Countries have agreed to phase down coal power and insufficient fossil fuel subsidies. When it comes to financing, the developed countries have pledged to deliver $100 billion annually to developing countries starting in 2023. Other announcements were – reversal of the forest loss in 137 countries by 2030; 103 countries aim to reduce methane emissions by 30% by 2030 contrary to 2020 levels; more than 30 countries aim to increase zero-emission vehicle sales globally by 2040; UK, USA and EU created a partnership with the Republic of South Africa to support its out phase of coal with $8.5 billion; the transition is also supported by central banks and private financial institutions [125].

Overall, the energy markets are diverse across the globe. The countries that are rich in natural resources are key for countries that import these resources; however, the energy richness does not determine country's manufacturing capabilities which could be a strong point of other economies. The globalization has bound most of the world; thus, most countries need to cooperate at some level. Although the parties that attend COP have different preconditions and energy sectors, they all face the inevitable climate issue. It appears that some of the conferences were successful and will boost the energy transition.

6. CONCLUSION

Energy transition is a fundamental process of restoring the unfavorable environmental impacts of the intense use of fossil fuels. Many scientific models have shown different energy transition scenarios and warned against long-lasting droughts, floods, and many other risks to all forms of life on Earth. There are numerous factors that can affect this shift towards renewable sources of energy positively as well as negatively.

New technologies must be implemented, and new infrastructure built which can withstand the energy demand growth and energy crises. Highly influential countries need to invest into energy transition and fulfill forward-looking agreements to ensure the world's environmental and economic stability, while motivating and supporting those countries which struggle. New startups are introducing innovative solutions that can positively contribute to solving newly emerging problems. Their potential to achieve something can be amplified by support from corporations and grants from governments. Energy outlooks will have as well socio-economic impacts. Old professions will fade away while new jobs and positions concerned with development or operation of renewable energy will be created.

Transition to renewable energy must include the whole of society. Energy poverty, which limits humans in their basic needs such as heating, cooling, and electrifying households, should be closely monitored, and competent authorities should make efforts to prevent it. The energy transition must proceed according to scientific studies and models with respect to global policies, market instruments and production competences of individual countries.

Energy production will be always likely higher than the final consumption but higher energy efficiency and conservation with help of circular economy can improve the environmental crisis and benefit to the society. Countries with complicated conditions for fully generating electricity from renewable resources will likely have to supplement renewable energy production with nuclear power until better technology develops. It is not possible to phase out fossil fuels suddenly, some countries that are world leaders in renewable energy should work side by side with those that lack the advance. Since natural gas is the least polluting fossil fuel it presents a good option, but the diversification of importers is for energy dependent countries crucial.

The people living in the developed democratic countries shall decide whether the purpose justifies the means. Thus, the big corporations which support exploitation and hazardous working environment during the acquisition of the desired earth's elements are permitted by governments to continue old practices to save and earn money. To that end, the sustainable energy that is these days more and more promoted will not be able to reach its intended potential and will likely become a utopian dream. On one continent people producing clean energy, on the other continent people making someone's dreams come true by doing the dirty work.

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