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Sustainable Investment—A Solution to Reduce Environmental Footprint

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Abstract: The environmental footprint (EF) indicator has emerged as a tool to measure human demand for productive land and water and it is used for the evaluation of the impact of products or economic activities on the environment. There are many indicators that are used in the decision making for the investment in the power sector, however, predominant are the economic indicators which underestimate the depreciation of natural capital (environment) and the value added generated by the public services. Many research studies have been carried out in an attempt to demonstrate the versatility of the EF by extending its applicability not only to environmental assessment, but also to use it, among other economic indicators, when assessing sustainable investment. Sustainable investment (SI) combines fundamental analysis and engagement with an evaluation of environmental, social and corporate governance (ESG) factors. The purpose of this article is, upon evaluating the EF, to identify the opportunities for the EF reduction through sustainable investment in the electricity production sector in EU countries. Environmental footprint analysis has been performed by using sustainable process index program SPIonExcel (SPI), which is one of the methods in the EF family. SPI is a useful tool for assessing ecological problems and finding sustainable solutions in the life cycle of energy production process. This research has revealed that the function of the footprint reduction depends directly on investments in renewable energy source (RES) technologies, but not all investments can be sustainable. Countries mainly invest in the development of wind energy and solar PV technologies and gradually reduce their inland production capacities from fossil fuel. Although SI in RES technologies reduces the EF, this is not enough to reduce it substantially because there are limitations for installing new power capacities. Consequently, countries tend to invest in the development of electricity networks. The conclusion can be drawn as follows: the reduction of the EF of electricity could be achieved by developing RES technologies since the major part of electricity is produced by using non-renewable resources. It is essential to develop new technologies as soon as possible in order to reduce EF as much as possible, and this can only be achieved through systematic sustainable investment.

Keywords: sustainable investment; environmental footprint; sustainable development; electricity production

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1. Introduction

Last year marked the 50th anniversary of Earth Day. Earth Day is widely recognized as the largest secular observance in the world, marked by more than a billion people every year as a day of action to change human behavior and create global, national and local policy changes [1]. After having spent the last decade creating and fine-tuning markets to accommodate ever-increasing shares of renewables, and having successfully embraced change, the EU needs to refocus the debate on which tools are most suited to ensure investments [2]. This shows that humanity cares about the issue of preserving the Earth. However, according to the methodology of the EF, one planet is not enough to sustain humans' needs. On average, during half of a year EU countries "eat" all resources that Nature can provide and for the next half of a year we borrow resources from our children. According to the EF methodology, this threshold is called the Earth Overshoot Day–the date when humanity's demand for ecological resources and services in a given year exceeds what the Earth can regenerate in that year. The environmental footprint is a measure of the resources necessary to produce the goods that an individual or population consumes and it is used as a measure of sustainability, though evidence suggests that it falls short [3]. EF illustrates the circulation of energy and matter needed for the functioning of various economies, and transforms it into the land and water area that the natural world provides in relation to maintaining these flows [4]. Nevertheless, EF offers a basic ecological accounting system and uses biologically productive surfaces of the Earth as its currency [5]. To sum up, the approach of EF is a holistic concept–starting from individuals and ending with whole planet. The process of globalization and the expansion of economic freedom can favour a sustainable ecological footprint by adopting more restrictive policies in the European countries, targeting large polluters, trade between states, tax system, ecological competition, and environmental responsibility [6]. In this respect, it would be helpful continuing the common policy application of the EU Member States in order to reduce the carbon footprint and to set and monitor national limits for greenhouse gas emissions. For this reason, there is an inevitable need for sustainable investment. Sustainable investment combines fundamental analysis and engagement with an evaluation of ESG factors in order to better capture long-term returns for investors, and to benefit society by influencing the behavior of companies [7]. There have been already conducted several empirical researches related to EF: it has been suggested that economic growth and energy consumption have negative relationship with the ecological footprint [8]; it has been identified that EF has robust influence on foreign direct investment [9]; the link between financial development and ecological footprint has been analysed [10]. But there is a lack of research on the importance of sustainable investment in reducing the EF in the electricity production sector. Therefore, the purpose of this article is, upon evaluating the environmental footprint, to identify the opportunities for environmental footprint reduction through sustainable investment in the electricity production sector in EU countries. The object of the paper is environmental footprint reduction through sustainable investment. The scientific question: how sustainable investment decisions can ensure the reduction of the environmental footprint. Research methods: scientific analysis, systemizing and generalization, the analysis of environmental footprint reduction possibilities proposed by scientists and international organizations. Environmental footprint analysis is performed by using sustainable process index program SPIonExcel and Ecoinvent databases.

2. The Environmental Footprint Evaluation in EU Countries

2.1. Measuring the Sustainable Development

The devastating impacts of the COVID-19 pandemic have influenced our economy and disrupted social life, but this is a good time to make an effort and try to change some sectors, such as energy, transport, agriculture, and make them more sustainable. Investing restarts the economy, providing solutions for climate change actions, reducing pollutants, creating new jobs, improving social life. Reduction of pollutants, especially CO_2 emissions, is one of the most actual problems, since it slows down the global warming. Other environmental damages, such as degradation of land, contamination of soil and water have negative impacts as well, but usually they are not considered as the major contaminators. The ecosystem is not closed and does not have borders thus the pollutants can easily spread out to other regions and have negative impact on the ecosystems. However, nowadays in the global economy the pollutants are spreading nationwide together with products. If you buy a CO_2-free product with an ecolabel in one of the EU countries, sustainability may not matter to you since you do not know how much pollutants were emitted during the production process somewhere in another part of world. More and more business entities care about sustainable economic activities and are trying to show the origin of a product in the whole chain of production. Nowadays the evaluation of economic activities is usually defined through the life cycle assessment (LCA) approach which uses an open loop methodology characterized as "cradle-to-grave" or "cradle-to-cradle" approach which attempts to reach 100 percent utilization of all types of wastes [11]. One of the LCA tools is the environmental footprint method which can evaluate the product life chain or production process by using input-output inventory databases. A concept of footprint accounting was originally proposed by Rees in the 1990s, however, possibly because of the intuitiveness of the footprint notion, the concept has not yet reached the same level of methodology unification and standardization as the LCA [12,13]. This approach entails calculations of the emissions to environment generated at all stages associated with a product, from raw-material extraction, through production, use, recycling, and disposal within the system boundaries. Many various methodological approaches are often hidden under the same name. This often leads to incomparability of assessments and overall confusion [12]. There are more than 80 currently available environmental footprint calculators or tools by using which you can evaluate your individual, household, mobility, shopping or country's footprint [11]. The environmental footprint method is based on the simple principle that human demand competes for a finite amount of biologically productive space [14]. Sustainable development indicators showed that all sustainable indicators are interrelated as the economic indicators are predominant but social and environmental indicators are also important for analyzing market environment [15]. A separate group of indicators are set up for the evaluation of environmental impacts. They show the level of air, water and soil pollution, assess the problems of waste production and management, as well accessibility and extraction of natural resources. While the global warming is a predominant problem encompassing the issues of sustainable development, consequently CO_2 emissions are normally the main environmental impacts. Hence, over the past few years, the CO_2 footprint, which estimates the rate of emissions over the full life cycle of a process or product, has become one of the most important environmental protection indicators [11]. Other footprint indicators such as climate footprint [16], methane footprint [17] and global warming potential footprint [18] are also suggested for the evaluation of GHGs emissions. Meanwhile, since water is widely used in huge amounts for production purposes, a separate water footprint indicator [19,20] has been suggested for the evaluation of consumption and pollution of fresh water. Water footprint integrates water usage and pollution over the complete supply chain and is measured in terms of water volumes consumed and polluted per unit of time or per functional unit [21]. In 2009, Global Footprint Network organization suggested the energy footprint which is defined as the sum of all those areas used to provide non-food and non-feed energy. Sustainability of economic activities can be compared within the same economic sector or the same group of production. EF index shows country's abilities to live within the nature limits. According to the Global Footprint Network organization, Finland and Estonia have the biggest degradation in the percentage of the EF, correspondingly, comparing the year of 2017 and 2008, the EF value increased from 7.4 to 11.4 gha/per capita and from 6.7 to 10.7 gha/per capita, respectively [22]. Belgium was within the top five nations with the largest EF in 2008 and in the third place in 2018 [23]. The leader among the EU countries in the EF category during the last decade was Luxemburg. Estonia was among the leaders as well (number two in 2008 and in 2018). Lithuania was number 8 in 2008 and number 7 in 2018. Half of imprints among the EU countries was allocated to CO_2 emissions, mostly from energy consumption in households and transport. Road transport is becoming too dense and usually the car policy of a company does not encourage to use public transport. However, some measures are still being taken and, for example, Belgium and The Netherlands managed to reduce their production EF almost by half, mostly by introducing ecological policies oriented towards the reduction of CO_2 emissions. One of the sectors contributing to an increase in the emission of CO_2 (about 30 percent from the total CO_2 emissions) is construction sector, so an increase in the insulation of houses, increasing the efficiency of heating and sufficient use of renewable energy resources can decrease the EF value. At the individual level and farming, the policies such as "Eating less and better" and "From fork to farm" are already good starting points for EF reductions. Especially meat eating habits have a fairly large footprint, thus promoting less meat consumption habits and vegetarian food products together with close to customers policies can also be taken into account.

2.2. Environmental Impact of Electricity Production

The environmental footprint indicator has emerged as a tool to measure human demand for productive land and water and it is used for the evaluation of the impact of products and economic activities on the environment. The purpose of the environmental footprint concept is to evaluate the assimilation of energy, resources and wastes needs of particular social community or farms according needed productive land for their activities [13]. EF provides with a possibility to assess the processes of production or service and to reveal the problematic areas from environment degradation viewpoint [22]. Each hectare of the area is forced to global hectare (gha), the size of which is larger than the actual land hectare. EF indicator shows the current resource demand for a certain economic process or service, therefore it can be used as a resource accounting tool to measure the status quo of consumption rate of resources; it can be a useful tool to create a database for the resource stocks and it can be an analytical tool for making predictions and proposing measures to achieve economic sustainability. The EF value is calculated through land occupied by a certain process, and calculations are usually carried out by using the LCA method. The primary production equivalents embodied in a finished product must be translated into the EF values (e.g., global hectares) by using primary conversion factors drawn from the National Footprint Accounts [24].

The EF calculation is based on annual use of resources (estimated in kg, tons, litres) estimating how much of area (land), water (a_i) and other resources are allocated for a certain production (service) type and which are assimilated by consuming the products (measured in hectares, ha). An annual consumption is divided by the land productivity or production yield (measured in kg/ha).

The environmental footprint calculation methods are based on the assessment of aggregated values of the consumption of non-renewable and renewable resources (energy, water, metals and other materials, chemicals) including the use of land and impacts on the environment such as air, water and soil pollution, emission of CO_2. These impacts influence the global warming and ozone layer, increase eutrophication and acidification.

The major contribution of the EU national footprint accounts to allocated CO_2 emissions. Since it is more appropriate to calculate CO_2 values by using LCA or input-output analysis tools, consequently the concept of carbon footprint more often than other environmental footprints captures the interest of businesses, consumers, and policy makers. Investors watch the carbon footprint of their portfolios as an indicator of investment risks, purchasing managers are curious about the carbon footprint of their supply chains, and consumers are increasingly offered carbon-labeled products [25]. However, CO_2 evaluation tool gives one side view to the life cycle chain of a product/service and hides some important elements that also impact the environment. The comprehensive evaluation tools give more specific information but require special expertize. One of the special footprint calculation tools is sustainable process index method (SPI), a family member of the environmental footprint methods. This method uses the SPIonExcel program, introduced by the group of scientists from Graz University of Technology (Austria) under the leadership by Sandholzer and Norodoslawsky in 2007, and allows one to calculate the EF of a process or service. This calculation is based on the assumption that an area is needed for the conversion of energy into products and services. An area has limited resources because the Earth has a finite surface. Area is the underlying dimension of the SPI index. The more area a process needs to fulfil a service, the more it costs from sustainable point of view. EF is an impact to global environment per good or service process. The more territory a process needs to fulfill a service, the more it costs from sustainable point of view. This is represented by the overall footprint of a product where a_{tot} is the specific (sustainable) service area and it is calculated with the equation where unit can be kWh, kg, m^3 or m^2 or another measure:

$$a_{tot} = \frac{A_{tot}}{S_{tot}}\left(\mathrm{m}^2/\mathrm{unit}\right) \quad (1)$$

S_{tot} is the number of unit services (e.g., product units, energy, goods or services) supplied by the process in question for a reference period of usually one year. This leads to the unit of the ecological footprint, as area use (m^2) per produced goods or service during a reference period (unit a^{-1}).

The total area A_{tot} is calculated by using the following equation:

$$A_{tot} = A_R + A_E + A_\xi + A_S + A_P\left(\mathrm{m}^2\right) \quad (2)$$

The areas on the right side of the equation are called partial areas and refer to the impacts of different productive aspects.

A_R–area required for the production of raw materials; it is the sum of the renewable raw material area (A_{RR}) and the non-renewable raw material area (A_{RN}).

A_ξ–area necessary to provide process energy.

A_E–area to provide the installation for the process; it is the sum of the direct use of land area (A_{ID}) and the indirect use of land area (A_{II}).

A_S–area required for the staff.

A_P–the area for sustainable dissipation of products and by-products. The reference period for these partial areas is usually one year.

The SPI is the fraction of the area per inhabitant related to the delivery of a certain product or service unit.

The SPI is calculated by using this equation:

$$SPI = \frac{a_{tot}}{a_{in}}(\mathrm{cap}/\mathrm{unit}) \quad (3)$$

Here a_{in} is the area per inhabitant in the region being relevant to the process. The lower the SPI is, the lower the ecological impact of providing a good or service on the ecosphere is.

Sustainability of the process or production is achieved if all processes of the region do not exceed "imported" and "exported" areas, including materials and energy embedded in traded goods and services. The SPI calculation index comprises different subareas for material resources, energy, personnel, process installation (e.g., machines for the production process), and product dissipation assessment of the waste quality and quantity of different material and energy flows and emissions. There are seven impact categories such as: (1) area for area, (2) area for non-renewable resources, (3) area for renewable resources, (4) area for fossil carbon, (5) area for emissions to water, (6) area for emissions to soil, and (7) area for emissions to air. According to the SPI method, there are seven partial footprints that represent different footprints [26].

SPI like other EF methods can help to identify the most actual problems in the whole chain of production and show decision actions. SPI method can improve understanding of the problems, provide evidence to the decision makers, which can help to prioritize policies and actions. SPI and also as other EF methods has the same strengths and limitations. The advantages of the SPI are that material and energy flows are aggregates within one measurement, and are adaptable to individual processes, activities or regions, and are also adaptable for importing and exporting [11]. SPI methodology enables the creation of economically-optimal regional energy technology networks that are subject to the consideration of environmental impacts [11]. The comparison of EF values shows the main ecological problems and provide a discussion about ecological improvement. The SPI has limited data availability, uncertainty of data, time intensiveness when finding the appropriate regional data to perform a complete calculation, high possible error relating to the conversion of emissions to an area unit [11].

The analysis carried out by the SPIonExcel program optimizes the processes from the ecological viewpoint, showing how the mass and energy flows convert into the surface area required by the process in EU countries during the period from 2008 to 2019. It summarizes the mass and energy flows over the life cycle of production or service [27]. The identification of ecological problems of the processes (electricity production in our research) is the prime goal of this program. The analyses allow for the ecological optimisation of processes [11]. The program uses the Ecoinvent database [28], one of the internationally recognized LCA datasets [29], for analysis of all non-elementary flows and some elementary flows, both for inputs (e.g., materials supply chain) and outputs (e.g., waste management operations) data. Contamination of water, air and soil are added to the overall footprint, however the impact of waste has already taken effect during their primal use before becoming a waste material. The EF of electricity associated with production technologies and the use of fossil (non-renewable, e.g., oil products, natural gas, nuclear energy) and renewable resources (e.g., solid and liquid biomass, biogas, wastes, wind, hydro and solar energy) have been estimated by using emission factors from the database of SPIonExcel 2.0 program. Electricity balance of the EU countries has been used in combination with physical data from the International Energy Agency [30].

The table below shows the results of impacts by different technologies used in the electricity production on the environment. The partial process footprint a_{part} (measured in m^2/kWh, cf. Table 1) is the amount of products obtained by the electricity production process. The major impact is allocated to the reduction of fossil coal C amount, impact on water bodies and air. The fossil or organic carbon is a major chemical element of organic matter and its degradation is observed in every step of the production process. Electricity production by using coal and oil products have major impact on fossil coal reduction (around 93%). The infrastructure area needed for the electricity production is higher for biogas, hydro energy and nuclear energy and this area is twice higher compared to other fossil fuel technologies. The emission to air stayed almost at the same level in all technologies, except geothermal, biomass and biogas. Nuclear energy, biomass and biofuels have the highest impact on water bodies. Other impacts such the consumption of renewable and non-renewable resources are negligible. The footprint of UCTE (synchronous grid of continental Europe) electricity in average is 40,770 m^2/kWh. However, the EF of net electricity is different in EU countries and it depends on inland electricity production technologies and the share of electricity import.

Table 1. Environmental impacts of electricity production.

Name of Technology	a_{tot} (m^2/kWh)	Area	Non-Renewable Resources	Fossil Coal C	Renewable Resources	Air	Water	Soil
Coal (lignite)	406.24	0.00	0.00	93.09	0.01	1.36	5.53	0.01
Oil products	406.28	0.00	0.00	93.09	0.01	1.36	5.53	0.01
Natural gas	199.51	0.00	0.00	88.56	0.00	5.99	5.44	0.01
Biomass, biofuel (wood chips)	12.87	0.02	0.00	24.48	0.01	27.49	47.95	0.05
Biogas (waste sludge)	74.15	0.01	0.00	73.48	0.00	4.21	22.27	0.03
Nuclear energy	606.57	0.01	0.00	1.36	0.00	4.87	93.75	0.00
Hydroenergy	1.40	0.36	0.00	46.25	0.00	10.70	42.58	0.11
Geothermal energy	14.05	0.00	0.00	11.31	0.00	81.78	6.87	0.04
Solar PV (thin film, CdTe, CIGS)	60.89	0.01	0.25	41.78	0.01	8.59	49.31	0.05
Wind energy	11.30	0.01	0.00	38.54	0.01	5.48	55.89	0.07
Other biogas (fuel cells)	21.35	3.80	0.03	54.56	0.00	25.73	15.27	0.61
Municipal waste	74.15	0.01	0.00	73.48	0.00	4.21	22.27	0.03
Waste renewable	28.00	0.00	0.00	80.77	0.01	3.46	15.73	0.04
UCTE-Electricity	407.70	0.01	0.00	3.29	0.00	0.14	0.64	0.00

The partial EF of nuclear energy in EU15 is 60,657 m^2/kWh in average (Table 1), however, the partial EF of nuclear energy is considerably higher in France (108,208 m^2/kWh) and Germany (89,893 m^2/kWh). It has also been observed that the share of electricity import is significantly increasing the countries' partial footprint.

3. Environmental Footprint of the Electricity Sector and Sustainable Investment in EU Countries

The supply chain of countries' electricity net mixture consists of different energy production technologies that are based on diverse fuel types. The electricity balance of the EU countries includes the amount of electricity produced within a country and the share of export/import amount. The period for comparison analysis is from 2008 to 2019. Total production capacity in GWh has been recalculated by the fuel type as a percentage rate, including the export part and excluding the import part of electricity. Data on electricity in the investigated EU countries for the year of 2019 is presented in Table 2 below.

Table 2. Proportion of resources used in electricity generation (percentage rate in the year 2019) in EU countries.

Resources	Austria	Belgium	Bulgaria	Czech Rep.	Denmark	Estonia	Finland	France	Germany	Ireland	Italy	Latvia	Lithuania	Luxemburg	The Netherlands	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	UK
Coal	5	3	39	45	11	70	12	1	30	8	6	0	0	0	16	74	11	9	28	5	1	2
Oil products	1	0	1	0	1	0	0	1	1	1	4	0	2	0	1	1	2	2	0	5	0	0
Natural Gas	15	28	5	7	6	0	6	7	15	53	49	50	13	9	59	9	32	10	3	31	0	41
Biomass/biofuel	6	4	4	6	17	17	18	1	7	2	6	14	12	12	3	4	6	4	2	2	5	10
Waste	2	3	0	0	6	2	2	1	2	2	2	0	3	7	3	0	1	0	0	1	3	3
Nuclear plants	0	47	37	35	0	0	35	70	12	0	0	0	0	0	3	0	0	56	36	21	40	17
Hydro energy	60	1	8	4	0	0	18	11	4	4	16	33	24	51	0	2	19	16	29	10	39	2
Geothermal	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
PV (mix)	2	4	3	3	3	1	0	2	8	0	8	0	2	6	4	0	2	2	2	3	0	4
Wind energy	10	10	3	1	55	9	9	6	20	31	7	2	38	15	9	9	26	0	0	20	12	20
Other/biogas	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
Municipal waste	1	2	0	0	6	2	2	1	2	2	2	0	2	7	3	0	1	0	0	0	3	2
Waste (renew)	0	1	0	0	3	1	1	0	1	1	1	0	1	3	2	0	1	0	0	0	2	1
Import	34	14	8	13	46	50	27	3	7	7	13	62	100	88	17	10	14	46	57	6	6	7
Export (-)	31	16	20	28	35	35	6	13	12	5	2	54	99	50	16	4	9	43	58	4	21	1

The percentage share is the ratio between a certain type of production and total production. The import percentage rate is the share of import and domestic supply. Analysis has showed that nuclear energy is dominating in the electricity production and in Belgium it accounts for 47% of the total electricity production, in Bulgaria–37%, Czech Republic–35%, Finland–35%, France–70%, Germany–12%, Slovakia–56%, Slovenia–36%, Spain–21%, Sweden–40%, UK–17%, and The Netherlands–3% Other countries that do not have nuclear energy use hydro, wind, hydro energy and natural gas, coal. It should be noted that those countries that cannot meet the needed domestic demand compensate the lack by the import of electricity. The use of coal for electricity production is still dominant in such countries as Poland (70%), Bulgaria (39%), Czech Republic (45%), Germany (30%), Slovenia (28%) and Estonia (70%). Estonia's inland electricity production (70%) is based on the use of coal (oil shale). It is worth mentioning that the oil shale industry in Estonia is one of the most developed industries in the world and this sector constitutes about 4% of Estonia's gross domestic product. Countries such as Germany, Portugal, Slovenia, Spain, and UK have the most diverse types of electricity production. The import/export balance is higher in such countries as Lithuania, Luxemburg, Finland, Latvia, and Denmark. Despite the fact that Denmark produces more than half of its electricity by using wind farms, its import/export balance is 11% It is worth distinguishing Lithuania and Luxemburg, where the import/export balance is 70% and 38%, respectively. In these countries electricity demand is met by import share. It should be noted that such renewable resources as hydro energy (i.e., Austria's inland hydro energy potential is 60% from the total electricity production) are constant and have no growth potential. However, wind energy, biomass and solar PV have the largest potential of growth.

The energy production process chain includes resources provision, transportation, storage/retailing, burning or using facilities, disposal of wastes. Environmental impact is calculated (Tables 3 and 4) as partial footprints of the use of water, air, soil, fossil carbon; the use of renewable and non-renewable resources; the use of area for installation. The information shows that the countries' EF varies from year to year.

Table 3. Environmental footprint (m^2/kWh) of electricity production in EU countries.

EU Countries\Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	312	291	298	308	306	318	312	302	286	273	271	261
Belgium	576	524	521	532	523	532	522	496	533	529	500	525
Bulgaria	499	503	499	494	498	499	502	498	505	501	508	512
Czech Republic	491	495	494	494	500	503	502	495	486	495	498	500
Denmark	360	362	355	353	349	363	359	340	348	328	344	284
Estonia	402	404	403	403	403	404	403	402	402	402	402	398
Finland	506	509	494	509	525	519	529	536	536	539	532	541
France	590	590	589	588	588	589	594	591	586	583	591	586
Germany	464	463	465	447	443	442	444	440	432	426	426	425
Ireland	310	298	284	291	305	301	302	310	297	283	264	243
Italy	297	297	292	295	300	299	302	293	279	270	268	246
Latvia	198	198	198	198	195	196	194	195	195	192	196	195
Lithuania	574	574	257	223	224	221	216	230	233	214	220	180
Luxemburg	196	196	196	195	194	189	189	180	149	141	133	129
The Netherlands	322	317	308	312	322	319	338	349	340	326	321	298
Poland	403	402	403	401	400	401	401	400	399	397	395	392
Portugal	333	335	309	320	344	349	350	344	330	320	318	276
Slovakia	559	554	555	551	554	559	565	564	542	562	560	561
Slovenia	528	524	522	527	522	522	542	530	525	531	528	529
Spain	427	426	448	445	455	464	471	464	471	459	463	454
Sweden	591	588	580	586	590	591	592	588	589	590	590	585
UK	397	417	407	424	439	442	436	444	428	429	424	409

Table 3 represents the values of countries' EF in m^2/kWh of electricity net mix including the share of import and export, meanwhile Table 4 represents the values of countries' environmental footprint in m^2/kWh of electricity production. It is worth mentioning that the import part influences the EF value of electricity. Such countries as Luxemburg, Lithuania, Latvia, Finland, and Denmark have the highest import rate among other EU countries, consequently the EF difference in produced electricity and net mix is much higher. The difference in EF values also occurs in countries that have shifted electricity production from one energy source to another. However, it depends on the type of resources, because the bigger is its EF value, the more difference it causes. However, due to the large amount of import share countries' EF is usually equalized and the deviation is not so big in the final result. Most countries are reducing the use of fossil fuel for electricity production (with an exception of Poland (coal use) and France (nuclear energy use) and investing in the development of facilities that use renewable resources, but renewable resources so far can supply only limited amount of energy due to physical territorial and environmental protection limitations. Therefore, countries tend to invest in the infrastructure for electricity network links and these SI instruments reduce the EF as much as SI increase the share of RES.

According to data presented in Table 4, the EF of the Lithuanian net electricity production in 2019 was 634 m^2 per year/per kWh and the EF value of produced electricity inland was only 180 m^2/per kWh. This difference can be explained by the fact that Lithuania does not have its own electricity production capacities and it can only supply about 30% of the total domestic demand. Lithuania stopped producing electricity that used natural gas and the footprint value of electricity produced by using gas burning facilities reduced by 52%, compared to a net electricity mix. The EF value of biomass fired stations for electricity production is near to zero, so biomass has an environmental advantage for electricity production. An exception was observed in Lithuanian electricity market due to the closure of Ignalina nuclear power plant in 2009, the partial EF decreased from 916.90 to 282.10 m^2/kWh. The tendency of decreasing was approached in 2015, however afterwards, in 2019, an increase was observed and the EF was 368 m^2/kWh. This result is among the 39% of other EU countries that have the same or lower EF value.

Table 4. Environmental footprint (m^2/kWh) of electricity net mix in EU countries.

EU Countries\Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	257	395	250	280	261	255	258	278	249	257	258	230
Belgium	554	549	573	571	510	518	504	483	520	517	487	509
Bulgaria	496	500	498	493	496	495	497	494	500	498	505	508
Czech Republic	491	494	493	493	499	500	501	496	485	495	496	496
Denmark	381	375	357	357	390	359	355	366	365	335	349	319
Estonia	408	419	408	410	415	414	418	424	417	412	415	426
Finland	476	488	474	485	491	493	482	497	500	498	494	503
France	588	587	586	587	586	587	593	590	583	580	588	583
Germany	459	457	456	438	434	434	435	430	424	416	415	408
Ireland	307	294	281	287	301	293	293	301	292	276	255	232
Italy	292	291	284	287	290	283	282	280	266	260	256	237
Latvia	434	383	323	349	395	405	505	469	384	283	393	376
Lithuania	759	749	575	541	539	535	539	528	637	637	665	634
Luxemburg	207	201	226	211	205	188	191	191	183	179	178	162
The Netherlands	320	313	306	309	327	445	464	357	341	326	323	297
Poland	403	402	402	401	399	401	399	398	396	394	392	386
Portugal	307	310	274	290	309	299	300	311	303	303	291	243
Slovakia	564	553	543	560	576	563	578	582	569	574	555	572
Slovenia	551	589	583	563	555	549	564	573	561	574	561	563
Spain	424	421	443	438	448	452	456	449	447	439	438	430
Sweden	556	539	538	551	558	560	558	556	552	559	561	562
UK	394	415	404	420	434	435	424	430	413	413	404	383

The partial footprint of the net electricity mix with import share and produced electricity within a country is different in all countries (Table 5). The percentage rate is fluctuating very much. Comparing the minimum and maximum EF values of a country during the period of 2008–2019, it is observed that the biggest difference was noted in Lithuania (from 31 to 252%) and in Latvia (from 47 to 160%). The differences in Lithuania's electricity market can be explained by the shift of production from nuclear energy due to the closure of Ignalina nuclear power plant in 2009. Since then, electricity market in Lithuania is based on electricity import. The share of import increased from 69% in 2010 to 97% in 2019.

Accordingly, the share of partial footprint of electricity produced in the country in 2019 was only 1798 m^2/kWh, while the partial EF value of import share was 45,395 m^2/kWh. When comparing other countries, it is observed that the biggest difference in the EF values were in Austria (36%), The Netherlands (40%), Luxemburg (34%), Slovenia (12%), Denmark (12%), and Estonia (7%). This difference can be explained by a large share of electricity imports.

The biggest variation between minimum and maximum EF values of produced electricity are noted in Latvia (44%), Austria (42%), The Netherlands (36%), Lithuania (30%), Luxemburg (28%), Ireland (25%), Portugal (22%), Italy (19%), Denmark (18%), Belgium (16%), UK (12%), and Germany (11%). The biggest variation between minimum and maximum EF values of electricity net mix (including import) are noted in Lithuania (69%), Luxemburg (34%), Ireland (22%), Denmark (22%), Portugal (21%), Italy (18%), Austria (18%), and The Netherlands (15%). The differences between maximum and minimum EF values in other countries do not exceed 10% The percentage variation can be explained by the share of imports. It is also observed that the increased share of RES does not contribute significantly to the reduction of EF because its share is not enough to compensate a large share of technologies based on fossil resources. Renewable technologies cannot compensate negative impact of non-renewable ones, because there is much energy embodied in their production chain and the installed renewable energy capacities are not enough to meet the domestic supply. An interesting point observed during the analysis of the EF: countries that have the large share of renewable electricity production (for example, hydro energy share in Latvia accounts for about 50% of the total produced electricity, in Austria this share is about 60%, in Denmark 55% of electricity is produced by using wind energy). While countries with more stable variation in the EF values usually have a wide range of energy resources and the major part of electricity is produced at nuclear power plants.

Table 5. Variation in the EF values for electricity production and electricity net mix in EU countries.

Countries	Production Values m^2/kWh		Impact with Import Share Values m^2/kWh		Production vs. Import, Change in %	
	Min Value (Year)	Max Value (Year)	Min Value (Year)	Max Value (Year)	Min	Max
Austria	230 (2019)	395 (2009)	261 (2019)	318 (2013)	36	20
Belgium	483 (2015)	573 (2010)	496 (2015)	576 (2008)	10	4
Bulgaria	493 (2011)	508 (2019)	494 (2011)	512 (2019)	0	1
Czech Republic	485 (2016)	501 (2014)	486 (2016)	503 (2013)	0	1
Denmark	319 (2019)	390 (2012)	284 (2019)	363 (2013)	12	1
Estonia	408 (2010)	426 (2019)	398 (2019)	404 (2009)	7	1
Finland	474 (2010)	503 (2019)	494 (2010)	541 (2019)	4	9
France	580 (2017)	593 (2014)	583 (2017)	594 (2014)	0	1
Germany	408 (2019)	459 (2008)	425 (2010)	465 (2010)	1	4
Ireland	232 (2019)	307 (2008)	243 (2019)	310 (2008)	1	5
Italy	237 (2019)	292 (2008)	246 (2019)	302 (2014)	2	6
Latvia	283 (2017)	505 (2014)	192 (2017)	198 (2010)	160	47
Lithuania	374 (2019)	759 (2009)	180 (2019)	574 (2009)	252	31
Luxemburg	162 (2019)	226 (2010)	129 (2019)	196 (2009)	34	0
The Netherlands	297 (2019)	464 (2014)	298 (2019)	349 (2015)	40	1
Poland	386 (2019)	403 (2008)	392 (2019)	403 (2010)	0	1
Portugal	243 (2019)	311 (2015)	276 (2019)	350 (2014)	5	14
Slovakia	543 (2010)	582 (2015)	542 (2016)	565 (2014)	5	2
Slovenia	549 (2013)	589 (2009)	522 (2013)	542 (2014)	12	4
Spain	421 (2009)	456 (2014)	426 (2009)	471 (2014)	1	6
Sweden	538 (2010)	562 (2019)	580 (2010)	592 (2014)	4	8
UK	383 (2019)	435 (2013)	397 (2008)	444 (2015)	1	6

It is essential to develop new technologies as soon as possible in order to reduce environmental footprint as much as possible. There are many ways to encourage sustainable investment in the electricity sector. It is necessary to mention foreign investments in the European electricity sector. China has been massively investing in the European electricity sector since 2000 as a part of its global strategy to create the first global electricity grid. China is investing in many technologies (photovoltaic, wind, nuclear, storage, electric vehicles, raw materials used in renewable energy technologies, etc.). Russia is focusing on its nuclear strength, especially in its traditional sphere of influence (Central and Eastern Europe). US investments mostly come from the private sector, particularly from the most successful tech companies that are looking for opportunities to invest in "green" electricity. In terms of the investment analysis at the European level [31], the main focus is currently on the European Green Deal–the ambitious EU climate policy that aims for Europe to become the first climate neutral continent by 2050. This requires a fundamental transformation of our energy system. The Energy Union is the main policy instrument to deliver this transformation, which aims at bringing secure, sustainable, competitive and affordable energy to all EU consumers households and businesses [32]. The European Parliament has conducted a study and determined that support schemes represent currently the major driver for investments in power generation capacity, while investments in grid assets are mainly driven by regulation that guarantees investors a reasonable return on equity [33]. Important barriers affecting investments in the energy industry are the following: the lack of regulatory certainty due to inadequate policies, in particular frequently changing and poorly harmonized national legislation; the lack of public acceptance of new infrastructure; an inappropriate regulatory framework (including complex permit granting procedures); and economic factors: low growth in electricity demand, lack of proper electricity and carbon markets price signals, low profitability of not subsidised power generation, long lead times and high upfront capital requirements for most infrastructure projects. Investments in interconnection capacity are particularly hindered by conflicting national interests and the administrative and regulatory complexity of multinational projects. Nevertheless, the European Investment Bank (EIB) may coinvest or provide co-financing to eligible projects alongside third parties, such as investment platforms, either under fully delegated structures or with active EIB involvement into due diligence and structuring process [34].

4. Discussion

There are many indicators that can be used in the decision making for the investment in the power sector, however, so far many of them have been used for explaining the economic sector (such as GNP, GDP). Until now the economic indicators have been predominant, but they have some disadvantages as they do not underestimate the depreciation of natural capital (environment depreciation) and exclude the value added generated by the public sector and natural economic activities. Thus, there was a need to find an indicator to better fulfill the U.N. Sustainable Development Goals (SDGs). One of such indicators–Environmental Footprint–has been chosen as the most suitable and the European Commission initiated a procedure for investigating the possibilities to use this indicator for the evaluation of product, process and organization impacts. The current situation of different methods to assess environmental performance is leading to confusion in environmental performance information and it also leads to additional costs for businesses if they are requested to measure the environmental performance of the product or the organisation based on different methods by public authorities, business partners, private initiatives and investors [35]. Consequently, on 9 April 2013, the European Commission issued a recommendation (2013/179/EU) on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. This document is a product environmental footprint (PEF) guide that provides a method for modelling the environmental impacts of the flows of material/energy and the emissions and waste streams associated with a product throughout its life cycle. The aim of this document is to provide a comprehensive technical guidance on how to conduct a PEF study [35]. The PEF Guide was developed as one of the building blocks of the flagship initiative of the Europe 2020 Strategy–"A Resource-Efficient Europe" aiming to propose ways to increase resource productivity and decouple economic growth from both resource use and environmental impacts, taking a life cycle perspective [36]. One of its objectives is to: "*Establish a common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life-cycle ('environmental footprint')*" [36]. The European Commission started the PEF pilot phase from the evaluation of document "Building the single market for green products" in 2013 and had been testing the PEF methodology for three years. Later, on 9 April 2013 it issued a recommendation (2013/179/EU) on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. One of the recommendations in the energy sector is if the electricity (or part of it) is renewable, it is important that no double counting occurs. Therefore, the supplier shall guarantee that the electricity supplied to the organisation to produce the product is effectively generated using renewable sources and is not put into the grid to be used by other consumers (e.g., Guarantee of Origin for production of renewable electricity [35]). The Association of Issuing Bodies (AIB) promotes the energy certificate schemes across the EU according to the Directive 2018/2001/EC for the promotion of the use of energy from renewable sources [37]. The main provisions of this Directive concerning guarantees of origin are contained in Article 19, which requires EU Member States to ensure that a guarantee of origin is issued on request by producers of electricity, gas, hydrogen, heating or cooling from eligible renewable energy sources. This system is voluntary and producers decide whether or not they wish to make such a request. However the EU set ambitious targets in the climate and energy frameworks with a aim to increase the share of RES at least 32% by 2030, to reduce carbon emissions by 55% by 2030 and to become carbon neutral by 2050. Consequently, EF methods can help to achieve these targets by modelling the environmental impacts of the flows of material/energy and resulting emissions and waste streams associated with a product from a supply chain perspective, through use, to final waste management [35]. The reduction of EF is based on the substitution of fossil through renewable energy carriers [27]. To substitute the fossil fuel by renewable resources for heating is a better and more economically valuable solution rather than to invest in thermal insulation [27]. EU countries are shifting electricity production towards the use of renewable resources, however all economic activities have negative environmental impacts. It is important to notice that SPI method is a good indicator in the decision making for the investment in the power sector, however not all investments in RES technologies gives the desirable reduction of EF. EF evaluations have showed that significant impacts are observed in the reduction of organic carbon, emissions to air and water and contamination of soil. Territorial aspects also influence the development of renewable resources. Since the sustainability consists of three pillars: environmental protection, economic growth and social equity, it is necessary to notice that economic indicators are predominant, but social and environmental indicators are no less important for analysing market [15]. EF mitigation measure has a positive effect when all sustainability goals meet the criteria of sustainability. It is important to notice that EF is a good environmental indicator, but only when you have similar type of products, because then you can compare it. In the production of electricity the following main hotspots have been revealed: the share of imported electricity, the type of resources for electricity production and the share of renewable resources. The reduction in the EF of electricity is ensured by the following investment options: increase in the share of imported electricity and inland electricity production by using renewable energy resources. The research has revealed that some EU countries invest in the development of electricity network links between countries, but do not tend to develop their own electricity generation capacities. Beyond reducing environmental impacts caused by business operations, some companies are developing a net positive schemes that aim to create values and deliver regenerative services to society [38]. Net positive impact approach enables businesses to think outside the box and develop new products and services that can solve societal problems and provide returns to shareholders, further demonstrating how sustainability drives innovation [39]. Therefore, overall investments in renewable resources either for electricity production or to the development of network can reduce the EF substantially. The evaluation of EF shows the best sustainable method of electricity production, however the composition of technologies depends on availability of resources, price and territorial characteristics. Resources and territorial characteristics are among the major factors influencing the final EF values and the price of electricity.

5. Conclusions

The analysis of the environmental footprint of electricity in EU countries is a good example to show how sustainable investment correlates with the reduction of EF and how the open loop of the ecosphere influences environment. Pollutants can easily spread out to neighbouring countries and have negative impact on the ecosystems assuming the EF value varies depending on the share of electricity import. The environmental footprint analysis explains the origin of pollutants. The EF value depends on the import/export balance and the share of RES. The EU countries usually cannot meet the needed domestic demand for electricity thus the lack of electricity supply is compensated by electricity imports. Countries tend to invest in the development of RES facilities, mainly in wind energy, biomass and solar PV technologies and gradually reduce their inland production capacities from fossil fuel and consequently reduce the EF. However, the flow of eletricty import/export balance distorts the EF value, so there is a need to identify these flows between countries. This could be a direction of further investigations. This research showed that the development of RES facilities is not enough to reduce the EF substantially because there are physical, territorial and environmental protection limitations for installing new power capacities. This is especially evident in countries that have developed hydro energy, since the capacity is stable over the decade and has no potential of growth. It is interesting to note that Estonia's inland electricity production is based on the use of the oil shale industry and this sector is the most developed in the world and constitutes about 4% of Estonia's gross domestic product.

Countries such as Germany, Portugal, Slovenia, Spain, and UK have the most diverse types of electricity production. The import/export balance is higher in such countries as Lithuania, Luxemburg, Finland, Latvia, and Denmark. Despite the fact that Denmark produces more than half of its electricity by using wind farms, however, its import/export balance is 11% It is worth distinguishing Lithuania and Luxemburg where electricity demand is met by the import share. However, wind energy, biomass have the largest potential of growth, thus it is worth investing in these technologies and thereby mitigate the EF value. However, the import part influencing the EF value of electricity increases or decreases the EF value in average from 2 to 10% The difference depends on the type of resources for electricity production and the size of the import share. Minimizing the environmental footprint of economic activities requires a shift towards the changes in the entire production chain system. Therefore, it is important to coordinate investments and to harmonize investment plans in EU countries. The conclusion can be drawn as follows: the reduction of the EF of electricity could be achieved by developing RES technologies since the major part of electricity is produced by using non-renewable resources. The substitution of fossil resources is a challenging task. There are not enough capacities because of the technological restrictions and physical limits to meet the needed amount of electricity demand. It is essential to develop new technologies and to reduce environmental footprint as much as possible, and this can only be achieved through systematic sustainable investment. Development of RES technologies do not always have a positive effect for reduction of EF, so an integrated approach to the management of the power sector is needed, investigating energy balance and the relationship between imports and exports between EU countries.

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