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*Original scientific paper*

# ETHICAL DILEMMAS OF RENEWABLE ENERGY

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A b s t r a c t: The world's economic growth has lea to increased energy needs that have to be satisfied with higher electricity production from both conventional and renewable energy sources. Due to the reduced fossil fuel stocks as well as environmental pollution caused by conventional power plants priority is given to the expansion of renewable energy sources. Motivated by the need to study the competitiveness, eco-friendliness and reliability of renewable energy, research was conducted on the effect that different energy types have on the environment, population, and economy. The aim of this paper is to analyze the ethical dilemmas of renewable energy as constraints for increasing the renewable energy share in the generation of electricity and replacement of fossil fuels, considering the production process intensity, noble materials depletion, and climate change caused. The extensive analysis showed that although renewable energy is in principle a clean and inexhaustible energy source, it can cause burdens on nature and society.

**Key words:** renewable energy; ethical dilemmas; carbon footprint; solar panels; wind turbines

### ЕТИЧКИ ДИЛЕМИ НА ОБНОВЛИВИТЕ ИЗВОРИ НА ЕНЕРГИЈА

А п с т р а к т: Светскиот економски раст води до зголемени потреби од енергија, кои треба да се задоволат со поголемо производство на електрична енергија од конвенционални и обновливи извори на енергија. Поради намалените резерви на фосилни горива, како и загадувањето на животната средина предизвикано од конвенционалните постројки, приоритет се дава на експанзија на обновливи извори на енергија. Мотивирани од потребата од проучување на конкурентноста, влијанието врз животната средина и сигурноста на обновливите извори на енергија, спроведовме истражување за ефектот што различните видови енергија го имаат врз животната средина, населението и економијата. Целта на овој труд е да се анализираат етичките дилеми на обновливите извори на енергија како ограничувања за зголемување на нивниот удел во производството на електрична енергија и замена за фосилните горива, имајќи ги предвид интензивноста на производствениот процес, исцрпувањето на благородните материјали и предизвиканите климатски промени. Направената обемна анализа покажа дека, иако обновливата енергија во принцип е чист и неисцрпен извор на енергија, таа може да предизвика оптоварување на природата и општеството.

**Клучни зборови:** обновливи извори на енергија; етички дилеми; јаглероден отпечаток; соларни панели; ветерни турбини

## 1. AIMS AND BACKGROUND

In recent years primary and final energy consumption are decreasing, however not reaching the target set by the European Union (EU) [1]. Meaning that global energy needs are still relatively high and have to be satisfied using conventional and renewable energy sources for heat and electricity production. The renewable energy use is constantly growing exceeding the prescribed target by EU for 2020 by 2% [2]. As a result of the increased use of renewable energy, motivation and interest arouse for research of the eco-friendliness, competitiveness, and profitability of this energy type. Background data showed that renewable energy can cause burdens on nature, society, equipment, and economy. Production process intensity and noble materials depletion for manufacturing of renewable energy systems present constraints for expansion of this energy type and replacement of fossil fuels. The energy dept of renewable energy regarding carbon footprint is analyzed and compared to conventional energy sources. Scientific materials were reviewed to define the usually questioned competitiveness of renewable energy by using Energy Return on Investment (EROI) for several renewable as well as conventional energy sources. Attention has been paid further in the paper to the Levelized Cost of Energy (LCOE) of renewable and fossil fuels in order to gain insight into the system profitability.

## 2. EXPERIMENTAL

The ethical dilemmas of renewable energy are considered from several aspects, including impacts on the environment, climate, eco-systems, population, equipment and economy. The negative consequences resulting from installation of hydropower plants are changes of water quality, fragmentation of aquatic ecosystems, relocation of inhabitants, changes in water temperature, dislocation of slopes, climatic changes. The implications on environment, economy and equipment deriving from installation of wind turbines are noise and visual pollution, wildlife harming, impact on house prices, obstruction of ship navigation. Installation of solar energy systems affects the nature by use of land, visual disturbance, and presence of hazardous and toxic materials in their composition [3]. Additionally, the production process of renewable energy systems is very material, labour, and capital intensive highly dependent from fossil fuels.

*Environment.* The negative consequences resulting from installation of hydropower plants are changes of water quality and temperature, fragmentation of aquatic ecosystems, dislocation of slopes, climatic changes due to evaporation and air humidity. The water quality changes due to the prolonged water retention in the basin which leads to increased eutrophication manifested through growth of vegetation, algae, presence of specific odors, and appearance of insects. This presents an anaerobic environment causing water supply problems, fish toxicity, and bad smell. Additionally, the excessive presence of plants can cause problems with transport through the water body. According to reference [4] the capture of increased amount of water in the water basin prior the dam of the hydropower plant impacts the water temperature. The data shows that the water is warmer than usual in winter and colder than normal in summer, which are not typical conditions for the living species. The water flowing downstream through the plant impacts the general river water temperature affecting the whole living environment. The local climate change generally is caused by evaporation and air humidity from large water reservoirs where the changes are influential due to increased evaporation rate. Specific example is the biggest water basin in Brazil, Sobradinho with daily amount of evaporated water equal to the daily water demand for the whole country [4]. The fragmentation of aquatic ecosystems is done by the dams which present a barrier to the fish in the rivers among which they are built, splitting the river flow into two parts, upstream and downstream.

The negative implications on the environment deriving from installation of wind turbines are causing noise, aesthetic or visual pollution, and harming wildlife, including birds and bats. The noise from the wind farms depends mainly on the distance and weather situation. According to studies it can have a negative impact on human health, leading to sleep disruption and psychological discomfort [5]. Also, the noise from the wind turbines is reported to be more annoying than other environmental noises [6]. The installation and operation of wind turbines impact bird population in several ways including loss and remolding of habitat, movement obstacles leading to collisions and mortality [7].

Geothermal energy has some minor effects on the environment resulting from the exploitation of geothermal wells. These effects impact the environment by polluting the air by ejecting non-condensable gasses, the surface and underground waters with waste water slats and harmful substances. The formation and use of boreholes causes noise and land erosion [8].

*Population.* Large hydropower plants occupy big areas of land where people have their dwellings and agricultural fields. Due to construction many families leave their homes and are relocated to other places which affects the overall quality of their life. Real-life examples for massive relocation of population are the Three Gorges Dam in China and Itaipu Dam between Brazil and Paraguay. The Three Gorges Dam is the biggest dam ever constructed due to which more than 3.5 million people were relocated [9]. Whereas the Itaipu Dam is the second by its size in the world causing displace of around 60 thousand people [10].

*Equipment.* Wind turbines can be installed onshore or offshore. Onshore wind turbines are located on land, whereas offshore are located over water. Onshore wind turbines occupy large areas of land that can be used for agricultural activities which can have direct and indirect impact on the soil. The effects are caused by installation and placement of the turbines on the soil considering that they are numerous in one wind farm. This reduces the area for fertilizing the land and leads to fragmentation and degradation of ecological habitat. Offshore wind turbines can be fixed or floating, the design depending mainly on the water depth [11]. Their main disadvantage refers to causing ships collide with the wind turbine due to obstacles in the ship movement. They can happen due to several reasons, mainly: equipment failure, human mistake, and weather conditions. Whereas, due to the activity performed and the consequences happened, collision situations can be categorized into accidental, operational, and catastrophic. They can be structural damages, as parts destruction, environmental damages, as shipwreck or ship capsizing and fuel spillage, and casualties of the employees present at the wind farm or crew members on the ship [12].

*Economy.* Installation of wind turbines can have a negative impact on the house prices located in the vicinity of the wind farm. Main factors affecting the house price change are the turbine height and its distance from the house. Tall turbines have greater effect on cost reduction at larger distance compared to small turbines. The price impact happens immediately when the first turbine is installed, not being additionally affected by the latter number of turbines placed. Based on calculations done for the Netherlands, the total value loss of houses near wind farms amounts 5 billion euro [13].

*Production process and materials used.* Solar and wind electricity is very material, labour and capital intensive leading to high energy and cost consumption for suppling and transporting the necessary materials and production of solar and wind farms itself.

PV systems are composed of around 40 single or multicrystalline silicon wafers compacted behind glass using an ethylene vinyl acetate (EVA) pottant material placed in an aluminum frame together with a junction box [14]. Number of panels are joined together on supporting structures that are placed on buildings or in open field [15]. The most abundant material present in the solar panels is glass. Other components present are aluminum, silicon, copper, tellurium, indium, silver, and hazardous materials, such as cadmium (Cd) and lead (Pb) [16]. Indium is a component of PV panels which is on the extinction level. These finite sources are mined at various locations around the world with constantly increasing demand striving to improve renewable energy production and meeting peoples' energy needs. The mining process results in sinkholes, loss of biodiversity, and contamination of nearby water streams from highly acidic metal waste. Production of solar panels consumes a lot of energy especially for the processes of melting and purifying of silicon which is the main component used for capturing and transducing sunlight. The melting process is done in electric furnaces at temperatures of 1414°C where fossil fuels are used for generating electricity which leads to $CO_2$ emissions [17]. Solar waste is generated when the life cycle of the solar panels is finished or when catastrophic damages occur. The chemicals present in the solar panels are harmful to the environment if not properly disposed. The prediction is that solar waste will start to become significant in around 15 years due to increased demand of solar panels now. Preferable technologies for treatment of solar waste are recycling and reuse of valuable materials [18]. However, there is still no convenient recycling technique defined and solar panels are usually discharged in landfills. Another problem regarding solar panels is their premature removal and disposal.

A wind turbine consists of around 8000 parts with 100 meters long blades and 80 meters high towers. Materials such as steel, concrete, copper, fiberglass are necessary for production of wind turbines. Precisely, the body of the wind turbine is made of steel, the blades are from fiberglass and the base in from concrete. The magnets located on the turbine blades used for electricity production require rare-earth metals for their production which are extracted by mining. According to reference [17], the needs for materials contained in one wind turbine per unit of capacity are 200 times higher compared to the materials in a modern combined cycle gas turbine. The blades of the wind turbine are made of carbon fiber and fiberglass composites are tough to recycle and usually end up being landfilled. More often the old blades are reused as cement for refilling by breaking down and grounding up [19]. Considering that blades are manufactured as a one-piece component and have complex structure, it is difficult to recycle them into any other application than blade. The recyclable material from wind turbine blades varies in quality and quantity, as well as design and material. This presents a problem for development of a sustainable recycling solution for blades [20].

Life Cycle Assessment (LCA) of renewable energy analyzes the environmental impact of every step of a product life including materials extraction, processing, manufacture, distribution, and use. According to LCA the extraction and processing of raw materials for solar panels and wind turbines is highly environmentally intensive considering the mining processes executed. Additional impact on the environment has the process of manufacturing of solar and wind farms due to consumption of large amounts of electricity.

## 3, DISCUSSIONS

By analyzing the LCOE the profitability and competitiveness of the renewable energy systems is defined, whereas the EROI provides information about the viability of the plants based on these energy sources.

*Carbon footprint.* Each energy source contains different amount of carbon footprint, also referred as carbon or energy dept throughout the life cycle of the specific, analyzed system. $CO_2$ emission footprint for one kWh of electricity generated from different energy types differs significantly. The carbon emissions of renewable energy are almost all front-loaded, whereas fossil-fueled power plant these emissions occur throughout the operation of the plants. In the calculation of net carbon footprint of renewable energy, the materials necessary for production must be taken into consideration together with the mining process, the process of transportation of raw materials to the production location, the power plant production process, and the anticipated lifespan of the system. The most considerable sources of emissions are the mining and transport of materials used in the manufacturing process [15].

Regarding wind turbines, manufacture and installation account for over 90% of the total life cycle carbon emissions of an onshore wind farm and 70% of an offshore farm. Transport and installation contribute for around 6% of total life cycle carbon emissions for an onshore wind farm. Operation and maintenance activities contribute for 6% of total life cycle carbon emissions for an onshore wind farm and 20% for offshore. Decommissioning accounts for an additional 6% [20]. The steel tower is the biggest contributor to the carbon footprint with total of 30%, the concrete foundation has 17% and the blades account for 12% of the total emissions [19].

Wind and solar energy have the lowest $CO_2$ emission per kWh from the renewable energy types with 4 g $CO_2$e/kWh and 6 g $CO_2$e/kWh respectively. Hydro and bioenergy account for significantly higher emissions with 97 g $CO_2$ e/kWh and 98 g $CO_2$ e/kWh. From all energy sources included lowest carbon footprint has nuclear energy, whereas highest $CO_2$ emissions has coal carbon capture and storage (CCS) power with 109 g $CO_2$e/kWh. Gas CCS are in between, with amount below hydro and bioenergy and above wind and solar, having 78 g $CO_2$e/kWh [22]. Consequently, this means that coal power plants with installed CCS technology generate 18 times higher carbon footprint compared to solar, while natural gas 13 times higher [15]. According to the abovementioned, the conclusion would be that in terms of carbon dept competitive energy sources are wind, solar, nuclear and gas.

*Profitability.* In order to present the energy system profitability, LCOE is used taking into consideration the investment and, operation and maintnance costs related to the energy produced throughout the unit life time. LCOE presents a measure of the overall competitiveness of different generating technologies. LCOE takes into consideration the capital costs, fixed operations and maintenance (O&M) costs, variable O&M costs, fuel costs, financing costs, the utilization rate for each plant type and decommissioning costs. For solar and wind technologies there are no fuel costs and relatively small variable costs, meaning that LCOE depends mainly from the capital cost of the technology [23].

In the period from 2010 till 2020 LCOE for different renewable energy sources has different trends. Drastic decline can be noted for solar and wind energy, whereas slight increase for geothermal and hydro-power. In 2020 the LCOE for biomass was 0.076 USD/kWh, for geothermal energy 0.071 USD/kWh, hydro-energy 0.044 USD/ kWh. In 2020 the LCOE for solar photovoltaic decreased for 7% compared to 2019 amounting 0.057 USD/ kWh and 16% for concentrating solar power amounting 0.108 USD/kWh. Additionally, the decrease of LCOE for offshore wind amounted 9% having value of 0.084 UDS/kWh and 13% for onshore presenting 0.039 USD/kWh. When comparing the LCOE of different renewable energy sources, it can be noted that the lowest LCOE has onshore wind, followed by hydropower, solar photovoltaic and geothermal energy. Even decreased, concentrating solar power and offshore wind still have slightly higher LCOE compared to the other renewable energy types. If compared with fossil fuel powered plants, renewable energy is competitive in Europe, but not in America and India, where the operating costs for coal plants are lower compared to plants using renewable energy. According to IEA 2020, the Levelized Cost of

Storage (LCOS) of fossil fuel-fired power generation for the G20 group is estimated to be between USD 0.055/kWh and USD 0.148/kWh [24]. This comparison shows that fossil fuel power plants are still competitive with renewable energy power plants.

*Competitiveness and viability.* The energy system's competitiveness and viability are presented based on the factor EROI which calculates the ratio between the total energy output from the system and the total energy input or invested to the system in order to deliver the necessary energy.

EROI of world oil and gas throughout the years has decreased but is still relatively high with mean value of 20:1. Coal has even greater EROI compared to oil and gas with 46:1, whereas EROI of nuclear energy has the lowest value of 14:1 compared to conventional energy sources. From the renewable energy sources the highest EROI has hydro-power with mean value of 84:1 which represents the most viable energy source currently. The calculations for EROI of wind power differed from study to study and the average value that could be adopted is 10:1 which is the closest to nuclear energy, but far from oil, gas and coal. EROI of solar energy also differs and depends on the methodology calculation and has a mean value of 10:1, same as wind. Bit lower EROI has geothermal energy with 9:1. Renewable energy sources generate high quality electricity but are less predictable and reliable. Considering these values, it can be concluded that plants based on renewable energy have relatively low EROI values compared to traditional conventional fossil fuel plants, and it takes many years to get back the energy produced from these sources. Also, as mentioned before most renewable energy systems are supported by fossil fuels [25].

*Energy transition cost.* The energy transition from fossil fuel-based energy to renewable energy intends to be fast considering that the International Energy Agency (EIA) is pushing the governments to triple the use of renewable energy in order to cut greenhouse gas emissions. However, according to economists increased penetration of renewable energy in the total share would increase the energy prices. Also, in order to reduce the reliance on fossil fuels and achieve baseload and balancing electricity through renewable energy use additional spendings will need to be implemented. In order to perform the energy transition modernization and construction of infrastructure is necessary leading to money investments [26].

All data related to the topics analyzed in this section regarding carbon footprint, profitability, and competitiveness of different energy type are given in the Figure 1 below.

| Energy | Hydro | Wind | Solar | Biomass | Geothermal | Coal | Gas | Oil | Nuclear |
|---|---|---|---|---|---|---|---|---|---|
| Carbon footprint [$CO_2$/kWh] | 97g | **4g** | 6g | 98g | - | 109g | 78g | - | **4g** |
| LCOE [USD/kWh] | 0.044 | 0.039 - 0.084 | 0.057 -0.108 | 0.076 | 0.071 | - | - | - | - |
| EROI | **84:1** | 10:1 | 10:1 | - | 9:1 | 46:1 | 20:1 | 20:1 | 14:1 |

**Fig. 1.** Data regarding carbon footprint, LCOE and EROI for each energy type

## 4. CONCLUSIONS

The data researched showed that all fossil fuel-based systems have higher EROI than renewable energy plants with exception to hydropower. Meaning that coal and hydropower are most competitive energy sources having the highest EROI of all analyzed energy types. If comparing the LCOE of renewable energy sources it is noted that onshore wind, hydropower, solar photovoltaic and geothermal energy have lower LCOE than concentrating solar power and offshore wind. LCOE of renewable energy depends mainly on the capital cost of the technology. Renewable energy sources prevail the fossil fuels regarding carbon footprint, considering that solar and wind have lower carbon footprints compared to both coal and gas power plants with CCS technology [15]. Considering all energy sources, the lowest carbon footprint has nuclear energy making it the least carbon intensive energy source together with wind and solar.

The material depletion for production of renewable energy systems, as well as the production process intensiveness itself lead to the conclusion that green energy is highly dependent on fossil fuel economy. Renewable energy sources generate high quality electricity but are less predictable and reliable. The current energy needs do not always correlate with the disposability of the renewable energy. This lack of reliability requires suitable back-up or storage in order to ensure security of supply at all times.

The aim of renewable energy is finding and using clean alternative energy sources for providing the necessary energy needs for whole population equally in conjunction with the environmental standards for preserving the planet. The above described ethical inequity should not present obstacle in the development and use of renewable energy, rather it should be taken into consideration to find ways to mitigate the negative implications. These ways include construction of fishways for reducing the consequences on the river ecosystem deriving from installation of hydropower plants or building smaller hydropower plants on isolated or uninhabited locations for minimizing the affect they have on people. The noise and aesthetic pollution caused by wind turbines can be reduced by installing better sound insulation on the nearby buildings. By implementing appropriate measures renewable energy could contribute to sustainable development from which the future generations will benefit.

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