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ENERGY TRANSITION AS A SOCIO-TECHNICAL CHANGE PROCESS INDUCED BY CLIMATE CHANGE

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ABSTRACT

Greenhouse gas emissions, that cause global warming and climate change, have been increasing since mid-19th century. To address this problem, thus, in 1988, Intergovernmental Panel on Climate Change was established in order to encourage national efforts as well as international cooperation. The Paris Agreement furthermore, aimed to keep the increase of global warming below 1.5 degrees. The energy resources and uses is the main area of such emissions reductions policies, which could only be achieved through Energy Transition. The focus of the discussion in this area, however, have been heavily focused only on CO2 and consequently, policies have been developed mainly to reduce its emissions, despite the fact that there are other greenhouse gases. The same is also true in the area of electricity generation. Transitioning away from fossil fuels to renewables is seen as a panacea, "the single solution", despite its intermittency and grid connection problems. Additionally, although a fossil fuel with heavy methane content, gas is presented (so-called a bridge fuel). The aim of this paper is to draw attention to the impact of the other potent emissions, contribute to the debate in the right policy, the other sizable sectors other than electricity generation, the nature of the socio-economic factors and the neglected role of local governments and civic initiatives in developing and implementing successful energy transition. Only with such a socio-technical transition perspective and recognizing the relevance and the need of just and equitable energy and climate policies, contribution of a wider part of the economy as well as a broader participation of local communities (from bottom-up via local climate action) can be secured in mitigation of and adaptation to climate change policies globally.

Keywords: *Greenhouse gases, climate change, energy transition, renewable energy, socio-technical change, local governments.*

JEL Codes: *C58, E44, C01.*

1. INTRODUCTION

Climate change has become apparent over the last decades, mainly because the anthropogenic Greenhouse gas (GHG) emissions have increased 50 times since the mid-1800s. Accordingly, surface

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temperature has also been increasing since 1800 in a way that the annual temperature has increased at an average rate of 0.07°C per decade since 1880 and the rate was increased more than twice (+0.18°C) since 1981. Moreover, from 1900 to 1980, a new temperature record was determined nearly at every 13.5 years; whereas, it has been repeated at every 3 years since 1981 (Dahlman, 2020). The main reason of this sharp increase has been explained by the anthropogenic global warming theory which tells human activities like industry and agriculture emits a mix of gases that include methane, carbon dioxide, water, and nitrous oxide which are called Greenhouse gases (GHG). These gases absorb the sun radiation, and reemit it as heat accordingly the global surface temperature has been increasing exponentially in the last decades. The main sources are energy, transport, industry and agriculture. Electricity generation alone is contributing roughly a third of it.

It should also be noted that about 2/3 of total GHG emissions come from just 10 countries (China and US is actually making up 40% the total), while the 100 least-emitting contributed less than 3% (ClimateWatch, 2020). Therefore, this phenomena could only be taken under control with close collaboration of the countries. Accordingly, Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to provide policymakers with regular scientific assessments on the current state of knowledge about climate change and present alternative policy options when necessary. Meanwhile many conferences have been organized by IPCC and at the 21st Conference of the Parties (COP21) in December 2015, 195 nations adopted the Paris Agreement. The main aim of the agreement was declared as to strengthen the global response to the threat of climate change by "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to limit global temperature rise to 1.5°C" (IPCC, 2020).

In the light of the foregoing observations and explanations therefore, there should be no denial that GHG, outcome of anthropogenic activities, has had an adverse effect in the global surface temperature increase, thus causing global warming. It is also true that following the establishment of IPCC, the research activities as well as focus of action have been heavily focused mainly on the CO2 emissions of the electricity generation by fossil fuels, mainly coal, in an unproportional manner. As noted above as a matter of fact, and will be explained in detail in the following sections however that, there are actually more potent GHGs other than CO2 as culprits in global warming. With the same token, there are areas needing urgent decarbonization other than electricity generation. In fact, electricity generation may even seems the easiest of the ways of transition to a decarbonized economy. Therefore, fossil fuel, especially coal, phase out and switching to renewable energy resources in electricity generation has been shown as a magic tool for decreasing CO2 emissions in order to keep global temperature rise well below 2°C above the pre-industrial levels. The aim of this paper, is thus, to assign due emphasis firstly to other (than CO2) GHGs and also sectors other than electricity generation for their role in global warming so that the actions can be taken accordingly in efforts of emissions reduction. Additionally, it is aimed to demonstrate that within the context of electricity generation, only switching to renewable resources without considering the socio-technical constraints is no short-term panacea at all. In other words, there is no one single solution or no one way to energy transition. Although by switching to renewable energy resources, it would be technically possible to achieve considerable amount of emissions reductions, the advantages of it should not be overemphasized while intermittency problem is still a major challenge from technical aspect (Gielen et. al., 2019). Thus, many ways of climate-friendly solutions need to be explored and should be evaluated for a sustainable and just energy transition which would be technically possible, socially acceptable and economically viable in the long term. Other socio-economic factors thus need attention and just climate policies should be developed with involvement and genuine participation of grass roots organizations and local governments in the general sense of environmental management. Thus, the energy transition should not be seen as technological change process only with top-down imposed approaches.

In Section 2 of this paper, the global warming phenomena has briefly been described and global warming potentials of different gases have been compared with each other. In Section 3, we move on to the role of power sector first by comparatively analyzing ratio of electricity in the total energy and the GHG emissions resulting from electricity generation as well as other emission sources. In the final section, we then proceed with our evaluations and discussions to give our perspective as to how a socio-politically inclusive energy transition with an emphasis on the role of local communities (due to the distributed, dispersed and democratized nature of future energy systems). The conclusions that are drawn are included in the same section, too.

2. THE GLOBAL WARMING PHENOMENA AND UNDERSTANDING THE GLOBAL WARMING POTENTIALS OF DIFFERENT GASES

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). GHGs warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space. In simple words, GHGs act like a blanket insulating the Earth. Different GHGs can have different kind effects on the Earth's warming. Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime") (Dahlman, 2020).

The most abundant GHG in the atmosphere is water vapour. The radiative efficiency of water vapor is fifty to sixty percent greater than that of CO2 (Watkins, 2020). However, it is not generally accepted as a typical GHG because water vapor cools down and falls on the earth as water. Therefore, the lifetime of vapor is approximately accepted as two weeks, which is negligible when it is compared with the lifetime of other GHGs, which varies between 100 years for methane and up to 1000 years for CO2. Accordingly, even there is large increase in anthropogenic water vapor emissions; this would have negligible warming effects on climate. Therefore, water vapor has been generally excluded in the models because it is impossible to differentiate the anthropogenic water vapor emissions from the naturally produced water vapor. Moreover, it is not possible to estimate the water vapor amount in the atmosphere at the pre-industrial ages; consequently a comparison cannot be made for a scientifically validated study.

The Global Warming Potential (GWP) was developed to compare the global warming impacts of different gases. Specifically, it is a measure of how much energy over a given period of time, could be absorbed by one ton gas, relative to one ton of carbon dioxide (CO2). The larger GWP means more heat could be trapped by that given gas which warms the Earth over a unit period of time, which is generally accepted as 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases (IPCC, 2020).

CO2, by definition, has a GWP of one regardless of the time period used, because it is the gas being used as the reference. CO2 remains in the climate system for thousands of years. The range most often quoted for the equilibrium global mean surface temperature response to a doubling of CO2 concentrations in the atmosphere is 1.5◦C to 4.5◦C. If the Earth lies near the upper bound of this sensitivity range, then climate changes in the twenty-first century would be profound (Held and Soden, 2000).

Methane (CH4) is estimated to have a GWP of 20–30 over 100 years. Methane emitted today lasts about a decade on average, which is much less time than CO2. However, methane also absorbs much more energy than CO2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The GWP of methane also accounts for some indirect effects, such as the fact that CH4 is a precursor to ozone, and ozone is itself a GHG.

Nitrous Oxide (N2O) has a GWP 265–310 times that of CO2 for a 100-year timescale. N2O emitted today remains in the atmosphere for more than 100 years, on average.

Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydro-chlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO2. (The GWPs for these gases can be in the folds of thousands or tens of thousands.)

Table 1. Global warming potentials of major species (retrieved from UNFCCC, 2021)

Species	Chemical formula	Lifetime (years)	GWP (Time Horizon)		
			20 years	100 years	500 years
Carbon dioxide	CO2	variable	1	1	1
Methane	CH4	12±3	56	21	6.5
Nitrous oxide	N2O	120	280	310	170

In the literature, it was seen that non-CO2 GHGs, like methane and nitrous oxide, have been converted to “CO2-equivalents” (CO2-e) with respective to their global warming potentials (GWPs).

There are also other methods available which shows the cost-effectiveness, by minimizing the cost for temperature stabilization in a target year in future. In any case, the aim of such metrics is to define a standard relationship between the GHGs in order to determine the concentration changes, which would have an effect on the climate and would create socio-economic and environmental impacts and finally would result in economic damages. Despite these shortcomings, GWPs are still in use in the climate change policy studies, probably because of their relatively simple interpretation and transparent definition when compared with the alternative measures (Newbold, 2011).

3. ELECTRICITY GENERATION AND ITS RESULTING EMISSIONS

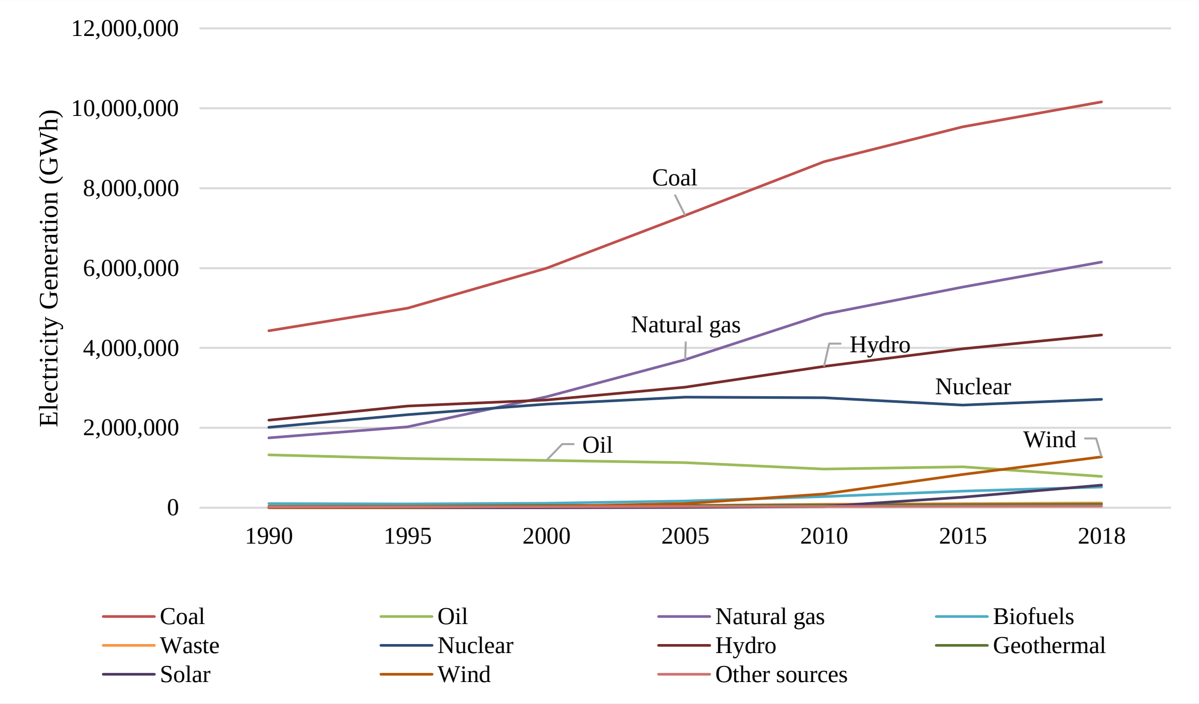
3.1. Share of Electricity in The Total Energy Consumption

In the recent years the share of energy generation by renewable resources in the total energy supply has been increased tremendously. With respect to the statistics of International Energy Agency (IEA) the worldwide total energy supply increased by 1,6 times from 1990 to 2018. In the same period the renewable energy supply from wind and solar has increased by eight times. However, the ratio of wind and solar in the total energy supply has just increased from 0,04% to 2,0% in approximately three decades starting from 1990 (IEA, 2021). In other words the most promising technologies for CO2 free energy supply, which are wind and solar, could only have supplied the 2% of the energy demand in 2018 and remaining 98% had to be supplied by fossil fuels (oil, coal and natural gas), nuclear and hydro etc.

The ratio of electricity in the total energy consumption was 19.4% in 2018. Fossil fuels with 64% share has the greatest ratio in the total electricity generation, which was 63% in 1990. Even though the share of fossil fuels has not been changed the total electricity consumption has increased by 125% therefore the electricity generation from coal and natural gas increased by 150% and 252% when 2018 figures have been compared with ones for 1990. Only electricity generation from oil decreased by 40% in the same period.

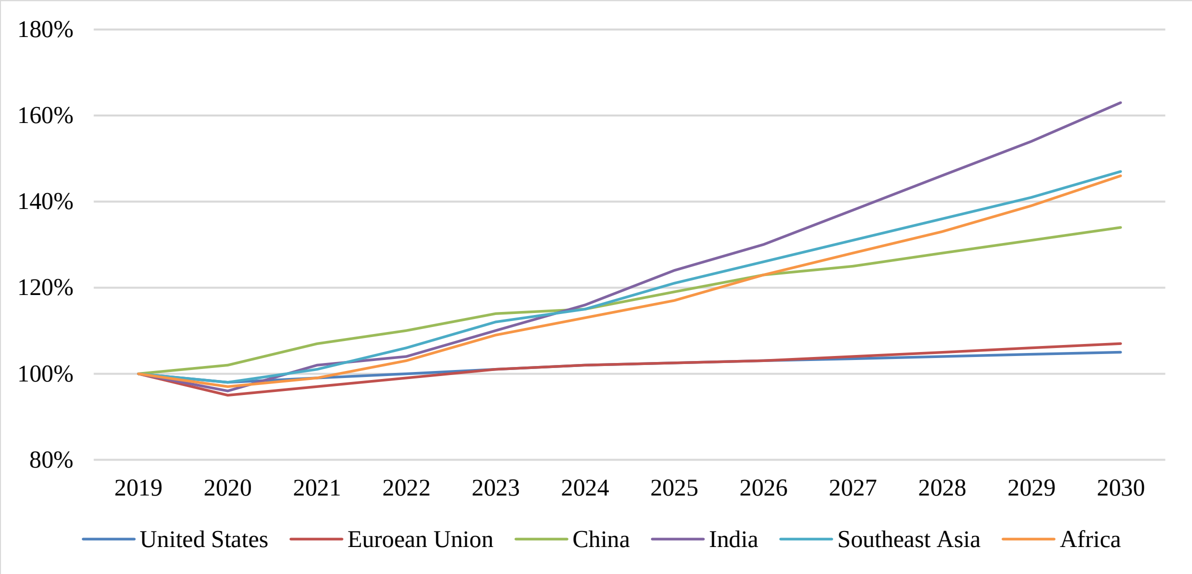
From 1990 to 2018 the ratio of wind and solar has increased from 0.04% to 6.88%, which shows the greatest increase among all other resources. However the ratio is still low and far below the demand. In summary, in 2018, the ratio of wind and solar, which have been the most promising renewable energy supply among the others, could have supplied approximately 2% of the total energy and 7% of the electricity demand.

Figure 1. Global Electricity Generation (IEA, 2020a)



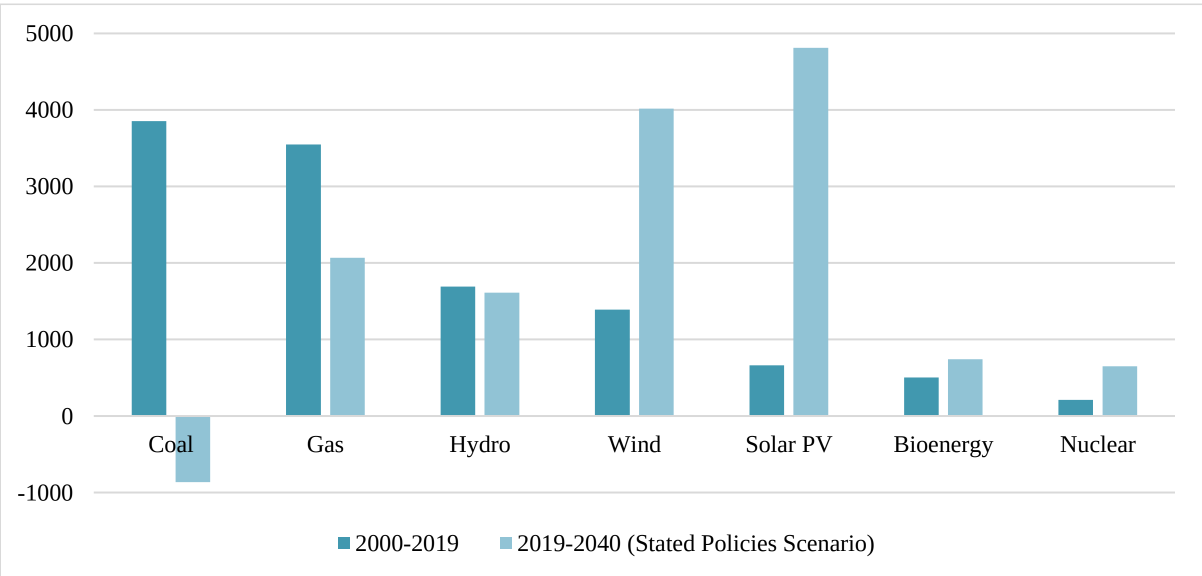
The electricity demand is going to increase with the increasing population and the additional demand are predominantly coming from the developing countries. On the other hand, technological developments increase the demand for electricity as well. For example, in the 1990s, the data centers were not big electricity consumers, however they have started to require significant amount of electricity. Similarly, the electricity demand of cryptocurrencies has been increasing tremendously. For example, with respect to the study of The University of Cambridge Centre for Alternative Finance (CCAF) in January 2021, the Bitcoin's total energy consumption was estimated somewhere between 40 and 445 annualized terawatt hours (TWh), with a central estimate of about 130 terawatt hours. This amount is as much as the consumption is nearly half UK's electricity consumption, which is is a little over 300 TWh, or similar as the consumption of Argentina or Nederland (Rowlatt, 2021). Accordingly, the electricity demand will continue to increase in US and EU countries as well; however, the increase would seemingly be moderate and mostly be compensated by efficiency improvement projects.

Figure 2. Electricity Demand Outlook in Selected Regions/countries in the Stated Policies Scenario, 2019-2030 (IEA, 2021a)



The International Energy Agency (EIA) developed the Stated Policies Scenario (STEPS), in which Covid-19 is gradually brought under control in 2021 and the global economy returns to pre-crisis level within the same year. This scenario reflects all of today's announced policy intentions and targets, insofar as they are backed up by detailed measures for their realization. On the other hand, when future electricity would continue similar as the developments between 2000 and 2019, then the increase in the electricity by solar and wind would be limited and coal and natural gas would continue to be the major electricity generation resources.

Figure 3. Change In Global Electricity Generation by Source In The Stated Policies Scenario, 2000-2040 (IEA, 2021b)



3.2. The GHG Emissions Resulting from Electricity Generation

The amount of carbon dioxide (CO2) emissions depends on the fuel type and the energy production amount. In 2017 the total amount of GHG emitted to the atmosphere was approximately 49.9 Gt and 37, 12 Gt out of this amount was CO2 and the rest was 8,63Gts of CH4 and 3.11 Gt was N2O. Energy makes up nearly three-quarters of global emissions, followed by agriculture. Breaking down the energy sector into its sub-sectors, electricity and heat generation make up the largest portion of emissions, followed by transportation and manufacturing. The CO2 emissions form the Electricity & Heat Sector only was 15.2 Gt (ClimateWatch, 2020).

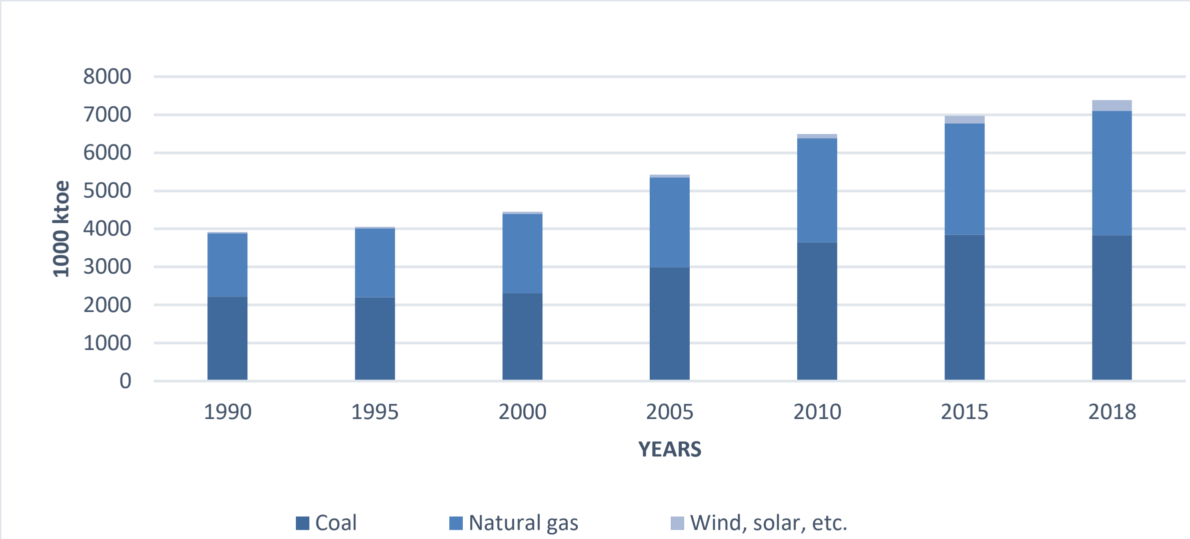
Even though the amount of CO2 has the greatest share among all the GHG, when the Global Warming Potential (GWP) are taken into consideration which is 28–36 times for Methane and 265–298 times for Nitrous Oxide (N2O) when compared with CO2 for a 100-year timescale then it could be seen that the cumulative greenhouse effect of CH4 and N2O is higher than the CO2. For example in 2017, 8,63 Gt of CH4 and 3.11 Gt of N2O were emitted to atmosphere which corresponds respectively to 241,64-310,68 and 824,15-926,78 Gt CO2 as GWP (British Petroleum, 2021). In summary the CH4 and N20 emissions in 2017, had had an approximately 20 and 80 times more global warming potential than CO2 emissions in the respective year.

3.2.1. Annual CO2 Emissions By Coal Consumption

Global coal demand has still been growing, however the share of coal in primary energy demand and in electricity generation slowly continues to decrease. Nevertheless, it remains as the largest source of electricity and the second-largest source of primary energy

In 2018, the coal consumption was declined by over 4%. This decrease was seemingly been compensated by gas while the NG consumption had increased by over 10%, despite the rise in gas prices in 2018 when compared with 2017. The gas demand was grown first time, since from the beginning of the shale gas revolution, at the expense of coal while the gas prices had been increased. (International Energy Agency (IEA), 2019) Consequently, in 2018, 4% less coal consumption must not had decreased the overall CO2 emissions because it was seemingly compensated by over 10% rise in NG consumption.

Figure 4. Total Energy Supply by Sources (IEA, 2021c)



Switching to NG from coal might even have increased the GHGs emissions, because the average CO2 emission for generating one million BTU energy by natural gas is 53 kgs while for coal it is in average around 100kgs (U.S. Energy Information Administration, 2016). Moreover, there is considerable methane emissions during NG production, which is more harmful than CO2. For example, with respect estimates of 2015, supply chain emissions of U.S. gas production was approximately equivalent to 2.3% of gross U.S. gas production. Methane emissions of this magnitude, per unit of natural gas consumed, produce radiative forcing over a 20-year time horizon comparable to the CO2 from natural gas combustion (Alvarez, et. all, 2018). Therefore switching to NG instead of coal, would not make considerable contribution to decrease the greenhouse gas emissions.

3.2.2. Natural Gas

The concentration of methane in the atmosphere is currently around two-and-half times greater than pre-industrial levels and is increasing steadily (IEA, 220b). Worldwide Natural Gas (NG) consumption grew by an estimated 4.6% in 2018, or 170 bcm, which has been the strongest increase since 2010 when gas demand was rebounding from the 2008 global financial crisis. Such historic demand growth was mainly driven by power generation and buildings. The ongoing switch from coal to gas in power generation also contributed strongly to the growth, adding 18 bcm to gas demand. The share of gas in power generation hit an all-time record of 34% (IEA, 2019). This steady increase would have considerable implications for the climate change as well.

The CO2 emissions by NG is approximately half of the coal. However, during production, transportation and processing of NG there is inevitable methane emissions. As an example, in January 2020, satellites spotted three different oil and gas facilities in Algeria, which have been emitting more than 25 tonnes of methane per hour that is roughly equivalent to the CO2 emissions from a 750-megawatt coal power plant (IEA, 2020c). The Intergovernmental Panel on Climate Change (IPCC) has indicated a GWP for methane between 84-87 when considering its impact over a 20-year timeframe (GWP20) and between 28-36 when considering its impact over a 100-year timeframe (GWP100) (IEA, 2020c). This means Methane has 28 to 36 times more potent in GWP than CO2 over 100 years. Therefore, the total GHGs emissions, including the methane emissions during the production, processing and transportation of NG, should be considered before switching to NG from coal in the context of reducing GHG emissions in order to limit the global warming.

3.2.3. The Underestimated Environmental Effects of Electricity Generation by Renewable Resources

There are different renewable resources, which have been used to generate electricity for decades. In general, these resources have been accepted as environmentally friendly resources when compared with fossil fuels. However the amount of electricity generated with these resources are still far below the demand, albeit incentives have been given to support these resources. For example, the ratio of wind and solar, which have the greatest share among the renewable resources, increased to 6.88% in 2018 from 0.04% in 1990. Nevertheless, the ratio is still low and far below the demand.

On the other hand, there are considerable environmental risks of renewable resources. For example, geothermal sources make surface pollution and emits non-condensable gases' (NCG) such as CO2, H2S, NH3, N2, H2, and CH4 to atmosphere. The vast majority of the NCG (95–99%) is CO2. Even though there is an important amount of CO2 have been emitted from the geothermal energy generation facilities, the CO2 from geothermal energy hasn't been registered as an anthropogenic based greenhouse gas yet. Because it is accepted as naturally diffusing CO2 to the atmosphere from the geothermal sites, and geothermal power plants have no additional contribution (Aksoy et. al, 2015). However, in any case geothermal resources increase the GHGs that would have stayed in liquid form in the caverns underneath the Earth, unless electricity is generated by the geothermal steam. Therefore, it is naïve to think that geothermal energy is completely free of GHGs emissions, environmentally friendly and sustainable renewable energy.

Solar and wind, the most promising renewable resources, have had major problems such as they are variable and intermittent; they are still expensive and the energy density is low. Solar and wind energy generation would inevitably require three fold back-up energy sources, such as fossil fueled generation in order continue supply electricity to the grid when there is no sun and wind. As an example, in August 2020, there was power shortages in California. Beforehand, California's goal is to procure 60% of its electricity from renewable resources by 2030, and source 100% clean energy by 2045. Accordingly, there is currently only one coal-fired power plant in California and 63-MW cogen plant, which accounts for less than 0.1% of the state's energy supply. In addition there is only one operating commercial nuclear, which generates about 10% of the state's electricity (Larson, 2020). However, the extreme heat storm across California had increased the demand for electricity much above the resource planning targets. Therefore sufficient reliable electricity generation facilities should be kept in operation during transitioning to renewable energy resources, in order to cope with sudden increases in electricity demand.

Moreover in the EIA's "levelised cost of energy" (LCOE), which is a measure of the average net present cost of electricity generation for a generating plant over its lifetime, electricity from a wind turbine or solar array is calculated as 36% and 46%, respectively, more expensive than from a natural-gas turbine (U.S. Energy Information Administration, February 2020). Moreover, the LCOE calculations do not take into account the potential costs which might occur to operate the grid 7/24 throughout the year by only wind and solar energy. Therefore, the International Energy Agency (IEA) developed "value-adjusted" LCOE, or VALCOE, in order to include the necessity of flexibility and the economic implications of availability. IEA calculations using a VALCOE method yielded coal power, for example, far cheaper than solar, with a cost penalty widening as a grid's share of solar generation rises (Hughes, 2012).

Battery has been shown as a magic tool to solve the intermittency problem of solar and wind. However, the cost of energy storage by battery is approximately 200 times more expensive than storing oil or natural gas for a couple of months and storing coal is even much cheaper (Mills, 2019). Moreover increasing the battery production, will drastically increase the energy consumption necessary for the battery manufacturing process itself. On the other hand, today's most advanced battery technology can only store 2.5 per cent of the energy that coal can store (Schernikau, 2020). Therefore, the size of the batteries should be huge enough to have the same energy storage capacity as like coal. Meanwhile, 50 to 100 times more materials, including lithium, copper, nickel, graphite, rare earths, and cobalt etc., are required to manufacture one kilogram of battery produced (Mills, 2019). In the near future, recycling the residues of solar/wind energy generation equipment, (including their electronic devices) and recycling enormous amount of batteries would be necessary. Therefore these kind of potentially adverse environmental consequences of solar and wind energy should be evaluated before switching too early to renewable energy only because of CO2 emissions of coal.

The solar and wind power have been in use since years but in the last two decade, the installed capacity has been increased from 0.04% in 1990 to 6.88% in 2018, mainly because of the reduction in the costs and the incentives given by the governments. However, the 10-folds of cost reduction, because of efficiency improvements of the equipment has been slowly but surely coming to the end. Moreover the most efficient locations for solar and wind have already been utilized. Therefore, the new locations may not be feasible, while the marginal cost of renewable energy always increases with the more installed capacity beyond a certain point (Schernikau, 2020) as exemplified in California in recent years.

4. DISCUSSION AND CONCLUSIONS

According to the U.S. Energy Information Administration's (EIA) International Energy Statistics, Global electricity consumption continues to increase faster than world population, leading to an increase in the average amount of electricity consumed per person (US Energy Information Administration, 2020). Therefore the electrification would continue to increase in the coming decades, especially in the developing countries. The supply of energy from renewable sources would not be enough to supply the increasing demand, at least until the intermittency problems of the renewable resources, which could only be solved by battery solutions or similar technologies in future. Moreover, the (un)measurable cost and effects of renewable energy to the environment would have to be taken into consideration during the transition from fossil fuels to renewable energy resources in electricity generation.

Even within the energy sector – which accounts for almost three-quarters of emissions – there is no simple solution. Even if we could fully decarbonize our electricity supply, we would also need to electrify all of our heating and road transport systems. In addition, there would still be emissions from shipping and aviation in which there are still no low-carbon technologies had been developed for them (Ritchie and Roser, 2020).

In the context of electricity generation, there are different priorities like, affordability, energy access and security, air quality, climate change impact, continuity of supply (managing intermittency), how to balance the grid and diversity of use, at different countries and regions of the world (Romsom & McPhail, 2020). Therefore, single solution fits all would not work and Socio-Technical transition in electricity generation is necessary to design the future energy systems by considering physical, societal and economic constraints. There is an increasing demand for energy especially in the developing countries. However, all of the countries should be treated in a fair way, when they are compared with each other, with respect to GHG emissions and electricity generation by renewable resources. Because so far 64% of GHG emissions come only from 10 countries, while the 100 least-emitting contributed less than 3% (ClimateWatch, 2020). Therefore, the least emitting and developing countries should be allowed to consume fossil fuels, in other words, "their fair share" in an environmentally friendly way, until they would be able to switch to renewable resources, by developing their physical infrastructure in an economic way.

In the meantime, until this socio-technical as well as just and fair energy transition is fully underway, additional efforts and measures are necessary to improve the thermal efficiency and reduce the emissions of coal-fired power plants. Among the alternatives, Carbon capture and utilization (CCU) has been accepted and recommended by IEA as a promising technology to reduce the CO2 emissions. The CCU technologies not only reduce the CO2 emissions but could also decrease mitigation costs and produce by-products like bio-oils, chemicals, fertilizers etc., which do create extra jobs, and economic benefits as well (Styring et al., 2011). Another promising technology is decreasing coal consumption by co-firing, Ammonia—a compound of nitrogen and hydrogen—in thermal power generation. In Japan, it was demonstrated that 20% ammonia could have been consumed at a coal-ammonia burner, which had been retrofitted to an existing coal plant and reduced the carbon emissions by 20%. Moreover, by co-firing ammonia, NOX emissions could be reduced significantly, and the capacity of the power plant did not change substantially (Patel, 2020). These kind of new developments at coal-fired power plants would reduce overall demand for coal as well.

The increase in electricity demand would not only come from developing countries but also from new inventions and new usage areas. For a just and comprehensive energy transition, not only power generation but also the transportation, industry (especially heavy one), residential heating need to be electrified. The expected demand in these areas is forecasted to continually increase the need of electricity supply. For example, every \$1 billion invested in the aircrafts leads to some \$5 billion in aviation fuel consumed over two decades to operate them. Similarly, every \$1 billion in data centers built will consume \$7 billion in electricity over the same period (Mills, 2019) . In 2018, the cooling sector consumes 17 per cent of the world's electricity and produces 10 per cent of its CO2 emissions. The demand for cooling would expected to increase significantly as well (Romsom & McPhail, 2020). Thus, it is indeed not only power generation emissions that we need to address but also in other sectors of the general economy (especially oil usage in transport and gas usage in heating and industry) as well. Even in the power sector, as explained above, coal and CO2 is not the only culprits, as one should also consider the climate effects of (as the European Union calls it rightly "unnatural") gas. Furthermore, as it was diligently threaded in Germany, the livelihoods and future restructuring of needs of coal regions should be taken care of by governmental policies and they should be protected against the upheavals of socio-economic impact of rapid changes in energy systems and transformations.

On the other hand, a just, equitable and feasible energy transition should also be socio-politically inclusive and respective of local democracy and grass-roots organizations in order to secure public acceptance. Thus, it is only through local energy democracy with the genuine involvement of local governmental bodies and citizen associations that new energy system of ours can take hold and flourish, mainly because the new energy system (which supposed to be brought about by the current energy transition) would primarily be based on a "three D system: distributed, digitalized and decarbonized" energy. For such a system to sustain in tomorrow's billions of number of "prosumers" (the citizen as the producer and the consumer of energy" society and economy, energy democracy is must at the local level as well as all other levels of decision-making politically. In other words, flexibility and participation would be key new futures and factors of the energy system. Accordingly, the market will be more volatile and customers would not only be consumers but at the same, they would supply electricity to the distributed local grids as well. Therefore, a holistic approach is required for a successful and just energy transition by taking the needs and priorities of all stakeholders and sections of the society (the "local prosumers" as producers as well as consumers, other customers and also generators and network companies, policy-making bodies at all levels) into consideration. It should be borne in mind that energy transitions do not involve only technical changes and technological revolutions but largely encompass socio-economic changes and transformations too. Thus, such movements need to be orderly organized or at least managed through the processes.

Another important note to the point at hand is that climate change mitigation and adaptation policies could be implemented effectively at the local level. That is, it is only when local governments and civic formations of voluntary citizen organizations adopt and own the climate policies or actively participate in decision-making in this area that one expect a successful end-result on the ground. Local climate action therefore is a key to truly tackle climate change problem.

In sum, as documented above, there is no single or simple solution to tackle climate change. Because emissions come from many sectors and individual solutions has to be developed for each of them in order to decarbonize the economy. Therefore focusing only on electricity, or transport, or food, or deforestation alone would be insufficient. Not only decarbonization but also a decentralized and distributed energy system supported by a grassroots energy democracy is also essential to both a fair transition as well as just climate policies. This implies socio-political approaches and measures in addition to technical and infrastructural changes. Therefore, any roadmap through a safe and sound energy transition aiming to ensure climate sensitive and resilient structure should include;

- Understanding energy sources are consumed to generate electricity, as well as for transport (including shipping, aviation) and heating, thus requires a holistic approach. Without this consideration, any attempt will fall short to become a solution.
- Although energy transition for any scale (individuals to companies or settlements through countries) and location objects to very similar outcomes, roadmap substantially needs to be differentiated, related to past and current state of the entities, including contribution to global GHG emissions.
- Energy efficiency should be a key element in each and every action plan, directly relating with social aspects.
- Technology development in energy utilization, efficiency, generation and storage is indispensable for a rapid transition, which should receive targeted subsidy.
- Localization of energy serves for climate-friendly structure, as well as energy democracy. Local governments have an exceptional potential to be substantial part of the solution.
- Energy transition is an urgent problem with wide and long lasting consequences and far reached action plan. Thus, solidifying public participation, implementing local governments and social bodies into the solution set is crucial.

It is by now an undisputed requirement for the future of humanity that reducing the anthropogenic GHGs emissions to keep the global temperature well below 2°C above pre-industrial levels and to limit global temperature rise to 1.5°C as per the IPCC target. Unfortunately, however, there is not a simple and “one size fits all” solution or one single approach to achieve that goal. Quite the contrary all walks of life (in addition to technical experts, innovators, central decision-makers and politicians, as the case so far) should involve in and contribute to an array of solutions in an unbiased way. Otherwise, there is a danger that, by energy transition it will be understood that there will only be a global "coal phase-out" and a rapid and unprepared switch to renewables at any price. Instead, however, a holistic approach needs to be developed to make socio-technical energy transition (including of course but not only electricity generation) in order to design the future energy systems, and thereby upon which our socio-economical and political structures built) by taking physical, societal and economic constraints and necessities of each locality, region and country and ultimately of course the world itself into account.

REFERENCES

Aksoy, N., Gok, O. S., Mutlu, H., & Kılınc, G. (19-25 April 2015). CO2 Emission from Geothermal Power Plants in Turkey. Proceedings World Geothermal Congress 2015. Melbourne, Australia.

Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., ... & Hamburg, S. P. (2018). Assessment of methane emissions from the US oil and gas supply chain. Science, 361(6398), 186-188.

British Petroleum (2021). Statistical Review of World Energy. https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

ClimateWatch (2020). Retrieved from: https://www.climatewatchdata.org/embed/ghg-emissions%3FbreakBy%3Dgas%26chartType%3Darea%26end_year%3D2017%26gases%3Dall-ghg%26sectors%3Delectricity-heat%26source%3DCAIT%26start_year%3D1990

Dahlman, R. L. (2020, August 14). Climate Change: Global Temperature. Retrieved from Climate.gov: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., & Wagner, N. (2019). The role of renewable energy in the global energy transformation. Energy Strategy Reviews, 38-50.

Held , I. M. and Soden, B. J. (2000). Water Vapour Feedback and Global Warming. Annu. Rev. Energy Environ., 25:441–75.

Hughes, G. (2012). The Performance of Wind Farms in the United Kingdom and Denmark. London: Renewable Energy Foundation.

IEA (2019). Global Energy & CO2 Status Report 2019. Paris: International Energy Agency (IEA). https://www.iea.org/reports/global-energy-co2-status-report-2019

IEA (2020a). Electricity Information 2020. https://www.iea.org/subscribe-to-data-services/electricity-statistics

IEA (2020b). Global methane emissions from oil and gas. IEA, Paris. https://www.iea.org/articles/global-methane-emissions-from-oil-and-gas

IEA (2020c). Methane Tracker 2020. IEA, Paris. https://www.iea.org/reports/methane-tracker-2020

IEA (2021a). Electricity demand outlook in selected regions/countries in the Stated Policies Scenario, 2019-2030, IEA, Paris. https://www.iea.org/data-and-statistics/charts/electricity-demand-outlook-in-selected-regions-countries-in-the-stated-policies-scenario-2019-2030

IEA (2021b). Change in global electricity generation by source in the Stated Policies Scenario, 2000-2040, IEA, Paris. https://www.iea.org/data-and-statistics/charts/change-in-global-electricity-generation-by-source-in-the-stated-policies-scenario-2000-2040

IEA (2021c). World Energy Balances 2020. https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics

IEA. (2021). IEA World Energy Balances 2020. https://www.iea.org/subscribe-to-data-services/world-energy-balances-and-statistics)

IPCC. (2020). Frequently Asked Questions. Retrieved from IPCC Special Report on Global Warming of 1.5°C: https://www.ipcc.ch/site/assets/uploads/sites/2/2018/12/SR15_FAQ_Low_Res.pdf

Larson, A. (2020, November 2). Understanding California’s Rolling Blackout Problem. Power Magazine. https://www.powermag.com/understanding-californias-rolling-blackout-problem/

Mills, M. P. (2019). The “New Energy Economy”: An Exercise in Magical Thinking. Manhattan: Manhattan Institute.

Newbold, A. L. (2011). Estimating the Social Cost of Non-CO2 GHG Emissions:. Washington, DC : U.S. Environmental Protection Agency.

Patel, S. (2020, November 02). JERA Planning to Shift Coal Power Fleet to 100% Ammonia. POWER Digest. https://www.powermag.com/jera-planning-to-shift-coal-power-fleet-to-100-ammonia/

Ritchie, H., & Roser, M. (2020). Our World in Data, Emmissions by Sector. https://ourworldindata.org/emissions-by-sector#direct-industrial-processes-5-2

Romsom, E. and McPhail, K. (2020). The energy transition in Asia Country priorities, fuel types, and energy decisions. WIDER Working Paper 2020/48, 1-49.

Rowlatt, J. (2021, March 01). How Bitcoin's vast energy use could burst its bubble. Retrieved from BBC NEWS: https://www.bbc.com/news/science-environment-56215787

Schernikau, L. (2020). The Truth Behind Renewable Energy. International Cement Review, 1-5.

Styring, P., Jansen, D., de Coninck, H., Reith, H., & Armstrong, K. (2011). Carbon Capture and Utilisation in the green economy Using CO2 to manufacture fuel, chemicals and materials. The Centre for Low Carbon Futures 2011 and CO2Chem Publishing 2012.

U.S. Energy Information Administration (2016 , February 2). Carbon Dioxide Emissions Coefficients. https://www.eia.gov/environment/emissions/co2_vol_mass.php

UNFCCC (2021). Retrieved from Global Warming Potentials (IPCC Second Assessment Report): https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials

Watkins, T. (2020, 11 26). Retrieved from Saturation, Nonlinearity and Overlap: https://www.sjsu.edu/faculty/watkins/radiativeff2.htm#:~:text=A%20diligent%20search%20of%20sources,on%20the%20climate%20see%20Water

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