Can a global transition from fossil fuels to renewable energy provide enough energy to meet future demand? Would this be economically viable?

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The renewable energy debate is one of the most pressing topics facing policymakers in the 21st century. The risks and costs of inaction in making meaningful changes to mitigate climate change are quickly mounting. Fossil fuel consumption emits vast amounts of greenhouse gases (GHGs) into the atmosphere which are damaging our environment and are now at their highest levels in millennia (Blunden et al., 2018). In recent years, significant progress has been made by global policymakers towards creating strong, sustainable and balanced growth that will benefit the environment and future generations, exemplified by the landmark international agreements of the Sustainable Development Goals and the Paris Agreement. At the centre of both of these agreements is a global shift from fossil fuels to renewable energy in order to meet global energy consumption demands. In this report, I aim to show that a global switch from fossil fuels to renewable energy to meet global energy demand is both technically and economically feasible but that the transition to renewables requires high levels of investment and the backing of policymakers worldwide if it is to be successful. I will support my argument with analysis and findings from leading scientists, economists and policymakers in the research spheres of climate change, economic development, energy and more.

To begin with, I feel it is necessary to highlight why the risks of climate change have come to the forefront of global discourse and hence why renewable energy is being touted as a key policy in mitigating its effects. The combustion of fossil fuels is the major anthropogenic contributor to climate change as it releases dangerous GHGs into the atmosphere which lead to increased atmospheric heat retention and a subsequent rise in surface temperatures across the globe (USGS, 2019). This is a dangerous phenomenon as global warming is predicted to cause detrimental long-term effects to the planet such as rising sea levels, heat waves and desert expansion which will threaten the well-being of future generations. This is coupled with the growing concern over how a changing climate will affect economic development and inequality as climate change is predicted to impact the poorest and most vulnerable, with the World Bank (2018) estimating that there could be over 140 million climate change migrants by 2050 if we continue with our current growth trajectory and consumption habits. Furthermore, the effects of climate change are beginning to be felt today as frequent and intense weather events are becoming more common, causing thousands of deaths and US$320bn in global losses in 2017 (Low, 2018).

The 2016 Paris Agreement, signed by 195 nations, sets out to limit the increase in the global average temperature to well below 2°C above pre-industrial levels, acknowledging that this would heavily reduce the risks and impacts of climate change (United Nations, 2016). Fossil fuel divestment and an increase in renewable energy's market share were underlined as key strategies in achieving this goal (United Nations, 2016). This was further outlined in the 2019 UN Climate Action Summit where sixty-five countries and the EU pledged to cut GHG emissions to zero by the year 2050 (Global Climate Action, 2019). As of 2010, fossil fuels are responsible for over 70% of GHG emissions primarily through carbon dioxide and nitrous oxide (REN21, 2010) but despite all the warnings of their negative impacts on the climate, they still amount to over 80% of the world's primary energy sources (BP, 2018). A global switch to renewables is seen as such an essential solution in combatting climate change as renewable energy technology is able to harness natural resources such as the sun, wind and ocean to provide energy in electricity generation, air and water heating/cooling, transportation and off-grid energy services (REN21, 2010) whilst emitting little to no GHGs. However, the question many are debating is whether a switch to low-carbon renewable energy would not only be able to meet current energy needs but also those of the estimated global population of 10 billion by 2050, with estimates pointing to a tripling or quadrupling of energy demand globally (UNDESA, 2018).

A plethora of academics, policymakers and organisations have shown their belief that renewable energy will be able to support the world's energy demand, with the IPCC stating that renewable energy could meet the majority of global energy supply by 2050 if supported by efficient and effective policies (Abatzoglou et al., 2014). Delucchi and Jacobson (2010) report that there are several ways to design and operate renewable energy systems so that they will reliably support global electricity demand. These include interconnecting geographically dispersed, naturally variable energy systems such as wind, tidal, wave and sonar in order to smooth out electricity supply whilst employing complementary non-variable energy sources such as hydroelectric power to fill the temporary gaps between demand in wind and solar generation. They also suggest storing electric power at the generation sites in batteries, hydrogen gas and molten salts for later use. As renewable energy is naturally replenished, it increases energy security for the poor and reduces volatility in the energy market because countries don't have to rely on importing fuels for fossil fuel or nuclear power stations which are often affected by unpredictable global fuel markets (Sovacool, 2010). Furthermore, power generation reliability is improved as renewable energy decentralises electricity supply by producing power close to the energy consumer over a vast array of different locations and terrains. Subsequently, a power outage affects a smaller amount of capacity than an outage at a larger power station improving energy efficiency (Sovacool, 2010).

It has already been shown in a number of countries that renewable energy is able to supply a large portion of electricity capacity with renewables estimated to provide more than 26% of global electricity generation by the end of 2018 (REN21, 2019). The Nordic countries have shown the potential of renewable energy with 98% of Norway's energy production coming from renewables whilst more than 50% of Denmark and Sweden's energy come from renewable sources as of 2019 (Graham, 2019). Whilst these countries have relied heavily on hydropower in providing the bulk of their renewable energy, nations such as Scotland and Spain have showcased the effectiveness of alternative energy sources such as wind and solar power. Scotland achieved its target of generating 50% of its electricity from renewable energy by 2015 (Scottish Renewables, 2019) with the vast majority coming from wind power, whereas the Extremadura region of Spain generated 25% of its electricity from solar whilst the whole country met 16% of its energy demand from wind in 2011 (Lovins, 2011).

However, despite the progress and promise renewable energy technology has shown, there are still doubts over whether switching from fossil fuels to renewables is feasible. One of the biggest criticisms of renewable electricity production, from sources such as wind power and solar power, is its variability and intermittency. Variability inherently affects solar energy as electricity production from solar sources depends on the amount of light energy in a given location which varies depending on the day, season, cloud cover and latitude on the globe. Similarly, wind power suffers from variability issues as the amount of electricity produced depends on wind speeds, air density, and wind turbine characteristics. If wind speeds are too low the turbines won't be able to make electricity and if they're too high the turbines will have to be shut down to avoid damage. As a result, capacity factors for photovoltaic solar and wind plants are relatively poor, varying between 10-20% and 20-35% respectively, meaning that more total capacity has to be installed to achieve an average output for the year (Energy Numbers, 2019).

Other cons include the physical obstacles facing renewables such as the Betz limit which restricts a wind turbine from capturing more than 59.3% of the kinetic energy in wind (Donev et al., 2018). Also, there is an issue of space as renewable energy makes a far greater demand of land use than fossil fuels, with solar panels and wind turbines requiring around 2.5 acres and 50 acres of land respectively per megawatt of power output (Gauthier, 2018). Furthermore, there are social and ethical issues that may arise in the expansion of green energy as the development of renewable energy plants can lead to the dislocation and disruption of people and ecosystems as well as the exploitation of vulnerable people in extracting material resources such as cobalt which is used to construct wind turbines as has been seen in the DR Congo (Gauthier, 2018).

Nonetheless, many academics and policymakers believe that these concerns over renewable energy technology are over exaggerated. The International Energy Agency state that there has been too much attention on the issue regarding the variability of renewable electricity production, as this problem only applies to a select number of renewable energy technologies and that energy storage systems will be able to help solve intermittency issues (IEA, 2007). This is further supported by physicist Amory Lovins (Hamilton, 2006) who says, “The variability of sun, wind and so on, turns out to be a non-problem if you do several sensible things. One is to diversify your renewables by technology, so that weather conditions bad for one kind are good for another. Second, you diversify by site so they're not all subject to the same weather patterns at the same time because they're in the same place.”

It appears that in theory there is little evidence to suggest that a switch from fossil fuels to renewable energy couldn’t support global energy demand from a technical standpoint. In 2011, the Intergovernmental Panel on Climate Change said that “there are few, if any, fundamental technological limits to integrating a portfolio of renewable energy technologies to meet a majority share of total energy demand” (IPCC, 2011). However, it is blatantly clear that this energy transition is taking place too slowly if we are going to reach the zero-emissions target by 2050. A successful energy transition can be defined as a 100% substitution of fossil fuels by renewable energy by 2050 which would allow us to stop generating the GHGs that are accelerating climate change. For this transition to succeed, renewable energy production would have to increase a gigantic amount by a factor 60 to make up for the shortfall in fossil fuel powered energy and the predicted doubling in the demand for energy over the next 32 years (Gauthier, 2018). Ken Caldeira, a senior scientist at the Carnegie Institution, calculated that the world would need to add about a nuclear power plant’s worth of carbon-free energy capacity (1100 MW) every day between 2000 and 2050 to make this transition and avoid catastrophic climate change. At our current rate of green energy adoption this transition would take almost four centuries (Temple, 2018).

It is likely that other forms of mitigation strategy will be needed to help us keep to the 2°C Paris Agreement target such as individuals making behavioural changes like switching to less meat-heavy diets and adopting more sustainable mobility options to reduce their GHG footprint (Dubois et al., 2019). Furthermore, nuclear power could play an important role in easing the transition away from fossil fuels by reducing the burden on renewables to take up such a massive share of energy demand in a short space of time although there are concerns about its costs, proliferation, safety, and waste disposal (The New Climate Economy, 2018). Geoengineering, the deliberate engineering of the earth's climate system, is also touted as a potential strategy in combatting climate change through solar radiation management and carbon dioxide removal but these methods also face heavy opposition due to being costly, technologically difficult and having unknown safety and environmental consequences (Abatzoglou et al., 2014). Nonetheless, the main barrier to the widespread implementation of large-scale renewable energy and low-carbon energy strategies seem to be political rather than technological. This is particularly true in fossil fuel-reliant nations like the USA where existing organisations and conservative political groups are disposed to keep renewable energy proposals out of the agenda at many levels (Lund, 2010). Key roadblocks to the renewable energy transition appear to be lobbying by fossil fuel companies, political inaction and Gidden's Paradox with many people still denying that climate change exists or refusing to engage in climate change mitigation due to the intangible nature of the dangers posed by global warming (Giddens, 2009).

It is understandable that policy makers may be opposed to an energy transition to renewables given the massive levels of investment that would be required and the current importance of the fossil fuel industry to the global economy, but a lot of research suggests that this transition would likely lead us into a new economic era defined by growth, innovation, sustainability and productivity. This is exemplified by 'The Risky Business' think-tank, led by Michael Bloomberg, former U.S. Secretary of the Treasury Hank Paulson and Tom Steyer, modelling that a transition to renewable energy will cost the USA around US$320 billion a year from 2020 to 2050 but create savings starting at around $65 billion a year in the 2020s, increasing to over $700 billion a year in the 2040s (Risky Business Project, 2016). In addition, a 2018 report released by the Global Commission on the Economy and Climate estimates that making the transition could unlock benefits worth $26 trillion from here to 2030 in the global economy compared to continuing with current fossil fuel consumption patterns (The New Climate Economy, 2018). This suggests that we should see renewable energy not just as an expensive solution to a wicked problem, but as a vast economic opportunity to adopt more efficient, clean technologies that will help reduce GHG emissions whilst promoting economic growth and improving our lives. However, these figures should be taken with some caution as they are derived from economic models and due to their inherent nature, they may contain inaccuracies and thus shouldn't be taken at face value.

Possibly the biggest economic reason in favour of transitioning from fossil fuels to renewable energy is the fact that studies have shown that if we don't reduce our GHG emissions and global temperatures continue to rise, this will spark natural disasters such as droughts, floods and storms which will create financial chaos. With the use of climate change models, Nobel Prize-winning economist William Nordhaus (1993) predicts that the side-effects of climate change caused by mankind "playing dice with the natural environment" will damage sectors of the economy that depend heavily on unmanaged ecosystems such as agriculture, forestry, outdoor recreation and coastal activities. This is further supported in a study by Citi Group which found that a 4°C increase in global temperatures by 2100 (the path we are on now) would shave US$72 trillion off world GDP (Tsitsiragos, 2016) whilst a report in the journal Nature found it could reduce average global incomes by nearly a quarter (Sterner, 2015). This would heavily reduce aggregate demand and supply in the global economy and almost certainly trigger a global recession.

In addition, it can be argued that the current fossil fuel-led energy industry we see today is allocatively inefficient and suffers from market failure as currently 1 billion people live without access to electricity and even in developed economies, around 200 million people suffer from energy poverty (Sustainable Energy for All, 2017). Local renewable energy power generation would greatly increase energy security since it reduces dependence on fossil fuel imports characterised by volatile prices, currency exchange and geopolitical risks, saving G20 countries that are currently net importers of fossil fuels US$1.95 trillion per year in energy import bills by 2050 (IEA and IRENA, 2017). Furthermore, it would reduce negative externalities from fossil fuel combustion such as air pollution which are responsible for 4.2 million deaths per year (IPCC, 2014).

Nevertheless, the energy transition would have to be handled carefully as the phasing out of fossil fuels would create significant job losses with the United States alone employing 151,000 people in fossil fuel power generation and an additional 887,000 in extraction (USDOE, 2017). Furthermore, some forms of renewable energy are characterised by high upfront costs with wind and solar generally requiring a higher cost of capital than other infrastructure projects (The New Climate Economy, 2018). Due to the limited track record of investments in the green energy sector, investors are less prone to commit funds to these projects and this is further accentuated in developing countries where capital is scarcer (The New Climate Economy, 2018). Models have estimated that phasing out fossil fuels over the next

50 years will require capital investment of around US$3 trillion per year (Floyd, 2016) whilst the IEA forecasted global investment for energy in 2035 to be $2 trillion per year implying that total spending on energy will have to increase relative to the share of world expenditure in order to facilitate this transition which could reduce scope for other expenditure and potentially put a strain on countries' budgets (James and Floyd, 2016).

However, the more renewable energy technology has developed, the cheaper and more economically viable it has become with the cost of solar and wind plummeting, down by 86% and 67% between 2009 and 2017, respectively (The New Climate Economy, 2018). Despite their high upfront costs, renewable energy plants tend to have low operating costs making them very competitive relative to their fossil fuel counterparts with wind power generally costing US$0.06 per kWh to produce whilst the cost for fossil fuels typically falls in a range of $0.05 to $0.17 per kWh (Dudley, 2018). An additional strategy could be to employ carbon pricing to help ease the burden of these high upfront costs and accelerate the energy transition by discouraging fossil fuel use and raising government revenue that could then be used to subsidise renewable technologies (The New Climate Economy, 2018). Furthermore, although jobs will be lost in the fossil fuel industry from the transition, it is expected that this will be offset by a rise in employment in the renewables and construction industries with the New Climate Economy report (2018) estimating that the transition will lead to a net global employment gain of 37 million jobs.

Further economic incentives to begin the energy transition sooner rather than later is the growing concerns of an impending carbon bubble which is believed to hit the fossil fuel industry in the coming decades. A recent study predicts that global demand for fossil fuels is going to plummet in the near future as more nations opt for alternative energy sources, causing a huge carbon bubble up to 16 times bigger than the bubble that caused the 2008 financial crisis with an estimated loss of between US$1-4 trillion in stranded fossil fuel assets (Mercure et al., 2018). Researchers warn that major oil exporters such as the USA, Russia and Canada must stop propping up their fossil fuel industries and begin embracing green alternatives to avoid experiencing severe financial losses in the future. The carbon bubble and continued slow expansion of renewable technologies by these nations would result in a decrease in the total energy available by 2050. This would lead to degrowth in which industrial production and global consumption fall and as a result GDP and living standards in developed countries would decrease to a more moderate level, with a 50% reduction in energy consumption believed to bring us back to a standard of living equivalent to 1977 (Gauthier, 2018).

Despite the obstacles facing the transition to renewable energy, the benefits it will bring from a welfare and development perspective will be massive. Air pollution, most of which is linked to fossil fuels, is estimated to have created global welfare costs of around US$3 trillion in 2015, potentially rising to $18-25 trillion by 2060 if we continue with our current rate of fossil fuel consumption (OECD, 2016). Furthermore, expanding electricity access through renewable energy in developing countries will help reduce poverty, improve health and raise the standard of living by stimulating productivity, investment and growth in these areas. This is already being seen with the expansion of off-grid solar markets in places like East and West Africa which have reached about 73 million households, allowing these users to save money whilst reducing the health risks and carbon emissions related to kerosene use (IFC, 2018).

In conclusion, I believe that the research featured in this report overwhelmingly suggests that a global switch from fossil fuels to renewable energy has the capacity to provide enough energy to meet future demand as well as be economically viable. Firstly, renewable energy technology is able to harness unlimited, naturally replenished natural resources to produce energy unlike fossil fuels which are finite resources. Through its ability to tap into these natural resources, renewable energy technology can be geographically dispersed across numerous terrains and locations, making electricity production more reliable and efficient as it decentralises supply and generates power closer to the consumer. There are valid concerns about the variability and intermittency of certain renewables but these fears are often over exaggerated, as increased investment and development of technology such as renewable energy storage systems will help overcome these issues. The fact that renewable energy already provides more than a quarter of global electricity production and some countries have already successfully made the switch to 100% renewables shows that the technology is ready.

From an economic standpoint, there appears to be wide consensus that a transition to renewable energy will provide a real growth opportunity for the global economy and offset the potentially insurmountable negative economic costs climate change will create. Continued fossil fuel consumption will cause global temperatures to rise and likely spark widespread natural disasters as a result of increased GHG emissions, creating financial chaos and threatening numerous sectors of the economy. Furthermore, the current fossil fuel-led energy industry suffers from market failure with over a billion people not having access to electricity and creates numerous negative externalities such as air pollution which a transition to renewables would help resolve. Although there is apprehension surrounding the risk of job losses in the fossil fuel industry and the high upfront costs of renewable energy plants, falling operating costs and anticipated employment boosts from the green economy show there is little substance to these fears. The decisions we take over the next few years will be crucial in addressing the impending climate crisis. Global policymakers and business leaders must enact widespread structural changes in the way we produce energy in order to reduce global GHG emissions and create sustainable growth for the future. A transition to renewable energy has been shown to be both technically and economically feasible, but if we are going to reduce the impending threat of climate change we need to trigger this transition sooner rather than later before it is too late.

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