Kanou Capital

The role of the energy transition in economic development and equality:

Evidence from a sector-level forecast of the economic benefits from clean energy investment in the United States

Contents

Executive Summary

The past 50 years have seen the energy consumption of the world double, with most of this energy coming from fossil fuels like oil and natural gas. As the global economy continues to grow, energy demand will skyrocket to power increased consumption and production. While fossil fuels may be historically cheaper than renewables, air pollution and global warming from greenhouse emissions are massive unmeasured costs.

If traditional energy sources continue to dominate, these negative externalities add up. Air pollution from fossil fuels kills 5 million people every year,[1] causing lung damage and ischemic heart disease, which strain the healthcare system. Global warming is increasing the frequency of natural disasters, which cause immense capital destruction and death. Hotter climates reduce agricultural yields and labour productivity.

Combining studies which quantify the costs of fossil fuels from these various pathways yields a **staggering annual cost of $3.4 Trillion to the global economy.** Not embracing renewables will hinder growth and development through these hidden damages. Not to mention, renewables are increasingly cheaper, with utility scale solar and wind projects now regularly cheaper over their lifetime than gas and coal. The renewable industry also serves as a beacon of growth for the economy, pulling in $300 billion of foreign direct investment a year and creating millions of jobs.

Alongside the sheer magnitude of the costs of fossil fuels, the distribution of these costs is extremely unequal. **The poorest people in the poorest countries suffer the most from global warming and air pollution**, both because they have a higher exposure to these risks and fewer resources to manage any damages incurred. All the research points to renewable energy as a possible driver of both growth and economic development across the globe, potentially reducing inequalities of income and wealth. Despite this, the large upfront investment required to build renewable capacity remains off-putting to many, as governments and companies fail to account for the value of the externalities discussed.

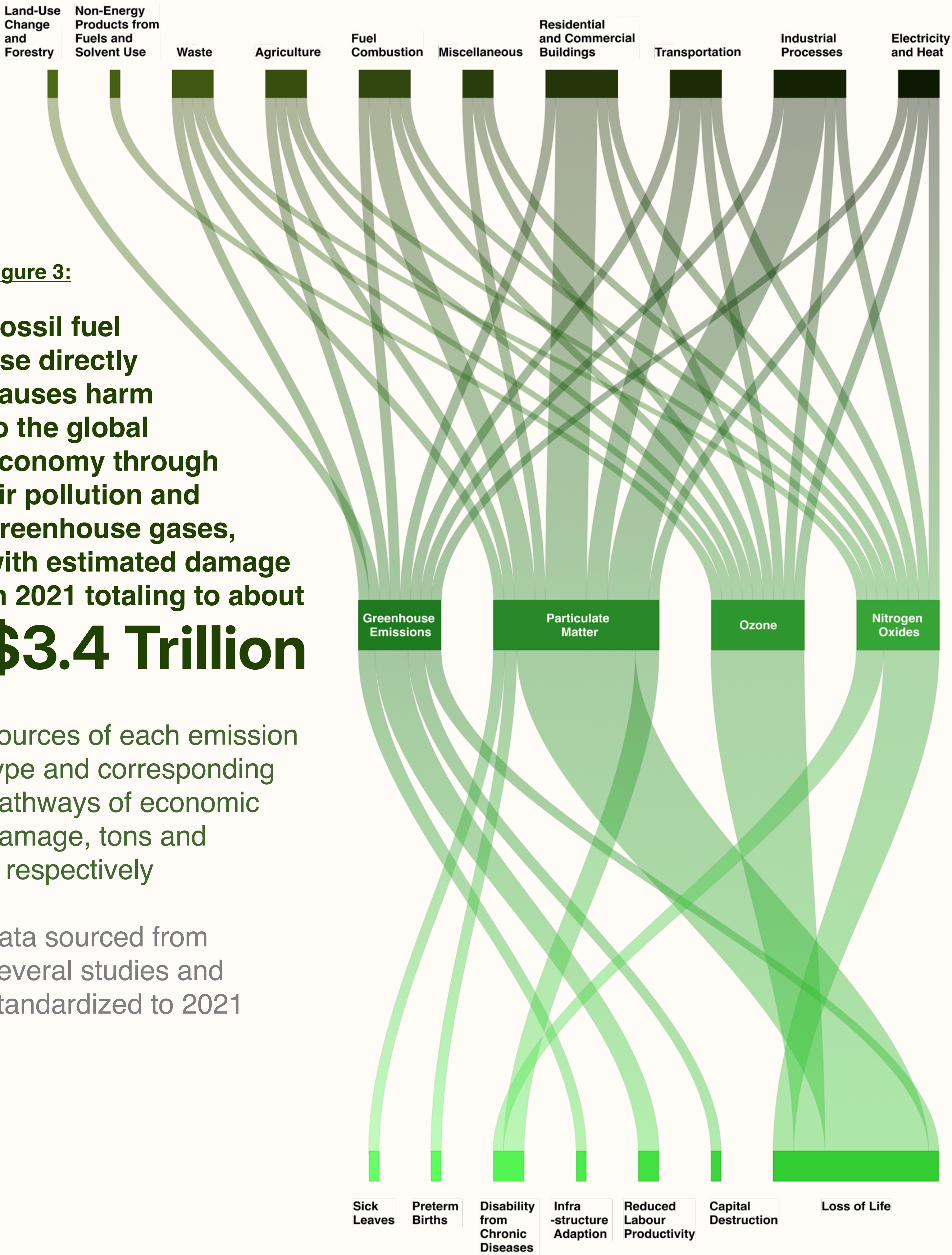
In order to truly assess the potential impact on growth and equality, this study will look at data and policy from the United States to compute the economic benefits from the clean energy transition on a sector level. Benefits from: **(1) reduced air pollution (2) reduced global warming & (3) reduced energy costs will all be considered**, and official government policy and statements will be utilised as the basis to forecast benefits in Energy, Transportation, Agriculture, Industry, Buildings and Trade until 2035.

[1] See: Lelieveld et al., *Air pollution deaths attributable to fossil fuels: observational and modelling study,* 2023

Figure 3:

Fossil fuel use directly causes harm to the global economy through air pollution and greenhouse gases, with estimated damage in 2021 totaling to about

$3.4 Trillion



sources of each emission type and corresponding pathways of economic damage, tons and $ respectively

data sourced from several studies and standardized to 2021

Figure 4:

The countries and people producing the least emissions per capita often suffer the most damages from climate change.

World Map Scaled to **magnitude and severity of the consequences of climate change for malaria, malnutrition, diarrhoea, and drownings, by country**

Source: Patz & Levy, 2015

By calculating the net reduction in the aforementioned factors over the next 15 years and assigning benefit-per-ton costs in line with recent research[2] , **the planned shift to clean energy in the United States will provide $2.36 Trillion in benefits**, most of this coming from greenhouse gas reductions in the energy sectors. The following are key insights from 2035 projections:

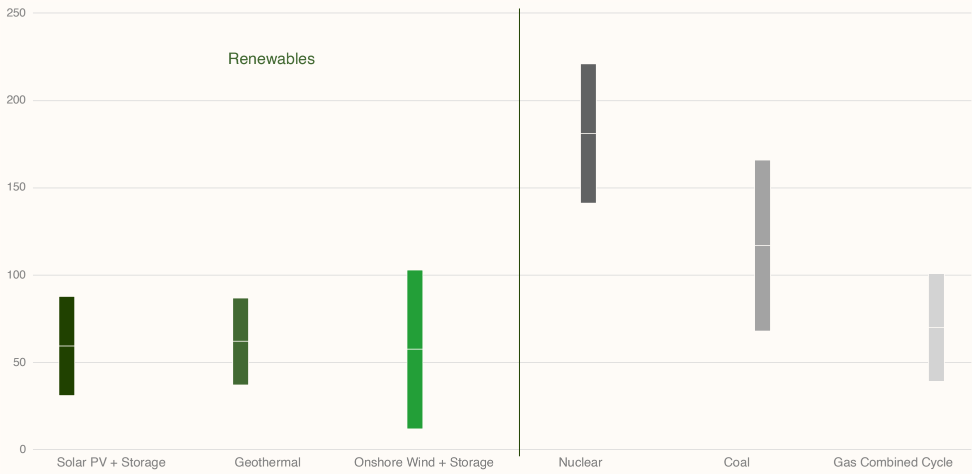
- The Energy sector could see **80% renewable energy, saving $1.61 trillion in climate and health costs as well as $300 billion in energy bills**
- Reaching the government's goal for EV sales is tricky and depends on tax benefits, but doing so **could save $273 Billion** in the Transportation sector.
- Agriculture's primary issue is soil management and not fossil fuels, **clean energy has little potential here until more processes are electrified.**
- Buildings can provide major reductions in emissions through better energy efficiency and retrofitting better heating. As a majority of the sector's energy use is electricity, **a cleaner grid can bring about $65 billion in benefits.**
- Industry also needs more research to electrify high-heat processes. But major industries like petroleum and chemicals offer **$130 billion in low-hanging benefits from better efficiency and less coal**.
- Renewables can shield the United States economy from geopolitical risk by reducing the reliance on imported oil and gas.

[2] See: Quantifying energy transition in United States, *A scientific framework to analyse the economic effect of energy transitions* for full methodology

Figure 6:

The Levelised Cost of Electricity for renewable sources continues to reduce drastically, now making large scale solar and wind cheaper to use than fossil fuels on average.

$/MwH, Solar and Wind estimates include additional storage costs



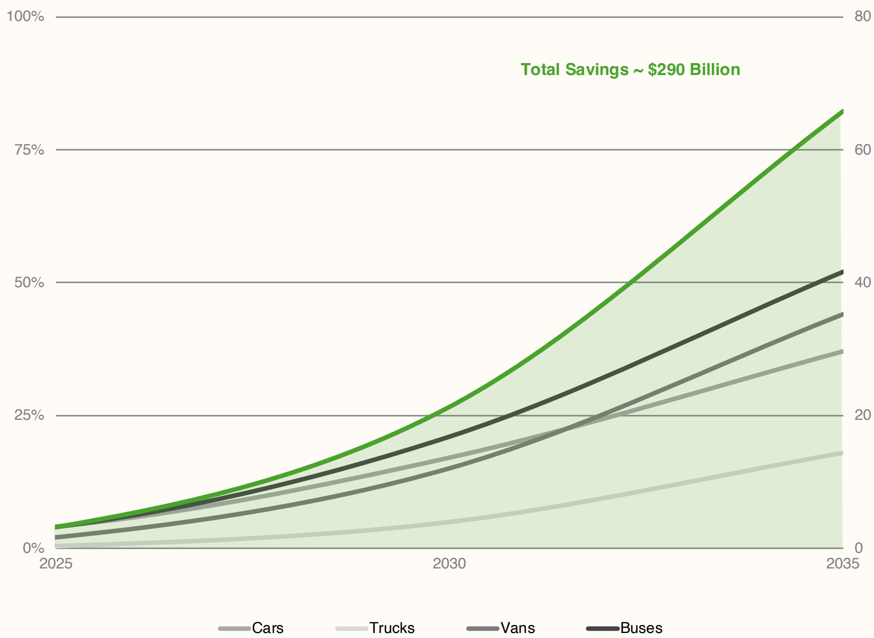
Source: Lazard 2022

Figure 8:

Electric Vehicles could save nearly 300 billion dollars in hospital fees and gas money for Americans by 2035, if sales stay on track.

Potential benefits from EV adoption in the United States (under APS* projections)

Projected Market Share of EVs (%) and **Economic Savings*** ($ Billions)



Source: IEA 2022,*Announced Pledges Scenario

If these benefits are assumed to accrue directly to American citizens, the average household saves almost $18,000 by 2035 in climate and health costs that would have materialised had fossil fuel usage not reduced. By scaling these total benefits to air pollution exposure and climate change risk,[3] the **relative benefits can be seen to decrease with income**. This supports the theory that the clean energy transition can help negate income inequality.

Figure 12:

Lower income households in the United States gain thousands of dollars more in benefits from clean energy compared to high income households, suggesting the energy transition could combat inequality.

15-year combined benefits from energy transition policy in the United States and household income

Source: Kanou Research

Applying these scaled benefits to the 2022 U.S. income distribution confirms these results. **The pre-tax income GINI coefficient** - a measure of inequality that compares the distribution of income and proportion of people – **reduces from 0.481 to 0.417.** This means greatly increased income for those near the very end of the distribution while still benefiting the entire population, with the adjusted distribution being similar to that of France or other European countries.

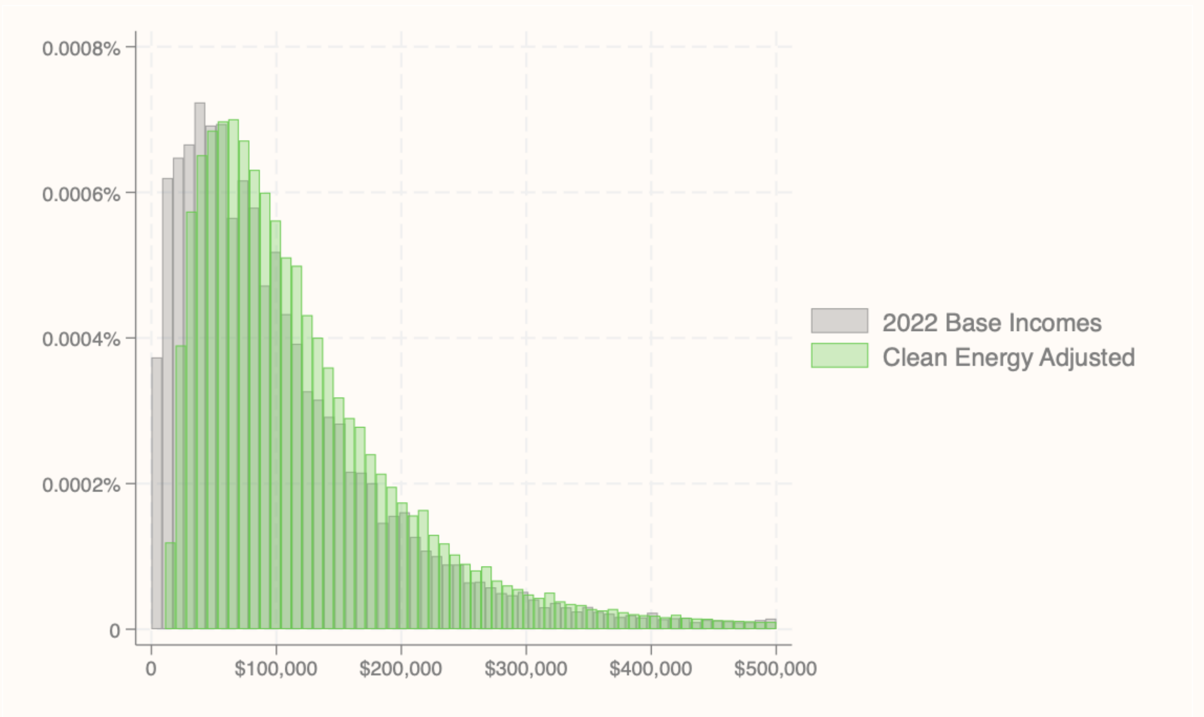
[3] See: Energy Transition and Income Equality? *Climate and air pollution risk by income group* for full methodology

Figure 13:

The energy transition can considerably shift the income distribution by 2035, providing upwards of $18,000 in benefits and reducing inequality.

2022 baseline & 2035 clean energy adjusted income distributions (assuming no other change from baseline)

Proportion of population (%) and Household income <500,000 ($)



Source: Kanou Research

Overall, this study has showcased the potential of the clean energy transition in bringing about not only growth but development and equality. While data limitations restricted the scope and of rigour of this analysis, all the evidence points towards a need for increased investment in renewable energy. With rising inequality and unbalanced growth in the modern world, clean energy investment by the government and the private sector can serve as a great equaliser.

Abstract

This report will look to quantify the impact of the energy transition on economic development outcomes through various pathways. By first establishing these pathways — air pollution, global warming and energy costs — through which fossil fuels directly impact the economy, this report will then move to analyse the next 15 years of energy transition in the United States. Utilising official government policy and statements, the uptake of renewable energy and related clean energy technologies will be forecasted at a granular level. After calculating the absolute reduction in greenhouse emissions and air pollutant concentrations as a result of the energy transition, these reductions will be converted to monetary benefits using reduced form tools like Benefit Per Ton estimates. A total benefit of $2.36 trillion dollars by 2035 is derive and this amount is applied to a representative sample of United States income to study the impact on income inequality. Benefits are fitted to the relative exposure to air pollution and climate risk across the United States and then distributed on an individual level. Results from an IPUMs microdata sample highlight that benefits are decreasing in income and the clean energy transition could reduce the pre-tax GINI coefficient from 0.481 to 0.417.

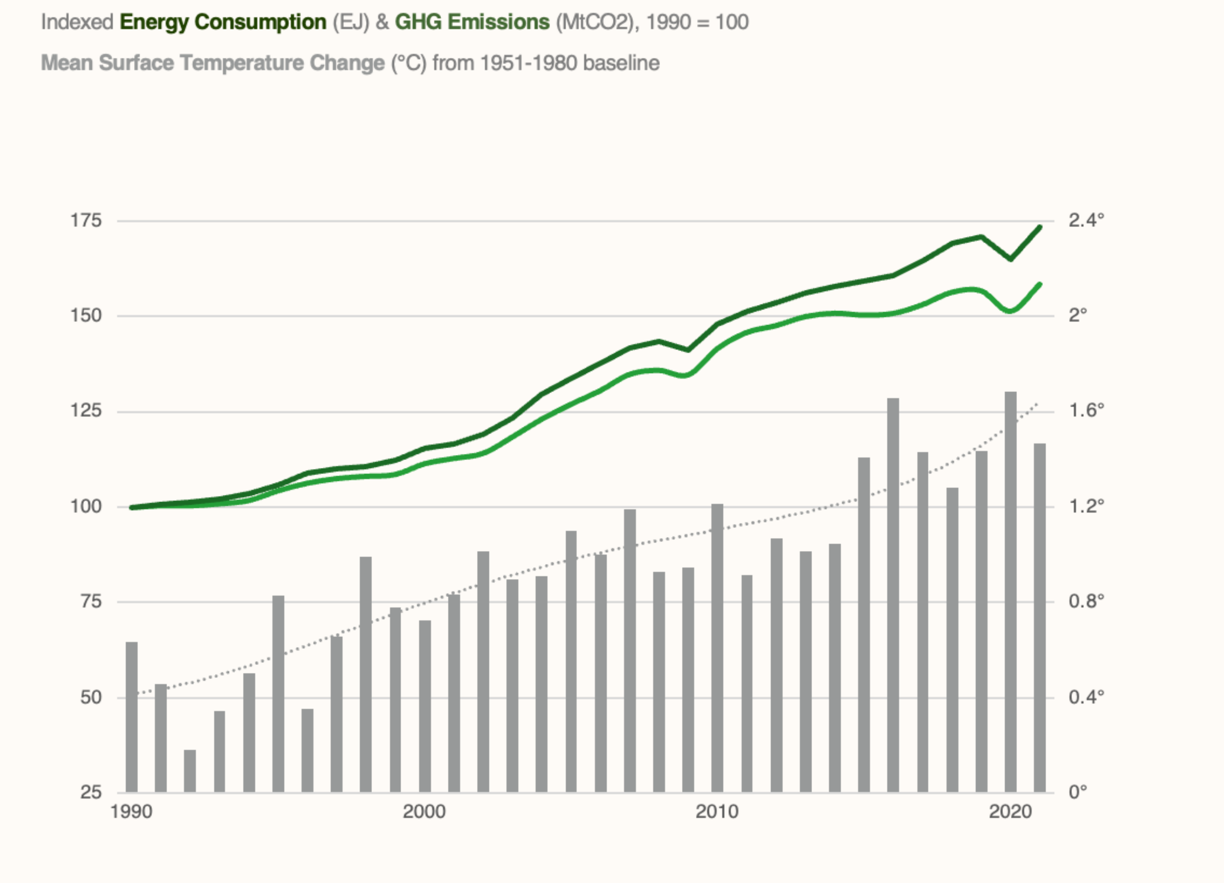
1. The Economics of Energy Consumption

Growth dynamics and fossil fuel usage

As economic growth has accelerated exponentially in the last century, the energy needs of the world to power megacities and industries have followed suit (and simultaneously the increased availability of energy has promoted growth). The growing demand for energy was satisfied by an uptick in fossil fuel usage and thus an increase in greenhouse gas emissions. While the developed world has benefitted from overutilising fossil fuels, the developing world faces a bigger challenge in meeting these energy demands without further causing damage to the environment.

Figure 1:

Growing energy consumption is the primary driver of increasing emissions and global warming.



Source: IMF, Energy Institute & Climate Watch 2021

Energy usage and economic prosperity are inextricably linked in the modern world[4] and thus boosting the development of the non-OECD countries will naturally come with an increased demand for energy. While the developed world has historically benefitted from fossil fuels, the developing world faces a bigger challenge in meeting these energy demands without further causing damage to the environment and economy. In order to decouple development from the usage of fossil fuels, the renewable energy transition in developing countries will be a key factor in the global economy in the coming years.

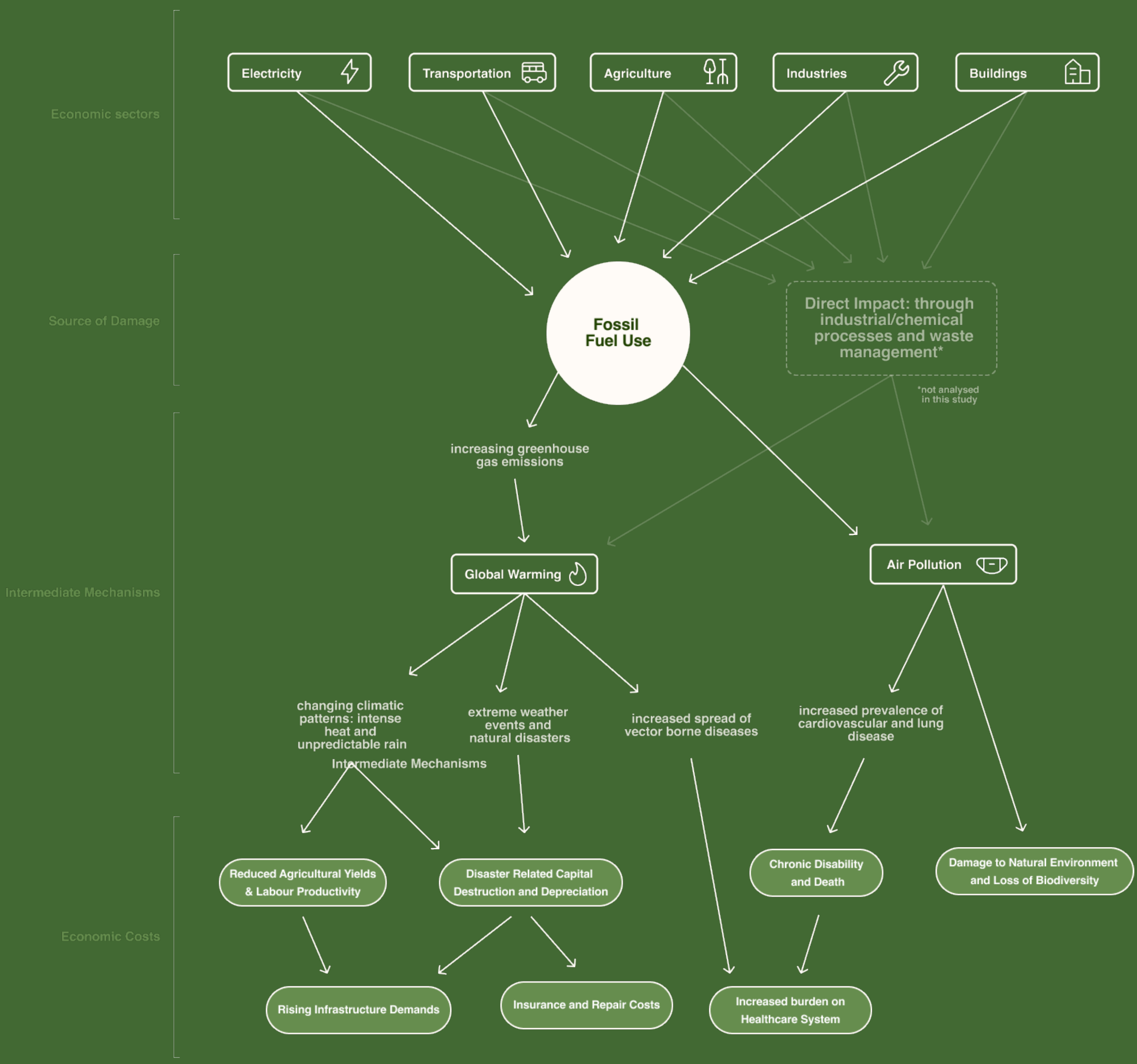
The IPCC Third Assessment report in 2001[5] put forth that the immense reliance of human activity on fossil fuels is the primary driver of global warming since 1950. Since then, the harmful impacts of climate change and pollution on the environment have become common knowledge, backed by decades of research.

On the other hand, the economic impact of these issues has only begun to be explored recently. A recent National Bureau of Economic Research working paper estimated that a 1°C increase in global temperature leads to a 12% decline in world GDP,[6] and a 2020 report by the Centre for Research on Clean Energy and Air (in collaboration with Greenpeace) modelled the cost of fossil fuel emissions to the global economy at nearly $3 trillion.[7] These staggering figures put into perspective how renewables could be a key not only unlocking sustainable economic growth but also contributing to it by abating the harmful economic effects of conventional energy.

Figure 2 presents some of the mechanisms through which fossil fuels directly and indirectly effect the economy.

[4]See: Stern, *The role of energy in economic growth*, 2011
[5] *Climate Change 2001: A synthesis report*, Intergovernmental Panel for Climate change, 2001
[6] Bilal & Känzig, *The Macroeconomic Impact of Climate Change: Global vs. Local Temperature,* 2024
[7] *Toxic Air: The Price of Fossil Fuels*, Greenpace Southeast Asia, 2020

Figure 2:
Reliance on fossil fuels generates a plethora of issues which negatively impact the global economy.



Three key economic pathways – Global warming, Air Pollution and Energy costs

As the primary energy source for most countries, fossil fuels are utilised across industry, transport, electricity generation and more. They contribute nearly 75% of all GHG emitted annually as per the UN.[8] Beyond this, the combustion of coal and gas produces air pollution, which causes lung and heart disease.

These represent the two major channels through which the use of traditional fuels leads to economic damage seen in Figure 2. The first is through climate change via the increase in extreme weather events as well as the impact on agriculture, biodiversity, and human productivity. The second is through health damages via pollution - an increased incidence of lung disease and premature births. Both channels do overlap, and it is important to consider the interaction of many sectors and mechanisms — for example climate change also increases the incidence of vector borne diseases like malaria which in turn add further health costs.[9]

Along with these channels, there also exists a third economic consideration — the opportunity cost of using fossil fuels. As renewable energy becomes cheaper and more efficient, an argument arises for reduced energy costs as well as increased job creation with further investment into the renewables sector. As per IRENA, 86% of newly commissioned renewable projects in 2022 had a lower levelized cost of energy (LCOE) than fossil fuel-fired cost by country/region.[10] As the investment into renewable energy accelerates exponentially — with the world adding 50% more renewable capacity in 2023 than in 2022[11] — the sector also serves as a source of employment and growth for the economy, with the capacity to prevent further economic damage from climate change and pollution.

Global research suggests 12 figure annual damages

Combining the various effects of fossil fuels on development outcomes through the various damage pathways discussed earlier has not yet been explored in detail. While many studies investigate the economic impact of fossil-fuel induced air pollution or climate change, these factors are usually analysed in isolation. In failing to consider this cumulative impact, the current research landscape underestimates the importance of the energy transition in creating efficient development.

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[8] *Causes and Effects of Climate Change*, United Nations, 2024
[9] Rocklöv & Dubrow, *Climate change: an enduring challenge for vector-borne disease prevention and control*, 2020
[10] *Renewable Power Generation Costs in 2022,* International Renewable Energy Agency, 2023
[11] *Massive Expansion of Renewable Power Opens Door to Achieving Global Tripling Goal Set at COP28*, International Energy Agency, 2024

To better represent these costs, Figure 3 breaks down the global economic cost of these factors by consolidating the results of several recent reports. Including a wider range of variables that could be impacted by increased fossil fuel usage — like health costs, impacts on productivity, capital depreciation and more — provides a more holistic overview of how traditional energy use can impact the economy.

This approach estimates an annual cost of nearly 3.4 trillion USD[12] incurred by fossil fuel usage across sectors (using 2021 estimates). This equates to nearly 3.5% of global GDP, comparable to the loss due to the COVID-19 pandemic in 2020. Particulate matter pollution is the largest avenue of damage, mainly through increased risks of heart and lung disease, which shorten lives and increase healthcare costs. Greenhouse gases alone cause $550 billion in losses annually, highlighting how fossil fuel damage is often understated due to the consideration of air pollution and global as separate mechanisms rather than a combined effect.

Despite costing the world trillions, fossil fuel consumption continues to increase. Developing countries have little choice but to rely on fossil fuels. With millions in poverty, these countries do not have the luxury to wait for the development of renewable energy infrastructure. Most developed countries — which have the wealth and time to invest heavily into renewables — are not on track for their net zero commitments. Continuing this trend of ignoring renewables in long term development plans is not only harmful for the environment but likely for every economy.

While the combination of several sources lends itself to a large degree of uncertainty, the sheer magnitude of damage calculated by doing so is enough to suggest a severe under-representation of renewables in current economic planning. Furthermore, understanding the proportional impacts of different damage mechanisms is invaluable to determine which policies and investments to prioritise.

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[12] Figure 3 utilises pollutant data from the Emissions Database for Global Atmospheric Research, 2024 and greenhouse emissions data from Climate Watch, 2021. Greenhouse gas related economic damage was estimated by combining global warming related capital destruction and death figures from Newman & Roy (2023), global warming related labour and agricultural productivity reductions from Parsons, Shindell et al. (2021) and infrastructure adaptation costs estimated by the United Nations Environment Programme (2023). Fossil fuel related air pollution costs were taken from Farrow, Miller and Myllyvirta (2020).

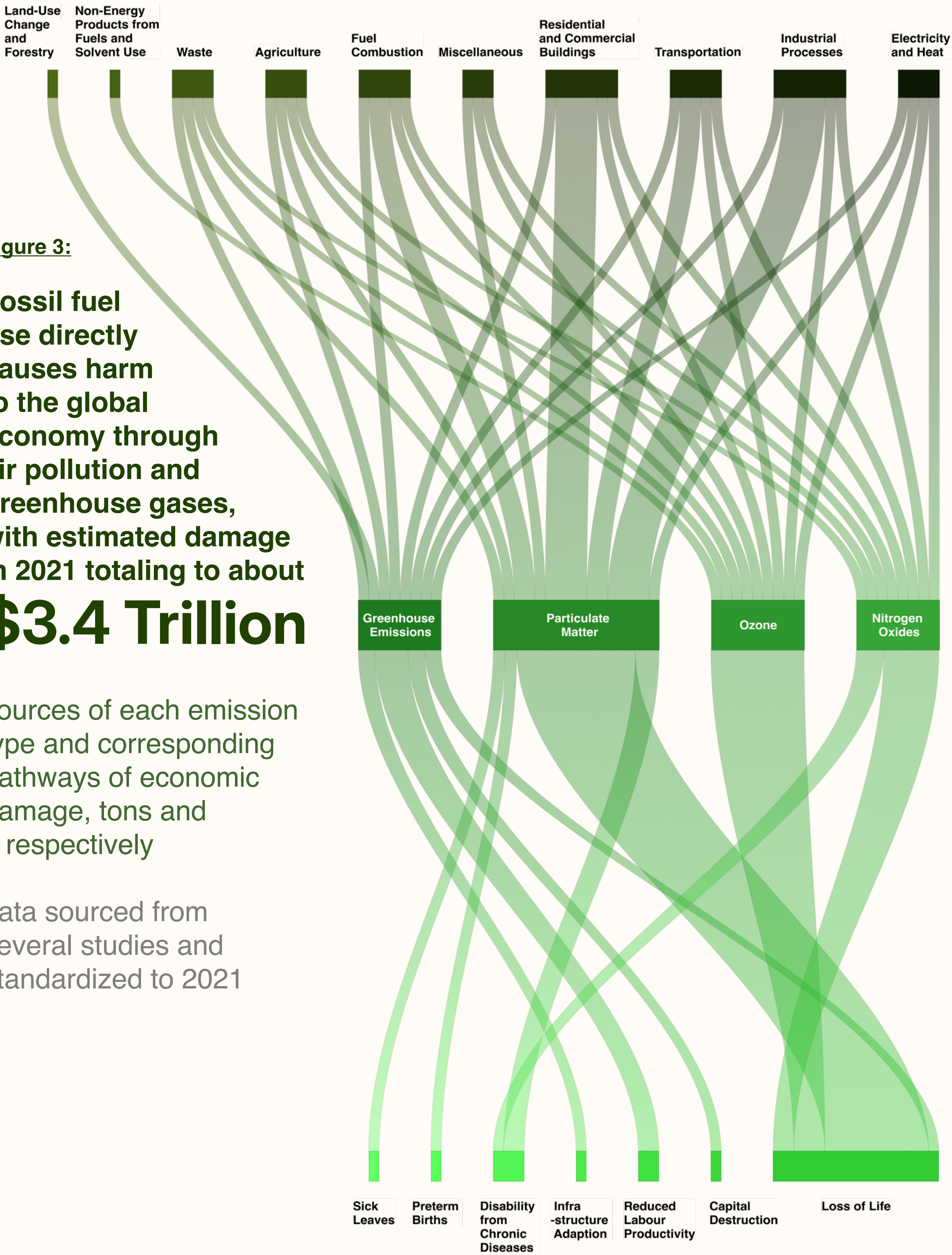

Figure 3:

Fossil fuel use directly causes harm to the global economy through air pollution and greenhouse gases, with estimated damage in 2021 totaling to about

$3.4 Trillion

sources of each emission type and corresponding pathways of economic damage, tons and $ respectively

data sourced from several studies and standardized to 2021

Direct benefits of the renewables and EV industries

Alongside the damages that come with fossil fuels, the energy transition also provides a unique opportunity for growth. The renewables industry is rapidly growing and thus serves as an important avenue for foreign direct investment and employment generation. Renewable uptake could push total energy jobs to 100 million as soon as 2050,[13] making it a sizeable portion of the world economy. Renewable energy projects also attract approximately $300 billion dollars in foreign direct investment yearly,[14] contributing to more economic expansion and technology sharing. These benefits are important to note but difficult to quantify long term, thus they will not be included in the quantitative section of this report.

Another quantifiable benefit of renewable energy is the reducing cost of renewable energy, especially when compared to fossil fuel prices. Energy prices can be measured using levelised cost of electricity (LCOE) which incorporates lifetime costs of installation and production by assuming a fixed discount rate. IEA's 2020 projections[15] and IRENA's 2022 analysis both suggest that renewable energy sources, despite their high infrastructure costs, will be increasingly cheaper than fossil fuels.

Who faces these costs? National and International inequality in fossil fuel impact.

Most of the damage illustrated in figure 3 is concentrated in poorer economies, and particularly the poorest sections of society within each country.[16]Developing countries in Asia and Africa are currently facing the most severe impacts of pollution and climate change, even though the majority of fossil fuel consumption over the past century has occurred in developed nations.

Increased natural disaster risk, waterborne and respiratory diseases, reduced productivity in manual labour, etc. are all much more likely to affect poorer countries in the Global South that lack the infrastructure to protect against such issues. Furthermore, the poorest people within each country are most likely to work manual jobs and lack access to healthcare and insurance, which makes them the most vulnerable to climate change. Such an effect exacerbates existing inequalities on the global and national scale. Inequality also fuels further emissions, with the top income decile contributing nearly half of all emissions[17] worldwide and the negative effects from these emissions harming the bottom 10% more than anyone.

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[13] Ferroukhi, Casals and Parajuli, *Measuring the Socio-economics of Transition*, 2020
[14] Irwin-Hunt, *three FDI charts to grasp the tension between renewables and fossil fuels*, 2023
[15] *Projected Costs of Generating Electricity 2020 Edition*, International Energy Agency, 2020
[16] Levy & Patz, *Climate Change, Human Rights, and Social Justice*, 2015
[17] Cozzi, Chen & Kim, *The world's top 1% of emitters produce over 1000 times more CO2 than the bottom 1%,* 2023

Analysing the Carbon Majors database (which tracks fossil fuel and cement emissions) reveals that 57 mega corporations and state entities to contribute nearly 80% of emissions.[18] With many of these organisations being fossil fuel primary producers, it is in their best interest to perpetuate this system.

Figure 4:

The countries producing the least emissions per capita often suffer the most damages from climate change.

World Map Scaled to **relative GHG Emissions**

World Map Scaled to **magnitude and magnitude and severity of the consequences of climate change for malaria, malnutrition, diarrhoea, and drownings, by country**

Source: Patz & Levy, 2015

[18] *The Carbon Majors Database: Launch Report*, Carbon Majors, 2024

These factors together create a doom loop of climate injustice, where the unabated consumption of the rich in developed countries leads to devasting climate effects that the poor suffer through disease, natural disasters and inhumane working conditions. Renewables can help tackle this problem head on by decoupling the growth of the economy and consumption with that emissions and climate change.

While the global inequity of fossil fuel usage is an important concept, this report will focus on within country inequality in the United States due to an abundance of data. This analysis will serve as a proof of concept to promote future studies that can apply similar methodology on a global scale when data becomes available.

A scientific framework to analyse the economic effect of energy transitions

Now that the costs of conventional energy and benefits of renewable energy have been laid out, this report will move to analyse key structural changes in the fossil fuel usage of the United States. The impacts on trade, emissions projections, and major blockades to the energy transition will also be discussed to give a more holistic view of the development impacts of renewables.

To calculate the net savings of renewable energy uptake and reduction of fossil fuels, this report will measure the realistic damage reductions through the three pathways discussed earlier, utilising the official clean energy goals of the United States government as reference. By forecasting the planned abatement of fossil fuels in each sector and thus calculating the reduction in air pollution and GHG emissions, the economic benefit of the energy transition can be quantified. Adding to this the estimated savings from cheaper electricity and removing the expected system costs of building infrastructure (the energy transition requires increased renewable capacity, storage, R&D investment and more), this report can arrive at a net benefit in each sector of the economy. This gives us the following equation for net benefit of the energy transition, discounted over a chosen time period.

$$= \Delta\, AirPollutant_i * BPT_i^s + \Delta GHG * SCC + Energy\ Savings - System\ Costs$$

where,

$\Delta Air\ Pollutant_i$ is the reduction in each specific air pollutant in tons. This study will consider directly emitted particulate matter/PM2.5, sulphur oxides/SO_x, nitrogen oxides/NO_x, ammonia/NH_4, and volatile organic compounds/VOCs. Nitrogen oxides and volatile organic compounds are reactive precursors, used to forecast ground ozone levels.

BPT_i^s is the benefit per ton of reducing the specific air pollutant (with the pollutants considered considered above) in a specific sector as per Environmental Protection Agency 2024 guideline.[19] If a sector considered is missing, the mean response surface model estimates for the source in questions will be utilized instead.[20]

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[19] *Benefit Per Ton Archive* [Data set], Environmental Protection Agency, 2024
[20] *Response Surface Model (RSM)-based Benefit Per Ton Estimates*, Environmental Protection Agency, 2024

ΔGHG is the decrease in greenhouse gas emissions, standardised to GtCO2.

SCC is the social cost of carbon, a measure of the total damage caused in the USA by emitting one additional ton of carbon. The cost is set at a conservative $100/ton as per historic IPCC recommendations to limit global warming to 1.5° Celsius.[21] Recent EPA estimates of an SCC are closer to $190/ton but have been criticised for including global impacts, co-benefits from PM2.5 reductions and the use of a high estimate for a “value of a statistical life”.[22] Thus, this measure is set at a more conservative amount. $100/ton has often used as a guideline SCC by international organisations.

Note the following assumptions made for this study –

1. The benefit per ton estimates are constant – as recent studies suggest a linear dose-response functions for common pollutants[23]. Those that prefer a non-linear fit tend to have larger risk estimates[24], thus assuming a linear relationship will at worst underestimate results rather than overestimate them. While research is mixed on minimum concentrations below which health impacts are negligible, reaching any reasonable lower threshold within the 15-year scope of this analysis is very unlikely.
2. Similarly, the domestic cost of carbon is also assumed to be constant for ease of calculation.
3. Discount rate for future benefits is set at 2%, in line with current literature, to match the risk-free rate of return.[25]
4. Due to the lack of historical accuracy regarding LCOE projections, current estimates as of 2023 will be utilised despite projected decreases in renewable costs throughout the next decade.
5. All prices are normalised to 2020 values for consistency. 2020 is chosen as the base reference period for the study to harness the most recent emissions inventory data from the EPA – an important data source for calculations.

This equation will be applied to the United States over the next 15 years, a period chosen to coincide with the major goal of decarbonising the energy grid set by the government. The sector-wise impact of policy changes expressed in the Inflation Reduction Act (IRA) and other clean energy plans will be quantified in terms of air pollution and global warming – which can then be converted to an economic benefit using the methodology discussed above. Alongside the increased uptake of renewable technology, this report will also include the impact of select technologies/innovations like Electric Vehicles (EVs) and electrification which directly contribute to fossil fuel abatement

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[21] *Special report: Global warming of 1.5°C*, Intergovernmental Panel for Climate change, 2001

[22] Report on the Social Cost of Greenhouse Gases, Environmental Protection Agency, 2023. See criticism in Lesser, *Missing Benefits, Hidden Costs: The Cloudy Numbers in the EPA's Proposed Clean Power Plan,* 2016

[23] Wei, Yazdi, Di et al., *Emulating causal dose-response relations between air pollutants and mortality in the Medicare population*, 2021

[24] Ru, Shindell, Spadaro et al., *New concentration-response functions for seven morbidity endpoints associated with short-term PM2.5 exposure and their implications for health impact assessment*, 2023

[25] Barrage & Nordhaus, *Policies, projections, and the social cost of carbon: Results from the DICE-2023 model*, 2024

2. Quantifying the energy transition in the United States of America: 2.36 trillion dollars of potential

Overview of U.S. policy regarding clean energy investing

As the second largest emitter of greenhouse gases and the largest on a per-capita basis[26], the United States plays a pivotal role in the creation of a global clean energy economy. Alongside this, the country has some of the best maintained data on air pollution, climate change and individual level incomes. The Inflation Reduction Act passed by the Biden Administration serves as the defining piece of climate policy legislation in the country – with a planned investment of nearly $400 billion into renewable energy.[27]

The United States nationally determined contribution (NDC) decided as per the Paris agreement aims for a 50-52% reduction in GHG emissions by 2030.[28] The government has also ambitiously planned to have a carbon-pollution free electricity sector by 2035 while simultaneously focusing on carbon management and capture.

The Environmental Protection Agency (EPA) serves as the primary agency of the government for climate-change related matters.

Figure 5 showcases forecasts based on U.S. national policy on emissions and highlights that GDP growth and emissions intensity have been decoupled in the country for years now. This is consistent with most of the developed world where emissions have already peaked. Despite this decoupling, the energy consumption of the country remains extremely high while renewables form a very small part of the energy mix.

The major sources of emissions and particulate matter in the U.S. are transportation and electricity generation – both of which can be massively transitioned towards renewables.

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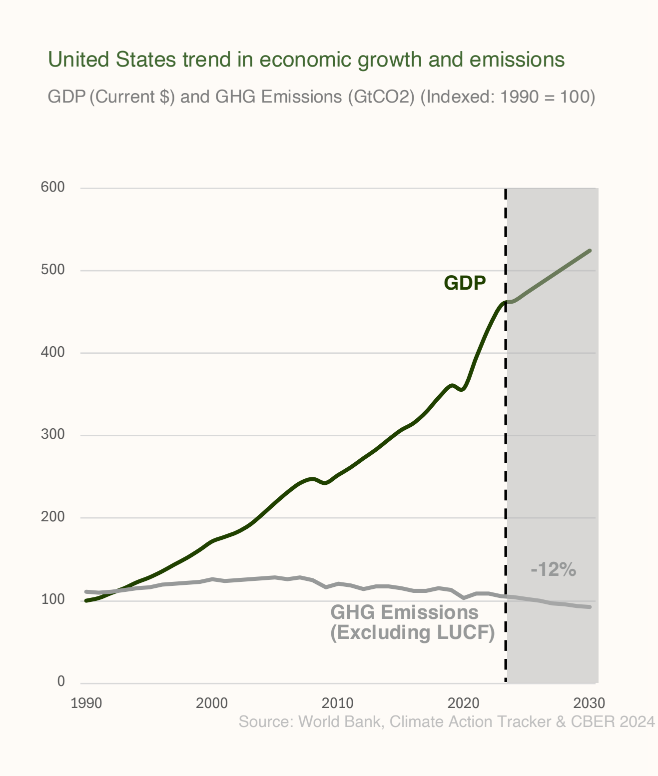
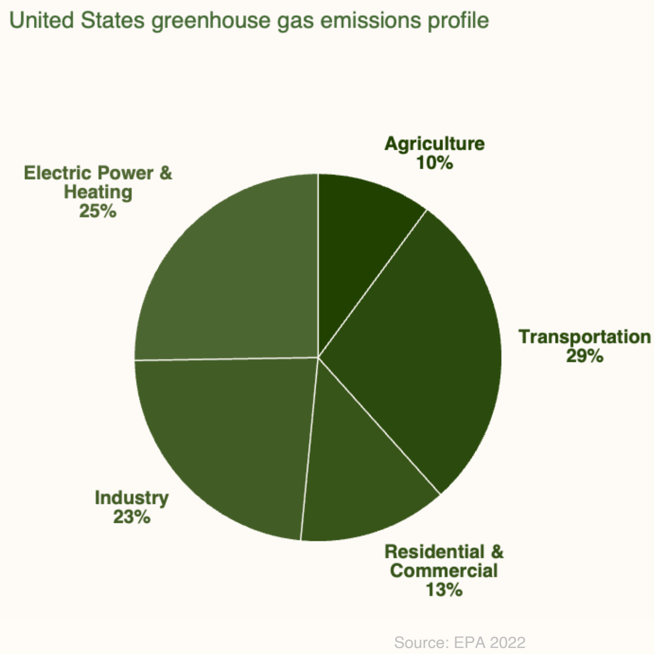
[26] *Historical GHG Emissions*, Climate Watch, 2021
[27] *Inflation Reduction Act*, 2023
[28] *Nationally determined contributions under the Paris Agreement*, United Nations Framework Convention on Climate Change, 2022

Figure 5:
The United States is on a slow path to green economic growth. Emissions are declining — mainly due to less carbon intensive fuels.





Key Sector Analysis

a. Energy

The United States has a low share of renewables in its energy mix for a developed country at about 19% – behind most of Europe. The country has massive potential in both solar and wind power, with estimates suggesting that each source could contribute nearly 80% of the USA's total energy needs if all this potential was harnessed[29].

President Joe Biden set a goal of a carbon-free electricity sector by 2035 and an 80% share of renewables in the electricity sector by 2030[30]. The National Renewable Energy Laboratory and US Department of Energy has forecasted different methods through which these goals can be achieved – primarily through expanding onshore wind and solar power. Utilising the "decarbonised" scenario from the Solar Futures study[31], a conservative prediction of increased renewable uptake, a net economic

[29] Denholm, Brown, Cole et al., *Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035*, 2022
[30] *FACT SHEET: President Biden to Catalyze Global Climate Action through the Major Economies Forum on Energy and Climate,* The White House, 2023
[31] *Solar Futures Study*, U.S. Department of Energy, 2021

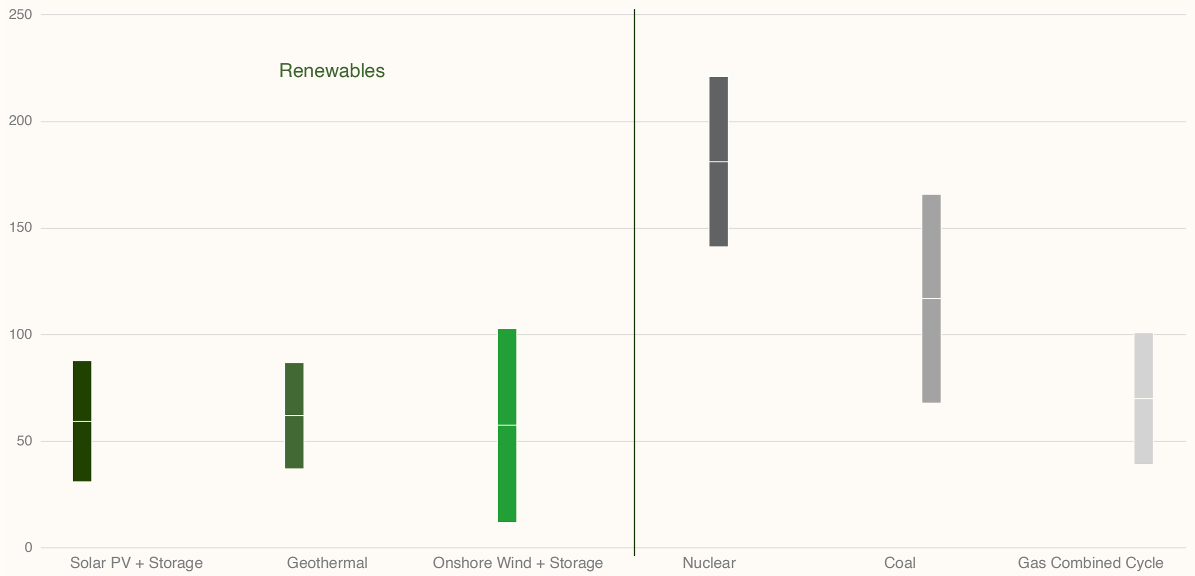
benefit can be calculated by looking at the projected LCOE of the energy mix as well as the reduction in emissions and pollutions compared to current day.

Using Lazard's LCOE+ 2023 projections[32] as a baseline for various energy prices, the savings throughout the energy transition can be quantified. Assuming no further decrease in the cost competitiveness of renewable sources like utility scale solar and on-shore wind (despite clear indications that renewable prices will continue to decrease while fossil fuel LCOEs stagnate[33]) and continued provision of IRA renewable tax credits, the USA's electricity sector in 2035 can save nearly $35 billion annually from lower costs of production when compared to the 2022 baseline. Figures 6 & 7 highlight the LCOE values and scenarios used to calculate this figure. This calculation takes the midpoint prices for the subsidized LCOE range for all sources and applies them to the projected change in energy mix.

Figure 6:

The Levelised Cost of Electricity for renewable sources continues to reduce drastically, now making large scale solar and wind cheaper to use than fossil fuels on average.

$/MwH, Solar and Wind estimates include additional storage costs



Source: Lazard 2022

[32] *Lazard's Levelized Cost of Energy Analysis—Version 16.0,* Lazard, 2023
[33] See: *Energy Transition Outlook,* DNV, 2023

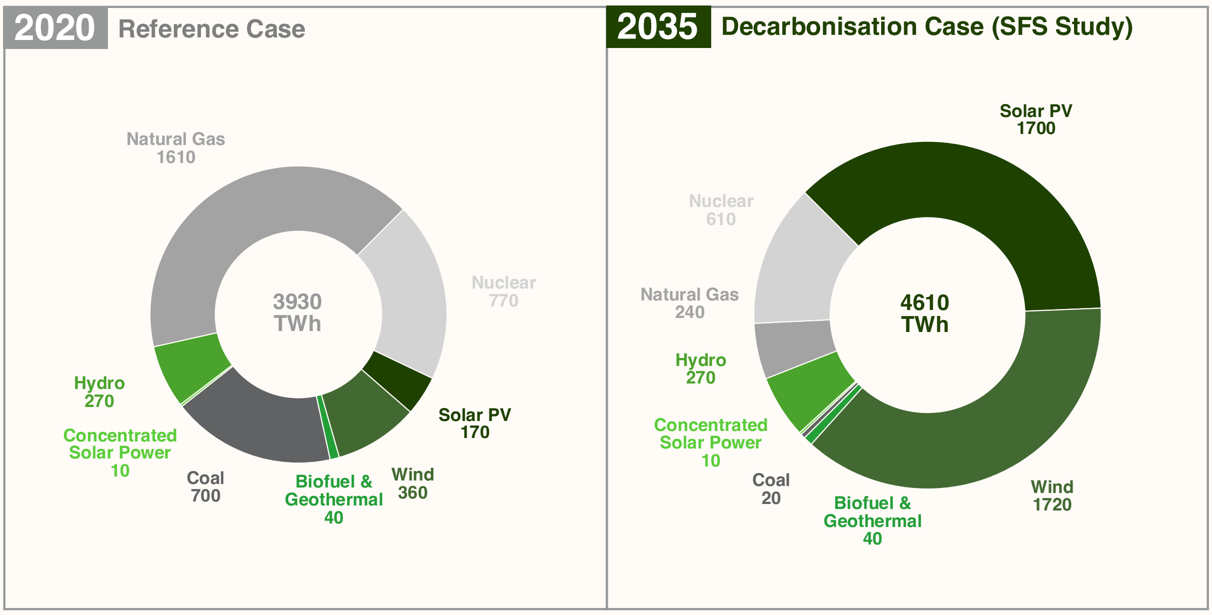
Adding to this, the major savings from the energy come from the decrease in air pollution and carbon emissions. By applying the earlier discussed SCC and BPT estimates to the reduction in emissions, a value can be estimated for this benefit. The projected decrease in carbon emissions is about 1.44 Gt of CO_2 a year by 2035 (in this constrained scenario) as the grid becomes 95% decarbonized, and for air pollution the individual emission factors are applied for each power source and air pollutant as per EPA mean estimates.

Utilising the methodology earlier yields total savings of nearly $1.86 Trillion from reduced air pollution and GHG emissions (when compared to 2020 pollution levels). Taking into account the higher estimate of system costs from the SFS study ($250 billion) and assuming energy cost savings accrue to consumers, energy transformation can yield a conservative net benefit of nearly $1.89 trillion over the 15 year period. This clearly points to the economic potential of renewable energy in the United States when internalizing the negative health and productivity effects associated with fossil fuels.

Figure 7:
With continued investment, the United States could produce more than 80% of its energy using renewables by 2035.

United States total energy generation by source

Terawatt Hour (TWh)



Source: US Department of Energy & NREL 2020

Note that sizable subsidies provided in the IRA to accelerate the uptake of renewable energy are not included as costs within this calculation. This choice is made to reflect that energy subsidies have always been a large part of government spending – including when fossil fuel industries were the dominant recipient of such benefits.[34]

b. Transportation

The transportation sector is the largest contributor to the USA's GHG emissions and offers an opportunity for rapid electrification in road vehicles. With the highest per-capita vehicle miles in the world[35], many parts of the country are entirely dependent on cars for transport. About 90% of vehicles utilise petroleum-based fuels[36] and 81% of all the energy use in transportation is for road vehicles (with 58% coming from cars and SUVs).[37]

While the electrification in sea and air transport will require far more research to safely implement, the EV market in the United States serves as a cost-effective opportunity to reduce emissions due to its car-centric infrastructure. Passenger vehicles account for about 17% of US emissions and the additional NO_2, O_3 and PM emitted is attributed to close to 50,000 premature mortalities in the United States.

An average electric car in the United States, throughout its life-cycle, produces 66% less greenhouse emissions than a petrol car,[38] with this number only improving as electricity production becomes less carbon intensive. While EVs do produce PM2.5 pollution from brake dust and other processes, nitrogen oxides and ammonia are almost entirely produced through combustion and thus are reduced to near zero in EVs. These figures suggest that increasing the share of EVs can be one of the simplest methods to reduce emissions and pollution but convincing consumers to switch can be difficult.

Electric cars reached a record 8% of market share in 2022, but growth in the industry has been slowing and uptake is much slower in the category of trucks and SUVs. The IRA aimed for EVs to constitute 50% of all new cars sold by 2030. – meeting these goals along with a 95% decarbonised grid by 2035 could save nearly $287 billion for the economy as seen in figure 8. To facilitate this change, the U.S. government has pledged over $15 billion to build a more comprehensive charging network for EVs and subsidies their purchase[39].

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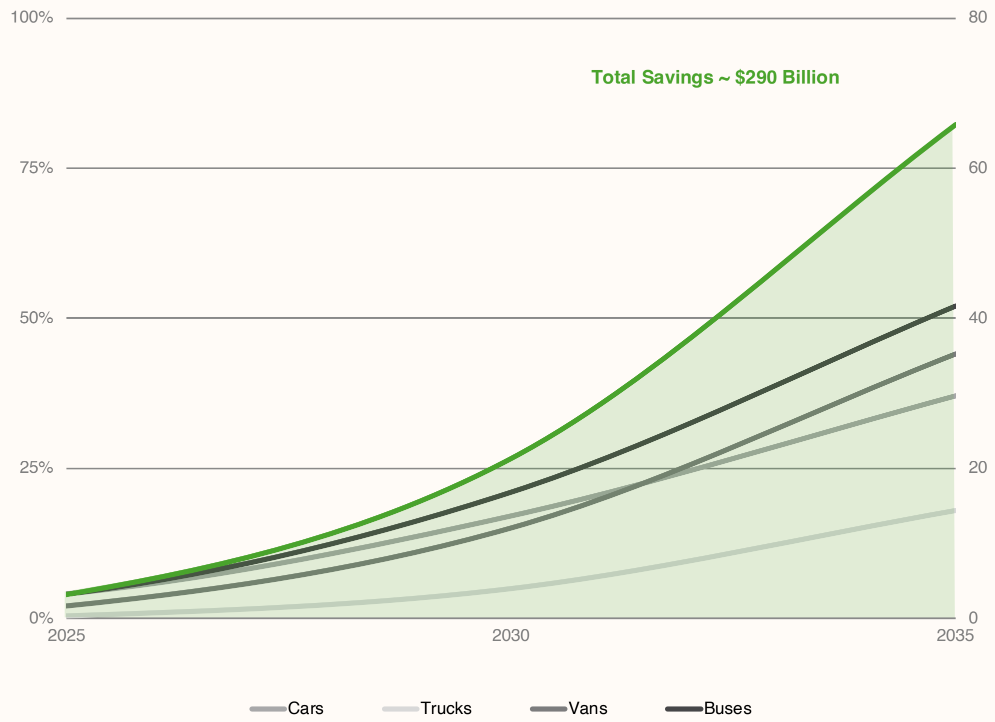
[34] Pfund & Healy, *What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America's Energy Future*, 2011
[35] *Automobile Profile* [Data set], Bureau of Transport Statistics, 2021
[36] *Transportation Fuels,* Department of Energy, 2021
[37] Davis & Boundy, *Transportation Energy Databook Edition 40, 2022*
[38] *How clean are electric cars? T&E's analysis of electric car lifecycle CO_2 emissions,* Transport & Energy, 2020
[39] Boushey, *Full Charge: The Economics of Building a National EV Charging Network,* 2023

Figure 8:
Electric Vehicles could save nearly 300 billion dollars in hospital fees and gas money for Americans by 2035, if sales stay on track.

Potential benefits from EV adoption in the United States (under APS* projections)

Projected Market Share of EVs (%) and **Economic Savings*** ($ Billions)



Source: IEA 2022,*Announced Pledges Scenario

Evidence is currently inconclusive on whether EVs provide cost savings to the average consumer, but continuing tax credits and cheaper electricity in the future will benefit owners alongside climate benefits and stability. Electricity has a more stable price due to its primarily domestic production in America while gas introduces the volatility of global market forces. Thus, EVs help maintain lower costs of fueling for Americans and prevent the loss of consumer confidence often seen with the fluctuation of gas prices[40] - building a more resilient and efficient economy and happier consumers.

c. Agriculture

While agriculture contributes only 10% of USA greenhouse emissions, farms are the number one human source of fine-particulate air pollution and adversely affect the

[40] https://kenaninstitute.unc.edu/commentary/the-ev-transition-makes-the-u-s-economy-more-resilient/

eastern and central parts of the country.[41] This primarily arises from N_2O entering the air – a byproduct of fertilizer use and disposal of animal waste.[42] The production of manure, livestock enteric fermentation and soil management are also large contributors to the overall footprint of the sector by emitting methane and nitrous oxide.

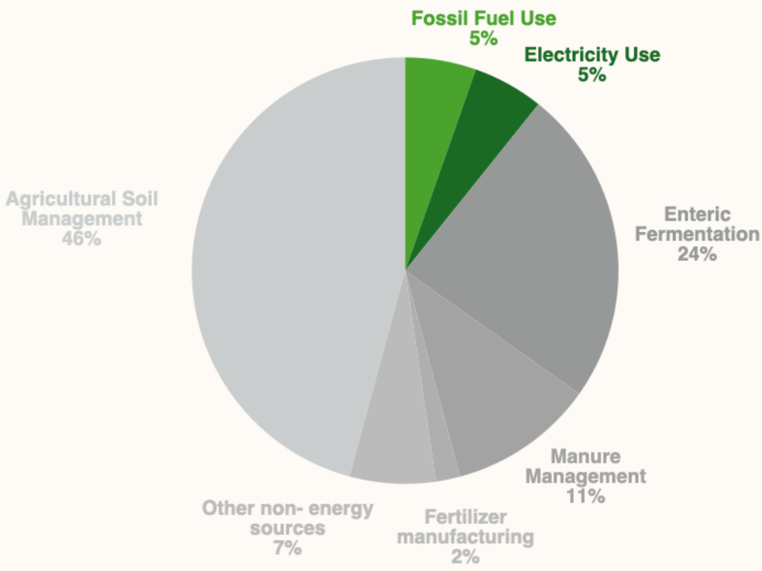
Agriculture suffers from being harder to electrify than other sectors, with heavy machinery like tractors being long-term[43], expensive investments that are unlikely to be replaced by electric versions in the next decade. This has led to 93% of the energy utilized in the US food system being fossil-fuel based.[44] Even with economic incentives from the IRA to promote "climate smart" policies by US farms, these policies are unlikely to reduce fossil fuel use as they do not focus on electrification or renewables. Aside from the Rural Energy for America Program (REAP) – which provides loans and grants to farmers to install renewable energy on their land – not many agricultural policies suggest a notable energy transition in the sector. Even with REAP contributing to a 30% increase in solar usage on American farms since 2019,[45] the total emissions of the sector have remained stagnant.

Figure 9:

Most emissions and pollution from agriculture are not caused by fossil fuels, thus the energy transition is less influential in the sector.

Sources of GHG emissions in the U.S. Agriculture Sector (2018)

MMT CO_2e, sources directly affected by energy transition in green



Source: USDA 2022

[41]Bauer, Tsigaridis & Miller, *Significant atmospheric aerosol pollution caused by world food cultivation,* 2016
[42]Wyer, Kelleghan, Blanes-Vidal, *Ammonia emissions from agriculture and their contribution to fine particulate matter: A review of implications for human health,* 2022
[43] The EPA classifies on-farm mobile fossil fuel use under industrial sector emissions rather than agriculture
[44] *The Role of Fossil Fuels in the U.S. Food System and the American Diet*, U.S. Department of Agriculture, 2017
[45] *Census of Agriculture* [Data set], National Agricultural Statistics Services, 2022

Only a small minority of emissions and an even smaller proportion of air pollution in agriculture is caused by fossil fuel use (see figure 9). Agricultural emissions have been steady for over 20 years and will likely continue to be steady until 2035. The switch to renewables will only affect agricultural emissions through a cleaner electricity grid (benefits which are already included in the energy sector).

Applying the earlier methodology yields no quantifiable impact of the energy transition on the agricultural sector by few notable non-pecuniary benefits do arise. Decoupling the food systems from fossil fuels will protect the consumers from fuel price volatility influencing food security. This is especially important for the lowest quintile of households by income who spend upwards of 30% of their income on food.[46] Farmers also benefit from generating their own electricity. The capacity to sell their excess electricity diversifies their income stream, which can be extremely useful as insurance in times of bad yields or drought.

d. Buildings & Household

Buildings and the residential use of energy contribute a third of American GHG emissions, a majority of which can be attributed to the generation of electricity for use.[47] Only about 10% of total emissions are directly attributed to the sector – primarily from on-site combustion for heating. Buildings offer a huge opportunity for cheap decarbonization, simply by moving away from fossil fuels and increasing electrification.

The DoE's updated 2024 Blueprint to decarbonise buildings seeks to reduce GHG emissions from US Buildings by 65% by 2035. Primary drivers of this reduction are retrofits and clear building standards[48]. These benefits are primarily found in the energy sector, coming from a carbon free grid and lower energy needs.

The blueprint also sets out a 25% reduction in onsite fossil fuel combustion, far greater than the 5% projected reduction in the Energy Information Administration's Annual Energy Outlook in 2023[49]. But a majority of space and water heating is expected to continue using fossil fuels, bringing no major reduction in direct emissions. Following DoE projections, an expected $65 billion in savings can be incurred (primarily through carbon reductions).

Retrofits are easy to implement as increased energy efficiency directly benefits consumers but using only electricity for heating and cooking currently offers fewer cost savings. Furthermore, electrification for these use cases is lower in high income households and commercial buildings[50] which tend produce more emissions and utilise more energy. Without increased uptake from this section of consumers, U.S. Buildings will contribute little to the energy transition and vice versa.

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[46] *Ag and Food Statistics: Charting the Essentials,* U.S. Department of Agriculture, 2023
[47] *A National Blueprint for the Buildings Sector*, U.S. Department of Energy, 2024
[48] Langevin, Aven Satre-Meloy et al. *Demand-side solutions in the US building sector could achieve deep emissions reductions and avoid over $100 billion in power sector costs*, 2023
[49] *Annual Energy Outlook 2023,* Energy Information Administration, 2023
[50] Frost, *Decarbonizing Housing: The State of US Residential Electrification,* 2024

e. Industry

The industrial sector accounts for about 23% of the GHG emissions in the United States and nearly 35% of the end-use energy consumption[51] with a large majority of this energy use coming in the form of natural gas, coal, and petroleum products. Due to the prevalence of fossil fuels in industrial process heating the sector is also a major contributor of air pollutants with an estimated 17%[52] share of PM 2.5 pollution in the USA.

The high temperatures required for some industrial processes make the sector difficult to electrify without further research. The DoE Industrial Decarbonization Roadmap lays out plans to decarbonize the major subsectors of industry: iron and steel, chemicals, food and beverage, petroleum refining, and cement, which collectively contribute more than 50% of industrial CO_2 emissions[53]. The planned reductions occur primarily through increased energy efficiency, electrification of low heat processes through heat pumps and later adoption of low carbon fuels and carbon capture.

Following the Near Zero GHG (Near Zero) Scenario from the study (which assumes aggressive electrification and CCU usage with future research), nearly 150 MTCO2 can be abated by 2035 through more efficient processes and electrification of heating. While the report does not explicitly mention the impact of the scenario on air pollutant emissions, projected energy mixes are reported for each major industry (except petroleum refineries). Adapting these energy mixes to calculate reductions in PM2.5, NOx, SO2 and VOCs (assuming renewable sources produce negligible amounts of these pollutants) adds substantially to the net savings in the sector from adopting an aggressive approach to decarbonization.

The Near Zero Scenario in the study could lead to $138 Billion in climate and pollution savings by 2035 in the cement, iron & steel and chemical industries alone. When accounting for the governments various investments into carbon capture technology and industrial electrification[54] required for this scenario, net benefits work out to around $130 Billion over the 15 year period studied.

Due to a lack of research and uncertainty in the market readiness of CCU and electrification technologies, this report will not consider other substantial subsectors within industry such as paper products etc. The DoE Industrial Roadmap utilized for calculations does not consider non-CO2 GHG emissions thus prompting the usage of the most ambitious scenario to counteract the general underrepresentation of emissions from the sector.

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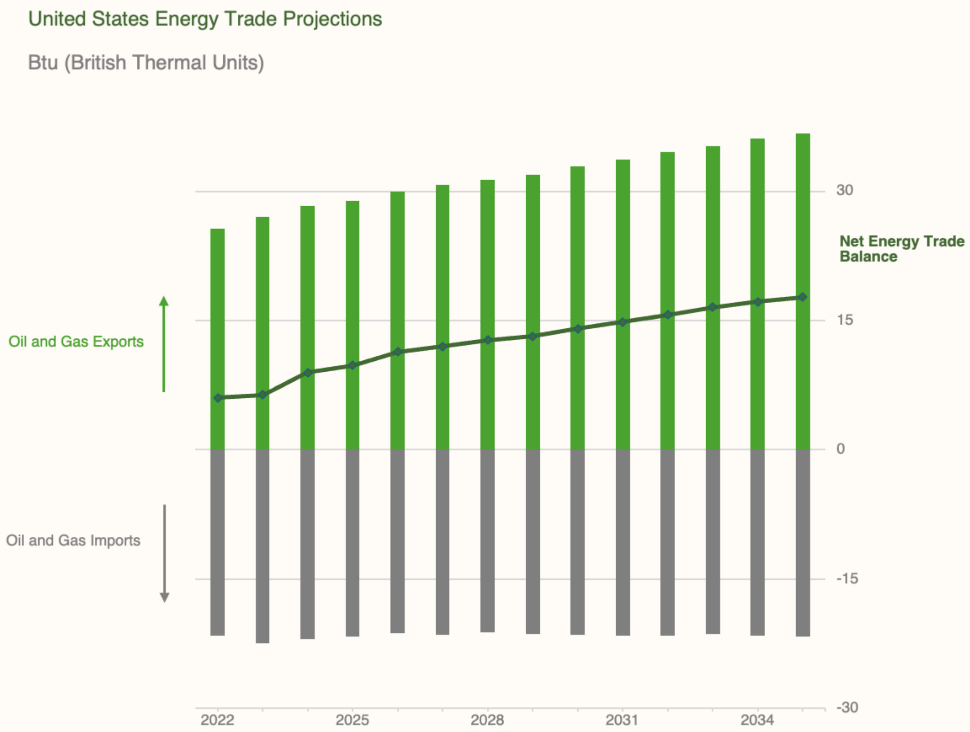
[51] *Monthly Energy Review*, Energy Information Administration, April 2024
[52] Mcduffie et al., *Source sector and fuel contributions to ambient PM2.5 and attributable mortality across multiple spatial scales*, 2021
[53] *U.S. Department of Energy's Industrial Decarbonization Roadmap*, Office of Scientific and Technical Information, 2024
[54] *Biden-Harris Administration Announces $6 Billion to Transform America's Industrial Sector, Strengthen Domestic Manufacturing, and Slash Planet-Warming Emissions*, U.S. Department of Energy, 2024

Trade balances

As a 6.3% net exporter of energy, the USA gains slightly in trade from adopting more renewables in the long run. Further investment into renewables would allow for increased energy exports through electricity as well as unused fossil fuels. Despite the overall surplus in energy, the country currently runs a net deficit in oil products. as well as electricity. Switching away from fossil fuels would shield its economy from the fluctuating prices and geopolitical risk that arise from trade in essential inputs. Figure 10 highlights the projected net balance of the USA regarding the trade of fossil fuels.

Figure 10:

America could improve its trade balance and stability with renewable energy adoption, but gains are marginal at best.



Source: USA Energy Infomation Administration 2024

Energy trade is far too dependent on the international geopolitical climate to predict accurately. The benefits from a strategic perspective can be useful but are unlikely to directly affect the average American. No quantifiable benefit from trade is considered for this study.

3. Energy transition and Income Equity?

Having quantified a net benefit of 2.4 trillion via the clean energy transition in the United States by 2035, this study will now analyse the distribution of these benefits and their impact on income equity and development outcomes.

Research has long suggested that the adverse impacts of air pollution and climate change disproportionately affect minority groups and those in the lowest portion of the income distribution (see Hallegatte et al. [55] & van den Brekel et al.[56]). A number of factors contribute to this relationship. Poor households tend to be exposed to more natural disasters and air pollution. Theories explaining this phenomenon mention the idea that climate risks may lower house prices, and the notion that poorer households are more likely to engage in manual labour, which increases their exposure to pollution.

Combined with increased exposure, these households also lack a safety net in the form of healthcare, insurance or access to credit. When a hurricane uproots a home or a family member develops asthma from poor air quality, poor households may not have the resources to ever fully recover financially. This combination of exposure bias and vulnerability bias can create poverty traps[57] as pollution and climate change get worse with time.

This highlights climate justice and the energy transition as important facets in economic development and poverty alleviation. This study will now look to quantify how much the energy transition in the United States can impact measurable development outcomes like income equality and poverty.

Climate and air pollution risk by income group

A 2018 study linked US census data on income with pollution concentrations to investigate a potential inequality in pollution exposure. By adapting this methodology to include climate change risk (alongside air pollution) and utilising 2022 data,[58] this report will estimate changes in the US income distribution associated with the previously calculated energy transition benefits.

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[55] Hallegate et al., *From Poverty to Disaster and Back: a Review of the Literature, 2020*

[56] van den Brekel et al., *Ethnic and socioeconomic inequalities in air pollution exposure: a cross-sectional analysis of nationwide individual-level data from the Netherlands*, 2024

[57] A situation in which poor households cannot escape poverty due to debt, lack of capital, poor education and healthcare amongst other factors.

[58] Note while the rest of this report utilizes 2021 prices, American Community Survey data was heavily skewed by Covid-19, thus the most recent data is chosen instead to better represent the average income distribution

IPUMs microdata[59] from 2022 provides household level data on income. As there exists no individual database for exposure to air pollution, county level estimates are used as all individuals living within a similar area are exposed to the same air quality. Average annual concentration data is compiled at the county level for PM2.5, Nitrogen oxides and Ozone[60]. For Sulphur oxides and Ammonia due to a lack of data, emissions data[61] is instead utilized as a proxy for concentration, by taking the average emissions of the gases from the 2017 and 2020 National Emissions Inventory. As annual emissions can be highly volatile, averaging across years reduces the risk of a single high pollution event skewing results.

Estimating the vulnerability of people to climate change is more complicated as this damage pathway operates through a large and unknown number of factors. It is difficult to estimate the changes in agricultural productivity, heat strokes and hurricanes in each county as well as estimate the relative contribution of each of these factors to the overall economic damage from climate change. To create a general overview of climate risk, the Climate Vulnerability Index[62] (CVI) is utilised. The CVI is a composite index of climate risk calculated using both baseline vulnerabilities and climate effects, taking the percentile risk of each county for each factor and combining these into one value. As baseline risks for this index include factors like income and insurance[63], only the climate impacts portion of the index is extrapolated to represent climate risk.

Due to the absence of energy expenditure details in American Community Survey, the distribution of calculated energy savings cannot be covered in this study. However poorer households tend to spend proportionally larger shares of their total income on energy[64], suggesting lower energy costs from renewables would help tackle energy burdens and improve equality. To offset this major benefit, energy systems costs are also dropped from this exercise as their total value is lower than projected energy cost savings.

Using this collected data, the relationships of income with air pollution exposure and climate risk can be seen below in figure 12. The overall benefit from clean energy clearly decreases in income at a statistically significant level. Furthermore, almost all of the individual exposures to each pollutant and climate risk (except for Nitrogen Oxides) follow the same pattern, suggesting that the poorer households bear a greater burden of the harms of fossil fuel usage despite consuming less. The energy transition could thus feasibly improve equity in the United States if the monetary costs of these risks are factored into the income distribution.

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[59] Ruggles, Flood, Sobek et al., *PUMS USA: Version 15.0* [data set], 2024
[60] Data is compiled from van Donkelaar et al. (2021), Goldberg et al. (2021) & Requia (2021).
[61] *National Emissions Inventory*, EPA, 2020. Assuming a majority of damage from emissions is concentrated within the county of origins.
[62] Tee Lewis et al., *Characterizing vulnerabilities to climate change across the United States*, 2023.
[63] As the data already includes income, including these would bias results by overstating the correlation between income and climate risk.
[64] Scheier & Kittner, *A measurement strategy to address disparities across household energy burdens*, 2022

Figure 12:

Lower income households in the United States gain thousands of dollars more in benefits from clean energy compared to high income households, suggesting the energy transition could combat inequality.

15-year combined benefits from energy transition policy in the United States and household income

Source: Kanou Research

Increasing income equity through the energy transition

Scaling the earlier calculating 2.4 billion in benefits to this sample, and distributing these benefits based on relative risk of each individual[65] will provide insights into how the income distribution will change by 2035. Assuming the base distribution remains similar, these benefits can be added to existing incomes to project this future income distribution seen below.

As the IPUMs data is a yearly measure, there are households with a measured income equal to zero or less (net debt) which may skew the interpretation of Gini coefficients. To prevent this these observations are dropped from both cases.

[65] This process involves separating the total benefits calculated into each risk pathway – the benefits from greenhouse gas reduction calculating using the domestic cost of carbon was scaled to the climate risk, the benefit from PM2.5 reduction was scaled to the PM2.5 exposure and so on.

Doing so shifts the whole income distribution to the right, with the median income increasingly significantly. Not only does each individual receive an average of $17,900 in benefits (or avoids $17,900 in "damages"), those near the bottom end of the distribution receive the most benefits on average.

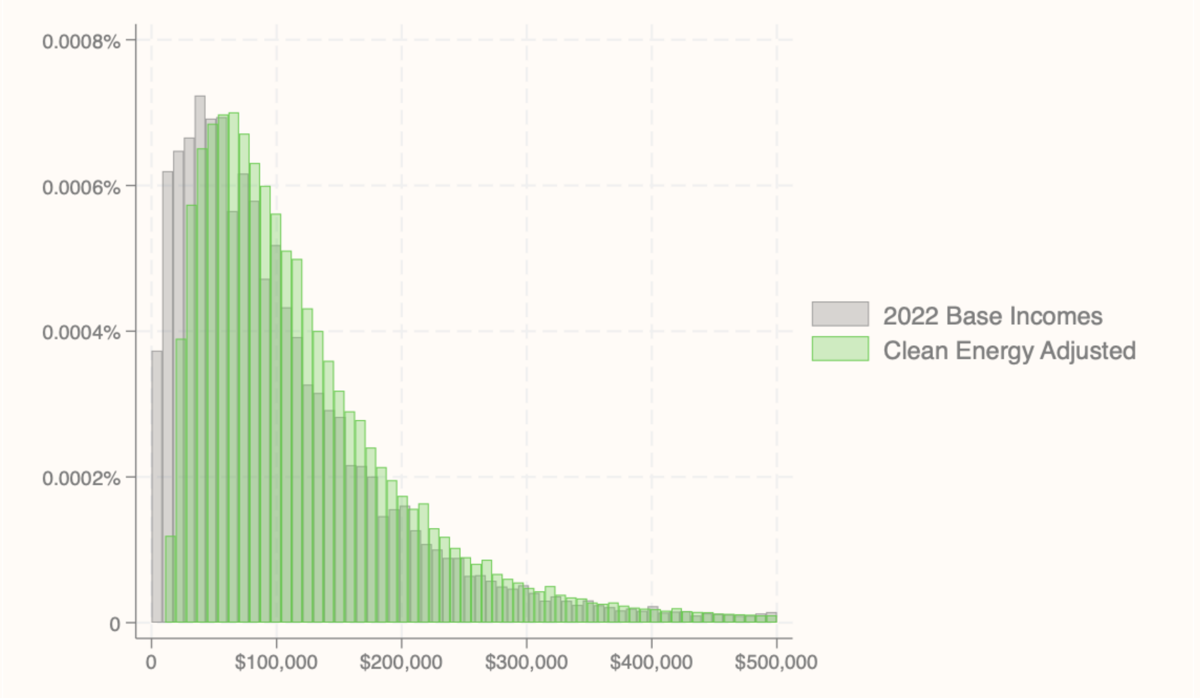
It is important to consider these results in context. The energy transition will not add 17,900 dollars to each American's bank account after 15 years. It can however save them from 17,900 dollars' worth of damages from lung disease, house repairs or funeral costs that they may face if fossil fuel use is not restricted. The clear evidence that poorer households receive higher benefits is also a promising factor which confirms the theories of many studies before.

Figure 13:

The energy transition can considerably shift the income distribution by 2035, providing upwards of $18,000 in benefits and reducing inequality.

2022 baseline & 2035 clean energy adjusted income distributions (assuming no other change from baseline)

Proportion of population (%) and Household income <500,000 ($)



Source: Kanou Research

To quantify these effects on income equality, the Gini coefficient is chosen. By comparing the distribution total income and total population by percentiles, the Gini index can be used to directly compare two different income distributions. Figures 13 and 14 highlight the differences between our baseline 2022 distribution and the distributions adjusted with climate benefits.

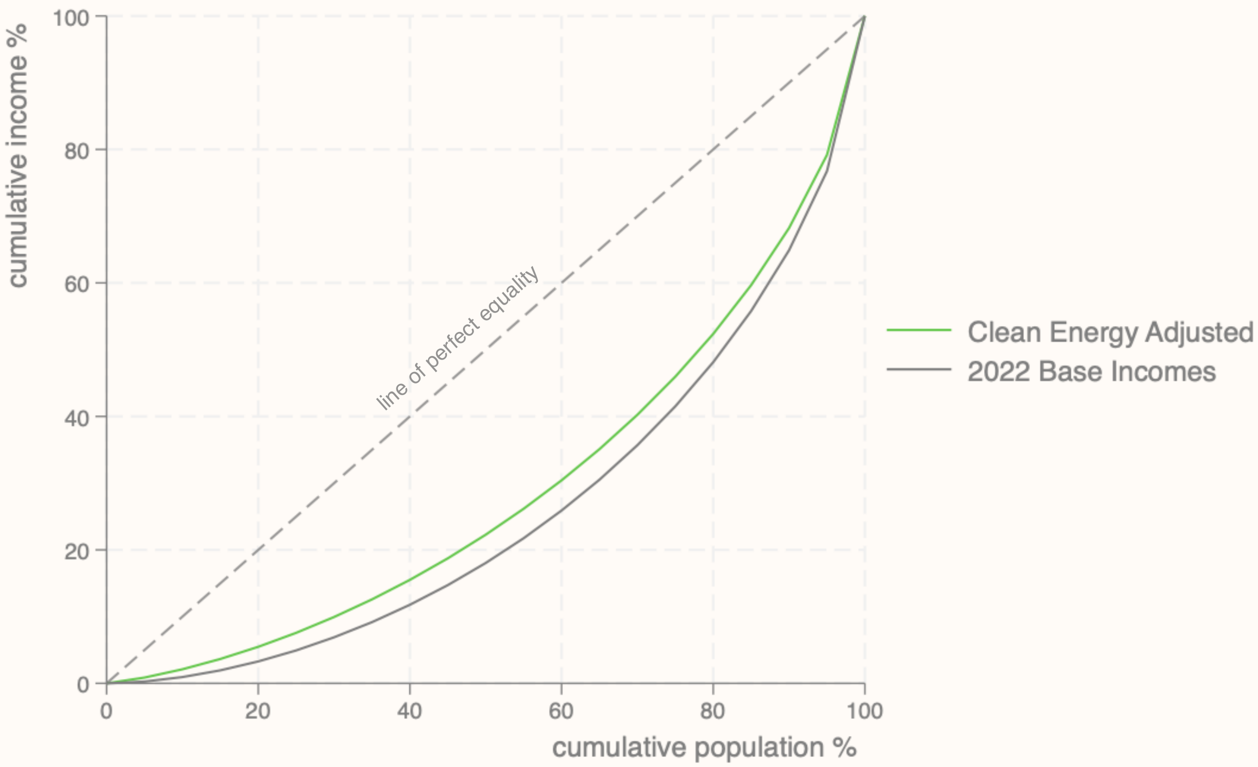
The baseline 2022 distribution yields a pre-tax Gini Coefficient of 0.4804 from around 800,000 observations. This value is very similar to the 0.488 value reported by the Census Bureau,[66] affirming the hypothesis that this dataset is a good representation of the overall American population.

The pre-tax Gini Coefficient for the adjusted distribution is 0.417, marking a sharp decline in inequality after 15 years of energy transition. Reduction is primarily driven by greatly increasing the income share of the bottom of the distribution – it can be argued these results may overstate the equity effects of the energy transition. But the point remains that the energy transition could certainly help those with near zero incomes increase their welfare greatly when compared to baseline fossil fuel use.

Figure 14:

Renewable energy could reduce the concentration of income in America, bringing income inequality down to European levels.

2022 baseline & estimated 2035 clean energy adjusted Lorenz Curves



Source: Kanou Research

[66] Guzman & Kollar, *Income in the United States: 2022*, 2023

The larger burdens of energy costs, medical bills[67] and home repairs[68] are leading factors in creating multi-generational poverty[69] - preventing households from ever leaving debt. Climate change and continued air pollution from fossil fuel use will only exacerbate these problems, as the poor continue to be disproportionately exposed to these risks. Such situations, known as poverty traps, limit upward social mobility and explain the persistence of zero income households even in developed countries with welfare programs. Whether due to new medical bills from breathing polluted air or increasing fuel costs, these households will struggle to move up the income distribution for generations without increased renewable energy uptake. Only by tackling the sources for these hardships, can the projected income distribution can be achieved.

[67] Collins, Roy & Masita, *Paying for It: How Health Care Costs and Medical Debt Are Making Americans Sicker and Poorer*, 2023
[68] Divringi, et al., *The Cost to Repair America's Housing Stock—and Which Homes Need It the Most*, 2019
[69] Balboni, Bandiera, Burgess et al., *Why Do People Stay Poor?* 2021

4. Caveats and future recommendations

Data limitations

While this study presents novel results from a large dataset, the field of climate economics is still fast evolving. To make sense of data from numerous sources, calculation requires several assumptions which may or may not hold true in time. Important inputs in this model — like the relationships between pollutant emissions and their concentration in the atmosphere or even estimated costs of carbon — are underexplored and constantly changing.

The combination of a wide range of data on air pollutant indicators, income and scaled climate indexed naturally yields itself to a level of uncertainty. Despite this, the results from this study are useful to gain an understanding of the underlying mechanism through which renewable use can impact the world. The immense magnitude of calculated benefits despite more conservative estimates of SCC and BPT suggest an observable relationship between development, equality and renewables.

With more research across climate, health and economics, this relationship can be quantified more precisely.

Global inequality

A within country analysis of climate justice in the United States has certainly highlighted the inequalities arising from non-renewable energy. Global inequality in fossil fuel usage and its impacts is at an even greater scale.

Emerging economies like China, India and Brazil will soon become the largest GHG and air pollutant emitters in the world and yet their emissions on a per capita basis are miniscule compared to wealthy countries. Developing countries also lack the infrastructure and revenue base to quickly transition away from fossil fuels, stuck to deal with issues created by the countries that industrialized before them. These countries have more poverty and inequality that may impact the distribution of clean energy benefits – perhaps even following a different trend to the United States.

Currently, conducting a cost-benefit analysis of the clean energy transition in these countries is nearly impossible due to a lack of organized data. Doing so when data becomes available is essential to understanding the future of clean energy from a development perspective.

5. Moving forward – does the world need more renewable investment

So far, this study has calculated both the scale of benefits from United States clean energy policy and the development effects of this projected energy transition.

However, while the scenarios considered are based on government plans, the true speed of transition is much slower. An independent analysis from the World Resources Institute[70] found that the current progress in the United States is insufficient to reach the goal of a carbon free energy sector by 2035. Electric vehicle uptake, international cooperation and other announced plans are similarly behind projections.

Despite the long-time horizon of renewable energy projects, this analysis demonstrates the increasingly positive impact of reducing fossil fuel usage. Official cost of carbon measures have increased more than 500% in just the last 10 years[71], suggesting that these benefits are yet underexplored and underestimated. Following this trend, the damages from traditional energy sources will continue to increase year on year while managing air pollution and global warming gets more expensive. Similar changes will likely occur for distributive effects. While households on two ends of the income spectrum may only experience a few thousand dollars of difference in damages by 2035, this gap will compound over time and intensify inequality.

To achieve the true benefits of renewable energy, the global energy transition needs to speed up. Investing more now will save more later. With most countries struggling to meet their clean energy commitments, private sector energy transition investing is crucial alongside government policy in creating sustainable economic development over the next 50 years.

[70] Lashof, *Tracking Progress: Climate Action Under the Biden Administration*, 2024
[71] Tol, *Social cost of carbon estimates have increased over time*, 2023

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