Founders Pledge

Climate Change Cause Area Report

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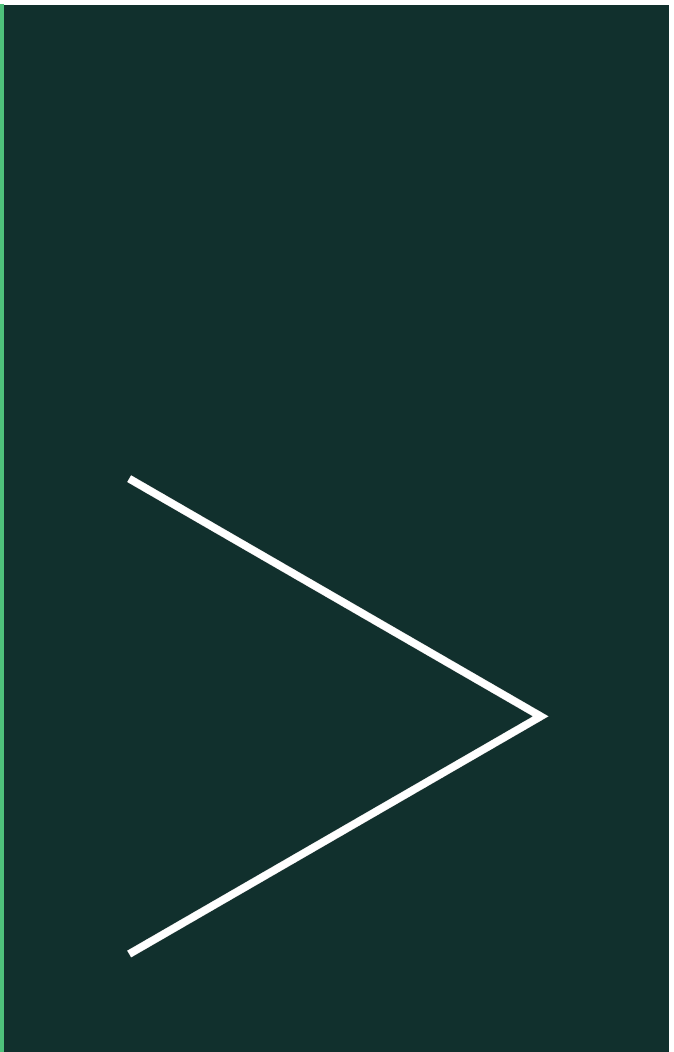

Executive Summary

Climate change is an unprecedented problem requiring unprecedented global cooperation. However, global efforts to reduce greenhouse gas emissions have failed thus far. This report discusses the science, politics, and economics of climate change, and what philanthropists can do to help improve progress on tackling climate change.

1. The climate challenge and progress so far

The first section provides an overview of the science of climate change, what needs to be done in order to avoid dangerous warming, and progress so far.

One can mark the advent of the Industrial Revolution with James Watt's patent for the steam engine in 1769. Until that point, for most of human history concentrations of carbon dioxide (CO_2) in the atmosphere had hovered around 280 parts per million (ppm). They recently passed 400 ppm for the first time in hundreds of thousands of years. This has been driven by the massive increase in deforestation and the burning of fossil fuels since the Industrial Revolution. CO_2 and other greenhouse gases, such as methane, remain in the atmosphere and trap some of the heat leaving the planet, causing global warming. The metric of CO_2-equivalent (CO_2e) expresses the warming effect of all greenhouse gases in terms of the warming effect of CO_2.

The challenge facing humanity is *not* to reduce emissions rates to a lower level: if emissions continue at a constant (even low) positive rate, atmospheric concentrations of greenhouse gas concentrations will continue to increase and so will global temperatures. Thus, we need to reach **net zero** emissions. In other words, unless we start removing CO_2 from the atmosphere, eventually there must be no emissions from power plants, industry, cars, ships, aeroplanes, or deforestation. Reaching net zero in the context of rapidly rising energy demand will be extremely challenging. Progress so far has been

poor. Emissions have increased almost unchecked since 1950, with recent increases in large part driven by China. The share of low carbon energy has barely increased in the last two decades.

Most low carbon energy is currently provided by hydroelectric power, nuclear power and sustainable biomass. The evidence suggests that *all* low carbon technologies will be needed to achieve deep decarbonisation, including the aforementioned technologies, as well as non-hydro renewables (such as solar and wind), energy storage, and carbon capture and storage.

2. Selecting interventions

The second section discusses which interventions are likely to provide the greatest impact per dollar donated. Problems that are important and tractable are likely to be more cost-effective to work on. Important problems affect a large portion of the pie of emissions. Tractable problems are easy to make progress on, on the margin. A key determinant of tractability is neglectedness, which depends on the attention a problem receives from philanthropists, governments and the private sector. Importance and neglectedness are relatively easy to quantify, and we score different interventions according to these two criteria. Having scored the interventions, we discuss whether the other factors that bear on tractability, aside from neglectedness, are strong enough to affect the overall ranking of interventions.

We evaluate and compare interventions focusing on six technologies and sectors:

1. Ensuring optimal deployment of solar and wind.
2. Ensuring optimal energy efficiency
3. Ensuring optimal deployment of nuclear power.
4. Ensuring optimal deployment of carbon capture and storage.

5. Ensuring optimal investment in low carbon technology innovation.
6. Ensuring optimal investment in preventing emissions from forestry and land use change.

We also evaluate interventions focusing on policy in four geographic areas: China, the US, India, and the EU. We conclude that carbon capture and storage, nuclear power, low carbon innovation, and forestry are the highest value sectors and technologies to work on. Advocacy for solar and wind and for energy efficiency are likely to be less cost-effective because they are not neglected. India is the highest priority geographic area, though work on the US and China is also likely to impactful.

This ranking of interventions guided our choice of recommended non-profits.

3. Charity recommendations

We have two recommendations for donors interested in climate change: the Coalition for Rainforest Nations and the Clean Air Task Force. Both organisations have an exceptional track record and we are confident that their future work will have a large impact on greenhouse gas emissions. Both organisations are engaged in political advocacy, which is difficult to evaluate but promises high leverage. This report evaluates the past counterfactual impact of each organisation at some length. Our discussion of their past counterfactual impact may be of methodological interest, as well as of substantive interest to the impact-focused philanthropist.

The Coalition for Rainforest Nations

The Coalition for Rainforest Nations (CfRN) is an intergovernmental organisation of more than 50 rainforest nations which works to promote environmental sustainability while creating opportunities for economic advancement within tropically forested developing countries. It was founded in 2004 by the Prime Minister of Papua New Guinea and the President of Costa Rica. CfRN participating countries

collaborate voluntarily in jointly developed initiatives led by the CfRN Secretariat headquartered in New York.

We believe that CfRN has had an extremely large positive impact on climate change by playing a pivotal role in establishing a global agreement on deforestation in UN climate change treaties. Beginning in 2005, CfRN launched and championed a mechanism known as Reducing Emissions from Deforestation and Forest Degradation (REDD+) in the United Nations Framework Convention on Climate Change (UNFCCC). Under REDD+, developing countries are provided with results-based compensation for preventing deforestation and degradation, and for conserving and enhancing carbon stocks.

Thanks in large part to CfRN, REDD+ was enshrined in Article 5 of the 2015 Paris Agreement. Forestry is the only sector with its own article. Having helped to establish REDD+ in global climate agreements, CfRN now focuses on consolidating and implementing REDD+, and on increasing public and private funding for REDD+.

Overall, CfRN is a unique donation opportunity because of its status as an intergovernmental organisation and its ability to leverage international forestry policy.

The Clean Air Task Force

The Clean Air Task Force (CATF) is a US-based non-government organisation which works to reduce climate and non-climate pollutants through research and analysis, public advocacy leadership, and partnership with the private sector. It was founded in 1996 with the aim of enacting federal policy reducing the air pollution caused by American coal-fired power plants. This campaign has been highly successful and has been a contributing factor to the retirement of a large portion of the US coal fleet. They have conceived and co-led numerous other successful campaigns, helping to establish CO_2

controls on the US power sector; regulations of diesel emissions; regulations of shipping emissions; and regulations of methane emissions from oil and gas production.

CATF's role in the environmental NGO ecosystem has often been to focus on sources of emissions that are neglected by other environmental NGOs, to conceive and design pragmatic campaigns to target those emissions, and to crowd in support from philanthropists and other larger environmental NGOs. CATF also produces high quality research, which is well regarded among the philanthropists, scientists, policy experts, and government bureaucrats that we have spoken to.

We have evaluated three of CATF's past projects:

1. Power Plant Campaign and Clear the Air: non-climate pollutants (1996 – 2006).
2. The Methane Partners Campaign (2000 – present).
3. Campaign for tax incentives for carbon capture and storage (2009 – present)

For all of these successful projects, CATF played a catalytic role in campaign conception, and in leading the campaigns.

CATF's current primary focus is on scaling up the rapid deployment of the low carbon technologies required for deep decarbonisation, with a particular focus on technologies that are important but neglected by environmental NGOs and governments. Overall, CATF is an outstanding organisation, which has shown the ability to achieve outsized impact on a relatively small budget.

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Acknowledgements

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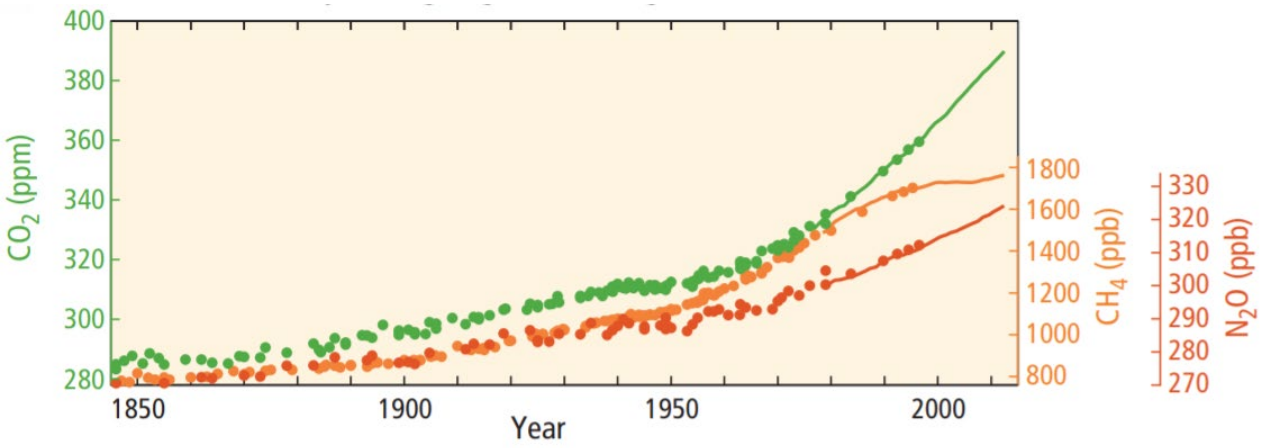
1. Overview of Climate Change

1.1. The causes of climate change

One can mark the advent of the Industrial Revolution with James Watt's patent for the steam engine in 1769. Until that point, for most of human history concentrations of carbon dioxide (CO_2) in the atmosphere had hovered around 280 parts per million (ppm).[1] They recently passed 400 ppm for the first time in hundreds of thousands of years:

Figure 1.1.

Globally averaged atmospheric greenhouse gas concentrations 1850-2014



Source: Intergovernmental Panel on Climate Change (IPCC), Synthesis Report 2014, Figure SPM.1.

Figure 1 also shows that concentrations of two other greenhouse gases, methane (CH_4) and nitrous oxide (N_20), have increased significantly. One can express the warming effect of all greenhouse gases in terms of CO_2-eqivalent (CO_2e), where 'equivalent' means "having the same warming effect over 100

[1] David MacKay, *Sustainable Energy - without the Hot Air*, 2009, 6.

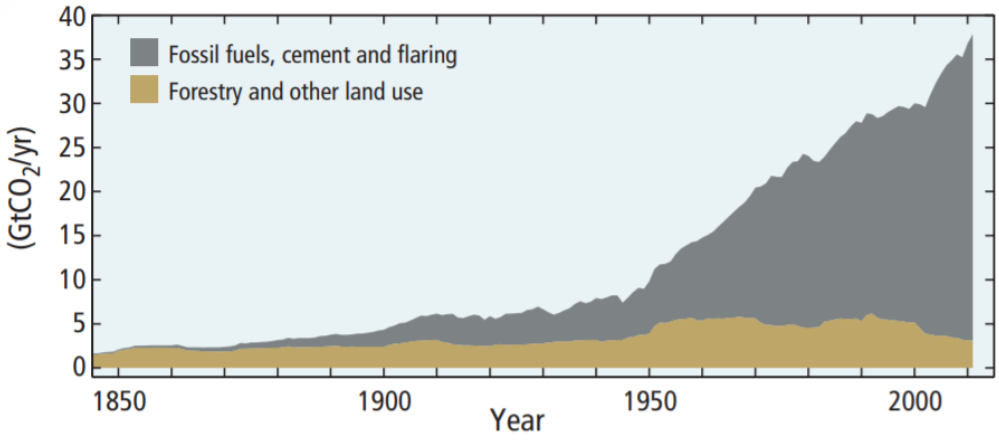
years".[2] For example, a tonne of methane causes around 28 times as much warming as a tonne of CO_2 over the course of a century, so a tonne of methane is worth 28 tonnes of CO_2e.[3] It will be useful to bear in mind the distinction between CO_2 and CO_2e in what follows.

Around two thirds of the unprecedented increase in CO_2 emissions was driven by a massive increase in the burning of fossil fuels, especially after 1950. The remaining third of the increase was driven by deforestation and changes in land use.[4]

[2] The choice of timeframe is controversial and implies a value judgement. Some greenhouse gases are much more potent over shorter timeframes. Most importantly, over the course of 20 years, methane is 87 times more potent.
[3] IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014), 87.
[4] "From 1750 to 2011, CO_2 emissions from fossil fuel combustion and cement production have released 375 [345 to 405] GtC to the atmosphere, while deforestation and other land use change are estimated to have released 180 [100 to 260] GtC. This results in cumulative anthropogenic emissions of 555 [470 to 640] GtC." Note that GtC is a Gt of carbon, which is different $GtCO_2$ – 1 GtC is equivalent to 3.667 $GtCO_2$. IPCC, *Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2013), 12.

Figure 1.2.

Global anthropogenic CO_2 emissions 1850-2014



Source: IPCC, Synthesis Report 2014, Figure SPM.1.

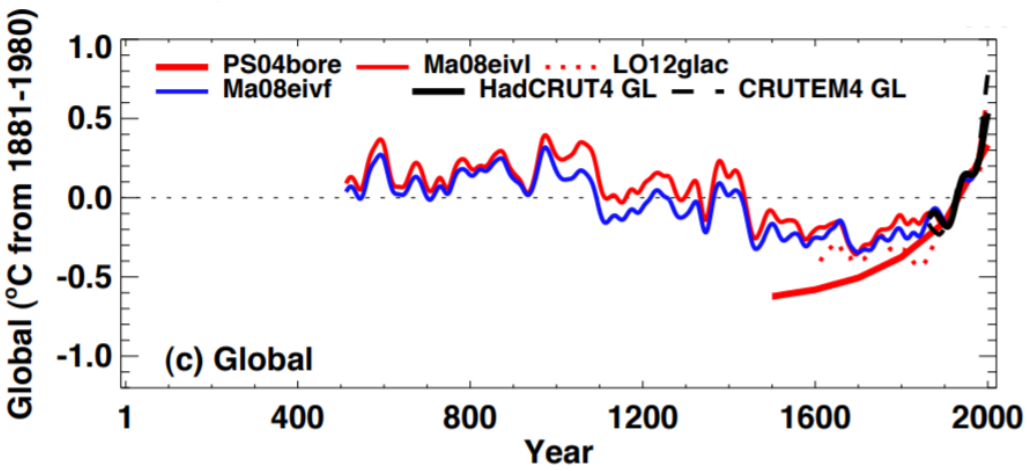
CO_2, along with other greenhouse gases such as methane, absorb heat heading out from the Earth and reemit it in a random direction; the effect of this random redirection of the atmospheric heat traffic is to return some energy to the planet causing the temperature to increase, just like a quilt.[5] So, greenhouse gases have a warming effect.

Due to an ever-stronger greenhouse effect, average temperatures have risen beyond what one would expect due to natural variation:

[5] David MacKay, *Sustainable Energy - without the Hot Air*, 10.

Figure 1.3.

Reconstructed global temperature over the last 2000 years



Source: IPCC, *The Physical Science Basis*, 2013: p. 409

The best visualisation of the magnitude and speed of recent temperature change in the context of human history is available here. Global temperatures in the past decade have been warmer than during ~75% of the last 11,300 years, known as the *Holocene*, an era in which human societies have flourished.[6] On all plausible emissions scenarios, global temperature will exceed Holocene temperatures by 2100.

[6] Shaun A. Marcott et al., "A Reconstruction of Regional and Global Temperature for the Past 11,300 Years," Science 339, no. 6124 (March 8, 2013): 1198–1201, https://doi.org/10.1126/science.1228026.

1.2. The costs of climate change

The eventual costs of climate change are dependent on:

- How large greenhouse gas emissions will be
- How much climate change they will cause
- How much damage this would do

After the Paris Agreement, political actors have tried to account for these factors with the idea of the carbon budget. This idea masks uncertainty about the eventual magnitude of warming.

The carbon budget

At the Paris Agreement, the international community agreed for the first time to limit global warming to below 2°C in 2100. To have a >66% chance of doing this, our best estimates suggest that we cannot emit more than 900 $GtCO_2e$ by the end of the century.[7] Thus, by convention, our remaining "<2°C carbon budget" is 900 $GtCO_2e$. In 2016, we emitted around 50 $GtCO_2e$. If this continues, we will use up our 2°C carbon budget by 2040.

Governments across the world have made various pledges and promises supposed to be in accordance with the <2°C goal of the Paris Agreement. Even if we take these at face value, the world will emit around 2900 $GtCO_2$ by the end of the century, more than treble the <2°C carbon budget.[8]

[7] "Limiting the warming caused by anthropogenic CO_2 emissions alone with a probability of... >66% to less than 2°C since the period 1861–1880, will require cumulative CO_2 emissions from all anthropogenic sources to stay between... 0 and about 1000 GtC (3670 $GtCO_2$) since that period... *These upper amounts are reduced to... 790 GtC (2900 $GtCO_2$), respectively, when accounting for non-CO2 forcings* as in RCP2.6." (Emphasis added). A 'forcing' is a warming or cooling effect. IPCC, *Climate Change: The Physical Science Basis*, 27.

[8] Joeri Rogelj et al., "Paris Agreement Climate Proposals Need a Boost to Keep Warming Well below 2 °C," *Nature* 534, no. 7609 (June 30, 2016): 635, https://doi.org/10.1038/nature18307.

Catastrophic risk

Although widely accepted in political agreements about climate change, the idea of the 'carbon budget' masks significant uncertainty. It only tells us the amount of greenhouse gases we can emit to have a 66% chance of staying below a certain threshold, which still leaves a sizeable **34% chance** of exceeding that threshold: greater than the ex ante chance of Donald Trump winning the 2016 US election.[9]

On the 'pledges and promises' trajectory mentioned above, we will *probably* end up with around 3°C of warming by 2100. But according to some IPCC models, we will also be left with a worryingly high **~8% chance of >6°C** of *eventual* warming.[10] This probability would continue to increase as emissions increase beyond 2100. Warming of this magnitude would be catastrophic. It would, for example, render most of the tropics almost uninhabitable and lead to enormous agricultural disruption.

How much damage would warming do?

Under most emissions scenarios, global warming is likely to impose substantial costs on human society. The costs are unevenly distributed and most likely to fall on the global poor due to their geographical location and their relatively low standard of living. Sea level is expected to rise by half a metre to a metre by 2100 and continue to rise beyond that, threatening coastal cities and island nations.[11] Perhaps the most serious threat to human welfare posed by climate change is that it would dry out dry areas and increase precipitation in wet areas, thereby reducing agricultural productivity.[12]

[9] https://projects.fivethirtyeight.com/2016-election-forecast/
[10] Gernot Wagner and Martin L. Weitzman, *Climate Shock: The Economic Consequences of a Hotter Planet* (Princeton: Princeton University Press, 2015), 54.
[11] IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Summary for Policymakers* (Cambridge University Press, 2014), 63.
[12] IPCC, *Climate Change Synthesis Report*, 69.

The impacts of warming of >4°C are understudied, which is surprising given the probability of this level of warming by 2100 (>10% on current pledges and promises). As discussed, warming of >4°C would likely render much of the tropics uninhabitable, and would lead to multi-metre sea level rise over the course of millennia.[13] All of these changes could in turn severely destabilise the global political order. Unprecedented mass migration could be an especially important driver of political conflict.

1.3. The climate challenge: net zero

The crucial point to realise about climate change is that the challenge is to get to **net zero emissions**; it is *not* to stabilise emissions rates or cut the rate of emissions to a lower but still positive level. Because the warming effect of CO_2 persists for 1,000 years after it is emitted,[14] if emissions are positive *to any extent*, atmospheric concentrations will continue to rise. In this way, the atmosphere is like a bathtub. Simplifying the system a great deal: there are two taps – one for natural emissions and one for man-made emissions – and a drain – the planet's ability to absorb that pollution in the oceans, forests and so on.[15] When the man-made emissions tap is switched off, the flows from the natural emissions tap and the drain are almost exactly in balance. However, when the man-made emissions tap is switched on, the bathtub fills up. This is true even if man-made emissions are stabilised at a constant level and even if that constant level is very low. Thus, to stop atmospheric concentrations from rising, the tap needs to be switched off completely – man-made emissions need to be reduced to *net zero*.

[13] David King et al., "Climate Change–a Risk Assessment" (Centre for Science Policy, University of Cambridge, 2015), www.csap.cam.ac.uk/projects/climate-change-risk-assessment/; Peter U. Clark et al., "Consequences of Twenty-First-Century Policy for Multi-Millennial Climate and Sea-Level Change," *Nature Climate Change* advance online publication (February 8, 2016), https://doi.org/10.1038/nclimate2923.
[14] Susan Solomon et al., "Irreversible Climate Change due to Carbon Dioxide Emissions," *Proceedings of the National Academy of Sciences* 106, no. 6 (February 10, 2009): 1704–9, https://doi.org/10.1073/pnas.0812721106.
[15] Wagner and Weitzman, *Climate Shock*, 15.

In other words: unless we go through the probably very expensive process of removing CO_2 from the atmosphere, all emissions from power plants, industry, cars, trucks, planes, ships and deforestation need to be stopped completely.

By 2050, in order to avoid very bad climate outcomes, energy-related emissions must be reduced by 50-90%: there must be deep decarbonisation of our energy system.[16] Over this period, the global population is expected to grow by two to three billion. In 2016, >1.2 billion people had no access to electricity.[17] As these people escape poverty, their energy demand is sure to grow significantly, along with the energy demand of billions of others. Due to these factors, global energy demand is projected to increase by 50% or more by 2050.[18] Reaching net zero in this context will be extremely challenging.

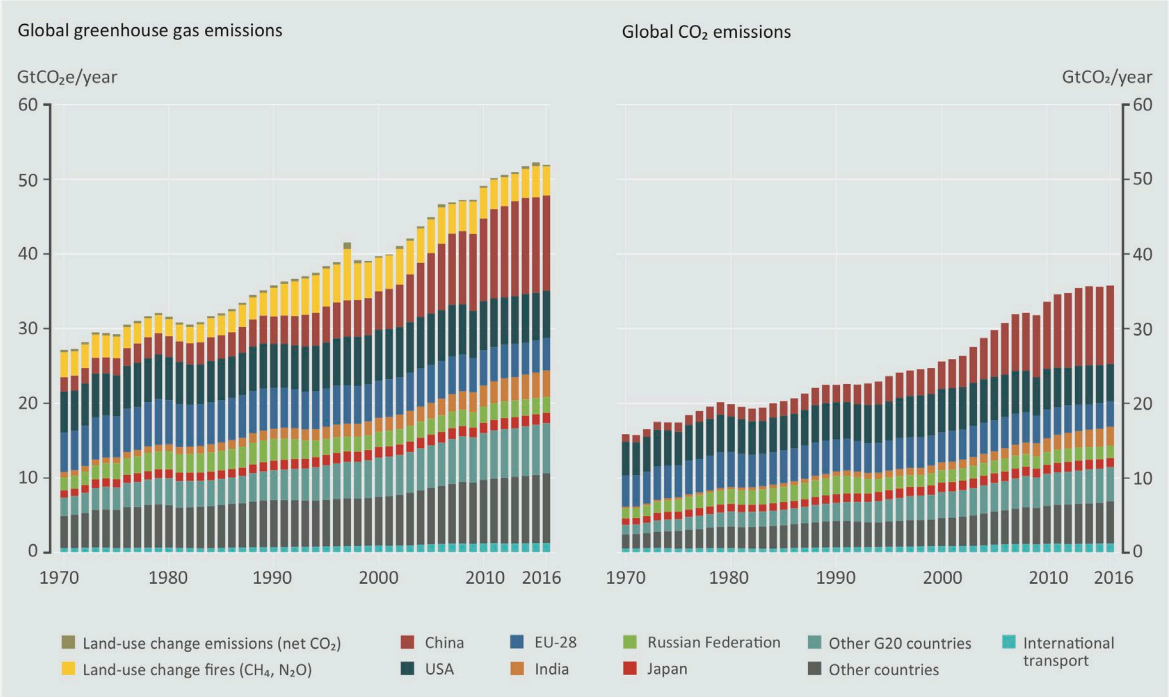
The geographical distribution of emissions

Over the last two decades, there has been an enormous increase in emissions mainly driven by China and land use change:

[16] "A variety of recent studies conclude that avoiding extreme climate change outcomes may require near-total decarbonization of the world's energy system during this century, with 50–90% reductions in energy-related CO_2 emissions required by 2050." Peter J. Loftus et al., "A Critical Review of Global Decarbonization Scenarios: What Do They Tell Us about Feasibility?," *Wiley Interdisciplinary Reviews: Climate Change* 6, no. 1 (January 1, 2015): 93, https://doi.org/10.1002/wcc.324.
[17] B. P. Heard et al., "Burden of Proof: A Comprehensive Review of the Feasibility of 100% Renewable-Electricity Systems," *Renewable and Sustainable Energy Reviews* 76 (September 1, 2017): 1124, https://doi.org/10.1016/j.rser.2017.03.114.
[18] "We calculated the median of all 28 scenarios in ten-year steps from 2000. Primary energy consumption in 2050 for the scenarios ranges from 535 EJ for the US Climate Change Science Program IGSM Level 1 scenario (1.2% below the actual primary energy consumption figure for 2014) to 1431 EJ (165% above 2014 actual primary energy). The median is 805 EJ (+49% above 2014)." An EJ is an Exajoule – one quintillion joules. Global primary energy demand is currently around 550 EJ. Heard et al., 1125–26.

Figure 1.4.

All greenhouse gas emissions (left), only CO_2 emissions (right) since 1970



Source: United Nations Environment Programme, The Emissions Gap Report 2017, p.4.

Although emissions stabilised between 2014 and 2016, they increased again in 2017.[19] As Figure 1.4 illustrates, China, the US, the EU, and India currently produce the majority of CO_2e emissions. Emissions per head tend to be much higher in rich countries than poor countries. Monthly emissions per head in rich countries are usually higher than the yearly emissions per head in poorer countries.[20]

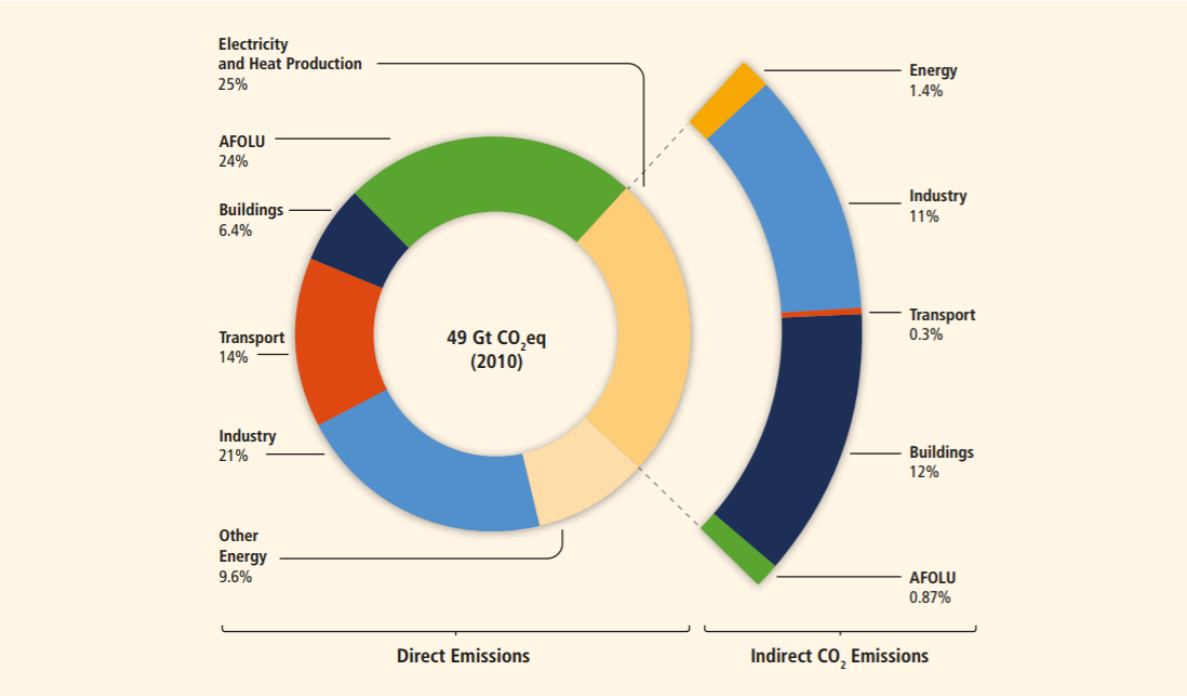
[19] https://www.cicero.uio.no/no/posts/klima/global-co2-emissions-likely-to-rise-in-2017
[20] https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

The sectoral distribution of emissions

It is also useful to consider the sectoral sources of emissions. Electricity is just one contributor to emissions among others. Coal and gas plants produce electricity that powers our homes and industries, and emits CO2 in the process, but there are other major energy-based contributors to emissions that do not stem from electricity use, such as oil for transport, and the production of industrial heat for goods such as cement and steel. In addition to energy-based emissions, the emissions from agriculture and deforestation are also substantial. Figure 1.5 breaks down the sources of emissions into different sectors – at present electricity and heat contributes only 25% of global emissions.

Figure 1.5.

Greenhouse gas emissions by sectors. (AFOLU = agriculture, forestry and other land use)



Source: IPCC, Mitigation of Climate Change 2014, p.9.

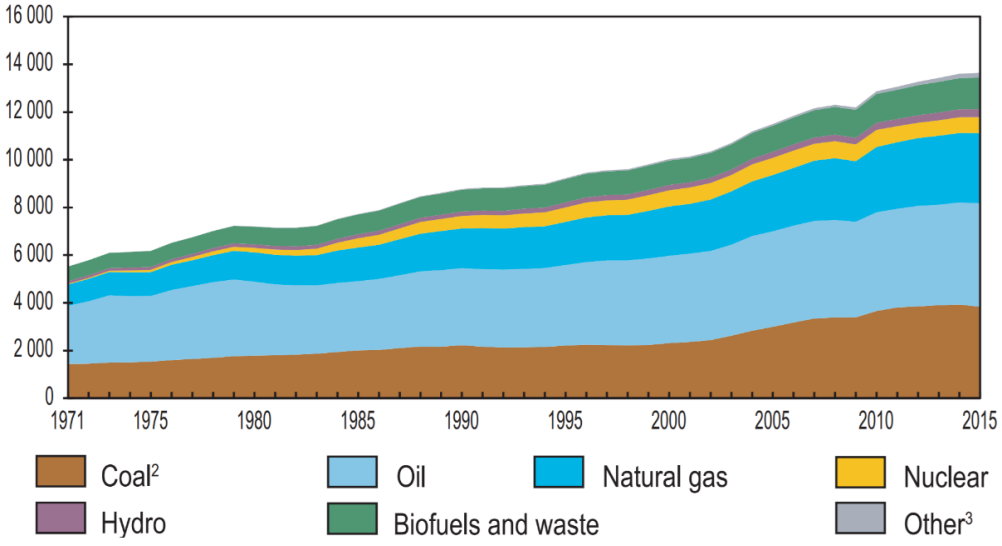
The electricity sector will be the easiest to decarbonise. Once electricity is decarbonised, it would then make sense to electrify transport and industry extensively. However, large portions of some of these sectors, including parts of industry, heavy duty transport, and air travel cannot be electrified. In these sectors, we need to explore options outside electrification.

1.4. Deep decarbonisation: progress so far and future prospects

Throughout recent history, fossil fuels have dominated global energy production:

Figure 1.6.

World total primary energy supply from 1971 to 2015 by fuel (million tonnes of oil equivalent)



Source: IEA, Key World Energy Statistics, 2017, 6

Figure 1.6 illustrates two notable points. Firstly, global climate policy has thus far been a failure. The share of low carbon energy (nuclear, hydro, some biofuels, and 'other') has barely increased over the last two decades. Secondly, solar and wind energy (included in 'other') at present supply only a tiny fraction of global energy. They will certainly provide a greater share in the future, but it is important to be clear on progress to date.

This being said, the historical record at least suggests that decarbonised electricity (not entire energy) systems are possible, as demonstrated by:

- Countries or regions with enough hydroelectric or geothermal power to cover their needs (e.g. Norway, Iceland, Uruguay, southern parts of Brazil, regions of Canada, south island of New Zealand, etc).
- Countries or regions reliant on nuclear power (Ontario, France, and Sweden).

For data on the technology mix in electricity supply across the world, see this interactive map.

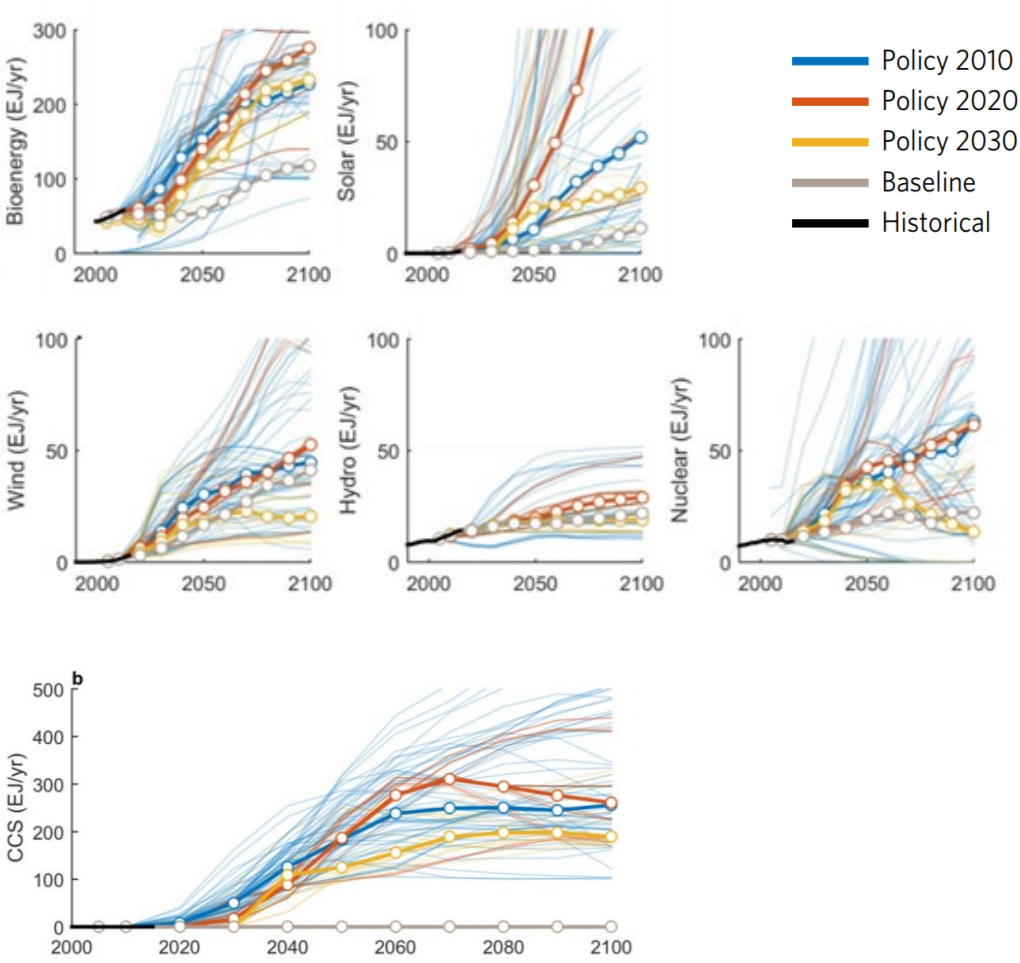
Hydroelectric and geothermal power are not a scalable or viable solution for most countries.[21] Consequently, countries need to explore other low carbon technologies. Those available at present are: non-hydro renewables (solar and wind power), some biofuels, nuclear power, and fossil fuels with carbon capture and storage. Each of these technologies has advantages and disadvantages. In our view, the evidence strongly suggests that *all* low carbon technologies will be necessary for deep decarbonisation at reasonable cost.[22]

IPCC integrated assessment models have been used to assess the role of different technologies in future energy systems under specific emissions budgets and cost constraints. According to these models, all low carbon technologies must scale up rapidly over the next thirty years if we are to meet our climate targets. Figure 1.7 shows the increase in energy supplied by various technologies in scenarios compatible with staying within our 2°C carbon budget within economic constraints.

[21] One possible exception to this is advanced geothermal, which is geographically ubiquitous but has not yet been explored.
[22] Loftus et al., "A Critical Review of Global Decarbonization Scenarios"; Heard et al., "Burden of Proof"; Jesse Jenkins and Samuel Thernstrom, "Deep Decarbonization of the Electric Power Sector: Insights from Recent Literature" (Energy Innovation Reform Project, March 2017).

Figure 1.7.

The role of different energy technologies in global energy systems compatible with a decent chance of staying below 2°C, for policy starting in 2010, 2020 and 2030.



Source: Peters et al, "Key indicators to track current progress and future ambition of the Paris Agreement", *Nature Climate Change*, 2017: Supplementary Information, pp. 6-7.[23]

[23] Bioenergy plays such a prominent role because almost all IPCC models assume massive future deployment of bioenergy with carbon capture and storage (BECCS). Deployment of BECCS on the scale required is extremely implausible. See Sabine Fuss et al., "Betting on Negative Emissions," *Nature Climate Change* 4, no. 10 (October 2014): 850–53, https://doi.org/10.1038/nclimate2392; Phil Williamson, "Emissions Reduction: Scrutinize CO2 Removal Methods," *Nature* 530, no. 7589 (February 10, 2016): 153–55, https://doi.org/10.1038/530153a.

These models are of course somewhat crude and aggregated, but they nevertheless indicate that, according to the scientific consensus at the moment, all low carbon technologies must be scaled up enormously if we are to decarbonise fast enough to have a decent chance of staying below 2°C.

With the background on climate change clarified, we can now look at what philanthropists can do to help improve progress on reaching net zero.

2. Interventions: What Works?

Experience with renewables deployment advocacy suggests that carefully deployed philanthropic money can have a large impact on climate policy. The challenge for the philanthropist is choosing where to direct their donations. This is a difficult decision because climate change is a hugely complicated problem, and there are many diverse options available. Some possible interventions include:

- Advocacy for renewable energy subsidies
- Advocacy for subsidies for other low carbon technology
- Advocacy for a carbon tax
- Research into solar geoengineering
- Direct funding of R&D into low carbon energy
- Advocacy for R&D into low carbon energy
- Funding direct forest conservation projects
- Advocacy for forest conservation in Brazil and Indonesia
- Etc.

In this chapter, we present a formal quantified framework to help select between different interventions within climate change. Interventions that are *important*, *neglected*, and *tractable* are likely to be more cost-effective to support. This framework is especially useful when we lack direct information on cost-effectiveness.

Readers wishing to skip the methodological discussion should skip straight to section 2.3. Applying the ITN framework to climate change interventions. Readers wishing to skip to the final selection of interventions should skip straight to section 2.3.2. Final intervention selection for technologies and sectors.

2.1. The Importance, Tractability, and Neglectedness framework

In this section, we will set out a quantified version of the Importance, Neglectedness and Tractability (ITN) framework. Quantification of these factors is important because it protects against the intuitive bias of scope neglect, incentivises evidence gathering, and clarifies the source of disagreements.

Background for the ITN framework

Ultimately, we care about marginal cost-effectiveness, which is a product of importance and tractability, defined in the following way:

Importance = Good done / % of problem solved

Marginal tractability = % of problem solved / marginal dollar

More informally, importance concerns how good it would be to solve the problem, whereas tractability concerns how much of the problem is solved for an additional unit of resources. Neglected problems are those that receive few resources or attention. Defined in this way, *neglectedness only matters insofar as it affects tractability*. Neglected problems are likely to be more tractable because they have not yet reached diminishing returns; for problems that already receive a large amount of money, the 'low-hanging fruit' may already have been taken. It is useful to evaluate neglectedness separately from the other factors bearing on tractability because neglectedness is much easier to quantify. The most uncertain part of any ITN analysis is the assessment of the other factors, aside from neglectedness, that bear on tractability.

Our scoring process proceeds in three phases. Firstly, we produce the scores on importance and neglectedness. We then aggregate the scores to get the ratio of (importance of the problem)/(current spending on the problem). This is indicative of how promising a cause area is.

As we will see, candidate climate change interventions vary by a factor of ten or more in terms of these criteria. For example, non-philanthropic spending on renewables is around 20 times greater than spending on forestry. When the numbers differ by this much, it is easier to use a logarithmic scale to rate each component.[24] We can structure the scoring such that every two points we add to a problem means that it is 2x more important or neglected. For instance, if we give one problem a neglectedness score of 4 and another of 6, then we mean the second one is 2 times more neglected. Using a logarithmic scale for each component also means that rather than having to multiply importance and neglectedness we can simply add them together. This is because log(AB) = log(A) + log(B).

Having completed the second phase, we proceed to assess the other factors, aside from neglectedness, that bear on tractability.

Assessing importance

> *Definition*: If we solved this problem how much would the impact of climate change be reduced, or what would be the effect on greenhouse gas emissions?

Other things equal, it is better to work on interventions that affect a larger slice of the pie of emissions. For instance, should we focus on unplugging our phone chargers or driving less? All the energy saved by unplugging one's phone charger for a day is used up in *one second* of car driving.[25] This suggests that focusing on reducing driving would be more impactful, other things equal.

We will use the following rubric to quantify the scope of the impact of different interventions on greenhouse gas emissions until 2050. As we will see, the scope of the impact of some interventions

[24] 80,000 Hours, "How to Compare Different Global Problems in Terms of Impact," 80,000 Hours, accessed December 20, 2017, https://80000hours.org/articles/problem-framework/.
[25] David MacKay, *Sustainable Energy - without the Hot Air*, 68.

differs by more than a factor of four. So, it will be useful to use a logarithmic scale such that every two points counts for a doubling of cumulative emissions averted.

Points	If we solved the problem, how good would it be in terms of GtCO2e?
12	512 GtCO2e
10	256 GtCO2e
8	128 GtCO2e
6	64 GtCO2e
4	32 GtCO2e
2	16 GtCO2e

To put these numbers in context, on current policies, average annual emissions until 2050 are projected to be around 55Gt of CO_2e,[26] implying cumulative emissions of (30*55) = 1,650GtCO_2e.

We focus on the emissions until 2050 for several reasons. It is important to focus on emissions not just next year but in the next few decades because emissions until 2050 obviously comprise a greater share of eventual cumulative emissions. It therefore makes sense to focus on the effect interventions will have over this timeframe. Ideally, we would estimate the effect of interventions on all future emissions, and not just those to 2050. However, this would make the projections involved in estimating importance, tractability and neglectedness considerably more uncertain. Moreover, relevant data for the 2050 time horizon is more easily available. In addition, we do not believe that focusing on the 100 year timeframe would affect which interventions we chose to investigate further.

[26] http://climateactiontracker.org/global.html

Assessing neglectedness

> *Definition*: How many resources currently are or have previously gone towards solving the problem?

Importance isn't all that matters. A problem could be very important but already receive enormous amounts of resources. If so, it is likely that we will have reached diminishing returns, and the best opportunities to do good have already been taken.[27] This is another way of saying that neglected problems are likely to be more tractable, on the margin.

We believe that, from the point of view of the philanthropist, special weight should be given to *philanthropic* neglectedness, as opposed to government or private neglectedness. This is because there are some activities that philanthropists can carry out, but governments and others cannot, such as political advocacy. If an intervention is philanthropically neglected, there is more scope for successful philanthropic campaigns on that intervention.

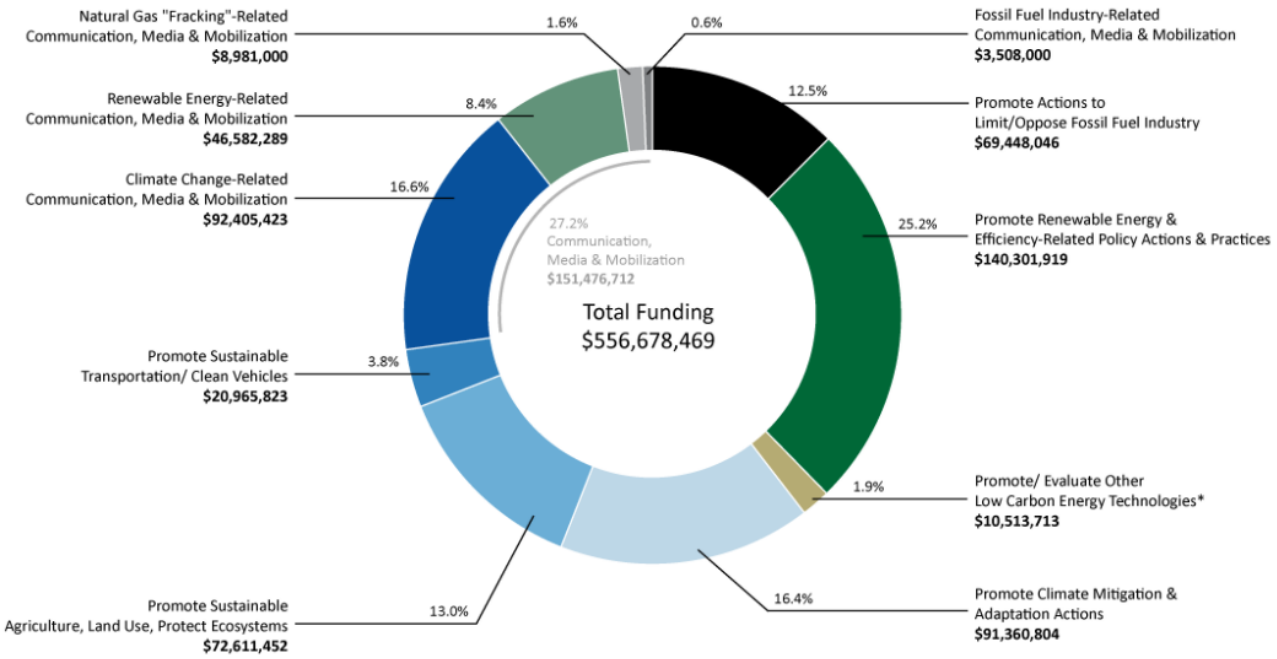
This suggests that there is a case for giving special weight to philanthropic neglectedness when one is assessing the effectiveness of philanthropic spending. One way to capture this is to provide an independent score for philanthropic and non-philanthropic neglectedness and give a weighting to the scores on philanthropic and non-philanthropic neglectedness.

Data on philanthropic support for different interventions is limited. The best data source we have found is from Nisbet (forthcoming), which reviews spending on climate and energy from 19 major US philanthropies from 2011-15. Nisbet provides the following pie chart on philanthropic spending by 17 major US philanthropists on climate and energy from 2011-2015:

[27] This is assuming that the money has been spent in a roughly rational way.

Figure 2.1.

Spending on climate and energy by 19 major US philanthropists from 2011-15



Source: Matthew C. Nisbet, (forthcoming) 'Strategic Philanthropy in the Post Cap-and-Trade Years: Reviewing U.S. Climate and Energy Foundation Funding', Wiley Interdisciplinary Reviews Climate Change

The note accompanying the chart states:

> "Based on analysis of 2,502 publicly reported grants available as of Spring/Summer 2016 which were distributed between 2011 and 2015 by 19 major environmental grant makers totalling $556,678,469. *Low carbon energy technologies include funding to make natural gas generation cleaner/safer ($8.3 million); to evaluate carbon capture and storage ($1.3 million); and to promote the role of government in fostering innovation ($673,000). No grants were

focused on promoting nuclear energy, though $175,000 in grants were devoted to opposing nuclear energy for cost and safety reasons."[28]

This data only tells us about spending among some US philanthropists, but we think that it is likely to be broadly representative of global philanthropic spending on climate. Here, neglectedness is scored using the data from Nisbet (forthcoming). It should be borne in mind that this is not an estimate of total global philanthropic spending on different interventions.

We can therefore use the following rubric to measure philanthropic neglectedness:

Points	How many philanthropic resources are already going to this problem
16	$2m
14	$4m
12	$8m
10	$16m
8	$32m
6	$64m
4	$128m
2	$256m

Non-philanthropic neglectedness is also relevant to how much progress philanthropic campaigns are likely to make. If an area already receives very large amounts of government or private money, then

[28] Matthew C. Nisbet, "Strategic Philanthropy in the Post Cap-and-Trade Years: Reviewing U.S. Climate and Energy Foundation Funding. Working Paper" (Boston, MA; Northeastern University, 2018).

there will be diminishing returns to government or private spending. Since philanthropic money usually has impact by affecting government or private spending, this suggests that there will also be diminishing returns to philanthropic spending on these areas.

It is much easier to get data on non-philanthropic neglectedness, including government and commercial spending. According to the United Nations Biennial Assessment and Overview of Climate Finance (UN BA), total global climate finance in 2014 was $930bn.[29]

We can therefore use the following rubric to measure non-philanthropic neglectedness:

Points	How many philanthropic resources are already going to this problem
16	$4bn
14	$8bn
12	$16bn
10	$32bn
8	$64bn
6	$128bn
4	$256bn
2	$512bn

[29] UNFCCC Standing Committee on Finance, "Biennial Assessment and Overview of Climate Finance Flows," 2016, 56, http://unfccc.int/cooperation_and_support/financial_mechanism/standing_committee/items/10028.php.

Aggregating the scores so far

As discussed earlier, because these rubrics use a logarithmic scale, we can add together the scores an intervention receives on each one. We assume here that philanthropic neglectedness and non-philanthropic neglectedness should receive equal weight when determining tractability. This is potentially controversial, though we do not believe that other plausible rankings would affect the overall ranking of interventions.

Suppose an intervention would avert 128Gt of CO_2e, receives $8m from philanthropists, and $128bn from governments and the private sector. In that case, the intervention would receive (8 + 0.5*(4 + 6)) = 13 points. This score tells us how much money is going into the problem relative to its importance: an important problem that receives no money would score highly, whereas a trivial problem that receives enormous amounts of money would score poorly. If intervention A receives a combined score 2 points greater than intervention B, this indicates that intervention B should receive twice as much money (provided there are not other factors that make it intractable on the margin (aside from neglectedness)).

There is uncertainty about importance and neglectedness, as well as about the other factors bearing on tractability. It is therefore best to use a margin for error to help select between scored interventions. We think uncertainty about importance would drive most of the uncertainty about the quantified scores. With respect to climate change interventions, we would not usually expect the importance estimate to be wrong by a factor of two in either direction, suggesting the margin for error should be ±4 points. There is also uncertainty about neglectedness, though we believe uncertainty here is lower and that this justifies adding a further two points to the margin for error. Thus, we think a reasonable margin for error is ±6 points.

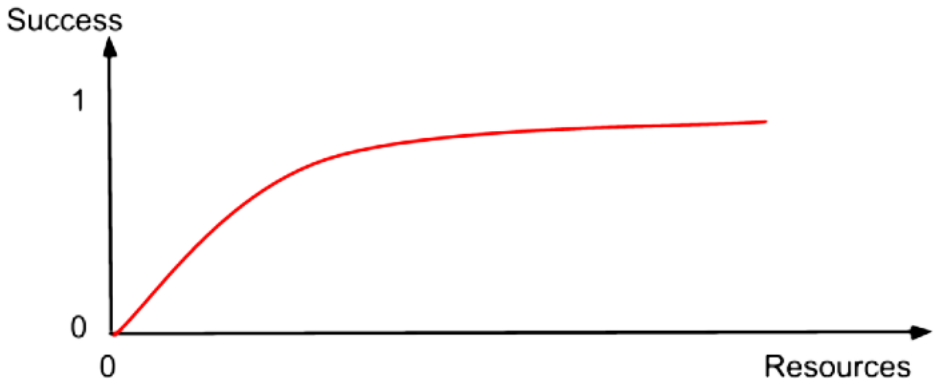
Assessing other factors that bear on tractability

Neglectedness is not the only factor that affects tractability. The invention of a perpetual motion machine would be extremely valuable and is very neglected, but also appears to be impossible. Therefore, extra work on this problem is unlikely to be valuable. Thus, other factors aside from neglectedness also bear on tractability.

These other factors determine the shape of the 'returns to philanthropic investment' curve. When there are diminishing marginal returns, the returns curve will look roughly like Figure 2.2.

Figure 2.2.

Diminishing marginal returns to investment



The importance metric tells us how good it is to move up the y-axis, that is, how good it is to solve a percentage of the problem. Neglectedness tells us where we are on the x-axis – it tells us how many resources have already gone into a problem. What we don't know at this stage is the shape of the returns curve. To know this, we would need to have direct information about marginal cost-

effectiveness. Since we lack this information, at this stage it makes more sense to use reasonable heuristics to help narrow down interventions.

Once we have taken the 6 point margin for error into account, the question we need to ask is: are the other factors that affect marginal tractability significant enough to justify investigating a lower scoring intervention further? Several factors bear on the tractability of climate change interventions, including:

- The financial cost to the government of spending money on the problem
- The degree of political support for and opposition to an intervention
- The quality of alternatives to the interventions

To avoid double-counting neglectedness, we need to 'control for' neglectedness when assessing the other factors that affect tractability.[30] Suppose we are comparing two interventions which are equally important, but intervention A receives $100m and intervention B receives $5m. If we asked how easy it would be to make progress on each problem given their current level of neglectedness, we would be double counting the diminishing marginal returns consideration. Thus, when assessing the other factors bearing on tractability, we need to ask: if intervention A and B both received $5m from other actors, would it be easier to make progress on A rather than B by spending additional resources on A and B? If we answer 'no', then B is a more cost-effective problem to work on: there is no reason to think that the other factors bearing on tractability are significant enough to overcome B's superiority in terms of *importance*neglectedness*.

[30] Robert Wiblin, "The Important/Neglected/Tractable Framework Needs to Be Applied with Care," Effective Altruism Forum, January 2016, http://effective-altruism.com/ea/ss/the_importantneglectedtractable_framework_needs/.

The other factors bearing on tractability are much more difficult to quantify than neglectedness. Ultimately, we need to make a judgement call about whether the other factors bearing on tractability are significant enough to overcome large and robust difference in terms of *importance* **neglectedness*.

Collated ITN Tables

For the reader's convenience, the ITN rubrics are collected below:

Importance

Points	If we solved the problem, how good would it be in terms of GtCO2e?
12	512 GtCO2e
10	256 GtCO2e
8	128 GtCO2e
6	64 GtCO2e
4	32 GtCO2e
2	16 GtCO2e

Philanthropic neglectedness

Points	How many philanthropic resources are already going to this problem[31]
16	$2m
14	$4m
12	$8m
10	$16m
8	$32m
6	$64m
4	$128m
2	$256m

[31] According to Nisbet (forthcoming)

Non-philanthropic neglectedness

Points	How many non-philanthropic resources are already going to this problem?
16	$4bn
14	$8bn
12	$16bn
10	$32bn
8	$64bn
6	$128bn
4	$256bn
2	$512bn

2.2. Applying the ITN framework to climate change interventions

Having set out the ITN framework, we can now apply it to different candidate interventions within climate change. We will divide possible interventions into two categories: firstly, those that target specific technologies and sectors, and secondly those that target policy in particular countries and regions. These interventions are cross-cutting: one could target particular technologies and sectors in particular countries. Readers wishing to skip straight to the final scores should go straight to section 2.3.2. Final intervention selection for technologies and sectors.

Guided by the 2014 IPCC mitigation book, and other climate policy papers, we have decided to evaluate the following interventions. (We discuss other possible interventions and why they are not evaluated here in Appendix 5. Other Possible Interventions).

1. Ensuring optimal deployment of solar and wind energy
2. Ensuring optimal energy efficiency
3. Ensuring optimal deployment of nuclear energy
4. Ensuring optimal deployment of carbon capture and storage[32]
5. Ensuring optimal investment in low carbon technology innovation
6. Ensuring optimal investment in preventing emissions from forestry and other land use

With respect to particular geographies, we discuss the countries and regions that will produce the greatest amount of emissions from now until 2050.

7. Climate policy in China
8. Climate policy in the United States
9. Climate policy in the EU
10. Climate policy in India

The intervention assessments of these countries and regions are comparable to one another, but due to lack of data, they are not comparable to the intervention assessments of the technologies and sectors.

Most of these interventions can only be approached in a very indirect way, though research or through political advocacy. In general, within climate change there are few direct interventions which

[32] The technologies mentioned in interventions 1,3 and 4 can be supported through policies to encourage deployment of existing technology or through innovation policy. The intervention evaluations 1,3 and 4 focus on encouraging these technologies with non-innovation focused policies. Intervention 5 focuses on innovation policy for all technologies that might help with decarbonisation.

promise high cost-effectiveness. We will now apply the ITN framework to each of these interventions and provide an overall ranking which will help to guide our charity search.

Providing accurate figures on each of these is an involved task. For example, to assess the scale of the impact of optimal renewables deployment, we need to assess what portion of future energy renewables should provide. This is an uncertain and controversial issue. Indeed, many of the calculations we make for each intervention are rough and "back of the envelope". It will be important to bear in mind this **uncertainty** in what follows. Nevertheless, this process will be informative insofar as it reveals **large and robust** differences between some interventions in terms of the ITN criteria.

We will discuss the other factors bearing on tractability in section 2.2.2.

2.2.1. Technologies and sectors

In this section, we evaluate action on the technologies and sectors listed above.

Ensuring optimal deployment of solar and wind energy

Renewable energy sources include hydroelectric power, wind power, solar photovoltaic, solar thermal, tidal power, geothermal, and sustainable biomass (such as wood). In the absence of a carbon price, many governments have encouraged wind and solar deployment through policy instruments such as subsidies and regulations. Many environmental groups advocate for continued and increased political support for renewable energy deployment, especially wind and solar energy.

Importance

To estimate the potential scale of the impact of political support for wind and solar energy, we need to estimate the future role they could play in a decarbonised electricity system. As noted in section 1.4, solar and wind currently supply only a small fraction of global energy. The costs of wind and solar power have declined significantly over the last few decades and are now cost competitive with fossil

fuels and nuclear in many places.[33] Wind and solar will therefore undoubtedly play a major role in future electricity systems.

The main downside of wind and solar power is intermittency. The aim of the power system is to match demand with supply, but for periods of hours and days at a time, wind and solar produce significant oversupply and undersupply. In our view, this means that it is unlikely there will ever be affordable energy systems reliant on >50-70% renewables, though renewables can play a major part in energy systems at lower levels of system penetration.

Large-scale storage with a capacity of more than ten hours is currently prohibitively expensive or technically infeasible, which means that, at present, systems reliant on >50% intermittent renewables are very expensive or technically infeasible.[34] Consequently, at present, intermittent renewables must be supplemented with non-intermittent sources, such as coal, gas, and nuclear. Looking to the future, there must be enormous improvements in the cost and performance of storage to economically justify large-scale deployment of storage.[35] Even if these improvements do occur, an electricity system reliant on >50%-70% intermittent renewables would still be very expensive. This is because there would need to be significant excess capacity of storage and renewables (more than triple peak demand on many studies), and low utilisation of storage.[36] In systems with at least 30% dispatchable

[33] International Energy Agency, "Renewables 2017," accessed January 10, 2018, https://www.iea.org/renewables/; Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017," 2017, https://www.eia.gov/outlooks/aeo/.
[34] Fernando J. de Sisternes, Jesse D. Jenkins, and Audun Botterud, "The Value of Energy Storage in Decarbonizing the Electricity Sector," *Applied Energy* 175, no. Supplement C (August 1, 2016): 368–79, https://doi.org/10.1016/j.apenergy.2016.05.014.
[35] de Sisternes, Jenkins, and Botterud.
[36] Stephen Brick and Samuel Thernstrom, "Renewables and Decarbonization: Studies of California, Wisconsin and Germany," *The Electricity Journal* 29, no. 3 (April 1, 2016): 6–12, https://doi.org/10.1016/j.tej.2016.03.001; John C. Platt, J. Pritchard, and Drew Bryant, "Analyzing Energy Technologies and Policies Using DOSCOE," 2017; Alexander E. MacDonald et al., "Future Cost-Competitive Electricity Systems and Their Impact on US CO2 Emissions," *Nature Climate Change* 6, no. 5 (May 2016): 526–31, https://doi.org/10.1038/nclimate2921; Jenkins and Thernstrom, "Deep Decarbonization of the Electric Power Sector: Insights from Recent Literature"; Bethany A. Frew et al., "Flexibility Mechanisms and Pathways to a Highly Renewable US Electricity Future," *Energy* 101 (April 15, 2016): 65–78, https://doi.org/10.1016/j.energy.2016.01.079..

or non-intermittent power sources, there does not need to be such huge excess capacity, and so the total system costs of electricity are much lower.

We can roughly calculate the scale of the effect of optimal deployment of solar and wind on emissions in two stages:

1. Estimate the amount of fossil fuel-produced energy that would be displaced.37
2. Estimate how many tonnes of CO2e that amount of fossil-produced energy would have produced.

We take IPCC integrated assessment models to represent the scientific consensus on the questions of the role played by solar and wind in future energy systems compatible with a 2°C carbon budget.[38] The simple rough model here uses the two stage process to calculate the total emissions averted by optimal investment in solar and wind power until 2050.[39] It suggests that optimal investment in solar and wind would avert around 136GtCO_2e. Thus, optimal investment in wind and solar receives a score of **8 points** in terms of scale or importance. This figure is highly approximate.

Neglectedness

According to the Nisbet (forthcoming) data on philanthropic spending, "renewable energy communications, media and mobilisation" receives $46m. "Promoting renewable energy and energy efficiency actions and practices" receives $140m. On the basis of our understanding of the non-profit space, we believe that advocacy for renewable energy receives around half of this latter figure

[37] This is a simplification: solar and wind might displace energy from other low carbon sources such as hydro.
[38] Glen P. Peters et al., "Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement," *Nature Climate Change*, 2017.
[39] Note that since a lot of the growth in energy supplied happens later on, taking the average of 2020 and 2050 will be biased upwards. However, we do not think this will have much impact on the overall ranking of interventions.

($70m). Overall, renewables receives ~$116m in total. Thus, it scores **4 points** on philanthropic neglectedness.

In 2014, around $284bn was spent on renewables by non-philanthropic bodies, giving it a score of **4 points** on non-philanthropic neglectedness.[40] This is nearly a third of overall climate spending.

Total score

If we weight philanthropic and non-philanthropic neglectedness equally, then this intervention receives the following total score:

8+(0.5*(4+4)) = **12 points**

Ensure optimal energy efficiency

One way to reduce future emissions is to replace high carbon energy sources with low carbon energy sources. Another way is to reduce the amount of energy we consume without reducing living standards, which we can do through improving energy efficiency.[41] Things such as draught excluders, double glazing, and efficient domestic boilers all aim to improve energy efficiency. Global energy efficiency has improved year on year since 1990, but economic growth has increased much more rapidly.[42]

Importance

According to the International Energy Agency, on current pledges and commitments, in 2060, annual primary energy demand will be around 850 Exajoules. On a pathway compatible with two degrees of

[40] UNFCCC Standing Committee on Finance, "Biennial Assessment," 56. This is the figure for spending on all renewables, but the vast majority was spent on wind and solar.
[41] Some argue that in some cases, energy efficiency does not actually reduce emissions due to the phenomenon of "rebound". We think this issue is overstated and that rebound will only erode up to 25% of the energy efficiency gains. See Kenneth Gillingham, David Rapson, and Gernot Wagner, "The Rebound Effect and Energy Efficiency Policy," *Review of Environmental Economics and Policy* 10, no. 1 (January 1, 2016): 68–88, https://doi.org/10.1093/reep/rev017.
[42] Peters et al., "Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement," 2.

warming, annual primary energy demand will be around 650EJ. In our simple rough model, we infer from this that between 2020 and 2050, optimal energy efficiency would reduce total primary energy demand by 2700EJ. If we assume that the energy mix that would have supplied this energy is the same as that in the "current policies" trajectory in 2060, then energy efficiency would avert 250.5Gt of CO_2e, giving it a score of **10 points**.

Neglectedness

According to Nisbet (forthcoming), advocacy for renewable energy and energy efficiency receives around $140m from philanthropists. On the basis of our understanding of the non-profit space, we believe that around half of this ($70m) goes to energy efficiency, giving this intervention a score of **6 points** in terms of philanthropic neglectedness.

According to the UN Biennial Assessment of climate finance, in 2014, private spending on energy efficiency was $337bn. This does not include government spending on energy efficiency measures. This suggests that energy efficiency should get a score of **3 points** in terms of non-philanthropic neglectedness.

Total score

Adding these together we get:

10+(0.5*(6+3)) = **14.5 points**

Ensuring optimal deployment of nuclear fission energy

Nuclear fission power is controversial but has played a large role in low carbon energy supply since the 1970s. It now supplies at least 26% of low carbon global primary energy supply.[43] France, Sweden, and Ontario rapidly decarbonised their electricity systems with large-scale deployment of nuclear

[43] International Energy Agency, "Key World Energy Statistics," 2017, 6.

power.[44] We discuss concerns around nuclear safety, waste, and proliferation at length in Appendix 6. Concerns About Nuclear Power.

Importance

We can again roughly calculate the scale of the effect of optimal investment in nuclear power on emissions in two stages:

1. Estimate the amount of fossil fuel-produced energy that would be displaced.[45]
2. Estimate how many tonnes of CO_2e that amount of fossil-produced energy would have produced.

To roughly estimate the scale of the impact of increasing use of nuclear power, we will again rely on the median IPCC integrated assessment model,[46] which suggests that nuclear power should roughly quadruple up to 2050. The simple rough model here uses the two stage process to calculate the total emissions averted by optimal investment in nuclear power until 2050. It suggests that optimal investment in nuclear would avert around 136GtCO_2e. Thus, optimal investment in nuclear power receives a score of **8 points** in terms of scale or importance.

Neglectedness

According to the Nisbet (forthcoming) data, nuclear power received no money from the 19 major US philanthropies surveyed. Armond Cohen, Director of the Clean Air Task Force, told us that they estimated that nuclear power received less than $3m in total over the period 2011-15 from smaller

[44] Staffan A. Qvist and Barry W. Brook, "Potential for Worldwide Displacement of Fossil-Fuel Electricity by Nuclear Energy in Three Decades Based on Extrapolation of Regional Deployment Data," *PLOS ONE* 10, no. 5 (May 13, 2015): e0124074, https://doi.org/10.1371/journal.pone.0124074.
[45] This is a simplification: renewable energy might displace energy from other low carbon sources such as nuclear or hydro.
[46] Peters et al., "Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement."

philanthropies.[47] We will give nuclear advocacy a score of **16 points** on philanthropic neglectedness. Around $25bn was spent on new nuclear power capacity by governments and the private sector in 2015, giving it a score of around **11 points** on non-philanthropic neglectedness.[48]

Total score

Adding these together we get:

8+(0.5*(16+11)) = **21.5 points**

Ensuring optimal deployment of carbon capture and storage

Carbon capture and storage (CCS) refers to a set of technologies that may offer the potential for large-scale removal of CO_2 emissions from a range of processes – potentially including the generation of electricity and heat, industrial processes, and the production of hydrogen and synthetic fuels.[49] Like other emerging low carbon technologies, CCS is not without risks or uncertainties, and there are various challenges that would need to be overcome if it were to be widely deployed. However, almost all analyses project that CCS must be deployed at very large scale if we are to stand a chance of staying within our 2°C carbon budget.

CCS could be used along with bioenergy as a form of *negative emissions technology*, which remove CO_2 from the atmosphere. CCS plays such a huge role in IPCC models in large part because of its contribution to massive amounts of negative emissions in the second half of the 21st century. Negative emissions will undoubtedly be important, but we, along with many experts, think the IPCC models drastically overstate the feasible scale of bioenergy with CCS.[50]

[47] Armond Cohen, personal correspondence, 16th March 2018.
[48] International Energy Agency, "World Energy Investment," 2017, 43.
[49] Paul Ekins et al., "The Role of CCS in Meeting Climate Policy Targets" (Global CCS Institute, October 2017).
[50] Williamson, "Emissions Reduction"; Fuss et al., "Betting on Negative Emissions."

Importance

Without CCS, most models cannot produce emissions pathways consistent with a <2°C goal.[51] To estimate the scale of the impact on emissions of optimal investment in CCS, we use the literature review by Ekins et al, which provides direct figures on emissions averted by 2050 according to a range of energy system models compatible with a 2°C carbon budget .[52] The median model projects that CCS will avert 164Gt of CO_2 by 2050, giving CCS a score of **9 points**. There is significant uncertainty involved in such modelling efforts. The estimate used here is intended to give an approximate idea of the importance of CCS.

Neglectedness

According to the Nisbet (forthcoming) data, $1.3m was spent on advocacy for CCS, giving it a score of **16 points**. Governments spent around £10bn on CCS in 2017, but this was anomalous, and the five-year average spend was less than $2bn.[53] Thus, we give CCS a score of **16 points** in terms of non-philanthropic neglectedness.

Total score

Adding these together we get:

9+(0.5*(16+16)) = **25 points**

Ensuring optimal investment in low carbon technology innovation

As all existing low carbon technologies have disadvantages, R&D into low carbon technology is widely recognised as a key policy tool for decarbonising energy systems in a cost-effective way. In the short to medium-term, improving the safety, cost and performance of low carbon technology, including

[51] Peters et al., "Key Indicators to Track Current Progress and Future Ambition of the Paris Agreement," 4.
[52] Ekins et al., "The Role of CCS in Meeting Climate Policy Targets," chap. 4.
[53] International Energy Agency, "World Energy Investment," 147.

solar and wind, energy storage, CCS, and nuclear fission would be valuable, while developing more speculative technologies such as nuclear fusion would be beneficial over longer time horizons.

Importance

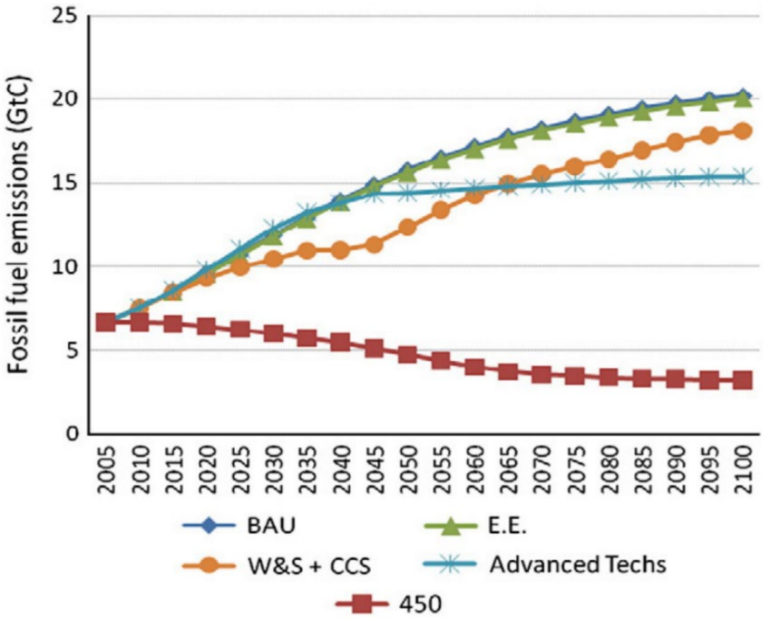
Total annual spending on clean energy R&D is around $35bn.[54] There is disagreement in the literature about the precise level of optimal investment in R&D, but there is agreement that it should at least double immediately,[55] and increase to more than $100bn after 2030.[56]

To estimate the effect of clean energy R&D on emissions, we use Bosetti et al (2011), which estimates the effect on emissions of a clean energy R&D portfolio costing 0.08% of global GDP (around $60bn today).[57] The portfolio includes energy efficiency, wind, solar, carbon capture and storage, and breakthrough technologies (defined as currently non-commercial advanced low carbon technologies that become available in the future). Figure 2.2 depicts the effect this has on emissions relative to business as usual (BAU) and to a scenario in which atmospheric concentrations are stabilised at 450ppm. (Note that the effect is measured in terms of GtC (gigatonnes of carbon) rather than in $GtCO_2$; 1GtC = 3.667$GtCO_2$.)

[54] See p.9 of https://www.iea.org/media/publications/investment/WEI2017Launch_forWEB.pdf
[55] Antoine Dechezleprêtre, Ralf Martin, and Samuela Bassi, "Climate Change Policy, Innovation and Growth," *Grantham Research Institute on Climate Change and the Environment*, 2016, 3.
[56] "Estimates of the additional funding needed for energy-related R&D range from 4.5 to 78 billion USD per year during 2010–2029... and from 115 to 126 billion USD per year in 2030–2049..." IPCC, *Climate Change 2014: Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014), 1220.
[57] Valentina Bosetti et al., "What Should We Expect from Innovation? A Model-Based Assessment of the Environmental and Mitigation Cost Implications of Climate-Related R&D," *Energy Economics* 33, no. 6 (November 1, 2011): 1313–20, https://doi.org/10.1016/j.eneco.2011.02.010. See also Valentina Bosetti et al., "Sensitivity to Energy Technology Costs: A Multi-Model Comparison Analysis," *Energy Policy* 80 (2015): 244–263.

Figure 2.2.

Fossil fuel emission paths under alternative innovation policies, compared with emission pathways in the baseline and 450 ppm CO2 only stabilisation cases.



BAU = Business as Usual

E.E. = Energy Efficiency

W&S+CCS = Wind and Solar + CCS

Advanced techs = Advanced technologies

450 = emission pathway consistent with 450ppm by 2100

Source: Bosetti et al, "What should we expect from innovation? A model-based assessment of the environmental and mitigation cost implications of climate-related R&D", Energy Economics, 2011: p. 1315

We can very roughly conclude from this graph that the portfolio averts on average 2GtC per year compared to business as usual. We can therefore calculate that over 30 years, it averts (2*30) = 60GtC = 220GtCO$_2$e. It therefore gets a score of **9 points** on importance. This figure gives a highly approximate idea of the scale of the impact of optimal R&D funding.

Neglectedness

According to the Nisbet (forthcoming) data, promoting energy innovation received ~$673,000 from 2011-15, giving it a score of **16 points** in terms of philanthropic neglectedness.

Total non-philanthropic spending on clean energy R&D is around $35bn,[58] giving it a score of **10 points** in terms of non-philanthropic neglectedness.

Total score

Adding these together we get:

9+(0.5*(16+10)) = **22 points**

Ensuring optimal investment in preventing emissions from forestry and other land use

Forests are profoundly important for the Earth's atmosphere. Growing forests capture and accumulate carbon slowly over decades, intact forest ecosystems capture carbon in vegetation and soils, but deforestation for burning or conversion to agriculture releases carbon into the atmosphere.[59]

Importance

Forestry and other land use change is responsible for 4.3-5.5GtCO_2e net emissions per year.[60] (Gross emissions from deforestation are larger than this but are partially cancelled out by forest regrowth.) Using World Bank estimates, Busch and Engelman project that in the absence of new conservation policies, emissions from tropical deforestation alone will be 169GtCO_2.[61] Thus, forestry scores **9 points** in terms of importance.

[58] See p.9 of https://www.iea.org/media/publications/investment/WEI2017Launch_forWEB.pdf
[59] Frances Seymour and Jonah Busch, "Why Forests? Why Now? A Preview of the Science, Economics, and Politics of Tropical Forests and Climate Change," Center For Global Development, November 2014, https://www.cgdev.org/publication/ft/why-forests-why-now-preview-science-economics-politics-tropical-forests-climate-change.
[60] IPCC, Climate Change: Mitigation, 86.
[61] Jonah Busch and Jens Engelmann, "The Future of Forests: Emissions from Tropical Deforestation with and without a Carbon Price, 2016–2050" (Center for Global Development), accessed January 31, 2018, https://www.cgdev.org/publication/future-forests-emissions-tropical-deforestation-carbon-price.

Neglectedness

Nisbet (forthcoming) shows that $72.6m is spent on "promoting sustainable agriculture, land use and protecting ecosystems". He does not disaggregate this data further, but we would estimate on the basis of our assessment of the non-profit landscape that around half of this is spent on forestry and other land use. Preventing emissions from forestry therefore receives a score of **8 points** on philanthropic neglectedness.

The Climate Policy Initiative estimates that $3bn was spent on mitigation in forestry and agriculture in 2012.[62] However, this figure does not include private sector financing for forestry, which is estimated to range from $1.8bn to $15bn.[63] Taking the mean of these estimates, we can roughly estimate that preventing receives $6.6bn + $3bn, or around ~$10bn in non-philanthropic money, thereby giving it a score of **14 points**.

Total score

Adding these together we get:

9+(0.5*(8+14)) = **20 points**

2.2.2. Final intervention selection for technologies and sectors

The combined importance and neglectedness scores for each of the sector and technology interventions are as follows (from highest to lowest). Philanthropic and non-philanthropic neglectedness each receive a 50% weight.

[62] UNFCCC Standing Committee on Finance, "Biennial Assessment," 133.
[63] UNFCCC Standing Committee on Finance, 54.

Ranking	Intervention	Importance	Philanthropic neglectedness	Non-philanthropic neglectedness	Final score
1	Carbon capture and storage	9	16	16	25
2	Low carbon innovation	9	16	10	22
3	Nuclear power	8	16	11	21.5
4	Forestry	9	8	14	20
5	Energy efficiency	10	6	3	14.5
6	Solar and wind power	8	4	4	12

As discussed, the final scores express the ratio of the size of the problem to a weighted sum of philanthropic and non-philanthropic money invested in the problem. Since the scores are logarithms, a gap of 2 points corresponds to a difference by a factor of two. A 4 point gap corresponds to a difference of a factor of $2^2 = 4$; a 6 point gap corresponds to a difference of a factor of $2^3 = 8$, etc.

CCS is the top scoring intervention. Since our aim is to find the best possible intervention, we need to consider whether the other interventions are close enough to CCS to justify investigating them further. According to our 6 point margin for error, the top four interventions are worth investigating further, provided they are not very intractable for other reasons (aside from neglectedness). Energy efficiency and solar and wind should not be investigated further unless there are large differences between them and CCS in terms of the other factors that bear on marginal tractability. Energy efficiency and solar and wind score poorly chiefly because they already receive large amounts of money.

Assessment of other factors bearing on tractability

Firstly consider whether the provisionally excluded interventions should be included. Even accounting for the margin for error, there is a difference of 7 points between CCS and solar and wind, which means that the ratio of importance to a weighted sum of spending on CCS is >8 times greater than solar and wind.[64] Solar and wind are getting >8 times as much money as we would expect compared to CCS (assuming that the two interventions are equal in terms of the other factors bearing on tractability).

In approaching these other factors, we need to control for neglectedness by asking whether it would be as easy to make progress on each problem if renewables received the same amount of money as CCS. Firstly, consider the cost to abate a tonne of CO_2 with CCS as opposed to solar and wind. The predicted cost in 2025-30 to abate a tonne of CO_2 with CCS ranges from $5-$60 per tonne depending on the sector, though the abatement cost will typically be greater than $20 per tonne.[65] Many governments have historically incurred much higher costs in subsidising the deployment of solar and wind. For example, according to one study of German renewables subsidies, the cost to abate a tonne of CO_2 with solar subsidies has been on the order of hundreds of Euros per tonne of CO_2.[66] Indeed, in the US, the estimated abatement costs of proposed CCS subsidies are comparable to the abatement costs of current renewables policies.[67] Thus, we do not believe that differences in financial cost of abatement have much of a bearing on marginal tractability.

[64] >8 times because 6 points corresponds to three doublings, which is $2^3 = 8$.
[65] International Energy Agency, "Carbon Capture and Storage," 2015, 5, https://www.iea.org/publications/freepublications/publication/CarbonCaptureandStorageThesolutionfordeepemissionsreductions.pdf.
[66] C. Marcantonini and A. D. Ellerman, "The Cost of Abating CO2 Emissions by Renewable Energy Incentives in Germany," in *2013 10th International Conference on the European Energy Market (EEM)*, 2013, 1–8, https://doi.org/10.1109/EEM.2013.6607312.
[67] Clean Air Task Force, "Incentives for CO2 Avoided: Comparison of Renewables Production Tax Credit and Proposed 45Q Legislation," December 2017, http://www.catf.us/resources/factsheets/files/Cost_of_CO2_Avoided.pdf.

Secondly, there are fewer substitutes for CCS than for solar and wind. In the power sector, renewables, biomass and fossil fuels with CCS, and nuclear can to an extent substitute for one another. However, in many industrial sectors such as steel (~5% of global emissions)[68] and cement (~3% of global emissions),[69] there are no other viable options to make significant emissions reductions aside from CCS. This is why certain countries are committing to extensive use of CCS in their climate plans.[70] Moreover, CCS along with biomass is the leading currently proposed form of negative emissions technology, which will need to be deployed at large scale if we are to keep to our <2°C target.[71] Solar and wind could be used to power direct air capture, another form of negative emissions technology, but this would be significantly more expensive than biomass with CCS.

Thirdly, turning to public opposition, our best guess is that if solar and wind and CCS received the same amount of philanthropic money, there would be more public opposition to CCS. CCS to some extent allows the fossil fuel industry to remain in business, which many in the public are likely to oppose. In part probably thanks to philanthropy, solar and wind appear to be generally well-regarded among the public. This being said, using renewables to generate equivalent amounts of power to energy dense sources such as coal, gas, and nuclear would take up very large amounts of space.[72] This raises the issues of public acceptability. One prominent analysis suggested that once public acceptability regarding the placement of wind turbines and solar panels is taken into account, *all*

[68] IPCC, *Climate Change: Mitigation*, 757–58.
[69] IPCC, 753.
[70] "Dutch Coalition Accord: Netherlands Claims Climate Leadership in Europe," *EnergyPost.eu* (blog), October 11, 2017, http://energypost.eu/dutch-coalition-accord-the-netherlands-goes-for-climate-leadership-in-europe/.
[71] Williamson, "Emissions Reduction."
[72] David MacKay, *Sustainable Energy - without the Hot Air*, pt. 1.

renewables within the UK could only meet around one sixth of UK energy demand.[73] Public acceptability was plausibly a major factor in the recent ban on UK subsidies for onshore wind.[74]

In sum, we think it is highly implausible that the other factors bearing on marginal tractability provide reason to believe that working on solar and wind is a better prospect than working on CCS.

The next relevant comparison is between CCS and energy efficiency. Accounting for the margin for error, the gap between the interventions is 4 points. Firstly consider financial cost. Many energy efficiency measures promise both to reduce emissions and to save people money. For example, using LED lightbulbs reduces energy consumption and therefore saves money and reduces emissions. A widely cited study by McKinsey suggests that there is large abatement potential from energy efficiency measures across a range of sectors, which could reduce energy consumption at *negative* cost.[75] If markets were efficient, these opportunities would be taken without regulation, but there are various market imperfections including:[76]

- Lack of awareness of the potential savings from energy efficiency.
- Agency issues – the agent making the investment does not always reap the benefit. For example, if a landlord invests in double glazing, the tenant would benefit from reduced heating costs. There is therefore no financial incentive for the landlord to invest in double glazing.
- Financing hurdles – the upfront cost of the efficiency investments might be prohibitive.

[73] David MacKay, chap. 18.
[74] "Onshore Wind Subsidy Ban 'Will Add £1bn to Nation's Energy Bills'," The Independent, October 25, 2017, http://www.independent.co.uk/news/business/news/onshore-wind-farms-uk-subsidy-ban-energy-bills-rise-1-billion-a8018561.html.
[75] McKinsey & Company, "Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve," September 2013, https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/pathways-to-a-low-carbon-economy.
[76] McKinsey & Company, 41.

This suggests that we should not conclude from the fact that the total social abatement cost is negative that the barriers to energy efficiency are necessarily low, or that the costs to those bearing the upfront costs are low. As McKinsey comment:

> "The fact that these opportunities offer a net benefit does not make them easy to realize. On the contrary, designing the right policy frameworks to capture this potential in a cost-effective manner is a significant challenge as it requires finding ways to overcome an array of market imperfections."[77]

This point notwithstanding, energy efficiency is still likely to offer lower abatement costs than investments in CCS for those bearing the costs.

Secondly, our best guess is that, if the two interventions were equally neglected, there would be less public opposition to energy efficiency measures. Encouraging energy efficiency does not appear to be politically controversial in any way, whereas, as discussed above, CCS appears to carry more political baggage.

Thus, energy efficiency involves lower abatement costs than CCS in most cases, and is more politically palatable. If CCS were at the same level of neglectedness as energy efficiency, then we would expect it to be easier to make progress on energy efficiency. However, although this is a difficult case, we do not believe this is sufficient to overcome a difference by a factor of 4 in terms of the scores on (*importance* neglectedness*). Because CCS is so much more neglected than energy efficiency – >50x more philanthropically neglected and >150x more non-philanthropically neglected – the differences in the other factors bearing on tractability would have to be very large to justify focusing on energy efficiency rather than CCS. We think there is some reason to believe that in many

[77] McKinsey & Company, 41.

cases, when the difference in neglectedness is this extreme, the other factors bearing on tractability are likely to be less important than one might expect.[78] As we have seen from the case of renewables, sustained advocacy for solar and wind power has been associated with an enormous increase in non-philanthropic spending on renewables even at very high abatement costs. Thus, within certain bounds, the cost of abatement does not appear to make a significant difference to the ability for philanthropists to make progress on a particular problem. For these reasons, we believe that excluding energy efficiency from further consideration is justified.

The next question we should consider is whether the currently included interventions should be excluded. We cannot think of any good reason that the other factors bearing on the tractability of energy innovation would make be sufficient to justify not considering energy innovation further. Regarding the financial cost of abatement, there is some evidence that, at least with respect to renewables, subsidies for energy innovation are more cost-effective than deployment subsidies.[79] As we have seen, deployment subsidies for renewables are currently roughly as cost-effective as CCS subsidies. We would therefore expect that in many cases, subsidies for energy innovation to be at least as cost-effective as subsidies for CCS. Moreover, we think there is likely to be less public opposition to energy innovation than to CCS due to the aforementioned potential association of CCS with the persistence of the fossil fuel industry.

Next, we need to consider whether there are other reasons to think that nuclear power should be excluded. While there are some obvious barriers to the expansion of nuclear power, we do not think these are so great that, if nuclear and CCS were equally neglected, it would be significantly harder to

[78] Owen Cotton-Barratt, "Estimating Cost-Effectiveness for Problems of Unknown Difficulty," The Future of Humanity Institute, December 4, 2014, http://www.fhi.ox.ac.uk/.
[79] Georg Zachmann, Amma Serwaah-Panin, and Michele Peruzzi, "When and How to Support Renewables?—Letting the Data Speak," in Green Energy and Efficiency, Green Energy and Technology (Springer, Cham, 2015), 291–332, https://doi.org/10.1007/978-3-319-03632-8_12.

make progress on nuclear power. Firstly, nuclear power remains the cheapest dispatchable or non-intermittent source of low carbon power,[80] so it is at least as financially attractive as fossil fuels or biomass with CCS. Secondly, nuclear power has smaller land use implications than fossil fuels with CCS. Nuclear fuel is an extremely energy dense power source and so nuclear power stations require very little land.[81] In contrast, CCS requires extensive pipeline infrastructure to transport CO_2. CCS is also to an extent geographically constrained because there is limited supply of geological locations with adequate storage capacity.

Thirdly, the main constraint on the expansion of nuclear power is public opposition on issues regarding safety, waste and weapons proliferation. (We discuss these in depth in Appendix 6. Concerns About Nuclear Power.) For instance, following the Fukushima accident after the Tohoku earthquake and tsunami in 2011, numerous countries scaled back their nuclear power sector, with Germany notably planning to completely phase out nuclear power by 2022.[82] However, this being said, in spite of the fact that, like CCS, nuclear receives almost no philanthropic support (as shown by the Nisbet data), much more is spent by governments and the private sector on nuclear, and nuclear is deployed much more widely. For these reasons there is good reason to think that if nuclear and CCS received the same amount of philanthropic money, nuclear power would be at least as easy to make progress on as CCS.

Finally, the difference between forestry and CCS is 5 points, so forestry is near the edge of the margin of error. Are there other reasons to think it would be harder to make progress on forestry than on CCS, assuming that they received the same amount of funding? We believe the answer is 'no'. Regarding the financial cost of abatement, abating CO_2 through preventing deforestation is estimated to be 2-5x

[80] IPCC, Climate Change: Mitigation, 71.
[81] David MacKay, Sustainable Energy - without the Hot Air, chap. 24.
[82] International Energy Agency, "Technology Roadmap: Nuclear Energy," 2015.

cheaper than with CCS.[83] Regarding public support, our best guess is that, if each problem received the same amount of philanthropic money, there would be much more support for preventing forestry emissions than for encouraging CCS. Deforestation produces a host of other costs to ecosystems and to forest-dwelling peoples, which provides additional reason for political support for preventing it, over and above reasons of climate change. In contrast, CCS only provides climate benefits. Philanthropic support for preventing forestry emissions is plausibly in part driven by the fact that this issue was already attractive to the public before philanthropists worked on it, though there is also likely to be an effect in the other direction. For these reasons, we believe that the other factors bearing on tractability do not plausibly justify excluding forestry from consideration.

In sum, when choosing charities, we prefer those focusing on the top four ranked technology and sector interventions: CCS, energy innovation, nuclear power, and forestry and land use.

2.2.3. Policy in particular geographies

Having examined sectors and technologies, we now turn to policy in regions and geographies. The intervention evaluations in this section are comparable to one another but are not comparable to those above due to lack of data. For each intervention, we will examine the magnitude of their future emissions, and current non-philanthropic spending on low carbon technology in those countries.

In each section, we discuss the state of carbon pricing in each area. It is widely agreed by economists that carbon pricing is the optimal policy solution to climate change.[84] Carbon pricing schemes that are implemented at the moment typically cover 40-50% of emissions in a country or region and have a

[83] Frances Seymour and Jonah Busch, *Why Forests? Why Now?* (Center for Global Development, 2016), chap. 5, https://www.cgdev.org/blog/why-forests-why-now-new-developments-new-year.
[84] Wagner and Weitzman, *Climate Shock*, 23ff.

price of less than $10 per tonne of CO_2. Economists are generally agreed that CO_2 should be priced at the very least at $20 per tonne.[85]

We will now discuss the importance and non-philanthropic neglectedness scores of work in these areas. We do not have comprehensive information on philanthropic neglectedness for these interventions. Readers wishing to skip straight to the final scores should go to section 2.3.4. Final intervention selection for particular geographies.

Climate policy in China

China is the world's largest emitter and will be for the rest of the century. The fate of global climate action therefore depends in large part on China. China introduced a national emissions trading scheme in late 2017.[86] Like most other carbon pricing schemes, it covers 40-50% of emissions,[87] and the starting price is $1 - $10 per tonne.[88] This is the largest carbon pricing scheme in the world.

Importance

China currently emits around 12Gt of CO_2e per year.[89] On current policies, this is expected to increase to 13Gt by 2030. We can therefore roughly assume that between 2020 and 2050, China will emit (30*12.5) = 375Gt of CO_2e, giving climate policy in China a score of **11 points** on importance.

[85] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html
[86] "China Aims for Emission Trading Scheme in Big Step vs. Global Warming," *Reuters*, December 19, 2017, https://www.reuters.com/article/us-china-carbon/china-aims-for-nationwide-emission-trading-scheme-in-power-sector-state-planner-idUSKBN1ED0R6.
[87] World Bank, "Carbon Pricing Watch 2017," 2017, 3 note h.
[88] World Bank, 12.
[89] http://climateactiontracker.org/countries/china.html

Non-philanthropic neglectedness

In 2016, $177bn was spent on nuclear, renewable electricity, renewables for transport and heat in China, and energy efficiency[90] implying a score of **5 points** on non-philanthropic neglectedness.

Total score

Adding these together we get:

11+5 = **16 points**

Climate policy in the US

The US is currently the second biggest emitter in the world. A handful of US states are taking fairly strong action on the climate, but in most states, action is very modest, and there is no federal carbon price. A carbon trading bill made it through the US Congress in 2009 but, due to opposition from the Republican party, was never brought to the floor of the Senate for a vote.

Importance

The US currently emits ~7Gt CO_2e per year. According to climate action tracker, if current policies continue, annual emissions will be roughly unchanged by 2030.[91] We can therefore roughly assume that on current policy between 2020 and 2050, the US will emit (30*6.5) = 195Gt of CO_2e, implying a score of **9 points**.

Non-philanthropic neglectedness

In 2016, $100bn was spent on nuclear power, renewables, renewables for transport and heat, and energy efficiency in the US,[92] implying a score of **7 points** on non-philanthropic neglectedness.

[90] International Energy Agency, "World Energy Investment," 22.
[91] http://climateactiontracker.org/countries/usa.html
[92] International Energy Agency, "World Energy Investment," 22.

Total score

Adding these together we get:

9+7 = **16 points**

Climate policy in the EU

The EU is currently the world's third largest emitter. The EU introduced an emissions trading scheme in 2005, which now has a price of around $12 per tonne.[93] Until the introduction of China's ETS in 2017, this was the largest emissions trading scheme in the world.

Importance

The EU currently emits around 4Gt of CO_2e per year. On current policy trends, emissions will be around 3Gt by 2050, with the aim of reducing this to ~1Gt by 2050.[94] We can roughly estimate that cumulative emissions between 2020 and 2050 will be (30*2.5) = 75Gt of CO_2e, implying a score of **6 points**.

Non-philanthropic neglectedness

In 2016, in the EU, $134bn was spent on renewables, renewable transport and heat, and energy efficiency implying a score of **6 points** in terms of non-philanthropic neglectedness.[95]

Total score

Adding these together we get:

6+6 = **12 points**

[93] The Economist, "Europe's Carbon-Trading System Is Better than Thought, and Could Be Better Still," *The Economist*, December 11, 2015, https://www.economist.com/blogs/freeexchange/2015/12/schr-dinger-s-emissions-trading-system.
[94] http://climateactiontracker.org/countries/eu.html
[95] International Energy Agency, "World Energy Investment," 22. The figures on energy efficiency are from European members of the OECD, almost all of which are in the EU.

Climate policy in India

India is currently the fourth largest emitter, but its annual emissions are expected to increase over the next few decades. India has not yet introduced carbon pricing, but is considering doing so in the near future.[96] India has imposed a tax on the use of coal, peat and lignite, which covers about 1% of total emissions.[97]

Importance

India currently emits around 3Gt of CO_2e, and on current policies will emit around 5Gt by 2030.[98] There are some reasons to expect that emissions will continue to increase up until 2050 to around 6Gt per year.[99] We roughly estimate that between 2020 and 2050, India will emit (30*5) = 150Gt of CO_2e, implying a score of **8 points**.

Non-philanthropic neglectedness

In 2016, $20bn was spent on nuclear energy, renewable energy and energy efficiency in India, implying a score of **11.5 points** in terms of non-philanthropic neglectedness.[100]

Total score

Adding these together we get:

8+11.5 = **19.5 points**

[96] World Bank, "Carbon Pricing Watch 2017," 22.
[97] World Bank, 75.
[98] http://climateactiontracker.org/countries/india.html
[99] Varun Sivaram, "The Global Warming Wild Card," *Scientific American* 316, no. 5 (2017): 48–53, https://doi.org/10.1038/scientificamerican0517-48.
[100] International Energy Agency, "World Energy Investment," 22.

2.2.4. Final intervention selection for particular geographies

The combined scores on importance and non-philanthropic neglectedness for the geographic areas are as follows.

Ranking	Intervention	Importance	Non-philanthropic neglectedness	Final score
1	India	8	11.5	19.5
2	China	11	5	16
2	US	9	7	16
4	EU	6	6	12

These rankings are not definitive because they exclude information on two important factors: philanthropic neglectedness and tractability.

Philanthropic neglectedness and tractability in China, the US, the EU and India

According to one piece of research, climate change receives around $200m from US foundations, and receives around $100m from European foundations,[101] though it is unclear what proportion of this money focuses on climate policy in the respective regions. We do not have information on philanthropic spending in India and China, but it is safe to assume that these are much more neglected than the US and the EU.

[101] "Foundation Spending on Climate Change," *Alliance Magazine* (blog), accessed March 4, 2018, http://www.alliancemagazine.org/feature/foundation-spending-on-climate-change/.

It is difficult to form precise estimates of the other factors bearing on tractability in these areas, holding philanthropic spending constant across each area. Our best guess is that work in the EU would be the most tractable because EU governments and citizens are at least committed to strong climate action.

In spite of the large amount of climate philanthropy in the US, advocacy for federal policy in the US is currently difficult because of entrenched and strong opposition to action on climate change in the Republican party.[102] This suggests that advocacy for federal carbon pricing is now highly intractable but might be worth examining if the Democrats gain majorities in the House and the Senate. This being said, it is possible to make progress at the state level and by carefully developing legislation which can achieve bipartisan support for other reasons.

It is very unclear how easy it would be to make progress on climate policy in China if climate philanthropy in China received the same amount of philanthropic money as the US or the EU. Our best guess is that work in China would be somewhat less tractable than work in the US. There are serious barriers to environmental advocacy in China because it is an authoritarian state. Nonetheless, the number of environmental NGOs operating in China has increased dramatically since the 1990s, with 5,330 in 2008 according to one estimate,[103] and several prominent international NGOs now work in China, including Environmental Defense Fund, Clean Air Task Force, WWF, and the Natural Resources Defense Council. Moreover, as shown above, the ratio of Chinese climate spending to its potential emissions is similar to that in the US.

[102] For a comprehensive account see Theda Skocpol, "Naming the Problem: What It Will Take to Counter Extremism and Engage Americans in the Fight against Global Warming," in *Prepared for the Symposium on the Politics of America's Fight against Global Warming* (Harvard University, 2013), http://www.scholarsstrategynetwork.org/sites/default/files/skocpol_captrade_report_january_2013_0.pdf.
[103] http://www.jpolrisk.com/rise-of-environmental-ngos-in-china-official-ambivalence-and-contested-messages/

It is also very unclear how easy it would be to make progress on climate policy in India if it received the same level of philanthropic support as the US or the EU. One non-profit has told us that when they worked in India a few years ago, it was harder to make progress there than in China. Moreover, China is committed to more stringent climate policy than India, and India is at an earlier stage of economic development.[104] There are therefore greater pressures for low cost fossil fuel-led growth. Our best guess is that work in India would be very roughly as tractable as work in China if the two areas were equally philanthropically neglected.

Overall, the difference in philanthropic neglectedness would increase the gap between India and China on the one hand and the US and the EU on the other, but this would be partly offset by the lower tractability of working in these areas. This suggests that work in India would be most impactful, with work in China and the US also valuable. There appears to be a case for deprioritising work in the EU to some extent.

Changing policy in these big emitters would be highly valuable, but if this is not currently feasible, philanthropists can nevertheless help to reduce emissions in these big emitters without affecting policy in those regions. The way to do this is to advocate for policies that produce *global technology spillovers*.[105] For example, one could support an advocacy campaign in the US that brings down the cost of low carbon technology such that the technology becomes competitive with fossil fuels in China, India and elsewhere. Experience with solar and wind has shown that deployment subsidies can

[104] Sivaram, "The Global Warming Wild Card."
[105] Johannes Ackva, "Mission Innovation: A Much Needed Policy-Innovation for International Climate Policy," Climate Diplomacy, March 16, 2016, https://www.climate-diplomacy.org/news/mission-innovation-much-needed-policy-innovation-international-climate-policy.

drastically reduce cost, producing global technology spillovers.[106] Our intervention evaluation suggests that reducing the cost of other low carbon technologies would also be highly valuable.

2.3. Charity selection process

The ITN analysis implies that we should prioritise charities working on CCS, energy innovation, nuclear power or forestry, and on policy in India, China and the US. We first attempted to identify promising charities by examining lists of international climate change charities, and examining their websites for information on their track record and impact. We found this approach generally ineffective. It turned out to be much more useful to identify other philanthropists who were impact-focused and broadly aligned with our take on climate change, and to ask them to recommend high quality organisations working on our selected interventions.

Having drawn up a long list of around 20 organisations, we asked for information and organised calls to discuss their track record and future plans. Following this, we filtered down to a short list according to the criteria enumerated in our methodology document. The charities we evaluated in some depth were:

- Clean Air Task Force
- Coalition for Rainforest Nations
- Energy for Humanity
- Third Way
- Center for Carbon Removal
- Sandbag
- Bellona

[106] J. Doyne Farmer and François Lafond, "How Predictable Is Technological Progress?," *Research Policy* 45, no. 3 (April 1, 2016): 647–65, https://doi.org/10.1016/j.respol.2015.11.001.

- Environmental Defense Fund Europe
- Cool Earth
- Environmental Progress

We asked each of these organisations for written information on their track record and their future plans. Our two recommended charities stood out especially in terms of their track record, strength of team, and in terms of the projects they plan to work on. We discuss our process for choosing between these charities in Appendix 3. Our Process.

We initially planned to recommend both low risk and high risk opportunities. However, we were unable to identify low risk opportunities which we were confident had high expected cost-effectiveness. In general, there are very few low risk direct charitable opportunities in climate change which promise large impact. The best candidates are project-based approaches to deforestation, and charities that enable individuals to destroy carbon credits in carbon markets. The latter project has now been discontinued.[107] We discuss why we do not recommend project-based approaches to deforestation in the review of the Coalition for Rainforest Nations.

Given that work on forestry and other land use scores lower than the other interventions on the ITN criteria, we were relatively surprised to end up recommending a forestry charity. However, the Coalition for Rainforest Nations is a unique organisation in the context of forestry non-profits. This illustrates that the ITN framework is not a perfectly reliable guide to the most cost-effective charities and that much depends on the specifics of the charities operating in the space.

[107] https://sandbag.org.uk/carbon-destruction-service/

3. Charity Recommendations

After a search through dozens of climate change charities, we have two recommendations: the Coalition for Rainforest Nations, and the Clean Air Task Force. Both organisations have an exceptional track record, a strong team, and they plan work on highly valuable projects. In this section, we review CfRN and CATF. The reviews are in no particular order. Both CfRN and CATF are advocacy organisations. Assessing the counterfactual impact of such organisations is challenging. Appendix 1. The Historical Impact of The Coalition for Rainforest Nations and Appendix 2. The Historical Impact of the Clean Air Task Force discuss the past counterfactual impact of these organisations. The discussion therein may be of methodological as well as substantive interest.

3.1. Coalition for Rainforest Nations

Summary

What do they do? CfRN work on reducing emissions from deforestation. It is an intergovernmental organisation of more than 50 rainforest nations promoting Reducing Emissions from Deforestation and Degradation (REDD+), a framework through which developing countries are compensated for reduced deforestation.

Do they have a good track record? CfRN has plausibly had an extremely large impact on reducing deforestation by proposing and advocating for REDD+ in UN climate negotiations. Thanks in large part to CfRN, forestry is now enshrined in the Paris Agreement; it is the only sector with its own Article.

Is their future work cost-effective? Going forward, CfRN plans to facilitate ways to expand finance from the commercial sector for REDD+. We roughly estimate that via their future work, CfRN will avert a tonne of CO_2e for $0.12, with a plausible range of $0.02 - $0.72.

Is it a strong organisation? CfRN has a very strong team that has shown the ability to achieve major geopolitical change under very difficult circumstances.

Is there room for funding? We believe that CfRN can productively use more than $2m over the next two years. We recommend unrestricted funding to CfRN to give them maximal flexibility to prioritise their projects.

What do they do?

The Coalition for Rainforest Nations (CfRN) is a non-profit Intergovernmental Organisation comprised of more than 50 rainforest countries,[108] which works to promote environmental sustainability while creating opportunities for economic advancement within tropically forested developing countries. It was founded in 2004 by the Prime Minister of Papua New Guinea and the President of Costa Rica. CfRN participating countries collaborate voluntarily in jointly developed initiatives led by the CfRN Secretariat headquartered in New York. The CfRN Secretariat is led by Kevin Conrad and Federica Bietta. CfRN provides diplomatic leadership and technical research, helps to coordinate regulatory frameworks, and to implement policies and initiatives.

Beginning in 2005, CfRN launched and championed a mechanism known as Reducing Emissions from Deforestation and Forest Degradation (REDD+) in the United Nations Framework Convention on Climate Change (UNFCCC) (the treaty under which global climate treaties, such as the Kyoto Protocol, are discussed). Under REDD+, developing countries are provided with results-based compensation for preventing deforestation and degradation, and for conserving and enhancing carbon stocks.[109]

REDD+ was enshrined in Article 5 of the 2015 Paris Agreement. Forestry is the only sector with its own article. Having helped to establish REDD+ in global climate agreements, CfRN now focuses on consolidating and implementing REDD+, and on increasing public and private funding streams for REDD+.

[108] These countries include Argentina, Bangladesh, Belize, Central African Republic, Cameroon, Chile, Congo, Costa Rica, DR Congo, Dominica, Dominican Republic, Ecuador, El Salvador, Equatorial Guinea, Fiji, Gabon, Ghana, Guatemala, Guyana, Honduras, Indonesia, Kenya, Lesotho, Liberia, Madagascar, Malaysia, Nicaragua, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, Samoa, Sierra Leone, Solomon Islands, Suriname, Thailand, Uruguay, Uganda, Vanuatu and Vietnam.
[109] For an overview of REDD+ see Seymour and Busch, *Why Forests? Why Now?*, chap. 1; The REDD Desk, "What Is REDD+?," accessed February 21, 2018, https://theredddesk.org/what-redd.

CfRN's past impact and cost-effectiveness

In this section, we discuss the general issues surrounding assessment of policy research and advocacy and will then discuss CfRN's past impact.

Issues surrounding evaluation of research and advocacy

Assessing the past impact of policy research and advocacy organisations is difficult due to:

- **Co-causation**: there are numerous other players pushing for the same outcome, making it hard to attribute responsibility.
- **Indirectness**: The interventions worked on are often very indirect with many links in the causal chain from non-profit action to benefit.

For more on this, see our brief on assessing policy advocacy. For these reasons, assessments of the past impact of policy research and advocacy organisations like CfRN involve significant uncertainty.

CfRN's past impact

It is plausible that most of the past impact of philanthropy comes from a handful of successful projects.[110] For example, in the 20th century, philanthropy funded the research that led to the Green Revolution, and many major advances in medical research (including the first combination drug therapy for AIDS and the development of the pap smear).[111] This is partly due to the fact that only a minority of research and advocacy projects succeed in changing policy, and secondly because only a minority of policies actually have an impact.

[110] See our brief on assessing policy interventions.
[111] Holden Karnofsky, "Philanthropy's Success Stories," Open Philanthropy Project, March 1, 2012, https://www.openphilanthropy.org/blog/philanthropys-success-stories.

We think it is reasonable that CfRN exemplifies this rule of thumb. We believe that CfRN's work until today has had or will have an **extremely large positive effect** on global greenhouse gas emissions from its formation until today, and we would be surprised if there were another forestry non-profit operating in the last thirty years that has been more impactful. We discuss CfRN's past impact at length in Appendix 1. The Historical Impact of The Coalition for Rainforest Nations. Here we provide a briefer summary.[112]

In spite of the large contribution to emissions made by tropical deforestation, it had been excluded from the UN Framework Convention on Climate Change (UNFCCC) 1997 Kyoto Protocol. (The UNFCCC is the treaty under which climate negotiations such as Kyoto and the 2015 Paris Agreement proceed). This was due to the following concerns:

- **Equity:** Lower income countries believed that legal restrictions on deforestation would be unfair, given that high income countries had already deforested their territories in the pursuit of economic development.[113]
- **Environmental integrity:** A number of countries were concerned that it was difficult to know whether deforestation had been prevented. The reasons for this in turn concerned:
    - **Leakage** – Will preventing deforestation in one area displace it elsewhere?
    - **Additionality** – How should we set the baseline or "reference level" against which to measure performance in reducing emissions? For example, how many hectares of Brazilian rainforest would be deforested if no REDD+ action is taken? Project-based approaches to deforestation do not have a reference level externally audited by the

[112] For an excellent book-length treatment of relevant recent developments in forestry, see Seymour and Busch, *Why Forests? Why Now?*, which is available for free at https://www.cgdev.org/blog/why-forests-why-now-new-developments-new-year.
[113] Seymour and Busch, 255.

UNFCCC. If reference levels are set too high, countries would be rewarded for emissions reductions that would have happened anyway, thereby failing the test of 'additionality': the failure of conservation efforts to add emissions reductions. If they are set too low, then genuine emissions reductions would not be counted.

- **Permanence** – Are emissions reductions in one period merely reversed in the next? If an acre of forest is protected for two years and is then permanently deforested, then all of the carbon stored in that forest is released into the atmosphere.
- **Monitoring and verification** – Are reductions in forest emissions measured with sufficient precision? Have they been externally checked?

In the context of more than a decade of failure to secure agreement on deforestation, CfRN submitted the proposal of **Reducing Emissions from Deforestation** (RED, later revised to REDD+) at the 2005 UNFCCC Montreal conference. Under REDD+, industrialised countries compensate poorer countries for reducing forestry emissions. REDD+ had a number of features that helped to overcome the aforementioned problems.

- **Equity**: REDD+ enabled industrialised countries to compensate developing countries for protecting their forests. Since performance was to be judged and rewarded ex post, there was no ex ante conditionality, which could threaten national sovereignty.
- **Environmental integrity**
  - **Leakage**: REDD+ should be implemented at the national scale rather than the project scale, preventing within-state leakage. National REDD+ results are to be independently assessed by forestry experts and according to UNFCCC guidelines, reducing the risk of intrastate leakage. Moreover, REDD+ is voluntary and designed to encourage widespread

participation, reducing the risk of interstate leakage. Almost all rainforest nations are now participating in REDD+.

- **Additionality**: a country must have in place a reference level against which performance will be vetted, which is externally assessed by the UNFCCC. This ensures the additionality of forest emissions reductions.
- **Permanence:** Some REDD+ funds used buffers to ensure permanence. With buffers, a portion of avoided emissions credits is set aside and held in escrow for a specific period, so the seller receives the funds only after the forest carbon stock has been maintained for that length of time.[114] National level monitoring, external assessment, and certainty of future payment streams also reduce the risk of subsequent reversal.
- **Monitoring and verification:** Advances in satellite technology have made monitoring and verification much easier.[115] The standardised external Monitoring, Reporting, and Verification required under REDD+ capitalises on these developments.[116]

Getting an item on the UNFCCC agenda is extremely politically complex, requiring unanimity from all parties. CfRN's secured agreement on RED in the face of scepticism or outright opposition from countries such as Brazil and the US. Since UNFCCC meetings occur on an annual basis, by being a first mover on RED, CfRN very likely brought a global agreement on forests forward by at least a year. Given the strong opposition to RED in some quarters, our best guess is that by proposing RED when they did, CfRN brought a global agreement on forestry forward by two years. This estimate errs on the conservative side, and there is a plausible case that CfRN's actual effect could be up to five years.

[114] Seymour and Busch, 272–73.
[115] Seymour and Busch, chap. 4.
[116] Seymour and Busch, 270–71.

CfRN also played a major role advocating for REDD+ in UN climate negotiations from 2005 onwards. Our uncertain realistic estimate is that if CfRN had not acted in these negotiations, a global agreement on forestry would have been delayed by 1-2 years. Overall, we estimate that CfRN brought a global agreement on forestry forward by 3 years, with a pessimistic estimate of 1 year, and an optimistic estimate of 6 years.

The benefits of CfRN's past work

We believe that by bringing forward a global agreement on forestry, CfRN has mobilised a large amount of additional funds which could help to reduce deforestation at low cost. These funds have not yet been disbursed, so our estimate of their effect is based on the projected impact of REDD+ money. We quantify the magnitude of this effect in our cost-effectiveness model. The calculation is explained in Appendix 1. The Historical Impact of The Coalition for Rainforest Nations.

Once one makes certain adjustments for counterfactual impact, our rough estimate is that due to its work between 2004 and 2018, CfRN has averted or will avert between 15m and 1.36bn tonnes of CO_2e, with a realistic estimate of 160m tonnes of CO_2e.[117] This is unusually high, which should lead us to be cautious, but there are good reasons to think that CfRN has been unusually impactful. On any reasonable analysis, CfRN has been hugely influential in global climate negotiations, which has given it enormous leverage over global forestry emissions, a huge sectoral contributor to global emissions.

CfRN's costs so far have been ~$39m. Our realistic estimate is that CfRN have averted a tonne of CO_2e for $0.24, with a pessimistic estimate of $2.60 per tonne and an optimistic estimate of $0.03 per tonne. Equivalently, for each $100, they averted 411 tonnes of CO_2e (with a range of 38 tonnes to

[117] This roughly corresponds to our 90% confidence interval.

3,509 tonnes per $100). For context, the average person in the UK causes around 10 tonnes of CO_2 emissions per year.[118] It is generally considered to be difficult to avert a tonne of CO_2 for less than $2.

Note that this model estimate excludes some of the benefits of CfRN's activities, such as forestry emissions reductions not attributable to additional funding, technical assistance with national REDD+ plans, and work to set up REDD+ funds. The model may therefore be somewhat on the conservative side.

CfRN's future impact and cost-effectiveness

In this section we will discuss the cost-effectiveness of CfRN's future work. We believe the projects CfRN plans to work on over the next few years will be highly impactful, and that, as the largest coalition of tropical rainforest nations and a leading voice on REDD+, CfRN is well placed to execute these plans.

CfRN is currently pursuing three projects. The first is 'Reporting for Results-Based REDD+'. Reporting for Results-Based REDD+ will help 21 countries develop greenhouse gas inventories by identifying and training technicians to report on greenhouse gas emissions. This project has been fully funded by the Norwegian Agency for Development Cooperation.

CfRN's other two main projects require additional financial support. Both projects aim to fill gaps in the current REDD+ landscape. Our rough model suggests that both projects have high expected cost-effectiveness, though there is **significant uncertainty** about our estimates.

[118] Adam Vaughan, "Carbon Emissions per Person, by Country," the Guardian, September 2, 2009, http://www.theguardian.com/environment/datablog/2009/sep/02/carbon-emissions-per-person-capita.

REDD+ Registry and Exchange

The UNFCCC has agreed how to measure, report and verify REDD+ results (successfully reduced emissions). Those results, having completed the UNFCCC Monitoring, Reporting and Verification process, are listed on the UNFCCC REDD+ Information Hub. However, the private sector cannot currently engage at this stage to access REDD+ results. Thus, National greenhouse gas Registries that are linked to a trading platform for REDD+ results are necessary to scale up private sector investment.

> *Tool Development:* To actively integrate private sector capital, further tools are needed, including trading mechanisms. Specifically, carbon registries are needed to secure ownership and related sales, transfers and retirements. Additionally, a trading platform is needed to provide price exploration and liquidity for private sector participants.
>
> *Goal:* To demonstrate electronic registries and/or trading platforms for REDD+ in partnership with leading private sector partners with a goal to scale up private sector finance over $1 billion in five years.
>
> *Next Steps:* Develop pilot electronic registries and trading platforms partnering with REDD+ countries and leading private sector partners.

We believe that the REDD+ Registries and Exchange project has the potential to be highly impactful because:

1. No other organisation is trying to set up a REDD+ Registry and Exchange.
2. CfRN is highly likely to succeed in setting up the Registry and Exchange, if CfRN receives sufficient funding.
3. It is plausible that the project will increase private funding for REDD+ by hundreds of millions of dollars over the course of five years.

4. The vast majority of this money would not otherwise be spent on emissions abatement.

We will now discuss each point in turn. CfRN have told us that they are not aware of any other organisation trying to set up a REDD+ Registry and Exchange.[119] The REDD+ Registry and Exchange would be the only exchange offering 'compliance grade' forestry offsets, i.e. offsets that are of sufficient quality to be eligible for carbon pricing schemes.

Secondly, CfRN's track record and organisational strength provides very good evidence that they will very likely succeed in setting up the Registry and Exchange. As mentioned above, CfRN has conceived and designed three forestry funds, now worth around $2bn. CfRN is also unusually well-placed to develop this tool, as the largest coalition of tropical rainforest nations in the world, which gives it the ability to easily partner with REDD+ countries. The technology platforms that CfRN plans to use for the Registry and Exchange are available and have been tested.

Thirdly, we believe that CfRN's stated funding goal of $1bn over five years is plausible. Between 2006 and 2014, only 10% of REDD+ finance (~$1bn) was from the private sector.[120] In spite of this, the potential future private sector demand is substantial. The Paris Agreement allows for *internationally transferred mitigation outcomes*, enabling countries to meet their climate obligations by purchasing REDD+ offsets, subject to environmental integrity and avoidance of double counting.[121] Carbon pricing schemes are covering an increasing share of global emissions over time. As these develop, private demand for REDD+ offsets will increase because REDD+ is among the most cost-effective ways to

[119] Kevin Conrad, personal communication,
[120] Marigold Norman and Smita Nakhooda, "The State of REDD+ Finance," SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, May 1, 2015), https://papers.ssrn.com/abstract=2622743.
[121] http://www.climatefocus.com/sites/default/files/20151223%20Land%20Use%20and%20the%20Paris%20Agreement%20FIN.pdf

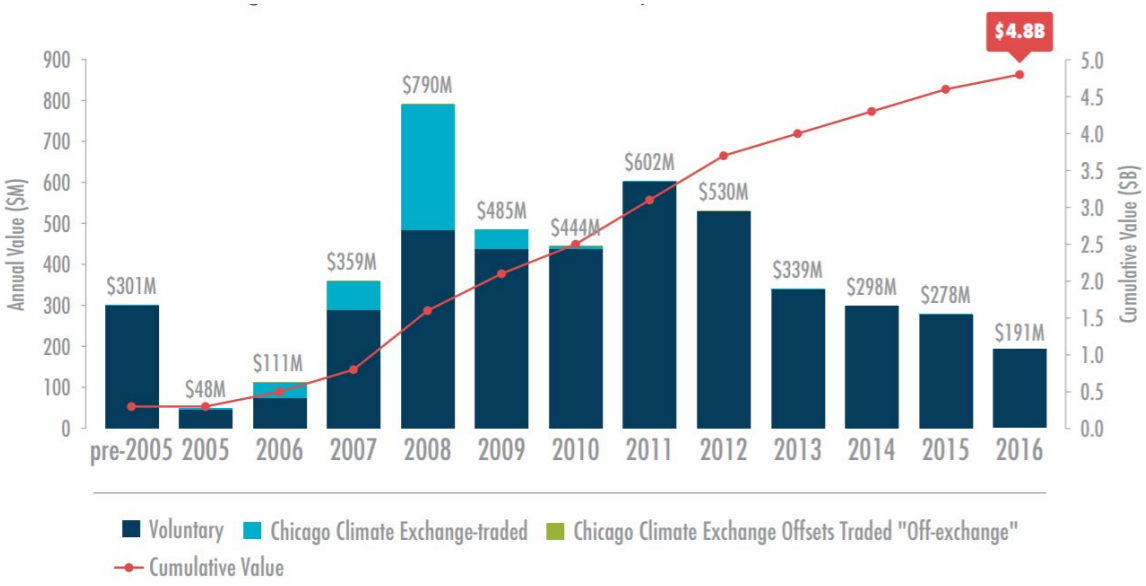
reduce emissions.[122] To give an idea of the scale of future demand, according to one analysis, the demand for forest offsets from the aviation sector alone could be more than $3bn per year in the 2020s.[123]

As of 2016, the total market value of voluntary offsets was $4.8bn. As Figure 3.1 illustrates, the market has declined since 2011:

[122] Especially notable is the introduction of China's Emissions Trading Scheme in 2017, covering 7% of global emissions. World Bank, "Carbon Pricing Watch 2017."
[123] Seymour and Busch, Why Forests? Why Now?, 388–89.

Figure 3.1.

Historical market-wide voluntary carbon offset transaction values



Source: Ecosystem Marketplace, Unlocking Potential: State of the Voluntary Carbon Markets 2017, p. 7.

CfRN believes that this recent decline in the market was due to increased unmet demand for compliance grade offsets. Part of the reason that demand has gone unmet so far is the lack of a registry of achieved REDD+ results and a REDD+ exchange that is easily accessible to the private sector. The private sector does not currently have access to a transparent registry of REDD+ results. Instead, there is an 'over the counter' dynamic, in which a private firm would call up the ministry of the environment in a REDD+ country to access information on REDD+ results. An exchange is also lacking and would increase the efficiency and liquidity of the REDD+ market.

For these reasons, we believe it is likely that the vast majority of the funding channelled via the Registry and Exchange would be genuinely additional and would not have been forthcoming

otherwise. Since the REDD+ Registry and Exchange will exclusively offer compliance grade offsets and REDD+ offsets are among the cheapest offsets available, the Registry and Exchange is likely to play a unique and major role in meeting private demand for REDD+ offsets, which, as discussed above, is plausibly in the hundreds of millions of dollars per year.

Finally, it might be argued that increasing private REDD+ finance merely decreases the cost of emissions reductions, it does not reduce emissions. If REDD+ credits are not available, then the private sector will move to the next cheapest mitigation opportunity. We believe that this factor only justifies a minor downward adjustment to the cost-effectiveness of the Registry and Exchange project. The reason for this is discussed in detail in Appendix 1. The Historical Impact of The Coalition for Rainforest Nations.[124] In brief, private sector demand is driven by the price of carbon in carbon pricing systems. Since carbon is priced below $10 per tonne of CO_2e in almost all carbon pricing schemes, if the marginal cost of abatement increases above $10 per tonne, private sector willingness to mitigate is for the most part reduced to zero. This suggests that REDD+ offsets are genuinely additional.

REDD+ catalytic public/private sector fund

REDD+ finance must be dramatically increased if deforestation is going to be prevented at sufficient scale. Funding mobilized so far is primarily public, not focused on REDD+ results, and insufficient to cover market needs.[125]

> *Tool Development:* CfRN is planning to establish the REDD+ Catalytic Fund ('RCF') to enable public and private institutions to invest together in REDD+ in a manner compliant with UNFCCC decisions and consistent with national GHG inventories, registries and allocation processes.

[124] See the discussion of the elasticity of the carbon budget to the cost of abatement.
[125] Seymour and Busch, Why Forests? Why Now?, chap. 12.

Goal: To mobilize around $500 million to pre-finance REDD+ actions secured by public REDD+ funds.

Next Steps: A pre-feasibility study is required prior to the design and implementation of the RCF to ensure major challenges, risks and impediments for the proposed investment model are identified and assessed, alternative solutions are evaluated, and the fund meets market needs.

Like the Registry and Exchange, the Catalytic Fund is designed to mobilise private funding for REDD+. We believe that the funding goal is reasonable given CfRN's track record. When CfRN set up the World Bank Forest Carbon Partnership Facility (FCPF), the goal was to raise around $500m, and it has raised $1.4bn so far.[126] FCPF funding is all public finance, and the Catalytic Fund is blended public and private. Innpact and Ernst & Young, CfRN's partners on the Catalytic Fund project, also believe that the estimate is reasonable, given their experience in setting up funds so far: many of these funds are worth in excess of $100m.[127]

We believe the project is likely to be highly impactful because:

1. No other organisation is trying to set up a REDD+ public/private fund based on the UNFCCC REDD+ mechanism.
2. CfRN is highly likely to succeed in setting up the Catalytic Fund, if CfRN receives sufficient funding.
3. It is plausible that the Catalytic Fund will increase funding for REDD+ by hundreds of millions of dollars over the course of five years.

[126] Kevin Conrad, personal communication, February 8th 2018.
[127] Innpact, "Dedicated to Impact Finance," Presentation for CfRN, 2017.

4. If the Catalytic Fund did not exist, the vast majority of the money raised would not otherwise be spent on emissions abatement.

We will discuss each of these points in turn. Much of the discussion in the previous subsection is relevant, so our treatment will be briefer her. Firstly, CfRN have told us that no-one else is setting up a public/private catalytic fund applying UNFCCC Standards,[128] and this has been confirmed by further research. CfRN is uniquely well-placed to set up such a fund and has already designed and set up some of the largest existing REDD+ funds. Secondly, given CfRN's track record, global political position, and experience with REDD+ funds, we believe they are highly likely to succeed in setting up the Catalytic Fund.

Thirdly, as discussed above, we believe that the funding goal for the Catalytic Fund is plausible. The Catalytic Fund appears to fill an important niche in the REDD+ landscape. At present, private investors fund forestry projects by donating to environmental NGOs.[129] The environmental NGO is supposed to derisk a specific country-level investment for the investor by certifying the success of the project in averting emissions. In contrast, the Catalytic Fund mobilises public funds to enable UNFCCC certification of REDD+ results, such that the investor does not take on any risk associated with the potential failure of a project run by an environmental NGO.

Fourthly, for the reasons briefly outlined in the previous subsection and in more detail in Appendix 1. The Historical Impact of The Coalition for Rainforest Nations, we believe that the Catalytic Fund would increase total abatement because the elasticity of the carbon budget to the cost of carbon is high.

[128] EDF and the Rockefeller Foundation are also setting up a public/private fund, but this does not use UNFCCC standards.
[129] This is the approach taken by the proposed EDF-Rockefeller fund.

CfRN future cost-effectiveness

Our cost-effectiveness model tries to take account of the various factors that could adversely affect the impact of CfRN's future work. Our realistic estimate is that via its future work, CfRN will avert around 40m tonnes of CO_2e, with a pessimistic estimate of 6m tonnes, and an optimistic estimate of 209 million tonnes. The approximate cost of the two unfunded projects will be around $4.5m. This suggests that a donation to CfRN will avert a tonne of CO_2e for around $0.12, with a range of $0.02-$0.72. Equivalently, a $100 donation to CfRN would avert ~857 tonnes of CO_2e with a range of ~138 tonnes – ~4,600 tonnes. There is **significant uncertainty** surrounding these estimates. Nonetheless, this rough model does suggest that CfRN is an exceptional donation opportunity.

We recommend unrestricted funding to CfRN, to give them maximal flexibility to prioritise their projects.

Is it a strong organisation?

We believe that CfRN has a strong team who have shown the ability to have large impact in difficult geopolitical circumstances. Two prominent and respected economists, Sir Nicholas Stern and Joseph Stiglitz sit on the CfRN Secretariat advisory board. Their Executive Director, Kevin Conrad, and Managing Director, Federica Bietta, both appear highly competent, and have been heavily involved in research and advocacy for REDD+ for many years. Kevin Conrad was named a Time Hero of the Environment after his intervention at the 2007 UNFCCC Bali Conference, which is widely seen to have been crucial in forcing the hand of US negotiators.[130] Individuals we have spoken to who were involved in UNFCCC climate negotiations have noted the quality of CfRN's work and their outsized impact on negotiations.[131] CfRN is the largest grouping of tropical rainforest nations in the world.

[130] See the video here.
[131] Conversation with Veerle Vandeweerd, 6th Feb 2018.

CfRN's approach is pragmatic and results-oriented, and they focus on gaps left by other actors working on global forestry. Kevin Conrad and Federica Bietta have been helpful throughout the evaluation process and have shared large amounts of relevant information.

Is there room for funding?

For its projects in 2018, CfRN has a funding shortfall of $1.6m, and for 2019, a funding shortfall of $800,000.

- **REDD+ Catalytic Fund**
    - 2018 budget: $2,074,152
        - Unfunded: $1,224,152
    - 2019 budget: $451,273
        - Unfunded: $451,273
- **REDD+ Registry and Exchange**
    - 2018 budget: $586,914
        - Unfunded: $436,914
    - 2019 budget: $370,133
        - Unfunded: $345,133

To date, CfRN have spent $150,000 on the Registries and Exchange, and $75,000 on the REDD+ Catalytic Fund. One of CfRN's long-term funders recently ended support having fulfilled the goal of including REDD+ in the Paris Agreement, which suggests their current funding situation is more uncertain than it has been previously.

3.2. The Clean Air Task Force

Summary

What do they do? The Clean Air Task Force (CATF) is a US-based non-profit which works to reduce climate and non-climate pollutants through research and analysis, public advocacy leadership, and partnership with the private sector.

Do they have a good track record? CATF have conceived of and led several successful advocacy campaigns in the US, which have had very large public health and environmental benefits. According to our rough model, through their past work, they have averted a tonne of CO_2e for around $1.

Is their future work cost-effective? Going forward, CATF plans to continue its work on power plant regulation and to advocate for policy support for innovative but neglected low carbon technologies. Given their track record and the nature of their future projects, we think it is likely that a donation to CATF would avert a tonne of CO_2e for $0.10-$1.

Is it a strong organisation? CATF produces very high-quality research and has shown the ability to achieve impactful policy change on a small budget.

Is there room for funding? We believe that CATF can productively use around $2m over the coming year. We recommend unrestricted funding to CATF to give them maximal flexibility to prioritise their projects.

What do they do?

The Clean Air Task Force (CATF) is a US-based non-profit which works to reduce climate and non-climate pollutants through research and analysis, public advocacy leadership, and partnership with the private sector. It was founded in 1996 with the aim of enacting federal policy of reducing the air pollution caused by American coal-fired power plants. This campaign has been highly successful and has been a contributing factor to the retirement of a large portion of the coal fleet. The campaign strategy has now been taken on by other larger NGOs and billion-dollar philanthropies. CATF have conceived and co-led a number of other successful campaigns, including:

- **Pollution controls on the power sector (1996-present):** Since its inception, CATF has advocated for pollution regulations on U.S. coal plants under the Clean Air Act, from 1996-2006 as part of the *Clear the Air Campaign*, and after as that campaign strategy was taken on by the Sierra Club. Under the Obama administration, CATF advocated and provided technical support for strict emissions requirements on coal plants. CATF is now defending those regulations against attacks by the Trump Administration.
- **The national diesel clean-up campaign (2003-12):** CATF conceived of and co-led the campaign to reduce harmful air pollution from diesel cars. CATF developed state, local and national legislation and rules to fund and require retrofit of diesel engines with emission controls, and supported regulations and legislation which successfully reduced US diesel emissions.
- **Global campaign against short-lived climate pollutants (2000-present):** CATF were the first environmental group to recognise the importance of short-lived but highly potent climate pollutants, such as soot, black carbon, and methane. They helped enact the first ever emission standards on ocean-going ships at the International Maritime Organization.

- **Reducing methane from oil and gas production (2009-present):** CATF conceived of co-led the campaign for the regulation of fugitive methane emissions from oil and gas production. This culminated in regulations which have dramatically reduced methane emissions since 2012.

CATF's role in the environmental NGO ecosystem has often been to focus on sources of emissions that are neglected by other environmental NGOs, to conceive and design pragmatic campaigns to target those emissions, and to secure support from philanthropists and other larger environmental NGOs, such as the Environmental Defense Fund, the Natural Resources Defense Council, and the Sierra Club. CATF also produces high quality research, which is very well regarded among the philanthropists, scientists, policy experts, and government bureaucrats that we have spoken to.

CATF's current primary focus is on scaling up the rapid deployment of all of the low carbon technologies required for deep decarbonisation, with a particular focus on technologies that are important but neglected by environmental NGOs and governments, such as carbon capture and storage, advanced nuclear, and low carbon heavy duty transport.

CATF's past impact and cost-effectiveness

In this section, we will discuss the cost-effectiveness of CATF's past work. Because CATF works on heterogeneous projects, rather than examining all of their work, we have evaluated three case studies.

CATF's past impact

In our review of CATF's past impact, we decided to focus on their work on three projects:

1. Power Plant Campaign and Clear the Air: non-climate pollutants (1996 – 2006).
2. The Methane Partners Campaign (2000 – present).
3. Campaign for tax incentives for carbon capture and storage (2009 – present)

We discuss these case studies at length in Appendix 2. The Historical Impact of the Clean Air Task Force. Our discussion here is briefer.

As mentioned above, CATF was founded in 1996 to advocate for regulation of the damaging air pollution produced by the US coal fleet, initially focusing on sulphur dioxide (SO_2) and nitrogen oxide (NO_x). They later advocated for controls on mercury emissions. The theory of change was that the cost of emission controls for conventional pollutants and mercury would result in the retirement or curtailment of coal plant operation resulting in reductions in CO_2 (and other) emissions. CATF conceived of the campaign goal, designed the strategy, and led the campaign, in turn drawing in philanthropic support and recruiting other environmental NGOs to the campaign. From 1998 onwards, CATF co-led a nationwide campaign called "Clear the Air", involving numerous other environmental NGOs. Their research, advocacy and litigation efforts spanned the Clinton, Bush and Obama administrations.

We believe that the campaign was very likely instrumental in the decision by the US Environmental Protection Agency to impose a number of new regulations on coal power plants under the Clean Air Act restricting SO_2, NO_x, and mercury emissions. We believe that CATF had a counterfactual impact in two ways:

1. By conceiving of the power plant campaign, and playing a catalytic role in crowding in philanthropic funding for a national campaign involving numerous NGOs.
2. By leading the ensuing campaign, providing high quality technical analysis on the health effects of air pollution, and litigating the EPA.

Through each of these mechanisms, CATF increased the probability that regulation was introduced earlier in time. Our highly uncertain realistic estimate is that through their work, CATF brought regulation on US coal plants forward by 18 months, with a lower bound of 9 months and a higher

bound of 4 years. CATF believe this to be a major underestimate, and have told us that they could have brought the relevant regulation forward by ten years.

The strategy of targeting coal plants with air pollution regulations has proven influential. From the mid-2000s onwards, the campaign strategy was taken on, with significant success, by the Sierra Club's Beyond Coal campaign, which has received more than $100m from Bloomberg Philanthropies alone.[132]

The goal of the Methane Partners Campaign was to reduce fugitive methane emissions from the oil and gas industry. CATF again played a catalytic role. In the early 2000s, CATF learned of the prominent climate scientist Dr. James Hansen's research into the impact of short-lived climate pollutants such as black carbon, methane, and hydrofluorocarbons. CATF's research revealed that reducing methane emissions from the oil and gas industry presented the best opportunity for cost-effective, politically-feasible mitigation in the near term.

CATF brought this analysis to the attention of the Environmental Defense Fund (EDF) and convinced them that it would be a worthwhile issue to focus on. From 2009 onwards, CATF and EDF co-led advocacy for regulation of methane emissions from the oil and gas industry. EDF's analysis was cited in the Obama administration's strategy to reduce methane, and from 2012 onwards, the EPA finalised a number of regulations, including:

- The 2012 New Source Performance Standards
- The 2016 New Performance Standards

[132] "Bloomberg Announces $64 Million in New Funding to Move America Beyond Coal as Trump EPA Tries to Prop Up Dead End Fuel Source," Bloomberg Philanthropies, accessed February 25, 2018, https://www.bloomberg.org/press/releases/bloomberg-announces-64-million-new-funding-move-america-beyond-coal-trump-epa-tries-prop-dead-end-fuel-source/.

Both regulations aim to reduce methane emissions from the oil and gas industry. We believe that CATF had an impact on US methane regulation in two broad ways:

1. Acting as a "first mover" in conceiving of, and catalyzing support for, the Methane Partners Campaign among a number of larger environmental NGOs.
2. Co-leading and contributing technical research to the campaign.

Through each of these mechanisms, CATF increased the probability that regulation was introduced earlier in time. We estimate that CATF brought the 2012 regulation forward by 11 months, and the 2016 regulation forward by 3 years.

Finally, CATF conceived and played a prominent role in a campaign for the expansion of tax incentives for carbon capture and storage. After a long campaign involving research, coalition building, and advocacy, the Furthering carbon capture, Utilization, Technology, Underground storage, and Reduced Emissions Act (FUTURE Act) finally passed through Congress in February 2018 as part of the Bipartisan Budget Act of 2018. The Act expands the 45Q tax credit for carbon capture storage for both Enhanced Oil Recovery and saline CO_2 storage.[133]

One government official and one former government official have told us that CATF played a substantial role in the campaign for the increased incentives. Their account is consistent with CATF's own account of their own impact on this issue. Our rough best guess realistic estimate is that CATF brought the relevant legislation forward by ~1.5 years.

The benefits of CATF's past work

The benefits of these three projects are substantial and are estimated in our cost-effectiveness model. We estimate that via its work on coal plant regulation, CATF averted ~18,200 deaths with a pessimistic

[133] These are explained in more detail in Appendix 2. The Historical Impact of the Clean Air Task Force.

estimate of ~5,580 deaths averted and an optimistic estimate of ~56,960 deaths averted. The coal plant regulations also helped, along with lower natural gas prices, to retire a significant portion of the US coal fleet, which in turn would produce significant reductions in CO_2e emissions. We estimate that CATF averted ~10.4m tonnes of CO_2e via this mechanism, with a pessimistic estimate of ~1.3m tonnes and an optimistic estimate of ~48.5m tonnes.

The Methane Partners Campaign helped to significantly reduce methane emissions, a major greenhouse gas. We estimate that through its methane work, CATF reduced methane emissions by ~41.2m tonnes of CO_2e, with a pessimistic estimate of ~14.8m tonnes and an optimistic estimate of ~100m tonnes.

We estimate that via the CCS tax incentives campaign, CATF will avert 30m tonnes of CO_2e, with a pessimistic estimate of 14m and an optimistic estimate of 60m tonnes.

Combining the impact of the three projects, CATF has averted ~81m tonnes of CO_2e, with a pessimistic estimate of ~30m tonnes and an optimistic estimate of ~208m tonnes.

It is difficult to infer conclusions about CATF's overall impact from this because these case studies only constitute a subset of CATF's work and it is difficult to know how representative they are of CATF's impact. CATF pursued four other apparently successful projects over this period.[134] We would roughly guess that the three projects we have assessed constitute 70% of CATF's impact, though this is highly uncertain. This suggests that CATF has averted ~26,000 deaths and ~116m tonnes of CO_2e.

CATF's typical annual expenditure has been around $7m since its creation in 1996, which implies that its total expenditure has been around $147m. This implies that through its past activities averted a

[134] They appear to be successful in that the changes CATF were advocating for occurred, though we have not looked into CATF's role in these campaigns.

death for ~$5,700. CATF work was also highly cost-effective in producing climate benefits, averting a tonne of CO_2e for $1.26 with a range of ~$0.35 to $4.40, or equivalently averting 79 tonnes of CO_2e per $100, with a range of 22 to 283 tonnes.

CATF's future impact and cost-effectiveness

In this section, we will discuss the prospective cost-effectiveness of CATF's future projects. CATF is currently seeking funding for the following projects:

- Fossil fuel decarbonisation
- Advanced nuclear energy
- Methane regulation work
- Power plant regulation
- Bioenergy

The case for donating to CATF rests on the following factors:

- **Track record and organisational strength:** CATF has an outstanding track record in achieving changes that benefit the climate. In our view, their research is of very high quality. The philanthropists, scientists, policy experts and government bureaucrats we have spoken to have all expressed a similar view.
- **Technology and geography intervention focus:** CATF will work on two technologies – fossil fuel decarbonisation (CCS), and nuclear energy innovation – which the ITN rubric discussed in section 2 suggests are among the most cost-effective to advocate for. Moreover, they plan to focus on countries – China and India – which we believe to be particularly important to target based on the analysis in section 2.

- **Intervention selection methodology:** CATF uses a similar methodology to that discussed in section 2 to choose which interventions to work on. They focus on interventions that can make a large impact on emissions, but that are neglected by governments and environmental NGOs. Therefore, we are confident that they will continue to work on high value projects in the future.

We will now discuss two of CATF's future projects in more depth.

CATF's future work on carbon capture and storage

CATF's CCS team has primarily focused on winning the tax incentives for CCS, as discussed in the previous subsection. We think it is plausible that through this campaign, CATF have had a greater impact on CCS than any other global NGO working on CCS. Their past work on CCS has also focused on encouraging demonstration of CCS in the US and advocating for the use of CCS in China.

In the future, they plan to focus on:

- Building on the CCS tax incentives in the US by:
    - Promoting CCS market ecosystem development through policies that expand pipeline infrastructure and develop carbon storage management entities
    - Focusing on developing gas power with CCS projects to help enable future regulatory frameworks
- Developing public and private sector interventions to accelerate advanced carbon capture technology commercialization
- Expanding their work on CCS in China to:
    - Further develop knowledge sharing on CO_2 geologic management know-how
    - Explore opportunities for advanced CCS technology development and deployment

    - Facilitate dialogue with key decision makers on CCS policy lessons from US and collaboration opportunities

- Identifying emerging CCS geographic opportunities, including in India and the Middle East.
- Exploring the opportunity for gas reforming with CCS as a zero-carbon fuel production option (for ammonia or hydrogen).
- Identifying and developing opportunities, beyond US incentives, to facilitate gas power with CCS.
- Identifying and developing opportunities, beyond US incentives, to facilitate Industrial CCS.

We have not tried to quantify the impact of CATF's future work on CCS. At present their CCS team is focused on developing a long-term strategy for concrete CCS advocacy around the priorities above. Since it is unclear what this strategy will look like, quantifying this effect would be very difficult, and would not provide more information than we already have regarding CATF's organisational effectiveness, and the prospective cost-effectiveness of working on CCS in China, India and the US.

We think it is plausible that much of CATF's prospective impact on CCS will come from China. To our knowledge, CATF are the only NGO actively promoting CCS in China. However, we are very unsure on how easy it is to make progress on CCS in China. This being said, we do have some information suggesting that CATF is better placed than other organisations. Julio Friedmann, a former US government official who has been working on CCS in China since 2006, told us that CATF has been the most effective foreign NGO working on CCS in China.[135] Friedmann also provided support for

[135] Conversation with Julio Friedman, 11th Jan 2018.

CATF's claim that they have directly contributed to the recognition of the importance of CCS by the Chinese government.

For these reasons, we think it is likely that whatever strategy CATF chooses, its work on CCS will be highly cost-effective. In light of CATF's outstanding track record on CCS, we believe that have a better chance of success on CCS than any other NGO working on the problem. Since CCS is so neglected, we believe this work will be highly valuable.

CATF's future work on nuclear power

The main constraints on the expansion of nuclear power as a climate mitigation tool are cost, build time overruns, and public concerns about safety and waste.[136] In the US and in many European countries, the cost of constructing a nuclear power station has increased over the last few decades. This cost trend has not, however, been observed in some countries, such as South Korea and Japan.[137] CATF's nuclear work since 2007 has focused on encouraging innovation in the nuclear sector to improve safety, increase proliferation resistance, lower costs, and reduce building time. We recognise that nuclear power is controversial. We discuss the issues surrounding nuclear power in Appendix 6. Concerns About Nuclear Power. Donors who are concerned about nuclear power should make a restricted donation to CATF.

Several generations of reactors are commonly distinguished:

> "Generation I reactors were developed in 1950-60s, and the last one shut down in the UK in 2015. Generation II reactors are typified by the present US and French fleets and most in operation elsewhere. [The first] generation III [reactors]... are in operation in Japan and others

[136] Laura D. Anadón et al., "Expert Judgments about RD&D and the Future of Nuclear Energy," Environmental Science & Technology 46, no. 21 (2012): 11497–11504.
[137] Jessica R. Lovering, Arthur Yip, and Ted Nordhaus, "Historical Construction Costs of Global Nuclear Power Reactors," Energy Policy 91 (April 1, 2016): 371–82, https://doi.org/10.1016/j.enpol.2016.01.011.

are under construction in several countries. Generation IV designs are still on the drawing board and will not be operational before the 2020s."[138]

CATF's nuclear work is primarily focused on accelerating the deployment of advanced reactors (Gen III+ and Gen IV) through improving innovation policy. Examples of advanced Gen III+ reactors include offshore light water plants and small modular reactors. Gen IV reactors include molten salt, high temperature gas reactors, and sodium fast reactors.

CATF's main accomplishments in nuclear include:

- In 2012, published the first US survey of advanced fission reactor technologies.
- In 2013, convened the Nuclear Innovation Alliance (NIA) to begin to develop federal policies to support advanced fission.
- In 2016, the NIA, staffed by CATF, produced a report providing US regulators a roadmap for licensing advanced fission plants, and engaged intensively with the Commission, staff, policymakers, and industry; the Nuclear Regulatory Commission has taken up this agenda and begun to staff up to achieve it;[139]
- Worked with US Congressional staff and US national laboratories to develop concepts for research development and demonstration programmes for advanced fission.
- In March 2018, the U.S. Senate passed the Nuclear Energy Innovation Capabilities Act (S.97). This bill strengthens partnerships between the private sector and government labs and

[138] http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/advanced-nuclear-power-reactors.aspx
[139] https://www.utilitydive.com/news/nrc-chair-outlines-reforms-for-advanced-reactor-reviews/518594/

authorizes investment in crucial testing infrastructure. Several other nuclear innovation bills have passed out of committee and await further action.

We believe that CATF's work on nuclear represents a high-risk high-reward opportunity. An individual who wished to remain anonymous has told us that CATF research has already had a major impact on US policy on nuclear innovation policy, and that its work in this domain would not have been carried out by another environmental NGO. We put significant weight on the opinion of this individual. Professor Per Peterson, Chair of the Department of Nuclear Engineering at the University of California at Berkeley has told us that "I would say that CATF, working along with two other key policy think tanks/organizations (Third Way and Nuclear Innovation Alliance [which was created by CATF]) have done more to change the future prospects for nuclear energy to play a major positive role than any other efforts of the last 4 decades."[140]

On the basis of a report by the Energy Options Network,[141] CATF believes that advanced reactors will be significantly cheaper than current designs if they take a modern manufacturing-based approach to fabrication and deployment. According to the estimates in that study, the average levelised cost of various advanced reactor designs would be $60/MWh, roughly comparable to gas power.[142]

We are sceptical that advanced reactors will be as cheap as this for a number of reasons. Firstly, this report relies on the "inside view" of advanced nuclear companies on the future costs of their plants (although this was checked against third party estimates in some cases and a standard costing model). We think that in general it is more reliable to use the "outside view", which would compare the

[140] Personal correspondence, Prof Per Peterson, Jan 30th 2018.
[141] The Energy Options Network was created by CATF.
[142] See p. 2 of http://innovationreform.org/wp-content/uploads/2017/07/Advanced-Nuclear-Reactors-Cost-Study.pdf. Levelised cost is an artificial metric used to compare the costs of different power sources. It is an especially misleading way to compare intermittent and non-intermittent sources.

future reactors to a class of past similar cases.[143] The outside view suggests that costs would be substantially higher.

Secondly, a 2008 expert elicitation survey showed that the average nuclear expert expected advanced reactors to be more expensive than current designs.[144] However, it is not clear how applicable this survey is to the innovation reform pursued by CATF. The Anadón et al survey studies the effect of historically publicly funded and government-designed RD&D into reactors that typically lacked a focus on cost reduction. By contrast, CATF's approach is focused on enabling the private sector, overall plant cost reduction, and is not primarily focused on improving the reactor portion of nuclear plants, as reactors comprise only 15% of total project cost.[145]

Thirdly, there is some evidence that nuclear innovation has historically *increased* costs in some countries.[146] Berthélemy and Rangel argue that homogeneity between reactor designs and repeated learning from building the same standardised model over time reduces costs.[147] However, it is not clear how applicable this is as a criticism of CATF's plans to encourage nuclear innovation. CATF plans to encourage some gains from industry standardisation, but also to have significant private sector variety.

For these reasons, we think that there is less than 10% chance that, if the reforms advocated for by CATF are implemented, advanced nuclear will have comparable costs to gas power. Nevertheless, our cost-effectiveness model suggests that even if the project has a 1% chance of success, its expected

[143] Daniel Kahneman, "Daniel Kahneman: Beware the 'inside View' | McKinsey & Company," accessed February 28, 2018, https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/daniel-kahneman-beware-the-inside-view.
[144] Anadón et al., "Expert Judgments about RD&D and the Future of Nuclear Energy."
[145] Armond Cohen, personal communication, Feb 9th 2018.
[146] Michel Berthélemy and Lina Escobar Rangel, "Nuclear Reactors' Construction Costs: The Role of Lead-Time, Standardization and Technological Progress," Energy Policy 82 (July 1, 2015): 118–30, https://doi.org/10.1016/j.enpol.2015.03.015.
[147] Berthélemy and Escobar Rangel.

benefits would be very large. The reason for this is that we think there is a reasonable chance that CATF will change the future trajectory of innovation policy and that if they succeed, their work will have large positive spillovers by creating global public goods. If nuclear does fall in cost precipitously, then there will be significant deployment of nuclear, which would have very large climate benefits. Consequently, we think the project would be worth investing in, as a high-risk high-reward opportunity.

Our model excludes some important benefits of nuclear innovation. Most importantly, we think it is likely that nuclear innovation will significantly improve the safety of nuclear plants.[148] This is valuable in and of itself and will also help to reduce public acceptability concerns, a major constraint on the scale-up of nuclear required for deep decarbonisation.

In addition, CATF has launched a partially funded project focusing on increasing the proliferation resistance of advanced nuclear. We believe it is likely that CATF's work would reduce proliferation risk by two mechanisms.[149] Firstly, if successful, CATF's work would strengthen America's standing in the nuclear export market relative to other powers such as Russia who are less concerned about proliferation. Control over the nuclear export market is one of the main ways in which the US executes its non-proliferation aims. Thus, expanding the role of nuclear in the US is likely to reduce proliferation risk. Secondly, the US has the strongest non-proliferation controls in the world, and if US advanced nuclear companies do not meet these standards, then the US will not permit them to export the technology abroad. In that scenario, advanced reactors from Russia and China are more likely to become available without the same level of proliferation controls. Thus, CATF's focus on ensuring that advanced designs meet US non-proliferation export standards is likely to produce security benefits.

[148] Anadón et al., "Expert Judgments about RD&D and the Future of Nuclear Energy."
[149] See Appendix 6. Concerns About Nuclear Power on the link between nuclear energy and nuclear power.

Is it a strong organisation?

We believe that CATF is a very strong organisation. We have been impressed with all of its research. We have spoken to more than a dozen philanthropists, energy policy experts, scientists, and government bureaucrats who have all praised the quality of CATF's work. Many of them have stated that CATF punches above its weight in achieving impactful changes on a small budget. CATF has conceived of and been involved in an unusually large number of successfully policy advocacy campaigns.

CATF's team have been extremely helpful throughout the process and have shared very large amounts of relevant information on CATF's past achievements, and future plans.

Is there room for funding?

For the 2018 financial year, CATF estimates a total budget of $5.5m for their current project work and organisational expenses. They anticipate that they will raise this money through renewals of grants.

In order to execute fully on their programs, however, CATF would need to raise approximately $2.1m in additional new revenue. Broken down by project area, this figure represents:

- $800,000 for Nuclear Innovation
- $600,000 for Decarbonised Fossil Energy
- $300,000 for Power Plant Regulations
- $300,000 for Methane Regulations and Best Practices
- $100,000 for Bioenergy

CATF are discussing this agenda with a small group of current funding sources, but to meet this ambitious goal they will need new donors.

We recommend unrestricted funding for CATF because we believe their process for selecting projects is highly likely to lead them to focus on cost-effective projects. Unrestricted funding would give them maximal flexibility to prioritise their projects.

4. Future Research and Recommended Reading

Climate change is an extremely complex scientific, political and economic issue. There are scarcely any policy approaches that are not contested by some experts or climate activists: support for each of renewables, energy efficiency, nuclear, carbon capture and storage, and preventing deforestation through REDD+ are strongly supported and opposed by some important constituencies. In light of this complexity and controversy, modesty about the findings of this report is appropriate. Climate change is an open hard problem, and this report is one contribution from an impact-focused philanthropic perspective; doubtless many other reasonable approaches could have been taken.

We have found the following literature especially useful:

- IPCC, Mitigation of Climate Change, 'Technical Summary', 2014
    - An 80 page comprehensive overview of the issues surrounding mitigation of climate change.
- Gernot Wagner & Martin Weitzman, *Climate Shock*, 2015
    - This discusses the science and economics of climate change with a focus on catastrophic risk. Wagner and Weitzman argue that we should pay more attention to the roughly 10% chance of catastrophe we are headed for without a drastic course correction.
- David Mackay, *Sustainable Energy – without the hot air, 2009*
    - An accessible overview of the technology options we have at our disposal to tackle climate change. It is also one of the greatest books on policy for the general reader ever written.
- International Energy Agency, *Key World Energy Statistics*

    - An overview of energy demand over time, and the main sectoral and geographical sources of energy supply and CO_2 emissions.

- www.electricitymap.org
    - An interactive map showing the mix of different technologies in electricity systems.
- World Bank, Carbon Pricing Watch, 2017
    - An overview of the (lack of) progress on the climate policy preferred by economists.
- Brick and Thernstrom, 'Renewables and decarbonization: Studies of California, Wisconsin and Germany', *The Electricity Journal*
    - An argument for the need for a range of energy supply technologies in decarbonised energy systems.
- Seymour and Busch, *Why Forests? Why Now?*, 2016
    - A comprehensive overview of the problem of deforestation, and the promise offered by REDD+.

Appendix 1. The Historical Impact of The Coalition for Rainforest Nations

1. The history of forestry in UN climate negotiations

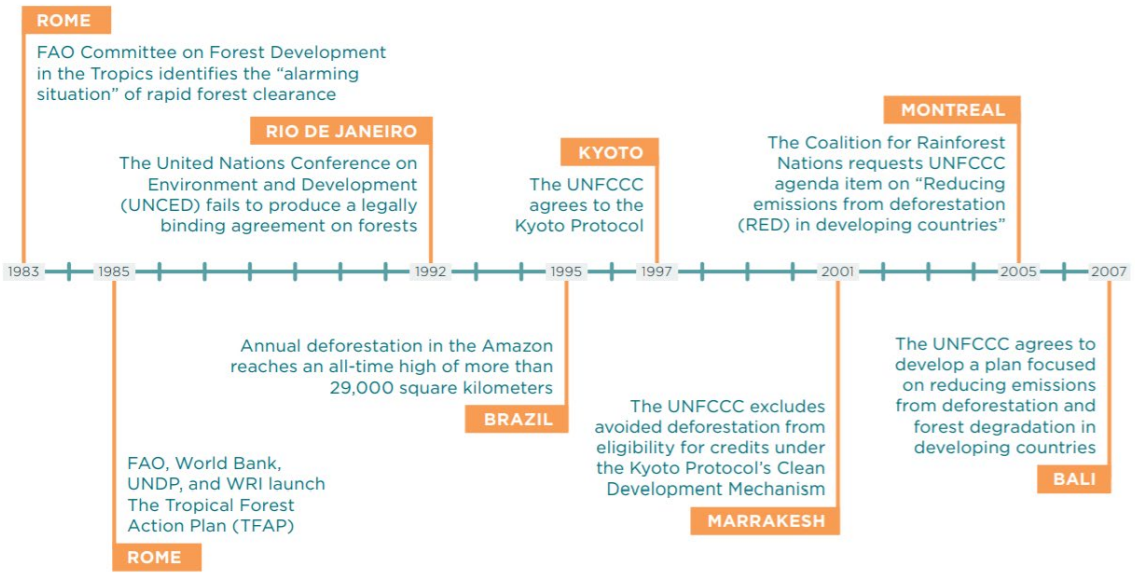
In this section, we will provide some background and context on global forestry negotiations leading up to the intervention of the Coalition for Rainforest Nations (CfRN) in 2005.

1.1. The divide on forests and the failure of Kyoto

As deforestation increased rapidly from 1970 onwards, it became of increasing concern to the international community and to environmental organisations. However, global action on forestry made little progress until the introduction of Reducing Emissions from Deforestation (RED) at the UN Framework Convention on Climate Change by the Coalition for Rainforest Nations (CfRN) in 2005. Figure 1 provides a timeline of key recent events in global forestry politics until 2007.

Figure A1.

Timeline of key events in global forestry politics, 1983 -2007. (The UNFCCC is the UN Framework Convention on Climate Change)



Source: Seymour and Busch, *Why Forests? Why Now?*, Center for Global Development, p. 253.

In the 1990s, a number of prominent organisations called for negotiations toward a global convention on forests. Forests were high on the agenda at the Rio Earth Summit in 1992. As Seymour and Busch write:

> "Ultimately, although UNCED [the 1992 Rio Earth Summit] succeeded in concluding conventions on climate change, biodiversity and desertification, an agreement on forests was

> limited to a non-legally binding statement of principles on the "management, conservation, and sustainable development of all types of forests.""[150]

The negotiations were primarily divided on North and South lines, with the US and the EU in favour of a legally binding treaty, and lower income countries opposed. One of the key objections concerned *equity*. Lower income countries believed that legal restrictions on deforestation would be unfair, given that high income countries had already deforested their territories in the pursuit of economic development.[151] Due to this and other reasons, there was no progress on a global forestry treaty. However, at Rio, the international community did agree on a climate change treaty, the UN Framework Convention on Climate Change (UNFCCC), which would open the door to international negotiations and agreements on climate change, enabling, amongst other things, the 1997 Kyoto Protocol and the 2015 Paris Agreement.

The Kyoto Protocol for the first time imposed legally binding emissions restrictions on industrialised countries. However, because the agreement was not binding on developing countries, most potential emissions from tropical deforestation were not included in its effective scope.[152] Tropical forests could have been included as part of the Clean Development Mechanism, which allowed industrialised countries to offset their emissions by investing in projects that would reduce emissions in developing countries. The inclusion of forestry offsets in the Clean Development Mechanism was highly contentious, and the debates that were to follow foreshadowed those over the 2005 Reducing Emissions from Deforestation proposal.

[150] Seymour and Busch, *Why Forests? Why Now?*, 254.
[151] Seymour and Busch, 255.
[152] Seymour and Busch, 255.

Those in favour included the US, Australia, Canada, Japan, and some Latin American countries, as well as some conservation groups such as the Nature Conservancy.[153] The main opponents were Brazil, the European Union, some scientists, and a few NGOs. The primary objection to the inclusion of forestry offsets in the Clean Development Mechanism regarded the lack of *environmental integrity*, or in other words, whether reduced deforestation could be known with confidence to have occurred.[154] Environmental integrity depends on the following factors:

- **Leakage** – Will preventing deforestation in one area would merely displace it elsewhere? If a small project prevents deforestation, loggers might instead simply deforest a nearby area. Indeed, there can be international as well as intranational leakage. Reducing deforestation in China could, for example, merely shift deforestation to Indonesia.
- **Additionality** – How should we set the baseline or "reference level" against which to measure performance in reducing forestry emissions? Project-based approaches to deforestation do not have a reference level externally audited by the UNFCCC. If reference levels are set too high, countries would be rewarded for emissions reductions that would have happened anyway, thereby failing the test of 'additionality': the failure of conservation efforts to add emissions reductions. If they are set too low, then genuine emissions reductions would not be counted.
- **Permanence** – Are emissions reductions in one period merely reversed in the next? If an acre of forest is protected for two years and is then permanently deforested, then all of the carbon stored in that area is released into the atmosphere. This does provide some climate benefit by delaying emissions and thereby slowing down the rate of warming, but it does not reduce peak warming, which might be important for some climate damages. In this respect, forests are

[153] Seymour and Busch, 256.
[154] Seymour and Busch, 270ff.

different to many energy-based emissions reduction projects. If a coal plant is replaced with a nuclear plant for five years and then coal is reintroduced, provided energy consumption is unaffected, those five years of averted emissions are permanently not added to the atmosphere. Thus, this project would reduce peak warming.

- **Measurement** – Are reductions in forest emissions measured with sufficient precision? Recent developments in satellite technology have improved monitoring of forests significantly.[155]

Due to concerns about equity, environmental integrity, and other factors, deforestation was not included in the Clean Development Mechanism at the Marrakesh Accords in 2001 (see Figure 1).[156] Only afforestation (establishing forest on previously unforested areas) and reforestation were included as eligible forest-related projects. The EU subsequently decided not to include forestry credits in the Emissions Trading Scheme launched in 2005, which until 2018 was the largest carbon compliance market in the world (China's scheme is starting in 2018).[157] Since emissions from deforestation contributed around 15% of emissions at that time, its omission from Kyoto was a serious failure. Indeed, following Kyoto, there was a surge in deforestation, mainly driven by Brazil and Indonesia.[158]

1.2. Progress on forestry from 2005 onwards

In the years following the failure at Marrakesh, some academics and NGOs proposed the idea of compensated reduction for deforestation.[159] The proposal was later elaborated on in influential scientific papers.[160]

[155] Seymour and Busch, chap. 4.
[156] Seymour and Busch, 257.
[157] World Bank, "Carbon Pricing Watch 2017."
[158] Seymour and Busch, *Why Forests? Why Now?*, 29.
[159] Seymour and Busch, 257–58.
[160] See for example Márcio Santilli et al., "Tropical Deforestation and the Kyoto Protocol," *Climatic Change* 71, no. 3 (August 1, 2005): 267–76, https://doi.org/10.1007/s10584-005-8074-6.

At around the same time as the Brazilian NGOs, scientists and politicians began discussing the compensated reduction idea, a group of forested nations called the Coalition for Rainforest Nations (CfRN) was formed. At the time, CfRN had 15 members, and was led by Papua New Guinea and Costa Rica.[161] As of February 2018, CfRN has 52 members.[162]

CfRN have told us that the academics and NGOs decided to publish the papers on compensated reductions after learning that CfRN had decided to make a decision in May 2005.[163] This suggests that the causation ran from CfRN to the academic paper, rather than vice versa. CfRN have also told us that, even though they had run small side events at COP-9 in December 2003, the Brazilian NGOs had very little effect on wider awareness of compensated reductions. When CfRN started meeting UN Ambassadors and Ministers in March 2004 "not one of them was aware of these small and low-level discussions".[164]

At the 2005 UNFCCC meeting in Montreal, CfRN submitted a proposal for a compensated reduction scheme they called Reducing Emissions from Deforestation (RED).[165] RED would eventually become REDD+, with the extra 'D' denoting degradation, and the '+' to denote conservation and regrowth of forest stocks. Countries at the Montreal negotiations welcomed the coalition's proposal and referred the RED idea to technical experts for development over the next two years.[166]

[161] William F. Laurance, "A New Initiative to Use Carbon Trading for Tropical Forest Conservation," *Biotropica* 39, no. 1 (January 1, 2007): 20, https://doi.org/10.1111/j.1744-7429.2006.00229.x.
[162] http://www.rainforestcoalition.org/nations.aspx
[163] Email correspondence with Coalition for Rainforest Nations, March 4th 2018.
[164] Email correspondence with Coalition for Rainforest Nations, March 4th 2018.
[165] Seymour and Busch, *Why Forests? Why Now?*, 258.
[166] Seymour and Busch, 259.

REDD+ was developed and refined over the years and enshrined in Article 5 of the Paris Agreement in 2015. It is the only sector with its own article. REDD+ is designed to overcome the barriers associated with equity and environmental integrity.

- **Equity**: REDD+ enabled industrialised countries to compensate developing countries for protecting their forests. Since performance was to be judged and rewarded on a results-based basis, there was no conditionality that could threaten national sovereignty.
- **Leakage**: REDD+ should be implemented at the national scale rather than the project scale. National REDD+ results are to be independently assessed by forestry experts and according to UNFCCC guidelines, reducing the risk of intrastate leakage. Moreover, REDD+ is voluntary and designed to encourage widespread participation, reducing the risk of interstate leakage. Almost all rainforest nations now have national REDD+ plans, with the main notable exception being Malaysia.[167]
- **Additionality**: a country must have in place a reference level against which performance will be vetted, which is externally assessed by the UNFCCC. This ensures the additionality of forest emissions reductions.
- **Permanence:** Some REDD+ funds used buffers to ensure permanence. With buffers, a portion of avoided emissions credits is set aside and held in escrow for a specific period, so the seller receives the funds only after the forest carbon stock has been maintained for that length of time.[168] National level monitoring, external assessment, and certainty of future payment streams also reduce the risk of subsequent reversal.

[167] Seymour and Busch, 197.
[168] Seymour and Busch, 272–73.

- **Monitoring and verification:** Advances in satellite technology have made monitoring and verification much easier. This development is independent of REDD+. However, the standardised external Monitoring, Reporting, and Verification required under REDD+ capitalises on these developments.[169]

In this way, REDD+ has overcome many of the recurrent and valid objections to the inclusion of forestry in UNFCCC treaties.

2. The role of the Coalition for Rainforest Nations

In this section, we will discuss the evidence on CfRN's counterfactual impact on global deforestation from their formation until today. We are confident that the Coalition for Rainforest Nations played a pivotal role in securing international agreement on and funding for REDD+. CfRN had an impact by proposing REDD+ in 2005 and by advocating for it throughout UNFCCC negotiations up to Paris 2015.

Without CfRN, our best guess realistic estimate is that an international agreement on REDD+ would have been delayed by three years. We also believe that REDD+ is superior to other forestry mechanism in terms of effectiveness and in terms of political support. By advocating for REDD+ rather than another possible forestry mechanism, CfRN had a large impact.

2.1. Counterfactual impact of the timing and nature of the initial proposal

As mentioned above, CfRN were the first to propose RED at the UNFCCC. Since there are gaps of one year between UNFCCC meetings, it is highly likely (>95% probability) that CfRN brought the proposal forward by at least one year. It is unclear how likely it is that RED or a similar idea would have been proposed at the subsequent UNFCCC (2006) meeting without CfRN. Our realistic estimate is that by acting when they did, CfRN brought the proposal forward by 2 years, though we can also see plausible

[169] Seymour and Busch, 270–71.

arguments that the true figure could be up to 5 years. In light of such uncertainty, we err on the side of conservatism. There are a number of pieces of evidence in favour of this conclusion.

Firstly, the process of getting a new item on the UNFCCC agenda is very complex.[170] A new item must be agreed unanimously by all countries. The evidence suggests that Brazil and the US were strongly opposed to a proposal on compensated reductions. Because unanimity is required, CfRN had to meet numerous delegations to secure support. This suggests that the barriers to a successful REDD+ proposal were high.

Secondly, according to a number of sources, it was crucial for the acceptance of RED that it was proposed by CfRN, a group of developing countries.[171] This allowed the proposal to avoid the optics of providing an 'escape clause for developed states', which would plausibly have led to the proposal being opposed by Brazil, as similar proposals were previously.[172] If Brazil had not been on board, there is almost no chance (<1%) that progress would have been made on RED. Moreover, before the formation of the CfRN, the nations involved had little voice or influence; CfRN helped to give them this influence.[173] There is very little chance (<5%) that the CfRN member-states acting alone would have had the negotiating power to push the proposal forward, or that they would have converged on RED in the absence of the leadership of CfRN strongly supporting it.

Thirdly, it is unlikely that Brazil would have proposed RED in 2006. It is true that parts of the Brazilian government were considering RED around the time of the Montreal meeting in 2005.[174] However,

[170] Personal correspondence with CfRN, March 4th 2018.
[171] Seymour and Busch, *Why Forests? Why Now?*, 261.
[172] Jen Iris Allan and Peter Dauvergne, "The Global South in Environmental Negotiations: The Politics of Coalitions in Redd+," *Third World Quarterly* 34, no. 8 (September 1, 2013): 1317, https://doi.org/10.1080/01436597.2013.831536; Laurance, "A New Initiative to Use Carbon Trading for Tropical Forest Conservation," 21.
[173] Conversation with Rubén Kraiem, 6th Feb 2018; Allan and Dauvergne, "The Global South in Environmental Negotiations," 1318.
[174] Seymour and Busch, Why Forests? Why Now?, 258.

Seymour and Busch comment that "discussions in Montreal in turn forced the government of Brazil to articulate a position on the RED idea".[175] According to Seymour and Busch, Brazil did not expect RED to move forward, and Brazilian negotiators were instructed to reject any binding commitments, conditions (including on how the money would be used), and any finance through carbon markets.[176] Thus, it seems unlikely that Brazil would have proposed a RED-type proposal in the following year.

Fourthly, although RED-type proposals were popular with some NGOs, such as The Nature Conservancy and the Environmental Defense Fund, and with some academics, CfRN was in a unique position because its leader, Kevin Conrad, served as Papua New Guinea's Ambassador to the UNFCCC and therefore could influence negotiations directly as a representative of a sovereign state. No pro-REDD non-governmental organisation could plausibly have had the same influence in the negotiations.[177]

Fifthly, there is some evidence that it was only due to CfRN strategy that the RED proposal was not struck down by the US at Montreal. The journalist Rhett Buttler writes:

> "The Coalition went to the U.N. Conference of the Parties (COP) meeting in Montreal in 2005 and immediately met opposition from the United States, which was content doing nothing on climate. The U.S. delegation told Conrad it would kill the Coalition's proposal, fearing that if developing countries put forth a plan committing to robust and meaningful reductions in greenhouse gases, the United States would no longer have an excuse not to take action on climate.

[175] Seymour and Busch, 259.
[176] Seymour and Busch, 259.
[177] Redstone Strategy Group, "The Linden Trust Syndicate's Support to Launch REDD+: An Independent Assessment," October 27, 2016.

> "The U.S. was going to block us simply for that," Conrad said.
>
> Conrad engineered a strategy for delaying U.S. action during the Montreal talks, persuading dozens of countries supportive of the proposal to push their voting buttons ahead of the United States.
>
> "If the U.S. went first, all the naysayers would pile on," he said. "But if they were fortieth following a long trail of positives I was hoping they wouldn't be able to kill the proposal."
>
> Sure enough the United States agreed to give the proposal two years, sending it out to committee with the expectation that it would collapse under the technical challenges of measuring, verifying, and monitoring emissions from deforestation. Should the proposal make it to COP 13 in Bali in December 2007, the U.S. delegation promised to kill the measure then."[178]

This suggests that even if another group had proposed RED in 2005 or in the 1-2 years following, without careful strategy, it would not have got through. Veerle Vandeweerd, who was Director of Environment at the UN Development Program at the time of the negotiations, told us that CfRN was successful because it had fully thought through the science and logistics of the proposal.[179] Even if another group had proposed it, it is plausible that their work on RED would have been of lower quality.

Sixthly, many of the most important tropical forest nations, with the exception of Brazil, went on to join CfRN after 2005, which suggests that CfRN provided leadership on the issue of RED.[180] Moreover, according to Allan and Dauvergne, many of the states outside CfRN, have shown "little or variable

[178] Rhett Butler, "Are We on the Brink of Saving Rainforests?," Conservation news, July 22, 2009, https://news.mongabay.com/2009/07/are-we-on-the-brink-of-saving-rainforests/.
[179] Conversation with Veerle Vandeweerd, 6th Feb 2018.
[180] Allan and Dauvergne, "The Global South in Environmental Negotiations," 1318.

interest" in REDD+.[181] A number of sources note that CfRN has been the most consistent voice in favour of REDD+.[182]

Seventhly, a number of sources suggest that there was significant opposition to RED, even at the 2007 Bali UNFCCC meeting. Rubén Kraiem, a pro-bono legal advisor to CfRN at the time, asserted this to us in conversation.[183] An independent assessment of CfRN's work over this time suggested that there was an "affirmative bias" against RED-type proposals at the time, and that the ex ante probability of success was low.[184] This is additional evidence for the view that RED would not have been proposed and passed in the year after Montreal, without CfRN's work.

The main uncertainty regards whether, if CfRN had not acted, another coalition or state would have proposed a RED-type system in the UNFCCC meetings in 2006 or 2007. Since many states joined CfRN after 2005, this does suggest there was some demand for it even without CfRN. Moreover, there was probably more scope for a global agreement on forests from around 2007 onwards because the improvements in technology made monitoring and verification much easier.[185] This being said, for the reasons outlined above, we think it is unlikely that it would have successfully proposed in the following year.

In summary, we believe that by proposing RED when they did, CfRN at least brought RED forward by a year, and most likely brought it forward by 2 years, though this estimate may be conservative. CfRN have told us that due to the political complexity involved in getting a new item on the UNFCC agenda, it is very unlikely that another actor would have successfully proposed RED in the next few years. Due

[181] Allan and Dauvergne, 1316.
[182] Redstone Strategy Group, "The Linden Trust Syndicate's Support to Launch REDD+: An Independent Assessment"; Allan and Dauvergne, "The Global South in Environmental Negotiations"; Butler, "Are We on the Brink of Saving Rainforests?"
[183] Conversation with Rubén Kraiem, 6th Feb 2018.
[184] Redstone Strategy Group, "The Linden Trust Syndicate's Support to Launch REDD+: An Independent Assessment," 8.
[185] Seymour and Busch, *Why Forests? Why Now?*, chap. 4.

to this factor, Kevin Conrad of CfRN estimates that if CfRN had not acted, it would have taken 5-7 years for another strong advocate to emerge.[186] We find this line of reasoning plausible, and this suggests that our estimate may be on the conservative side.

2.2. Impact of CfRN throughout the negotiating process

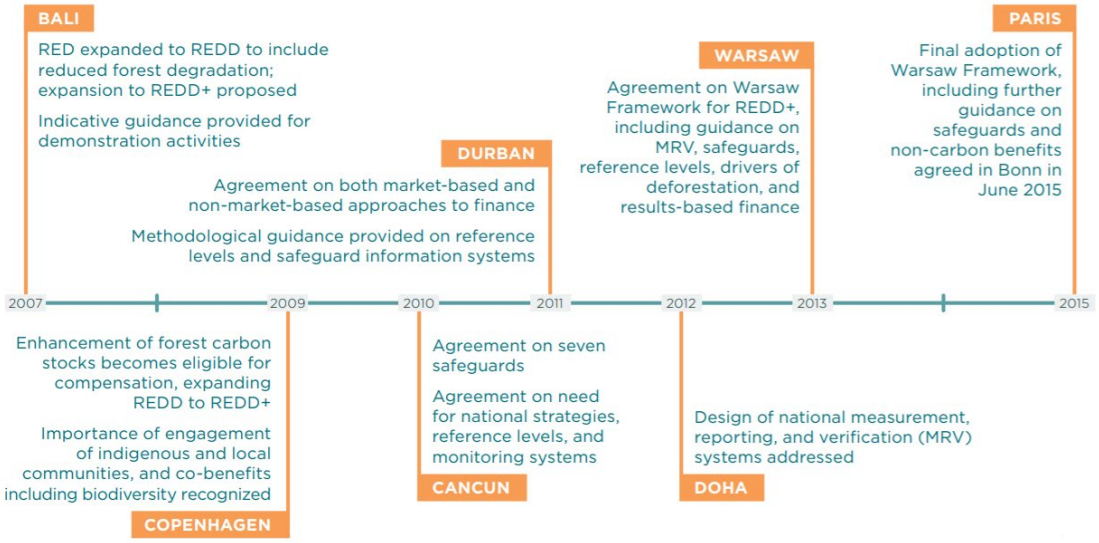
CfRN plausibly had a very large impact not just by proposing RED, but also by their work in the negotiating process from 2005 onwards. As Figure A2 shows, there was progress on key components of REDD+ from the 2007 Bali meeting onwards. If talks had collapsed at any of the UNFCCC meetings from 2005 to 2015, then agreement on REDD+ would have been delayed by at least a year. CfRN's impact via this mechanism is somewhat harder to judge, but our best guess realistic estimate is that, through this mechanism, CfRN brought a global agreement on forestry forward by 1-2 years.

It will be useful first to provide some background on post-2005 developments (see Figure 2):

[186] Personal correspondence with CfRN 4th March,

Figure A2.

Timeline of key events in global forestry politics, 2007-2015



Source: Seymour and Busch, *Why Forests? Why Now?*, Center for Global Development, p. 253.

A number of sources suggest that from 2005 onwards there were major barriers to progress on REDD+ and that CfRN played a crucial role in the negotiations, which eventually culminated in the completion of the REDD+ framework at the Warsaw meeting in 2013, and the inclusion of REDD+ in Article 5 of the 2015 Paris Agreement.

- At the Bali Conference in 2007, CfRN leader Kevin Conrad famously challenged the US's intransigence on climate action by saying "we ask for your leadership, we seek for your leadership, but if for some reason you are not willing to lead... please get out of the way".[187]

[187] This is available to view on YouTube here.

This set off a burst of applause at the meeting and is widely thought to have caused the US to capitulate, paving the way for the Bali Action Plan.[188]

- Allen and Dauvergne cite CfRN as the most influential voice in the REDD+ negotiations, along with Brazil.[189]
- Veerle Vandeweerd, Director of Environment at the UN Development Program at the time of the negotiations, told us in conversation that CfRN performed high quality scientific work, and was efficient and well organised.[190] She concluded that there would be no REDD+ without CfRN, and said that she is advising them now because of admiration for their previous work.
- Rubén Kraiem, a pro-bono legal advisor to CfRN, told us that CfRN were the facilitator and leader of the REDD+ negotiations.[191] He said that at the 2007 Bali meeting, there was continuing opposition and hostility to REDD+, and CfRN was the most consistent advocate for it.
- Seymour and Busch note that "small groups of developing countries, such as the Africa Group and CfRN, played more prominent roles in REDD+ negotiations than the G77 and China, which generally represented common positions among developing countries".[192]
- The external assessment of CfRN by the Redstone group cites a number of interviews of individuals present during the negotiations stating that there were significant barriers to success and without CfRN's work from 2005 onwards, there would have been no REDD+.[193]

[188] Seymour and Busch, *Why Forests? Why Now?*, 259–60; Butler, "Are We on the Brink of Saving Rainforests?"
[189] "Those states and coalitions, such as Brazil and the CfRN, able to retain a consistent, cohesive voice have, not surprisingly, emerged as influential actors in the REDD+ negotiating process." Allan and Dauvergne, "The Global South in Environmental Negotiations," 1315.
[190] Conversation with Veerle Vandeweerd, 6th Feb 2018.
[191] Conversation with Rubén Kraiem, 6th Feb 2018.
[192] Seymour and Busch, *Why Forests? Why Now?*, 265.
[193] Redstone Strategy Group, "The Linden Trust Syndicate's Support to Launch REDD+: An Independent Assessment," 6ff.

In addition to this, it is notable that talks collapsed at the 2009 UNFCCC Copenhagen meeting, but there was agreement on a number of aspects of REDD+.[194] This suggests that securing agreement on REDD+ was a major achievement given the wider progress of climate negotiations.

Moreover, after 2005, CfRN grew appreciably,[195] with Indonesia, the second largest producer of deforestation emitters joining in 2006.[196] This suggests that CfRN was seen by other sovereign states as one of the most important players in the negotiations.

Our **uncertain and subjective** view is that this evidence combined suggests that without CfRN's work from 2005 onwards, there was a >60% chance that talks on REDD+ would have collapsed at one of the UNFCCC meetings, delaying REDD+ agreement by at least a year. This would have delayed progress by at least one year. Our realistic estimate is that this would have delayed an agreement by 1-2 years.

3. Overall impact of CfRN's work

We have argued that CfRN brought forward an international agreement by being first mover in proposing RED, and by its prominent role in RED negotiations from 2005 onwards.

- Our realistic estimate is that by being a "first mover", CfRN brought forward a RED-type system by two years.
- Our realistic estimate is that through its work in the forestry negotiations from 2005 onwards, conditional on RED being proposed in 2005, CfRN brought forward agreement on a RED-type system by 1-2 years.

[194] Seymour and Busch, *Why Forests? Why Now?*, 262–64.
[195] Allan and Dauvergne, "The Global South in Environmental Negotiations," 1318.
[196] Seymour and Busch, *Why Forests? Why Now?*, 269.

These time periods cannot strictly be added together to evaluate CfRN's overall counterfactual impact, because these are not independent events. Nonetheless, adding is likely to approximate the true effect. Our "best guess" realistic estimate is that CfRN brought forward global agreement on forestry by 3 years.

How good was this for the climate? We quantify this by assessing the expected future impact of the REDD+ funding mobilised as a result of CfRN's work.

3.1. Quantified benefits

Countries such as Norway plausibly would not have pledged billions of dollars to deforestation prevention had there not been agreement on the specifics of REDD+ and the expectation that REDD+ would be recognised in the UNFCCC as counting towards their national emissions reductions. Between 2006 and 2014, a total of $9.8bn had been pledged in forest finance, with ~$400m disbursed.[197] The apparatus required to credit REDD+ results is still being set up, so to estimate the impact of this money, we have to project the expected impact of this money in the future. If a significant portion of this money is spent on REDD+, and REDD+ is as cost-effective as many experts believe, a naïve estimate (multiplying additional funding by cost per tonne averted) suggests CfRN's impact would be extremely large.[198]

One problem with the naïve approach is that it is does not adjust for various factors which might affect the counterfactual impact of CfRN's work. The most obvious such factors are:

1. **Reducing emissions reduction cost rather than reducing emissions:** If REDD+ mitigation opportunities are not available, funders would have spent their money on other forms of CO_2e

[197] Norman and Nakhooda, "The State of REDD+ Finance," 19.
[198] See our cost-effectiveness model.

mitigation. Increasing the availability of REDD+ offsets would merely reduce the cost of mitigation, it would not increase total mitigation.

2. **Temporal funding shifting effect:** It might be that CfRN merely brought forward REDD+ funding, but did not increase the total amount of REDD+ funding and so did not increase the total amount of deforestation emissions prevented.

We think both effects are likely to have a small effect on CfRN's counterfactual impact. With respect to the first factor, the argument is as follows. Preventing deforestation is one of the cheapest way to abate emissions, and at current levels of spending, the next cheapest mitigation option is 2-3 times more expensive.[199] Since for the next few billion dollars it costs ~$5-$10 to abate a tonne of CO_2e via preventing deforestation, states would otherwise have to pay upwards $20 per tonne to abate the same amount of CO_2e through some other mechanism. Few states have shown the willingness to pay >$10 to abate a tonne of CO_2e.

One can roughly quantify the size of this effect by examining global carbon pricing schemes. As of 2017, there were 47 regional, national, and subnational carbon pricing schemes, covering around 20% of global emissions. However, three quarters of covered emissions remain priced at less than $10/t$CO_2e$.[200] Only a handful put a price on carbon in excess of $20/t$CO_2e$, and these schemes cover only ~5% of global emissions.[201] This suggests that if the cost of abatement increased from $5-$10/tonne to >$20/tonne, the vast majority of states would merely increase emissions, rather than incur a higher financial cost. In technical terms, the elasticity of the global carbon budget to the cost

[199] See Seymour and Busch, *Why Forests? Why Now?*, chap. 5, and especially p. 137.
[200] World Bank, "Carbon Pricing Watch 2017," 4.
[201] World Bank, 7.

of abatement is very high. We can roughly conclude that this factor would most probably justify revising the naive estimate down by around 5%.[202]

The second factor is also likely only to justify a small adjustment of the naive estimate. For this factor to be important, it would have to be the case that increased REDD+ funding in the first few years would lead to counterfactually decreased REDD+ funding in the years that follow. It might be thought that states will devote a set amount to forests over the next few decades, and that the overall effect of this money is independent of timing.

This seems unlikely to be the case. By making cost-effective deforestation prevention available 3 years earlier, CfRN allowed countries to protect areas that would otherwise be deforested in that time. If the deforested area would regrow in 3 years, then that area could be protected with the help of increased REDD+ finance in 3 years' time. However, the evidence suggests that the area would not regrow in 3 years' time, and instead that ~95% of deforested tropical land does not regrow 12 years after it has been deforested.[203] It is unclear how long these areas will remain deforested for. But this suggests that bringing REDD+ finance forward increases the total area that can be protected from deforestation. Since this increased area of forest will be eligible for REDD+ funding, and REDD+ emissions reductions are so cheap, CfRN have increased the total amount of funding for REDD+. Our best guess is that this factor does not justify adjusting CfRN's impact by more than 5-10%.

[202] It might be argued that prices are so low because of the availability of REDD+. In response, firstly, most of these carbon pricing schemes were set up before REDD+ was agreed in 2015; and secondly, many of these schemes do not include REDD+ credits. For example, the EU's carbon pricing scheme, the largest in the world until late 2017 does not currently allow REDD+ credits.

[203] "A total of 2.3 million km^2 of forest were lost due to disturbance over the study period and 0.8 million km^2 of new forest established. Of the total area of combined loss and gain (2.3 million km^2 + 0.8 million km^2), 0.2 million km^2 of land experienced both loss and subsequent gain in forest cover during the study period." M. C. Hansen et al., "High-Resolution Global Maps of 21st-Century Forest Cover Change," *Science* 342, no. 6160 (November 15, 2013): 850–53, https://doi.org/10.1126/science.1244693. Figure 1 of Hansen et al suggests that most of this effect is driven by regions outside the tropics.

Overall, this suggests that by bringing REDD+ forward by 3 years, CfRN had a substantial effect, though probably lower than a naïve estimate (multiplying additional annual funding by the time CfRN brought the money forward) would suggest. Our best guess is that, due to these factors, CfRN's counterfactual impact should be adjusted downwards by ~10-15%, though this figure is uncertain. CfRN's past impact is calculated in our cost-effectiveness model.

3.2. Other benefits

CfRN's work also produced some other benefits, which we have not included in our model. These are potentially quite substantial, though we think they are likely to be lower than the modelled benefits.

Effect on national forestry plans

REDD+ encourages deforestation prevention through the provision of financial incentives. However, securing global agreement on REDD+ at the UNFCCC probably encouraged action on forestry even if results-based funding is not forthcoming to support this action. Thus, focusing only on the funding mobilised may understate CfRN's impact. Under the Paris Agreement, each state submits a Nationally Determined Contribution, which is a national plan of emissions reductions that is supposed to be consistent with the <2°C target. Reductions in forestry emissions are now eligible to be part of state's emissions reductions.[204] Had there not been agreement on the various mechanisms to ensure the environmental integrity of forestry offsets, it is unlikely that forestry offsets would have be eligible as part of a state's Nationally Determined Contribution. As we have seen above, concerns about environmental integrity led to the exclusion of deforestation from the Kyoto Protocol.

Therefore, insofar as states are willing to keep to the forestry commitments in their Nationally Determine Contributions even if they do not receive REDD+ compensation, bringing forward

[204] Seymour and Busch, *Why Forests? Why Now?*, 370ff.

agreement on REDD+ will have been impactful, independent of REDD+ funding mobilised. Three countries – Brazil, Ecuador and Malaysia – have completed the process to have REDD+ results credited.[205] 67 countries have now developed national REDD+ plans, including most of the leading emitters from deforestation (Indonesia, Myanmar, Zambia, Tanzania etc).[206] In 2004, by contrast, only one country had conceived of a REDD+ strategy (Costa Rica). Had the details of REDD+ not been worked out at the UNFCCC, such plans would not have been developed. As we have argued, there is reason to think that CfRN brought these plans forward by 3 years.

It is difficult to know how far countries will be willing to reduce deforestation emissions in line with the Paris Agreement without receiving REDD+ compensation. There are incentives to free ride in international climate action, giving states incentives to make pledges and then not to keep to them. We would therefore expect concrete REDD+ financial incentives to have a greater effect than stated climate pledges. Nevertheless, because so many countries (covering nearly all tropical rainforest) have now made pledges, even very small reductions in each country could produce substantial overall effects. This in turn would mean that CfRN had an effect by bringing forward agreement on REDD+. As our model demonstrates, even if deforestation is reduced by 0.2% per year over three years, this would mean that CfRN reduced emissions by 29m tonnes. This figure is not based in any data, and so is not included in our estimate of CfRN's past impact, but it does illustrate that the benefits excluded from the model could be substantial.

Impact via conceiving and helping to develop REDD+ funds

In addition to its work in the UNFCCC negotiating process, CfRN has helped to conceive and design three funds for REDD+ activities:[207]

[205] http://redd.unfccc.int/info-hub.html
[206] http://redd.unfccc.int/submissions.html
[207] Coalition for Rainforest Nations, internal document, 2018.

- World Bank Forest Carbon Partnership Facility (FCPF) – 47 nations and $1.1 billion.
- Forest Investment Program (FIP) – 23 nations and $775 million.
- UNREDD Programme – 64 countries and $300 million.

The combined value of these three funds is $2bn. Even if CfRN was causally responsible for 5% of this increased funding, which seems conservative, they would have secured $100m in forestry finance. Given the cost-effectiveness of deforestation prevention, CfRN has had an extremely large impact by this mechanism alone.[208] Because adding this into the cost-effectiveness model would double count some of the forestry finance benefits discussed above, we exclude this from our model. Nonetheless, some portion of this money could be genuinely additional to the funding CfRN mobilised through its work in the UNFCCC process.

[208] See CfRN cost-effectiveness model.

Appendix 2. The Historical Impact of the Clean Air Task Force

In this appendix, we review the past impact of the Clean Air Task Force (CATF). CATF is typical of research and policy advocacy organisations in that it has worked on heterogeneous projects. This makes it difficult to evaluate all of CATF's past work, as this would require us to assess their counterfactual impact in a range of different contexts in which numerous actors are pushing for the same outcome. Here, we focus on a sample of three case studies of projects CATF has worked on:

1. Power Plant Campaign and Clear the Air: non-climate pollutants (1996 – 2006).
2. The Methane Partners Campaign (2000 – present).
3. Campaign for tax incentives for CCS (2009 – present);

These case studies provide evidence of CATF's past impact, but also are indicative of their prospects of success going forward: they provide evidence of the strength of CATF's team, the way they choose projects, and the way they to bring about policy change.

1. Power Plant Campaign and Clear the Air: non-climate pollutants (1996-2006)

In this section we discuss CATF's role in the campaign to regulate non-CO_2 pollutants produced by coal plants in the US, and the benefits of this work.

1.1. CATF's counterfactual impact on the campaign

CATF was founded in 1996 to promote the clean up or retirement of the U.S. coal power plant fleet. Its founding policy objective was to win requirements that older coal plants meet new plant emission standards for two key pollutants: sulphur dioxide (SO_2) and nitrogen oxide (NO_x). CATF later advocated for controls on mercury emissions. The theory of change was the cost of emission controls

for conventional pollutants and mercury would result in the retirement or curtailment of coal plant operation resulting in reductions of CO_2 emissions. It was based on this theory that the founding funder, Pew Charitable Trust, supported the effort.

These pollutants and toxics impose very large burdens on public health. CATF's strategy to win comprehensive national emissions standards was two-fold: (1) creating patchwork of state power plant regulations that a federal policy could harmonize; and (2) pursuing a regulatory "death by a thousand cuts" strategy to win as many costly environmental mandates on coal plants as possible to force the plants to clean up or shut down.

From 1998 until 2006, CATF co-led a nationwide campaign called "Clear the Air", involving numerous other environmental NGOs. When "Clear the Air" ended in 2006, CATF continued its advocacy to clean up coal plants, with support from the Energy Foundation and other philanthropies. CATF's research, advocacy and litigation efforts spanned the Clinton, Bush and Obama administrations.

Forms of the regulations advocated for by the campaign were imposed from 2005 onwards. The US Environmental Protection Agency imposed a number of new regulations on coal power plants under the Clean Air Act, restricting SO_2, NO_x, and mercury emissions, the most important of which are:

- The Clean Air Interstate Rule (2005) later replaced by The Cross-State Air Pollution Rule (2011).
- The Mercury and Air Toxics Standards (2011).

The campaign also successfully advocated for controls on CO_2 emissions, but the impact of these controls is not included in this analysis (though the impact of the two aforementioned regulations on CO_2 emissions is included). Assessing CATF's role in bringing about these regulations is challenging. The question we are trying to answer is: "what is the probability that CATF brought relevant regulation forward by x months?". This is inherently difficult to answer because it is unclear what the base rate of

such changes is, and it is difficult to disentangle the effects of the numerous different groups involved.

We believe that CATF had influence in two broad ways:

1. By conceiving of the power plant campaign and playing a catalytic role in crowding in support from other philanthropic funders and environmental NGOs.
2. By leading the campaign, providing high quality technical analysis on the health effects of air pollution, and litigating the EPA.

Catalytic "first mover" effect on the campaign

CATF staff have told us that they conceived the idea of focusing on the local effects of coal power plants. Until then, NGOs had focused on the long range transport of pollutants in the context of acid rain, and the local effects were overlooked.[209] Having conceived of and developed the campaign, CATF, working with their regional partners, were able to win funding support from other regional funders e.g., Joyce Foundation in the Midwest, Turner Foundation in the Southeast, Heinz Endowments in Pennsylvania, and John Merck Fund in New England. A number of environmental NGOs went on to be allied with the campaign, with Natural Resources Defense Council playing the most prominent role.[210]

CATF's account has been borne out by discussions with funders involved at the time. The Power Plant Campaign was funded by the Pew Charitable Trusts and Lea Aeschliman, who oversaw these grants, informed us that CATF saw the opportunity to target coal plants and developed a strategy to implement this effort before other major environmental organizations.[211] Aeschliman told us that Pew

[209] CATF, report on CATF's role in three national campaigns, December 2017; Ruth Hennig personal communication, January 23rd 2018.
[210] CATF, report on CATF's role in three national campaigns, December 2017.
[211] Lea Aeschliman personal communication, January 17th 2018.

Charitable Trusts offered the initial grant to CATF because they thought it offered a more cost-effective and focused approach than funding a larger environmental NGO.[212]

Another major funder of the campaign commented that:

> "While there were certainly other groups involved over the years, there is no doubt in my mind that this strategy was designed and driven initially by CATF. Without their work, I highly doubt that the more recent coal campaigns would have been nearly as successful."

There is reason to think that focusing on the local effects of coal plants improved the campaign's prospect of success. CATF have told us that:

> "At the outset of the campaign, the Northeast states were blaming their pollution problems on coal plants in upwind states of the Midwest. While helpful to some extent (at least someone was complaining that there was a problem with coal plants pollution), this frame had the negative impact of the Northeast accepting little responsibility for its own air quality and the Midwest states feeling that they were being asked to carry the burden of pollution clean-up solely for downwind states' benefit. CATF's solution was to launch campaigns in each region, holding power plant owners and state officials accountable for the local pollution impacts from their respective plants."[213]

We find this line of reasoning plausible. Indeed, the campaign approach of advocating for air pollution regulation of coal plants appears to have been very successful. From the mid-2000s onwards, the campaign strategy was taken on, with significant success, by the Sierra Club's Beyond Coal campaign,

[212] Lea Aeschliman personal communication, January 17th 2018.
[213] CATF, report on CATF's role in three national campaigns, December 2017.

which has received more than $100m from Bloomberg Philanthropies alone.[214] The campaign has expanded to have an international focus, with efforts now focused on retiring the European coal fleet.[215]

CATF have told us that at the time the campaign was conceived, major environmental organisations were opposed to reopening the question of plant emissions after the Clean Act Amendments of 1990, as they feared the possibility that legislative debate would unravel other parts of the Act.[216] This is based on conversations at the time with the American Lung Association, Environmental Defense Fund, and the Natural Resources Defense Council.

It is difficult to know how much CATF brought relevant regulation forward by conceiving of the local air pollution focus, and of the strategy pursued in the power plant campaign. We think it is likely that environmental NGOs would eventually have turned their attention to air pollution from coal plants anyway. The question is therefore how many years CATF brought regulation forward by conceiving of the campaign goal and strategy. CATF have told us that had they not acted, in their view a similar initiative would have taken a decade or more. There may be a threshold effect at play here because the Clinton EPA issued numerous air pollution regulations between 1998 and 2000, which set the stage for the Obama era regulation.[217] It is very unlikely that these regulations would have been

[214] "Bloomberg Announces $64 Million in New Funding to Move America Beyond Coal as Trump EPA Tries to Prop Up Dead End Fuel Source."
[215] "Michael R. Bloomberg Commits $50 Million to International Effort to Move Beyond Coal, Reinforcing Leadership on Global Climate Action," Bloomberg Philanthropies, accessed February 25, 2018, https://www.bloomberg.org/press/releases/bloomberg-commits-50m-international-effort-move-beyond-coal/.
[216] Personal correspondence with CATF Executive Director Armond Cohen, 12th March 2018.
[217] "The Clinton EPA issued the NO_x State Implementation Plan Call under the "Good Neighbor" provision of the Clean Air Act (CAA) requiring reductions in emissions of power plant nitrogen oxides because they were contributing to downwind states violating ozone smog standards. This was in response to state petitions under CAAA section 126 by downwind states seeking to hold upwind coal plants accountable for their emissions. The Clinton EPA issued the Regional Haze rule, which set a long-term trajectory for SO_2, NO_x, and PM2.5 emissions to reduce haze in national parks and other federally-protected lands. The Clinton EPA also issued Mercury and Hazardous Air Pollution (HAP) studies to Congress pursuant to requirements in the CAA that led to EPA's determination that regulating mercury and HAPs under the CAAA is "appropriate and necessary" and listing coal and oil-fired power plants under section 112 of the CAA." Personal correspondence with Armond Cohen, 12th March 2018.

advanced by the Bush EPA from 2000-08. Thus, if CATF ensured regulation from the Clinton EPA before 2000, this may have enabled the Obama era regulations.

Nonetheless, it is difficult to calculate CATF's counterfactual contribution. As we understand the claims of the funders involved, their view is that CATF focused on local air pollution from coal plants at least a year before other environmental NGOs would have. This is consistent with CATF's own account of the campaign, but there might be reason for these funders to overstate the role of their grantees in the campaign. Our very rough realistic estimate is therefore that CATF brought the relevant regulation forward by 12 months. The 90% confidence interval around this estimate is 6 months to 2 years.

Impact via co-leading the campaign

CATF also appears to have had an effect in its work in leading the Power Plant Campaign from 1998 onwards. It is much harder to evaluate their impact via this mechanism because from this point, numerous other environmental and public health NGOs were involved in the campaign.

The evidence for this is as follows. Firstly, as CATF states:

> "After two years, the Pew Charitable Trusts elevated the priority of the campaign and facilitated the creation of an enhanced national campaign, named "Clear the Air", as a joint effort of CATF and two of Pew's chief grantees: the National Environmental Trust (specializing in media and lobbying) and the U.S. Public Interest Research Group (specializing in grassroots activism). A central campaign staff was hired to coordinate the Campaign and CATF served with National Environmental Trust and US Public Interest Research Group as the Steering Committee. At its apex, the "Clear the Air" Campaign's budget was $6 million per year with supporting grants for

regional and state partners from regional foundations totalling again roughly half that amount."[218]

The Clear the Air Campaign involved dozens of other environmental NGOs. The fact that CATF were chosen to lead the campaign suggests that their work between 1996 and 1998 had been of high quality, and that they played an important role in the Clear the Air campaign after 1998.

During the Clear the Air Campaign, the Natural Resources Defense Council was the other major environmental organization most focused on the power plant agenda. NRDC were co-litigants and advocacy leaders in most of the major administrative and court litigation that led to the Obama-era regulations.[219]

It is inevitably difficult to assess which organisations were most effective. Ruth Hennig, who previously was Executive Director of the John Merck Fund (which funded much of the non-carbon air pollution campaign) told us that CATF should take 75% of the credit for the coal plant regulations.[220] Since John Merck Fund was a major funder of this effort, this is important information. However, it is not straightforward to translate this into an estimate of counterfactual impact because it might be the case that had CATF not acted, another group would have taken up some or all of the slack. However, this updates us towards the view that CATF would have been more effective than the next best campaign leader.

Secondly, CATF produced large amounts of first-of-a-kind research on the air pollution effects of coal plants. This suggests that CATF was at the forefront of research and advocacy on this issue. For example, CATF commissioned a 2000 study by the Harvard School of Public Health demonstrating the

[218] CATF, report on CATF's role in three national campaigns, December 2017.
[219] CATF, report on CATF's role in three national campaigns, December 2017.
[220] Ruth Hennig personal communication, January 23rd 2018.

local health effects of the SO_2 and NO_x produced by power plants.[221] This research was then used in the local campaigns. In 2004 CATF produced the first ever study of the national health effects of coal power in the US, using the U.S. EPA's own air pollution benefits consulting firm and using EPA's own peer-reviewed, published methodology.[222] CATF has updated that analysis several times since.

To elevate the myriad environmental impacts from coal plants, CATF produced over a dozen reports focused on various aspects of environmental damages including: human health, children's health, African-American health, Latino health, acid rain, visibility impairment in national parks, mercury in fish, water use, water pollution, climate change, and several on combustion waste. In addition, CATF produced several reports with a regional focus. The Clear the Air campaign released these reports with state and local allies to maximize both national as well as local press coverage. We have discussed CATF's research with government officials, policy experts, and philanthropists, all of whom have strongly praised CATF's research.

Thirdly, CATF has led litigation against the US EPA for coal plant regulations. For example, in 2008, CATF along with Earthjustice and on behalf of eleven other environmental and public health organisations filed a federal lawsuit seeking a firm deadline for regulation of mercury and other non-carbon pollutants.[223] The court ruled against the EPA, requiring it to propose air toxics standards by March 2011.[224]

Overall, it is difficult to assess the impact of CATF's strategic leadership of the campaign. CATF clearly played a prominent role and key figures have suggested that they should take >50% of the credit for

[221] http://www.citizensinaction.org/documents/Harvard_Study.pdf
[222] http://www.catf.us/resources/publications/files/Dirty_Air_Dirty_Power.pdf
[223] "Conservation Groups Sue EPA Over Toxic Air Pollution From Power Plants," Conservation Law Foundation, accessed February 25, 2018, https://www.clf.org/newsroom/conservation-groups-sue-epa-over-toxic-air-pollution-from-power-plants/.
[224] "EPA to Release Long-Awaited Rules on Toxic Power Plant Emissions...," *Reuters*, March 14, 2011, https://www.reuters.com/article/idUS404824926520110314.

the success of the campaign. The fact that key philanthropic funders chose CATF to lead the campaign also provides some evidence that they were more cost-effective than other possible leaders. Nonetheless, it remains unclear how to quantify CATF's impact via this mechanism, given that there were numerous other NGOs working on the same project.

One possible way to constrain intuitions about this is to estimate how much more effective CATF was than the next best possible campaign leader and calculating the typical annual impact this would have on the effectiveness of the campaign in terms of bringing forward regulation. On this approach, the longer a campaign, the more scope there is for an effective leader to have an impact. For example, suppose that for each year of campaign leadership, CATF most probably brought forward effective regulation by ~3 weeks. Over the course of an eight year campaign this suggests that they brought the relevant regulation forward by ~6 months. We find this estimate fairly intuitively plausible, but our confidence interval around this estimate is large; we would not be surprised if the effect were 3 months or 2 years. It is difficult to reduce this uncertainty given the large research time cost involved in gathering further information on the campaign.

Combining the two estimates suggests that CATF most probably brought regulation forward by 18 months, with a pessimistic estimate of 9 months and an optimistic estimate of 4 years.

Was the campaign successful?

The foregoing discussion has assumed that the campaign caused the EPA regulations. We think it is highly likely that without the campaign, the regulations would not have been passed. Firstly, Clear the Air had advocated for regulations on SO_2, NO_x and Mercury from 1996 onwards, and these pollutants were eventually regulated by the EPA. Secondly, as discussed above, CATF successfully litigated the EPA for these specific regulations, which strongly suggests that they had a counterfactual effect. Thirdly, as discussed above, CATF published the first work demonstrating the local and national health

effects of coal plants. According to CATF, thanks to their work, the goal of cleaning up coal plants was accepted by both Bush and Gore in the 2000 presidential race.[225] Fourthly, CATF provided technical support to the EPA in designing the relevant regulations.[226]

1.2. The benefits of CATF's work

CATF's work on this campaign had produced two broad kinds of benefit:

1. Improved human health due to reduction in SO_2, NO_x and Mercury.
2. Reduced greenhouse gas emissions due to coal plants retirement brought about by additional EPA regulation.

Each of these effects is likely to be substantial. We will take each in turn.

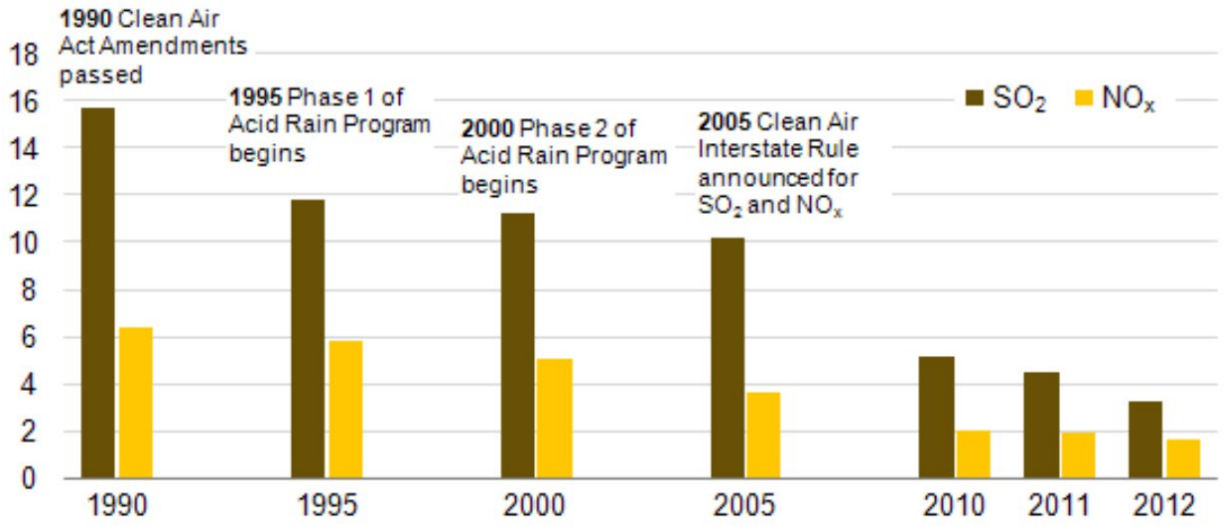
Improved human health due to reduction in SO_2, NO_x and Mercury.

Following the introduction of the Clean Air Interstate Rule in 2005, SO_2 and NO_x emissions declined substantially:

[225] http://www.catf.us/resources/publications/files/RGGI-Report.pdf.
[226] CATF, report on CATF's role in three national campaigns, December 2017.

Figure A3.

SO_2 and NO_x emissions from the power sector (short tons)



Source: US Energy Information Administration - https://www.eia.gov/todayinenergy/detail.php?id=10151

According to the EIA, "The decline in emissions is due primarily to an increasing number of coal-fired units retrofitted with flue-gas desulfurization, or scrubbers, to coal plants switching to lower sulfur coal, and to selective catalytic reduction, selective non-catalytic reduction, or low NOx burners to limit NOx emissions".[227] The decline after 2005 was primarily due to the Clean Air Interstate Rule encouraging a large portion of the coal fleet to use flue-gas desulfurization scrubbers.

The EIA notes that decreased coal plant air pollution has been due firstly, to air pollution regulation, and then from late 2008 onwards, to declining natural gas prices, which helped to retire a significant portion of the US coal fleet.[228] This effect should not be counted as part of CATF's counterfactual

[227] https://www.eia.gov/todayinenergy/detail.php?id=10151
[228] https://www.eia.gov/todayinenergy/detail.php?id=10151

impact. If we assume that the decline in natural gas prices was responsible for ~50% of the decline in fine particulate emissions in 2009 and 2010 (33% of the period over which emissions declined) this suggests that we should adjust CATF's impact downwards by (50%*33%) = ~16%.

The health benefits of this have been substantial. These are calculated in our cost-effectiveness model.

Turning to mercury pollution, in 2016, mercury air emissions from power plants were 90% lower than in 2000 (51 pounds per year down to 5 pounds per year) driven by implementation of the Mercury and Air Toxics Standard rule and the curtailment and retirement of coal generation.[229] The EPA projected that the 2011 Mercury and Air Toxics Standards would avert 4,200-11,000 (mean = 7,600) deaths per year once implemented.[230]

If, as we suggest, CATF most likely brought these regulations forward by 18 months, this suggests that CATF's work on this project averted ~18,000 deaths.

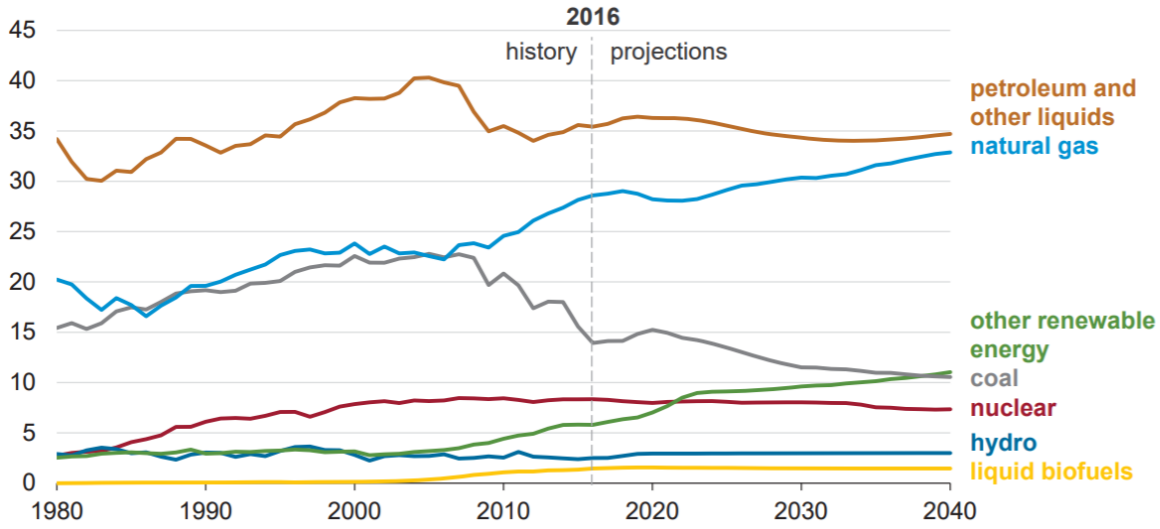
Reduced greenhouse gas emissions due to coal plants retirement brought about by additional EPA regulation

Another effect of the air pollution regulations on the coal plants was that they increased the cost of coal power generation. This, combined with the drop in natural gas prices, has contributed to the large number of coal plant retirements since 2008.

[229] Data are available here: https://ampd.epa.gov/ampd/
[230] https://www.epa.gov/mats/healthier-americans

Figure A4.

US domestic energy consumption by source, with a projection to 2040



Source: IEA, Annual Energy Outlook 2017, p. 9 https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf

It is inevitably difficult to disentangle the effect of the regulations and the natural gas prices. A survey of the literature in the Bipartisan Policy Center suggests that the mercury, SO_2, and NO_x regulations will lead to retirements of between 14 and 70 GW of coal capacity until 2035.[231] Our cost-effectiveness model roughly calculates the effect this would have on CO_2 emissions. We conclude that by bringing forward this regulation, CATF averted ~10.4 million tonnes of CO_2e.

This figure excludes some of the other benefits of the coal plant campaign. For example, CATF has been involved in defending the EPA regulations against repeal by the Trump Administration. The

[231] Bipartisan Policy Center, "Environmental Regulation and Electric System Reliability," n.d., 22, http://bipartisanpolicy.org/wp-content/uploads/sites/default/files/BPC%20Electric%20System%20Reliability.pdf.

estimate also excludes the catalytic effect of providing the model currently used by the now heavily funded Beyond Coal Campaign.

2. The Methane Partners Campaign (2009 – present)

In this section, we discuss CATF's impact via the Methane Partners Campaign.

2.1 CATF's counterfactual impact on the campaign

CATF conceived of and co-led the Methane Partners Campaign advocating for regulations of fugitive methane form the oil and gas industry. From 2012 onwards, the EPA finalized a number of regulations, the most important of which are:

- The 2012 New Source Performance Standards
- The 2016 New Source Performance Standards

Each of these reduce methane emissions from the oil and gas industry.[232] A number of states also imposed regulations that went beyond what the EPA proposed.[233]

As for the first case study, we believe that CATF had an impact on US methane regulation in two ways:

1. Acting as a "first mover" in conceiving of, and catalysing support for, the Methane Partners Campaign among a number of larger environmental NGOs.
2. Co-leading and contributing technical research to the campaign.

As for the first case study, it is difficult to assess CATF's counterfactual impact on this campaign because it is difficult to know what other NGOs would have done if CATF had not acted. However, the

[232] https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-industry/new-source-performance-standards-and
[233] See for example https://www.colorado.gov/pacific/cdphe/summary-oil-and-gas-emissions-requirements.

evidence required for CATF to have had a large impact in this case is lower due to the particularities of the political context surrounding the 2016 New Source Performance Standard. We will discuss the campaign for each regulation in turn.

Impact on the 2012 New Source Performance Standard

The main evidence we have that CATF conceived of and drew in support for the methane campaign is CATF's own written submission. We think it is likely that the claims made are accurate because the information CATF have provided in verbal and written discussion that we have verified with external partners has been accurate.

CATF's account of their role in conceiving of the focus on methane emissions is as follows.[234] In the early 2000s, CATF learned of the prominent climate scientist Dr. James Hansen's research into the impact of short-lived climate pollutants such as black carbon, methane, and hydrofluorocarbons. Following this, CATF began a strategic review of opportunities to reduce methane by examining the emissions and abatement potential from the major domestic methane-emitting sectors: agriculture, oil and gas, coal mines, and waste disposal. CATF's review determined that reducing methane emissions from the oil and gas industry presented the best opportunity for cost-effective, politically-feasible mitigation in the near term.

To broaden environmental community concern and support for this agenda, CATF briefed the leadership (CEO and Chief Scientist) at the Environmental Defense Fund (EDF) about the implications of Dr. Hansen's research. EDF initially was resistant, believing that any focus on short-lived climate pollutants could distract attention from mitigating CO_2 emissions. However, EDF eventually agreed with the focus on mitigation of methane emissions from the oil and gas industry.

[234] CATF, report on CATF's role in three national campaigns, December 2017.

Following this, to verify the actual leak rate, EDF launched a joint research effort with the gas industry conducting sixteen peer-reviewed, published scientific studies of the leak rate of different segments of the gas supply chain. To date, the studies have found that the methane leak rate is higher than official government estimates and can be significantly reduced.[235]

In 2006, EDF launched a series of state-level campaigns seeking state regulations on the sector. CATF also worked at the state level, but primarily focused its advocacy on federal methane regulations.[236]

A former major donor to CATF has confirmed to us in correspondence the view that CATF saw the value of focusing on short-lived climate pollutants such as methane long before other organisations that were at the time mainly focused on CO_2.

It is difficult to know how much CATF brought forward the 2012 New Source Performance Standard by conceiving of the methane campaign and drawing in support. On the basis of the above information, our very rough guess is that via this mechanism CATF brought the regulation forward by ~8 months, with a lower bound of ~2 months and a higher bound of ~12 months. Even a small temporal effect such as this promises a large impact in terms of emissions.

There is good evidence that CATF also played a major role in campaign leadership and strategy. CATF's Sarah Uhl was elected to co-lead the campaign along with Felice Stadler at EDF. The campaign leadership seems to have been very successful in terms of achieving process goals and in securing the end result. CATF writes:

> "To take advantage of the federal opportunities, CATF hired a staff member specifically assigned to coordinate the advocacy efforts of the co-litigant groups and build a grassroots

[235] https://www.edf.org/climate/methane-studies
[236] CATF, report on CATF's role in three national campaigns, December 2017.

> coalition to support these regulatory efforts. Within a year, CATF helped win funding support from the Energy Foundation, Pisces Foundation, ClimateWorks Foundation, and Hewlett Foundation for the formation of the Methane Partners Campaign, which added the American Lung Association, EarthWorks, Blue-Green Alliance, and other regional and state organizations to the five original co-litigant groups on the MPC Steering Committee. Today, over 80 groups participate in the Campaign and the MPC and its partners have a combined budget devoted to this effort of over $3 million per year."[237]

There were numerous other large environmental NGOs involved in the campaign, including Environmental Defense Fund, the Natural Resources Defense Council, and the Sierra Club. Had CATF not acted as co-leader, one of these groups would plausibly have stepped in. It is difficult to know how effective they would have been in comparison to CATF. The fact that CATF were elected to co-lead does show that they were perceived to be more effective campaign leaders than the next best alternative, which provides some evidence that they were in fact more effective.

In addition to its role as co-leader of the campaign, CATF, along with EDF, played a leading role in the technical research for the campaign, which would eventually assist the EPA in drafting regulations. CATF has produced the majority of the reports publicly released by the campaign including: Fossil Fumes: A Public Health Analysis of Toxic Air Pollution from the Oil and Gas Industry; Gasping for Breath: An Analysis of the Health Effects of Ozone Pollution from the Oil and Gas Industry; Latino Communities at Risk: The Impact of Air Pollution from the Oil and Gas Industry; and Fumes Across the Fence-line: The Health Impacts of Air Pollution from the Oil and Gas Industry on African-American Communities.

[237] CATF, report on CATF's role in three national campaigns, December 2017.

We can try to constrain intuitions about the overall effect of CATF's strategic and technical leadership using the method described in the previous section. Suppose that for each year of CATF co-leadership, they brought forward regulation by one month compared to the next best counterfactual campaign leader. Over the course of three years leading to the 2012 New Source Performance Standard, this suggests that CATF brought forward regulation by ~3 months via this mechanism. Once again, our confidence interval around this estimate is wide, with a lower bound of ~1 month and a higher bound of ~10 months.

Combining CATF's impact via co-leading and conceiving of the campaign suggests that CATF brought the 2012 New Source Performance Standard forward by 11 months, with a lower bound of 3 months and a higher bound of 22 months. This estimate is very uncertain and is hard to further constrain given the available information.

Impact on the 2016 New Source Performance Standard

With respect to the second relevant piece of regulation, the 2016 New Source Performance Standard, the evidence required to support the proposition that CATF had a large impact is much lower. The reason for this is that this regulation was introduced at the tail end of the Obama administration (June 2016), and would not have been introduced by the Trump EPA, as demonstrated by the fact that the Trump EPA has tried to repeal the methane regulation.[238] If the regulation had been delayed by around three or more months, it would likely have been repealed under the Congressional Review Act, which allows Congress and the President to repeal a bill that is passed within a window of 60 legislative days (i.e. days Congress is in session).[239] Thus, even if CATF brought regulation forward by three months,

[238] Lisa Friedman, "Court Blocks E.P.A. Effort to Suspend Obama-Era Methane Rule," *The New York Times*, July 3, 2017, sec. Climate, https://www.nytimes.com/2017/07/03/climate/court-blocks-epa-effort-to-suspend-obama-era-methane-rule.html.
[239] Amber Phillips, "Why Republicans' 100-Day War on Obama Is about to End," *Washington Post*, April 25, 2017, https://www.washingtonpost.com/news/the-fix/wp/2017/04/25/why-republicans-100-day-war-on-obama-is-about-to-end/. There are typically around 15 legislative days per month. Trump was inaugurated on 20th January 2017. To stay within the 60 legislative day window, the regulation could have been delayed by at most three months.

that would be the difference between the existence and non-existence of the regulation. Their campaign is therefore likely to have had very large benefits.

A former major funder of the campaign has told us (with moderate confidence) that without CATF's technical expertise, it is very unlikely that any EPA methane regulations would have passed at all.[240] The evidence outlined in the previous subsection lends weight to this. In addition, CATF have provided the following narrative account of their role in securing the 2016 New Source Performance Standard;

> "However, even as late as 2012, EDF was publicly focused on a state-by-state approach to methane regulation. Had CATF not continued to push them and other groups to realize the opportunity of a federal play, it is unlikely that they would have pivoted soon enough for federal methane standards to have been issued during the Obama Administration. Had CATF not convinced NRDC, EDF, and other key players of methane's importance, it likely would not have been featured in the President's Climate Action Plan of June 2013, which set the stage for action.
>
> The following year, with no other group stepping up to take the lead, CATF developed and published a blueprint for the policy (*Waste Not*). Issued in collaboration with NRDC and Sierra Club and with the endorsement of EDF and Earthjustice, *Waste Not* made a strong case for regulating methane emissions from the oil and gas industry by documenting the available technologies and practices to cut emissions by half for very low cost. Still, EPA was resistant to moving forward on the rule, thinking it was too soon to regulate the oil and gas industry again after issuing the 2012 standards. API and others were putting up real resistance. The rule only moved forward because CATF and their partners in the Methane Partners Campaign went over EPA's head and put significant pressure on the White House, which ultimately forced EPA's

[240] The individual wished to remain anonymous.

hand. This work involved a series of meetings with senior officials including John Podesta, Counselor to the President, Dan Utech, Deputy Assistant to the President for Energy and Climate Change, and others. Meanwhile, our technical intervention showed EPA how they could write the rules."

We think it is very likely (>90% chance) that without CATF, the regulation would have been delayed by three months and so failed to exploit the threshold effect discussed above. This implies that CATF produced all of the benefit of the 2016 regulation from June 2016 until it is repealed. The regulation has been in place for 20 months so far.

The Trump EPA tried and failed to suspend the 2016 regulation in 2017.[241] CATF's Executive Director has told us that it is highly likely that the Trump EPA will issue a final rule to repeal the 2016 regulation, most likely in 2019.[242] However, CATF, EDF and others will challenge this in court, and may be successful. Our best guess is that the regulation will be repealed in mid 2019. Our lower bound is that it will be repealed in mid 2018 and our higher bound is that efforts to repeal will fail, and the Democrats will win the presidential election in 2020 (they are favourites as of March 2018). This does not mean that CATF's counterfactual impact will necessarily stretch into a two term Democrat presidency. The reason for this is the possible post-2020 Democrat EPA would have introduced the regulation anyway at some point from 2020 onwards, even if CATF had not acted. We would guess that, given all these hypotheticals, the regulation would have been introduced in 2022: this is our upper bound.

[241] Friedman, "Court Blocks E.P.A. Effort to Suspend Obama-Era Methane Rule."
[242] Armond Cohen, personal correspondence, 13th March 2018.

Was the campaign successful?

Putting CATF's role in the campaign to one side, the next question is whether the campaign plausibly brought about the methane regulation. We think it is highly likely (>90% probability) that without the campaign the relevant regulations on methane would not have been proposed. Firstly, as noted above, some funders have told us that without CATF, the regulation would not have passed at all. Secondly, the campaign litigated for the specific regulations eventually imposed by the EPA. CATF, along with four co-litigant groups, EDF, NRDC, EarthJustice and Sierra Club, had already sued U.S. EPA to force it to regulate methane from the oil and gas industry under the Clean Air Act. Together these groups also challenged a 2012 oil and gas emissions regulation that failed to set limits on methane emissions.[243] Simultaneously, CATF along with the Wilderness Society and EarthWorks advocated for limits on methane waste from oil and gas operations on federal lands administered by the Bureau of Land Management.

Thirdly, the Obama Administration's Strategy to Reduce Methane Emissions, which resulted in the EPA regulations, explicitly mentions EDF's research on methane emissions.244 An anonymous major funder of the campaign told us that CATF provided legal and technical advice to the administration that helped the EPA draft its regulations. This provides a strong signal that without the campaign, methane regulation would have been unlikely (<10% chance).

2.2. The benefits of methane regulation

We quantify the benefits of CATF's work on methane in our cost-effectiveness model. According to the EPA, once the 2012 New Source Performance Standard is fully implemented, it will avert between

[243] CATF, report on CATF's role in three national campaigns, December 2017.
[244] See p. 9 and 11 of https://obamawhitehouse.archives.gov/sites/default/files/strategy_to_reduce_methane_emissions_2014-03-28_final.pdf

~19m and ~33m tonnes of CO_2e per year (mean = 26m).[245] Our model adjusts for the lag prior to the rules having peak effect. We estimate that by bringing forward the 2012 regulation, CATF averted 3.8m – 57.37m tonnes of CO_2e with a realistic estimate of ~21.5m tonnes. These estimates are highly uncertain but are indicative that CATF had a large impact.

The 2016 regulations will reduce emissions by ~11m tonnes of CO_2e per year once fully effective.[246] Our model adjusts for the lag prior to the rules having peak effect. If, as we estimate, CATF brought the regulation forward by 3 years (with a range of 2 – 5 and a half years), this implies that via its advocacy for the 2016 regulation, CATF averted 19.8m tonnes of CO_2e (11m - 42.4m). The combined effect of CATF's work on methane is therefore ~40.5m tonnes (14.8m – 99.7m).

This estimate excludes some of the other benefits of the methane campaign. Perhaps most importantly, plausibly as a result of the methane campaign, Mexico and Canada have also pledged to reduce methane emissions from the oil and gas sector 40-45% by 2025.[247] CATF is also involved in the efforts to prevent the methane regulations being rolled back by the Trump Administration.[248]

3. Campaign for US tax incentives for carbon capture and storage (2009 – present)

From 2009 onwards, CATF advocated for an expansion of US tax incentives for carbon capture and storage (CCS). CATF has outlined the policy details, developing the coalition in favour of the proposal, and acting as a public interest voice for the measures.

[245] See p. 2 of https://www.epa.gov/sites/production/files/2016-09/documents/natural_gas_transmission_fact_sheet_2012.pdf
[246] See p. 4 of https://www.epa.gov/sites/production/files/2016-09/documents/nsps-overview-fs.pdf.
[247] https://pm.gc.ca/eng/news/2016/06/29/leaders-statement-north-american-climate-clean-energy-and-environment-partnership
[248] https://www.theguardian.com/environment/2017/jul/03/epa-methane-rule-trump-scott-pruitt

3.1. CATF's counterfactual impact on the campaign

In the wake of the failure to impose adequate carbon pricing schemes across the globe, many governments have pursued their climate goals by subsidising the deployment of low carbon technology. The vast majority of this has thus far been directed to renewable energy, especially solar and wind power, which has helped to reduce the cost of these technologies significantly. CATF and other environmental NGOs, unions and industry groups have advocated for a similar approach to be taken to other low carbon technologies, including carbon capture and storage.

After a long campaign involving research, coalition building, and advocacy, the Furthering carbon capture, Utilization, Technology, Underground storage, and Reduced Emissions Act (FUTURE Act) was included in Senate Finance Committee Chairperson Orrin Hatch's (R-UT) larger tax extenders bill, before finally passing through Congress in February 2018 as part of the Bipartisan Budget Act of 2018.[249] The Act expands the 45Q tax credit for carbon capture storage for both Enhanced Oil Recovery (EOR) and saline CO_2 storage.[250] In other words, it provides financial incentives for CO_2 producers to store CO_2 in oil wells or in saline formations underground. By 2026, incentives ramp up to $35/tonne for EOR and $50/tonne for saline storage.[251] The bill has managed to obtain bipartisan support.

We believe that CATF had a potentially substantial impact on the passage of the increased 45Q tax credit.

[249] https://www.huntonnickelreportblog.com/2018/02/section-45q-tax-credit-enhancements-could-boost-ccs/
[250] EOR is the use of CO_2 captured from point sources like power plants, to recover oil from existing oil wells. In EOR systems that maximise climate benefit, the CO_2 is then stored permanently in the oil well. CO_2 can also be stored in saline aquifers. This has lower economic returns and so requires a higher tax credit.
[251] CATF, personal communication,

CATF have told us that they played an important role in conceiving of the bill and outlining the policy details, developing the coalition in favour of the proposal, and producing research which helped to secure bipartisan support in the legislature.

- One government official and one former government official, each with close knowledge of the political context surrounding the CCS bill, provided support for the claim that CATF was instrumental in designing the bill and conceiving the policy details.[252]
- These sources also stated that CATF has played a bigger role than any other environmental NGO involved in the campaign.
- Both sources told us that CATF's research on the impact of the bill was crucial for securing the required bipartisan support. This research was not published but was circulated widely in Washington.
- One of the sources stated that without CATF, it is very unlikely that the bill would exist at all.

It is difficult to know what would have happened had CATF not acted in the way they did, and it is possible that another group would have stepped in to fill their role. But the above evidence suggests that CATF's work was probably not replaceable in this way. The bill was initially introduced in February 2016.253 According to the evidence in the last bullet point, it is very unlikely that the bill would exist at all as of February 2018 had CATF not acted. If this account of the counterfactual is correct, then CATF brought the legislation forward by at least two years (the gap between February 2016 and February 2018). We are unsure how much weight to put on this individual's judgement, but this impression was broadly supported by our other source. In order to avoid putting too much weight on

[252] These individuals wished to remain anonymous.
[253] http://www.catf.us/newsroom/releases/2016/20160225-45Q_House_Bill_Introduction_Press_Release_-_Final_February_25_2016.pdf

the view of one individual, our perhaps conservative realistic estimate is that CATF brought the relevant legislation forward by ~1.5 years.

The benefits of the CCS tax incentives

CATF's own modelling suggests that the increased 45Q tax incentive will avert a large amount of CO_2 emissions in the short to medium term.[254] The US Department of Energy National Energy Modeling System produced similar results. The model suggests that if the incentives are in place by 2020, they will lead to the abatement of around 40,000,000 tonnes of CO_2 in 2025. Assuming a linear increase, this suggests that the incentives will lead to the abatement of ~20,000,000 tonnes of CO_2 per year between 2020 and 2025.

In our cost-effectiveness model, we use these figures to calculate the effect CATF had by bringing forward the CCS legislation. Our realistic estimate is that via their work on this campaign, CATF averted 30m tonnes of CO_2, with a pessimistic estimate of 14m tonnes and an optimistic estimate of 60m tonnes.

This estimate is likely to be conservative. It is plausible that the main benefit of the tax credit will be the construction of enough CCS projects to speed up learning and drive costs down, as happened for wind and solar. In this way, the tax credit will produce global technology spillovers, which could increase deployment of CCS worldwide.

[254] *CCS Deployment in the US power sector*, analysis by Charles River Associates for Clean Air Task Force, 2016.

Appendix 3. Our Process

In this section, we outline why we decided to recommend Coalition for Rainforest Nations (CfRN) and Clean Air Task Force (CATF) over the other shortlisted charities. In brief, the case for each recommended charity rested on the following:

- Coalition for Rainforest Nations
    - Works on a high priority intervention – deforestation prevention.
    - Has an extremely strong track record – CfRN has had a large effect on global forestry prevention.
    - Can leverage very large amounts of money for forestry protection.
    - Supports a policy, REDD+, which we believe to be among the best ways to reduce deforestation.
    - Given its position at the UNFCCC, we would be very surprised if there were another charity better placed to prevent deforestation as cost-effectively as CfRN.
- Clean Air Task Force
    - Works on high priority interventions – CCS, nuclear advocacy and policy, and energy innovation.
    - Works in high priority geographic areas – CATF works in the US and China, and prioritises which geography to focus on according to the importance, neglectedness and tractability of work in those areas.
    - Has an extremely strong track record – CATF has been involved in an unusually large number of successful and important advocacy campaigns since 1996, mostly in the US.

We also have some evidence that it has been one of the most effective NGOs working in China.

- Produces high quality research – this makes it more likely to advocate for good policies, and to influence the public discourse in a positive direction.

The climate charities that made our shortlist were:

- Energy for Humanity
- Third Way
- Center for Carbon Removal
- Sandbag
- Bellona
- Environmental Defense Fund Europe
- Cool Earth
- Environmental Progress

We will now briefly discuss why we decided to deprioritise these other charities. Once we learned of CATF and CfRN's track record, strength of team, and track record, we used them as benchmarks against which to judge the other shortlisted charities.

Forestry charities

We will first discuss why we deprioritised the other forestry charity we looked at.

Cool Earth

Aside from CfRN, the only other forestry charity we looked at was Cool Earth, a UK-based charity carrying out project-based deforestation prevention efforts. We looked at Cool Earth chiefly because we wanted to offer a lower risk option to pledgers. However, upon reviewing the evidence on forestry,

for the reasons outlined in our review of CfRN, we concluded that project-based approaches were likely to be much lower impact than the jurisdictional approach pursued by CfRN. We are not confident that project-based approached would be effective, and we would encourage NGOs pursuing project-based approaches to join the UNFCCC REDD+ process.

An initial examination of CfRN's track record showed that it potentially has had an extremely large impact on past international climate policy, and it has potential for huge leverage in the future. We therefore concluded that it is unlikely that other forestry charities would be better than CfRN.

Charities working on CCS, nuclear power, and energy innovation

We will now discuss why we deprioritised the charities we looked at that worked on CCS, nuclear and general energy innovation. In general, CATF seemed to do better than the alternatives in terms of track record, in terms of how it selected its projects, and its future potential impact.

Energy for Humanity

Energy for Humanity is a UK and Switzerland-based charity that advocated for nuclear power, mainly in the EU. We were positive about Energy for Humanity's work, as they seem to have been involved in some important successful campaigns, to have a strong leading team, and to produce high quality research. However, CATF appeared to be a better bet for several reasons. Firstly, as Energy for Humanity is a young organisation, CATF has a much stronger track record of being involved in very impactful campaigns. Secondly, Energy for Humanity mainly focuses on the EU, whereas CATF focuses on what we believe to be higher priority geographic areas. Thirdly, in addition to nuclear, CATF works on other high priority areas, including CCS and energy innovation.

Third Way

Third Way is a US-based centrist think tank that, like CATF, advocates for CCS, nuclear and energy innovation, three of our high priority interventions. Third Way and CATF often work together on campaigns, such as the campaign for the 45Q tax credit. We deprioritised Third Way's energy and climate programme chiefly because, while Third Way seems to have had some advocacy successes, CATF's track record appears to be superior, as they have been involved in more major policy successes.

Center for Carbon Removal

The Center for Carbon Removal is a US-based non-profit that advocates for CCS and forms of CO_2 removal. Although we were positive about some of their work, we decided not to recommend them for a number of reasons. Firstly, CATF has an advantage in that it works on nuclear as well as CCS, so covers more of our high priority interventions. Secondly, CATF has a stronger track record of achieving high impact policy change, whereas Center for Carbon Removal has thus far had fewer past successes, with its work mainly focusing on higher level research projects, which currently appear lower impact than object-level policy work. We therefore believe it more likely that CATF will have impact in the future. Thirdly, some of Center for Carbon Removal's future projects, such as their Carbon Recycling Labs, seemed to work on problems with much lower emissions reduction potential than projects worked on by CATF. In general, we were more confident in CATF's approach to choosing which projects to work on.

Sandbag

Sandbag is a UK-based charity that advocates for improved carbon pricing and for CCS in the UK and the EU. We deprioritised Sandbag for the following reasons. Firstly, unlike CATF, it has not yet had any major policy wins in its advocacy for CCS. Secondly, it works on lower priority geographies, with most

of its work focused on the UK and the EU, whereas CATF focuses on the US and China, and is open to work in India.

Bellona

Bellona is a non-profit founded in 1986 with headquarters in Norway and offices in Russia and Brussels. We short-listed Bellona because it is one of the few NGOs that has consistently advocated for CCS. We decided not to recommend for the following reasons. Firstly, although Bellona has had some policy successes on CCS in Norway, CATF appears to have a much stronger and more impactful track record thanks to its advocacy work in the US. Secondly, Bellona works on a lower priority geographic area than CATF, in that it chiefly focuses on the EU. Finally, we were concerned about some of Bellona's anti-nuclear power work, which we believe to overstate the risks from nuclear waste. We believe that this aspect of Bellona's mission could be bad for the climate.

Environmental Defense Fund Europe

Environmental Defense Fund Europe was founded in 2016 as the European branch of Environmental Defense Fund, a large environmental NGO based in the US. EDF Europe has a very strong team and we looked at them because of their willingness to work on China. They were deprioritised for a number of reasons. Firstly, CATF has a much stronger track record of policy success than EDF Europe. Secondly, CATF works on more of our high priority intervention areas, including strong advocacy for CCS and nuclear. Thirdly, EDF Europe chiefly works in the EU, whereas CATF works on higher priority geographies.

Environmental Progress

Environmental Progress is a US-based NGO that advocates for nuclear power globally, but mainly in the US. We deprioritised Environmental Progress chiefly because it takes a confrontational approach to its advocacy, which we think may be counterproductive in the medium to longer term.

Appendix 4. Key Methodological Learnings

Some aspects of the approach used in this report could be improved. Firstly, we are not completely confident that the version of the ITN framework we have used in this report is correct. Other organisations, such as 80,000 Hours, have proposed alternative versions of the framework.255 We initially used the 80,000 Hours version, but found it to have certain drawbacks that led us to develop an alternative. Chiefly, we found it difficult to constraint intuitions about tractability as defined by 80,000 Hours. We plan to research the most appropriate version of the ITN framework in the coming year.

The approach we used to narrow down charities at the stage after the ITN analysis could have been improved. It turned out to be much more efficient to ask aligned philanthropists for recommendations than to try to draw conclusions based on charities' own websites.

It is also notable that one of our recommended charities – CfRN – works on an intervention that scores lower than others on the ITN criteria. We found this charity by speaking with an impact-focused philanthropist. This suggests that there might be a case for using this method – in addition to the ITN framework – to find impactful charities.

[255] 80,000 Hours, "How to Compare Different Global Problems in Terms of Impact."

Appendix 5. Other Possible Interventions

There are some possible interventions that we did not evaluate in the ITN framework. These include:

- Research into solar geoengineering
- Work to reduce population growth
- Reducing consumption of animal products

We will discuss each intervention in turn. The arguments here are difficult to incorporate into an ITN analysis.

Solar geoengineering

Solar geoengineering, sometimes called Solar Radiation Management involves cooling the Earth by reflecting sunlight back to space.[256] The most researched proposed form involves injecting particles such as sulphates into the stratosphere (the upper atmosphere), which would be distributed around the planet by stratospheric winds and would reflect sunlight back to space. The evidence suggests that if it could be governed properly, it would reduce the damages from climate change.[257] However, solar geoengineering would be hard to govern and researching it creates moral hazard risk – the risk that research could reduce willingness to mitigate. Mainly due to the moral hazard concern, we are very unsure whether research into solar geoengineering would be beneficial, though we think it would be on balance.[258] However, we think that those concerned about climate change should focus

[256] For good overviews see J. G. Shepherd, Geoengineering the Climate: Science, Governance and Uncertainty (Royal Society, 2009); David W. Keith, A Case for Climate Engineering, Boston Review Book (Cambridge, Mass.: Cambridge, Mass: The MIT Press, 2013); Oliver Morton, The Planet Remade: How Geoengineering Could Change the World (London: Granta, 2015).
[257] Ben Kravitz et al., "A Multi-Model Assessment of Regional Climate Disparities Caused by Solar Geoengineering," Environmental Research Letters 9, no. 7 (2014): 074013, https://doi.org/10.1088/1748-9326/9/7/074013.
[258] John Halstead, "Stratospheric Aerosol Injection Research and Existential Risk," Futures, March 9, 2018, https://doi.org/10.1016/j.futures.2018.03.004.

primarily on improving the progress of climate mitigation, rather than on speculative technology that is only likely to be used in several decades' time.

Reducing population growth

Population growth is a major driver of emissions growth. So, there might be a case for focusing advocacy attention on reducing population.[259] However, we believe that: (1) tractable versions of this intervention would have little effect on emissions; and (2) versions of this intervention that would have an effect on emissions are very intractable.

In the vast majority of countries, fertility is converging to around 2 births per woman.[260] The 'fertility decline' is happening at earlier stages of economic development than before. This is chiefly because women are gaining more control over their fertility. The increasingly exceptional countries in which women appear not to limit births at all are in very poor countries such as Niger, Afghanistan and Mali. It is in these countries that population growth is highest. We think that there could be cost-effective ways to empower women and to reduce fertility in these countries.

However, because these countries are so poor, they contribute a tiny fraction of global greenhouse gas emissions. As we show in the main report, emissions are driven by large rich and/or rapidly growing countries, such as China, the US, and India. Thus, if one were to reduce population growth in high fertility countries, this would have a very small effect on emissions, at least over the next few decades. Although these places will grow economically in the future, once energy demand grows in those places low carbon technologies will be more widely available. Note that because these places are poor, interventions affecting fertility rates will likely have negligible effects on the development of

[259] For a sceptical discussion of this argument see Hilary Greaves, "Climate Change and Optimum Population," *The Monist*, forthcoming.
[260] For an excellent overview of this issue see David Roodman, "The Impact of Life-Saving Interventions on Fertility," *David Roodman* (blog), accessed March 5, 2018, https://davidroodman.com/blog/2014/04/16/the-mortality-fertility-link/.

low carbon technology. Moreover, fertility probably influences economic growth, though assigning causality is very challenging. Existing estimates in the literature suggest that the effect is small or positive, so efforts to reduce fertility could partly offset the population growth effect via the economic growth effect.[261]

It would arguably make a bigger difference to reduce population growth in the major emitters. However, the vast majority of these countries are converging to around 2 births per woman. There is good evidence that this is in large part because women have gained significant control over their fertility.[262] This in turn suggests that fertility rates in those countries could not be greatly affected by tractable interventions.

Reducing consumption of animal products

Reducing consumption of animal products is potentially highly impactful as a climate change intervention. However, we did not have enough research time to evaluate this adequately for this year's report. We plan to investigate this further when we update the report in a year's time.

Consuming animal products increases greenhouse gas emissions because the food used to feed them leads to deforestation, and because animals emit large amounts of methane in the digestive process. According to a 2009 study, preventing the use of all animal products globally would prevent 8Gt of CO_2e emissions per year.[263] This suggests that reducing consumption of animal products scores very

[261] Quamrul H. Ashraf, David N. Weil, and Joshua Wilde, "The Effect of Fertility Reduction on Economic Growth," *Population and Development Review* 39, no. 1 (March 2013): 97–130, https://doi.org/10.1111/j.1728-4457.2013.00575.x.
[262] https://ourworldindata.org/fertility-rate
[263] IPCC, Climate Change: Mitigation, 850.

highly on importance. Reducing animal product consumption also appears to be neglected. Farmed animal advocacy receives less than $100m per year in the US.[264]

We are very unsure how tractable the problem is. Interventions such as vegan advocacy appear to have made little progress on reducing animal product consumption over the last few decades.[265] One potentially more promising solution is research into animal product alternatives, whether plant-based or cultured animal products.[266] If research were to discover foods that had the same flavour and nutritional value as animal products, then this could plausibly have a very large effect on animal product consumption. Indeed, there would be a strong case for banning animal products if identical viable alternatives were discovered. Such alternatives could have much lower environmental impact. However, we are very unsure how easy it is to make progress on animal product alternatives, and we did not consider this option in depth due to time constraints. According to one review of the evidence, it will be extremely difficult to make progress on clean meat,[267] whereas others are much more optimistic, predicting that there will be reasonably priced clean meat within ten years.[268] We plan to investigate this intervention in more depth when we revisit the climate change report in 2019.

[264] "Why Farmed Animals?," Animal Charity Evaluators (blog), accessed March 6, 2018, https://animalcharityevaluators.org/donation-advice/why-farmed-animals/.
[265] Chase Purdy and Chase Purdy, "Millennials Are Deluding Themselves about Eating Less Meat," Quartz (blog), accessed March 6, 2018, https://qz.com/770016/millennials-want-to-eat-less-meat-but-cant-be-bothered-to-do-it/; "The Number of Vegetarians & Vegans Hasn't Changed in 30 Years. What Can We Do about That?," 80,000 Hours, February 19, 2018, https://80000hours.org/2018/02/bruce-friedrich-good-food-institute/.
[266] "The Number of Vegetarians & Vegans Hasn't Changed in 30 Years. What Can We Do about That?"
[267] Nick Beckstead, "Animal Product Alternatives," Open Philanthropy Project, December 14, 2015, https://www.openphilanthropy.org/research/cause-reports/animal-product-alternatives.
[268] "The Number of Vegetarians & Vegans Hasn't Changed in 30 Years. What Can We Do about That?"

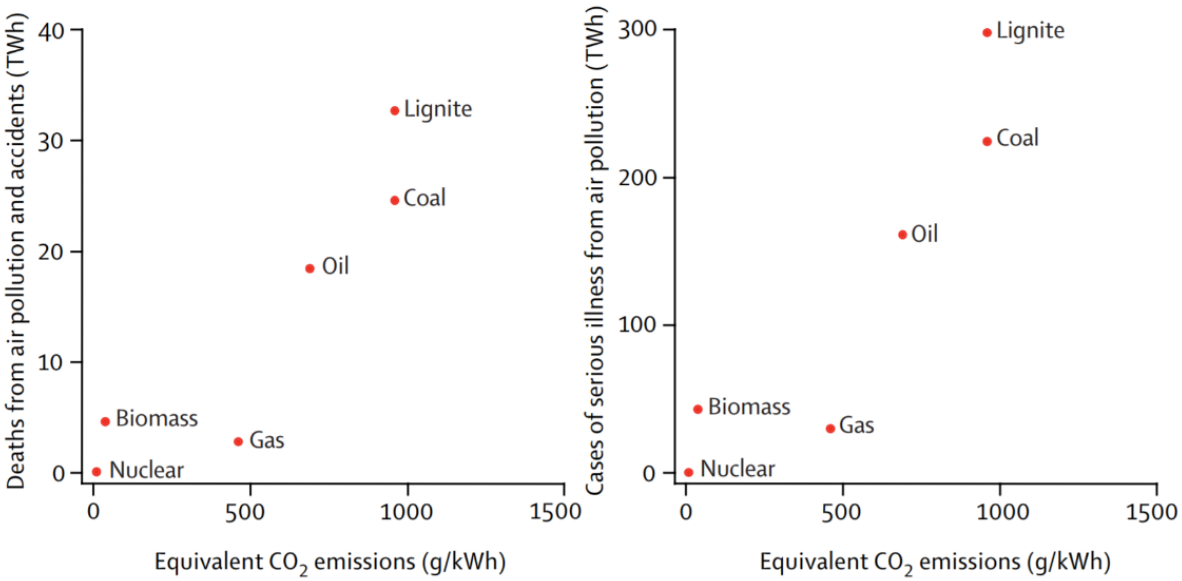
Appendix 6. Concerns About Nuclear Power

Nuclear power is controversial, mainly due to worries about effects of nuclear power on human health, nuclear waste, and proliferation of nuclear weapons. In this section we discuss the scientific evidence and expert consensus on these worries.

We will firstly look at the threat that nuclear power poses to human health. The evidence suggests that nuclear power is one of the least damaging power generation technologies, and is roughly as dangerous to human health as wind power.[269]

Figure A3.

Health effects of electricity generation per terawatt hour



[269] David MacKay, *Sustainable Energy - without the Hot Air*, 168.

Source: Markandya and Wilkinson, "Electricity generation and health", *The Lancet*, 2007: p. 983

This implies that the widespread use of nuclear power has had large health benefits by preventing additional deaths from fossil fuel power. Kharecha and Hansen calculate that nuclear power prevented 1.84 million air pollution-related deaths until 2009.[270] The main reason for this difference in health costs is that most of the deaths from biomass, oil, gas and coal are from air pollution, and nuclear power does not produce any air pollution. The health costs of nuclear power are driven by accidents. Although nuclear accidents are highly salient, the health costs of such accidents tend to be overestimated.

Another concern is nuclear waste. This might be thought to be problematic because of radiation-related deaths or because of creating other problems for the ecosystem. The evidence above suggests that the health risks from nuclear waste have been minimal. Indeed, the volume of waste from nuclear reactors is very small:

> "Whereas the ash from ten coal-fired power stations would have a mass of four million tons per year (having a volume of roughly 40 litres per person per year [in the UK]), the nuclear waste from Britain's ten nuclear power stations has a volume of just 0.84 litres per person per year – think of that as a bottle of wine per person per year."[271]

France gets around 80% of its electricity from nuclear power, and all of its reprocessed high level waste is stored under the floor of a single facility about the size of a basketball court.[272] Even in a nuclear power-reliant country, the typical per person per year volume of nuclear waste would be three

[270] Pushker A. Kharecha and James E. Hansen, "Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power," *Environmental Science & Technology* 47, no. 9 (May 7, 2013): 4889–95.
[271] David MacKay, *Sustainable Energy - without the Hot Air*, 169.
[272] Mark Lynas, *Nuclear 2.0: Why a Green Future Needs Nuclear Power*, 1st edition (New York: UIT Cambridge, 2013), 65.

orders of magnitude lower than the per person per year volume of other non-nuclear hazardous waste.[273]

It needs to be borne in mind that all forms of energy production involve waste. Fossil fuel energy produces untreated waste (air pollution) which causes millions of deaths a year. Insofar as nuclear power replaces fossil fuels in energy systems, the total amount of dangerous waste exposed to humans will be dramatically reduced.

It is true that high level nuclear waste must be stored for upwards of 1,000 years. However, well over 99% of the toxicity from nuclear waste decays after 500 years.[274] Thus, the volumes are very small compared to other forms of hazardous waste we routinely manage. Moreover, technological progress over the next 100 years and beyond will make this problem easier to deal with.

The final major concern with nuclear power regards the risk of nuclear weapon proliferation from civilian nuclear power. There is disagreement among experts about the effect that civilian nuclear power has had and will have on the spread of nuclear weapons.[275] There are two causal factors to consider when approaching this question. On the one hand, nuclear power programs increase the technical capacity of a state to build nuclear weapons by increasing within country nuclear expertise and access to some weapons materials. On the other hand, they also have important countervailing political effects that limit the probability of proliferation. Specifically, due to international conventions on civilian nuclear, nuclear energy programs (1) increase the likelihood that a parallel nuclear weapons program is detected and attracts outside non-proliferation pressures, and (2) increase the costliness

[273] David MacKay, *Sustainable Energy - without the Hot Air*, 170.
[274] Sharon Tanzer, Steven Dolley, and Paul Leventhal, eds., *Nuclear Power and the Spread of Nuclear Weapons: Can We Have One without the Other?*, ebook (Potomac Books Inc., 2002), loc. 509.
[275] For contrasting views see Tanzer, Dolley, and Leventhal, *Nuclear Power and the Spread of Nuclear Weapons*. For a good overview of the literature see Nicholas L. Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation," *International Security* 42, no. 2 (November 1, 2017): 40–77, https://doi.org/10.1162/ISEC_a_00293.

of non-proliferation sanctions, which would in turn undermine nuclear power programmes.[276] It is important to note that civilian nuclear power is not *necessary* to acquire weapons, and that other means, which may be much easier and cheaper, are available.[277]

Historically, the effect of civilian nuclear power on the probability that a country will pursue or acquire nuclear weapons is unclear.[278] The number of data points is small, which makes it hard to achieve statistically significant results, and much of the effect is driven by a handful of cases, which makes qualitative analysis preferable to quantitative analysis. There is also some disagreement about which states should be classed as having had civilian nuclear power or nuclear weapons. Due to the small sample size, these disagreements are consequential for the results.

Miller (2017) is the best quantitative data source we have found on the historical effect of civilian nuclear power programmes on the probability that a state pursues or acquires nuclear weapons after 1954. Miller starts in 1954 "to be charitable to the argument linking nuclear energy programs and proliferation, because the countries that proliferated before 1954 arguably did not have the option of pursuit with an energy program".[279] We will now discuss Miller's findings. He focuses on the statistical relationship between civilian power and the *pursuit* of nuclear weapons, and also the *acquisition* of nuclear weapons. Miller's data tells us about the historical correlation between civilian nuclear power and nuclear weapons. Qualitative information on the particular cases is needed to build a case for civilian nuclear power having a causal role.

[276] Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation."
[277] Gwyneth Cravens and Richard Rhodes, *Power to Save the World: The Truth About Nuclear Energy*, ebook (New York: Vintage, 2008), loc. 263; loc 2701ff.
[278] For an overview of the divergent views see Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation."
[279] Miller, 53.

Firstly, consider the effect of nuclear power on the *pursuit* of nuclear weapons. We can approach the question in two ways:

- The probability that a country with a civilian power programme pursues nuclear weapons in a given year.
- The proportion of countries that have pursued weapons that had a civilian power programme prior to pursuing nuclear weapons.

28 countries with energy programmes have not pursued nuclear weapons.[280] Thus, having nuclear power certainly does not guarantee that a country will pursue weapons.

However, the more relevant question is whether countries with nuclear power have been more likely to pursue nuclear weapons. 17 countries have pursued nuclear weapons since 1954. Miller's data shows that the annual probability of pursuing nuclear weapons was 0.51% for countries with civilian nuclear programmes, and 0.2% for countries without civilian nuclear programmes, a difference by a factor of 2.5. This effect has a *p*-value of 0.1, which is near statistical significance.[281] However, in only five countries – Argentina, India, Brazil, Iran, and Pakistan – did the energy programme predate the pursuit of nuclear weapons.[282] The remaining 12 countries that pursued nuclear weapons did not have a power programme prior to pursuing nuclear weapons. The question of whether an energy programme predated a weapons programme seems the most relevant for establishing whether nuclear power played a causal role in a state's pursuit of nuclear weapons. Miller's data suggests that there is not much evidence that, across the population of all states, power programmes increase the likelihood of pursuit of weapons.

[280] Miller, 53.
[281] Miller, 56.
[282] Miller, 53.

This being said, even if weapons programmes started before energy programmes, energy programmes could still assist progress in *acquiring* nuclear weapons by making acquisition easier during the pursuit of nuclear weapons. We discuss this possible effect below.

Another factor which should lead us to deflate the significance of the 0.2% vs. 0.51% relationship mentioned above is that this statistic does not correct for potential confounders. As Miller notes:

> "Countries with nuclear energy programs are likely to be systematically different from countries without them, and these differences may lead them to proliferate at different rates for reasons that have nothing to do with energy programs. For example, countries with nuclear energy programs almost certainly are wealthier and have higher levels of industrial development than those without such programs. These factors could increase their capability to pursue or acquire nuclear weapons independently of whether they have nuclear energy programs. Alternatively, countries with nuclear energy programs may have fewer incentives to seek nuclear weapons because they live in less threatening security environments or have nuclear-armed allies."[283]

Once one corrects for confounders such as these[284] the correlation between power programmes and annual probability of pursuit of weapons becomes very small or slightly negative, and none of the effects are statistically significant.[285]

Due to the small sample size and the small number of relevant data points, the statistical power of these tests is limited. In addition, as discussed above, the more relevant question with respect to

[283] Miller, 56–57.
[284] Miller states that he seeks to avoid post-treatment bias – "in other words, I do not control for possible mechanisms through which energy programs might influence the likelihood of proliferation". Miller, 57.
[285] Miller, fig. 1. The full regression tables are provided in the online appendix to the Miller paper. Related to this point, it is important to note that concerns about proliferation risk should be applied to all possible actions, and not just to spreading nuclear power. For instance, industrial capacity appears to be a much stronger driver of proliferation than nuclear power. By consistency, this effect needs to be taken into account when we are assessing policies to increase economic growth.

assessing causality seems to be whether energy programmes predate weapons programmes, and the evidence shows that this has happened in only a small proportion of the overall number of cases of weapons pursuit.

Overall, the effect of nuclear power on the pursuit of nuclear weapons has been small to negligible. The effect has been very small compared to other factors such as industrial capacity,[286] and whether a state faces an existential threat or is a major power.[287]

We now turn to the question of whether civilian nuclear power programmes have made it more likely that weapons are acquired. Weapons acquisition seems more important than weapons pursuit because weapons acquisition drives the potential for geopolitical instability and the use of nuclear weapons. The relevant facts are that:

- Four countries – France, India, Pakistan and South Africa – have successfully acquired nuclear weapons while running a civilian nuclear energy programme.
- Three countries – China, Israel, and North Korea – acquired nuclear weapons without a civilian nuclear energy programme.
- South Africa has now ended its nuclear weapons programme.

There is some disagreement in the literature about whether some countries should be classed as having energy programmes and/or pursuing weapons programmes. Consequently, there is disagreement about whether countries with civilian nuclear power were more or less likely to acquire weapons.[288] Due to the small number of data points, to establish causality, it is more useful to look at

[286] Miller, 59.
[287] Mark S. Bell, "Examining Explanations for Nuclear Proliferation," *International Studies Quarterly* 60, no. 3 (September 1, 2016): 520–29, https://doi.org/10.1093/isq/sqv007.
[288] Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation," 62.

qualitative information on individual cases. Bunn (2001) provides a brief overview of each case. In the cases in which countries with energy programmes acquired weapons, civilian nuclear power appears to have played some causal role in helping states acquire weapons.[289] This being said, the countervailing factors mentioned above may also have made successful acquisition less likely in other countries.

The foregoing discussion concerned the historical link between nuclear energy and the spread of nuclear weapons to previously non-nuclear states. Another way to look at the proliferation question is to consider the relationship between nuclear power and the number of warheads, which has a bearing on the scale of the risk from nuclear war. The data suggests that there is no correlation between the two.[290]

Overall, it is unclear what effect, historically, civilian nuclear power has had on weapons proliferation. The main driver of proliferation is the political concern about security and international status. In our view, the evidence suggests that civilian nuclear power has historically had at most a small positive effect on proliferation, with our best guess being that it has had close to zero effect. However, for something as serious as nuclear weapons, small effects are important.

For the purposes of this report, we are interested in whether nuclear advocacy would increase the risk of proliferation *in the future*. There are several factors to consider on this front. Firstly, an increase in nuclear power in some countries would increase proliferation risk, but in others an increase in nuclear power would *reduce* proliferation risk.[291] The US has in the past used its control over nuclear

[289] Matthew Bunn, "Civilian Nuclear Energy and Nuclear Weapons Programs: The Record," *Cambridge, MA: Belfer Center for Science and International Affairs* 5 (2001).
[290] Compare: https://thebulletin.org/nuclear-notebook-multimedia; and the nuclear electricity production chart in http://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx.
[291] Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation," 71ff.

technology and enriched uranium to execute its non-proliferation agenda.[292] However, as civilian nuclear power has diminished in the US, Russia has assumed a dominant role in the export market, with France and South Korea also playing significant roles, and China and Japan planning to do so in the future.[293] Since the US has historically been strongly committed to non-proliferation, these trends suggest that non-proliferation could be threatened if the US assumes a marginal role in the nuclear export market.[294]

This suggests that expanding nuclear power in the US is likely to *reduce* proliferation risk because it would protect the US's relative standing in the nuclear export market, allowing the US to execute its strong non-proliferation aims.[295] By contrast, on the basis of past experience, increasing nuclear power in Russia or Pakistan (for example) would be much riskier for proliferation. Similarly, it is very unlikely that countries or blocs that are allied to the US and pursuing civilian nuclear power would pursue nuclear weapons against the wishes of the US or other powerful countries that are strongly opposed to proliferation. Indeed, nations seeking nuclear power plants must sign the Non-Proliferation Treaty, and no nation that has signed the treaty as a non-weapon state has then proceeded to become a weapon state.[296]

For this reason, increasing nuclear power in the US and among other US allies seems likely to reduce proliferation risk.[297] Thus, supporting charities advocating for the expansion of nuclear power in these regions would either have no effect on proliferation or would reduce the risk of proliferation. The main

[292] Miller, 50–52.
[293] Miller, 71.
[294] This argument has been made by Ernest Moniz, Secretary for Energy under Obama and currently head of the Nuclear Threat Initiative. See https://energyfuturesinitiative.org/news/2017/7/12/moniz-the-national-security-imperative-for-us-civilian-nuclear-energy-policy.
[295] Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation," 71ff.
[296] Tanzer, Dolley, and Leventhal, *Nuclear Power and the Spread of Nuclear Weapons*, 1249.
[297] Miller, "Why Nuclear Energy Programs Rarely Lead to Proliferation," 63ff.

effect of the Clean Air Task Force's work, if successful, is likely to be to expand the US's relative position in the nuclear export market.

Secondly, reactors can be designed to minimise proliferation risk. A survey of nuclear experts suggests that nuclear reactor R&D will partially or moderately address proliferation concerns.[298] R&D should be targeted specifically to reduce the risk of proliferation. As Bunn notes:

> "Technologies that reduced or eliminated the rationale for civilian use of [highly enriched uranium] or separated plutonium (such as low-enriched fuels for research reactors and approaches to extending uranium resources that never separate plutonium into weapons-usable forms), or that allowed existing stockpiles of separated plutonium to be transformed rapidly into forms that were no longer usable in weapons, could ease the burdens on safeguards and security systems and reduce the risk of diversion or theft of weapons-usable material."[299]

Reduced need for highly enriched uranium and for plutonium reprocessing would also reduce states' ability to justify acquiring enrichment technology to support their civilian energy programme. Reducing the complexity of nuclear designs would reduce the need for an indigenous technical base to support the nuclear energy programme, thus reducing the expertise which could be applied to weapons technology.[300] These technology features should be a key focus of research into advanced nuclear reactors. The Clean Air Task Force, one of our recommended charities, is currently running a programme focused on improving the proliferation resistance of advanced reactors.

[298] Anadón et al., "Expert Judgments about RD&D and the Future of Nuclear Energy," 11501.
[299] Bunn, "Civilian Nuclear Energy and Nuclear Weapons Programs," 9.
[300] Bunn, 9.