



Achieving the Paris Climate Goals in the COVID-19 era

FOREWORD

How can the Paris Climate Goals be achieved in the COVID-19 era?

This policy briefing was written during the COVID-19 crisis, a time of unprecedented challenges. Governments around the world are preparing for the continued fallout from the pandemic, while also developing economic stimulus packages to avoid a collapse of national economies and global markets. Shocks have been particularly hard in the fossil fuel sector, with the IEA projecting a 9% drop in oil demand, 8% in coal and 5% in natural gas in 2020. Meanwhile, solar is expected to grow by 15% and wind by 10%, with total CO₂ emissions from the energy sector falling by at least 8% in 2020.¹

As the world recovers from the COVID-19 pandemic, we have to think carefully about the future that we want to create. The recovery cannot be a return to 'normal' because the pre-COVID world was not normal. It was, and still is, a time of crisis with record global temperatures and loss of biodiversity. Instead, we must prioritize a coordinated global response that helps solve the climate crisis and makes our societies more resilient and less destructive. Any stimulus based on a 'business as usual' approach could trigger the next global crisis.

The European Commission has recently pledged to put fighting climate change at the heart of its 750 billion euro (\$826.3 billion) recovery plan.² This stimulus package and those to follow must be invested in line with the 1.5°C limit of the Paris Climate Agreement and the Sustainable Development Goals (SDGs). Failure to do so could lead to further environmental degradation, severe flooding and drought, and risks to public health from future vector-borne or zoonotic diseases.

This executive briefing, produced in partnership with One Earth and the University of Technology Sydney, sets out the roadmap for a good (66%) likelihood of achieving the 1.5°C limit and shows that doing so will save trillions of dollars in avoided costs, allowing for a more rapid and sustainable economic recovery following the COVID-19 pandemic.

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OVERVIEW

Below 1.5°C - A breakthrough roadmap to solve the climate crisis

In 2018, the IPCC made clear that the world must be kept below 1.5°C global average temperature rise. Their special report *Global Warming of 1.5°C* showed that it becomes increasingly difficult to solve climate change beyond this threshold, and every tenth of a degree increase in temperature risks multiplying impacts.³ However, no model existed that shows how this ambitious target could be achieved using only existing and rapidly scalable solutions, without a risky overshoot of the 1.5°C limit. For this reason, some have abandoned the 1.5°C goal or believe it can only be achieved through large-scale implementation of risky and expensive technologies, such as bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), or solar radiation management (SRM). These technologies may play a role in the future, but they cannot be relied upon to solve the current climate crisis.

Now, for the first time an advanced climate modeling framework, published in the book **Achieving the Paris Climate Agreement Goals (APCAG)**, shows that it is possible to stay below 1.5°C with widely available, rapidly scalable solutions.⁴ Furthermore, the 1.5°C model demonstrates:

We can meet all of our energy needs with 100% clean, renewable energy and energy efficiency measures, using existing technologies by 2050.

Nature-based solutions like forest restoration are crucial to removing carbon from the atmosphere, making the 1.5°C limit possible.

The transition to 100% renewable energy will cost an additional \$1.1 trillion a year – far less than we are paying now for our current fossil-fuel based system.

The APCAG 1.5C model is a breakthrough because it changes the frame of discussion – the key question is no longer “can we?” It’s “will we?” Achieving 1.5°C is now a choice, not a wish. We don’t need to wait for novel technologies. There is a clear pathway to success with meaningful, effective solutions that can be implemented immediately. Moreover, achieving the 1.5°C limit will save trillions of dollars in avoided climate change impacts and will allow for a more rapid and sustainable economic recovery following the COVID-19 pandemic.

The scenario to achieve the 1.5°C limit (LDF1.5C) is published in the book *Achieving the Paris Climate Agreement Goals (APCAG)*. It is the culmination of a two-year collaboration with 17 leading scientists at the University of Technology Sydney (UTS), two institutes at the German Aerospace Center (DLR), and the University of Melbourne’s Climate & Energy College. The book was released by the prestigious scientific publisher Springer Nature and quickly became the most downloaded climate text in the publisher’s history, cited in over a dozen scientific papers.

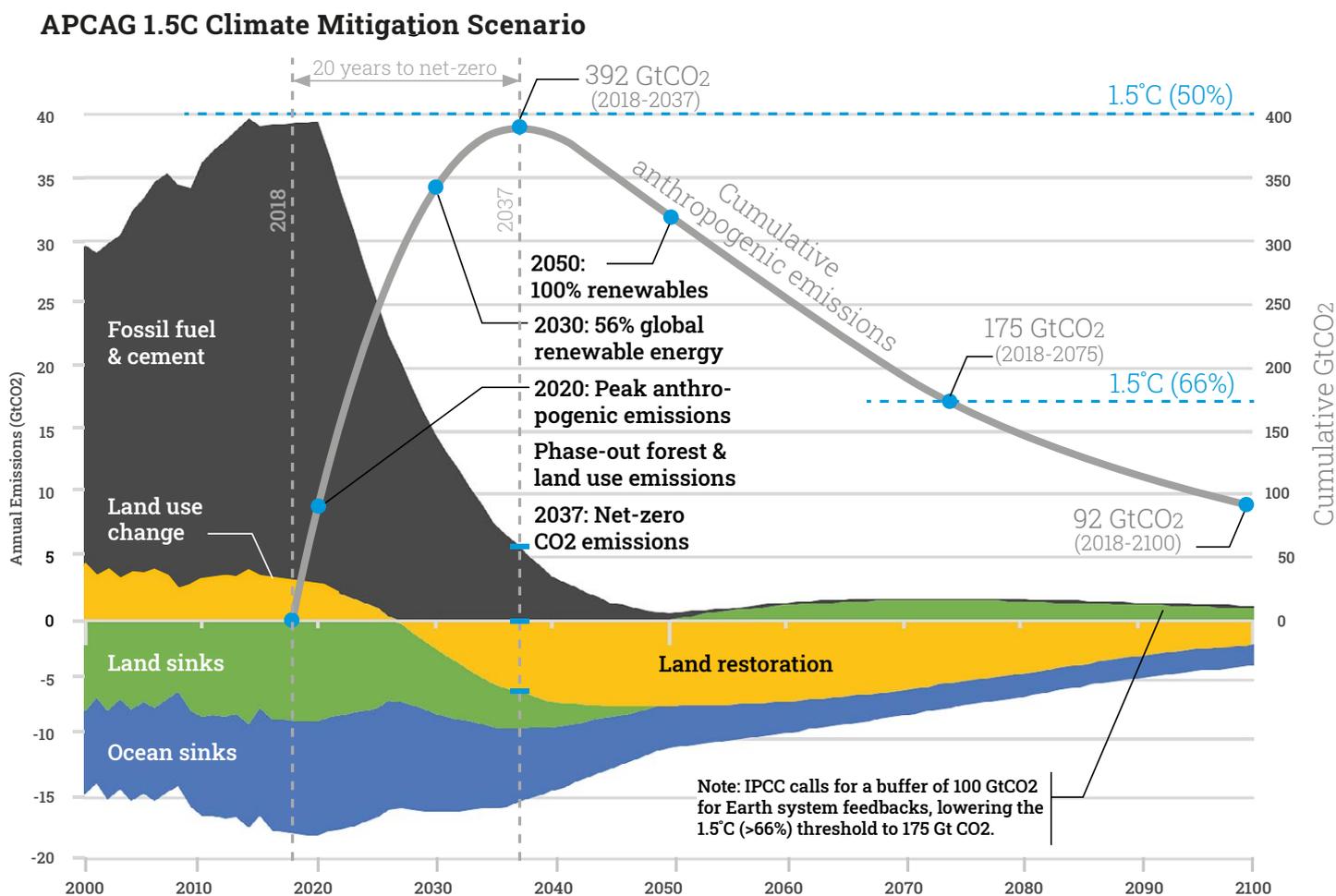
Why the 1.5°C limit matters

We are already seeing the devastating consequences of the current 1°C in global average temperature rise above pre-industrial levels – rapid glacial melting, rising sea levels in many coastal cities, extreme storms, prolonged droughts, and intensified wildfires. And because temperature intensity varies across the world, we can glimpse a 1.5°C future today. Australia, with its recent unprecedented wildfires, is already at a regional average temperature rise of 1.5°C.⁵ Antarctica is experiencing a rise of more than 3°C, resulting in much faster glacial melting than had been previously expected.⁶

This briefing will set out a clear transition pathway to avoid the dangerous threshold of 1.5°C, including the actions, targets and timescales we need to hit.

What does the 1.5°C limit look like in practice?

Here is the APCAG 1.5C scenario in one graph:



The APCAG 1.5C model achieves net zero annual CO₂ emissions in approximately 20 years, from 2018-2037. The black area represents emissions from fossil fuels, which must decline by more than half by 2030. The gold area represents emissions from land use, including deforestation, which declines and becomes a source of negative emissions in the late 2020's through forest restoration. The blue area represents natural ocean carbon sinks, which continue absorbing CO₂ through the century. The green areas represent natural land carbon sinks, which become a contributor of CO₂ emissions in the second half of the century due to biosphere feedbacks. The blue dotted lines show the carbon budgets (commencing Jan. 1, 2018) for a 50% chance (top line) and >66% chance (lower line) of staying below 1.5°C.

The APCAG 1.5C scenario is summarized here in two main parts:

Clean, renewable energy transition

Increasing energy efficiency measures and decarbonizing global energy supplies through a transition to 100% clean, renewable energy across all sectors – transport, industry, and buildings/other – including electricity, heating, and liquid fuels.

Nature-based solutions and land use

Protecting the world's remaining natural carbon sinks, ending deforestation and restoring forests; cutting methane emissions from agriculture in half, cutting nitrogen use by a third, and planting trees on croplands to absorb carbon dioxide.

Societal benefits of achieving the 1.5°C limit

The 1.5C model demonstrates that not only is it possible to switch to 100% renewables for all energy uses, but that it will cost much less to operate compared to today's energy system while creating valuable social and economic co-benefits. It will improve public health worldwide by eliminating the air pollution associated with the burning of fossil fuels, estimated to be the cause of 4.2 million premature deaths per year.⁷ The renewable energy transition will also drive economic development, providing 30 million people currently working in the energy sector with permanent, good-paying jobs and creating 12 million additional new jobs.

The vital nature-based strategies included in the model not only serve as a means to sequester carbon, but also to make ecosystems more resilient and to enhance biodiversity. This increases sustainable livelihoods in the developing world, offering improved water supplies, reducing soil erosion, and providing higher quality crop yields. Protecting and restoring nature also protects human health by reducing the risk of zoonotic diseases such as COVID-19.⁸

“
Scientists cannot fully predict the future, but advanced modeling allows us to map the best scenarios for creating a global energy system fit for the 21st century. And with momentum around the Paris Agreement lagging, it's crucial that decision-makers around the world see that we can, in fact, meet global energy demand at a lower cost with clean renewables.
”

DR. SVEN TESKE

CO-AUTHOR AND EDITOR AND RESEARCH DIRECTOR
OF THE INSTITUTE FOR SUSTAINABLE FUTURES AT THE
UNIVERSITY OF TECHNOLOGY SYDNEY (UTS)

FINDINGS ON ENERGY

Top-level findings: clean, renewable energy transition

The APCAG 1.5C energy transition model calls for a rapid decarbonization of final energy delivery (approximately 8-10% per year), including both electricity and non-electrical energy carriers, such as direct solar heating and liquid renewable fuels. Globally, total energy supply goes from 21% renewables in 2020 to 56% by 2030, 88% by 2040, and 100% by 2050. Some of the main implications of the model for the way we generate and use energy include:

1

The size of the global market for renewable power plants and energy storage and dispatch will increase significantly.

Each of the three major energy end-use sectors – Transportation, Industry, Buildings/Other – will be increasingly electrified, meeting approximately 23% of total energy demand in 2020, 38% in 2030, 52% in 2040, and 59% in 2050. Electricity generation from renewable, carbon-free sources will rapidly scale up from 29% in 2020 to 73% by 2030, 94% in 2040, and 100% by 2050. Nearly all of this expansion is from renewables, with nuclear fission gradually phased out due to rising costs. The world market for energy storage (e.g. hydro-pumped storage plants and batteries) and dispatch technologies and services will increase significantly.

In order to create a decarbonization model to achieve 1.5°C, the scientists at UTS developed a sophisticated computer simulation of the world’s electrical grids – with 10 regional and 72 sub-regional energy grids modeled in hourly increments to the year 2050, along with a comprehensive assessment of available renewable resources like wind and solar, minerals required for manufacturing of components, energy efficiency measures, and configurations for meeting projected energy demand and electricity storage for all sectors through 2050.

2

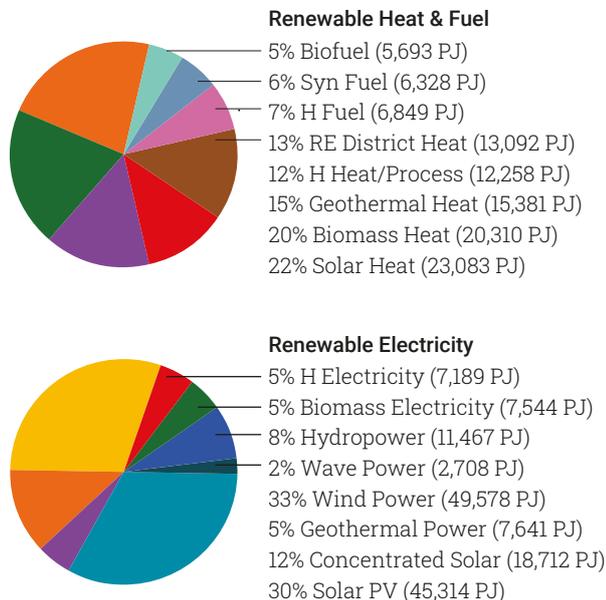
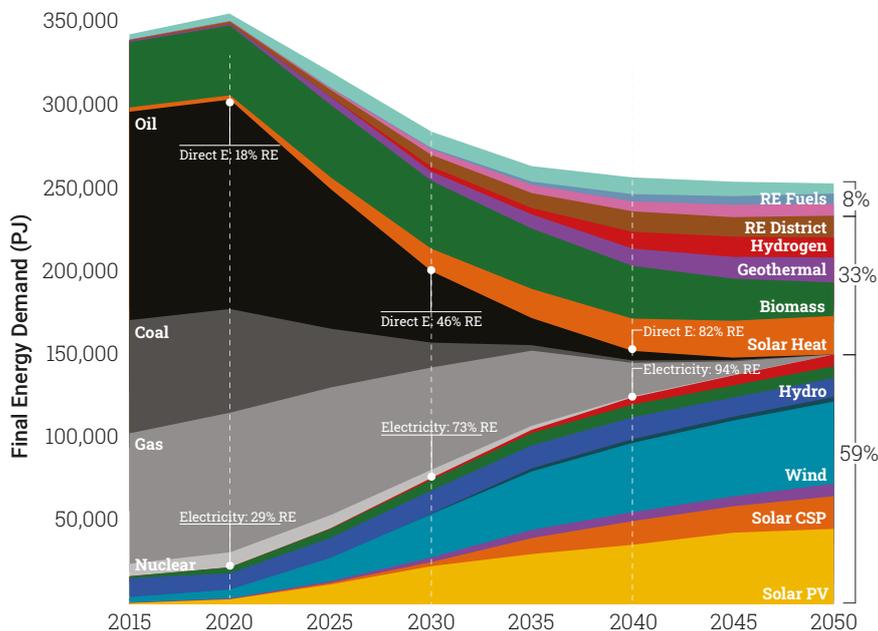
Fossil fuels are rapidly phased out, replaced by renewable energy supplies.

Coal: global coal-fired emissions are reduced by 40% by 2025, 75% by 2030, and phased out by 2050, with electricity needs met increasingly by solar, wind, and other renewables.

Oil: production volume is decreased by 30% by 2025, 58% by 2030, and 4% annually after 2030, with transportation increasingly electrified along with a ramp-up of sustainable liquid fuels.

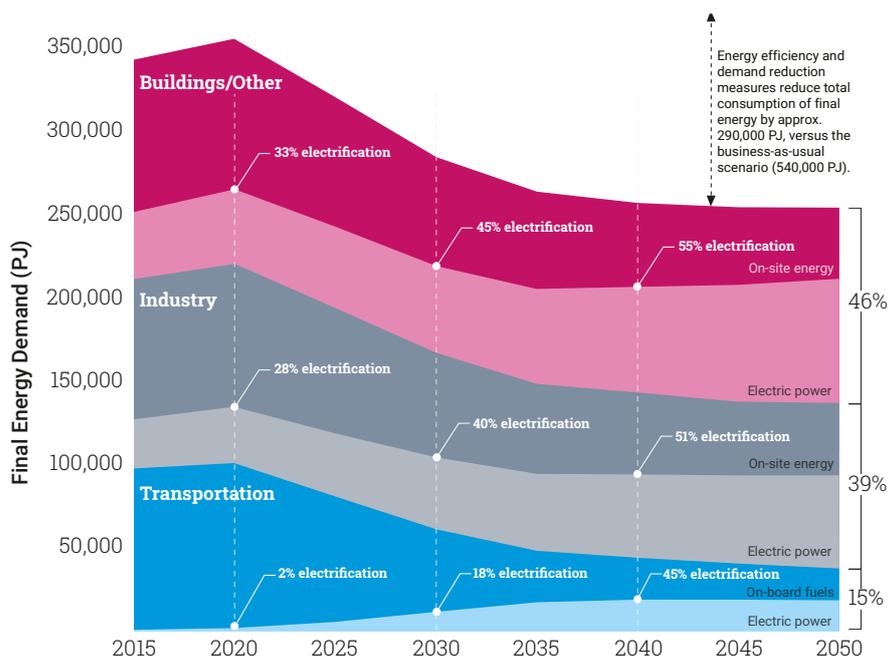
Gas: a gradual phase-out to allow the industry to transition to hydrogen and renewable heating sources, with production decreasing by 0.2% per year to 2025, by 1% to 2030, and by 4% annually after 2030.

Global Expansion of Renewables to Achieve the 1.5°C limit 2050 Energy Supply by Carrier

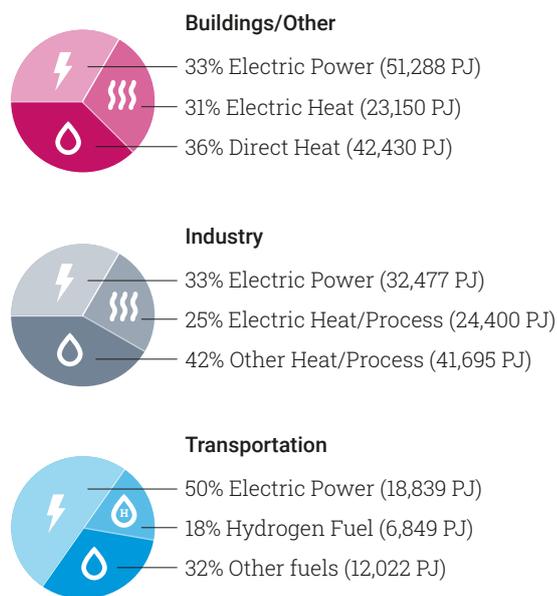


Coal, Oil, and Gas are gradually phased out as electricity demand is met increasingly through renewable power generation, while fossil fuel-based liquid fuels are replaced by renewable fuels. Fossil fuels required for building heat and industrial processes are also phased out as renewable solar, geothermal, and other forms of renewable heat are ramped up. In 2050, approximately 59% of total final energy demand is met by renewable electricity.

Global Electrification to Achieve the 1.5°C limit



2050 Energy Supply by Sector



All three sectors are increasingly electrified through 2050. Transportation moves from 2% electrification to 50%. Industry moves from 28% to 58%, with a large amount of heat/process demand met through electrified heat in 2050. Electrification of the Residential/Other sector moves from 33% to 64%, with nearly half of heating demand met by electricity. Note: Total energy demand is decreased through energy efficiency and demand reduction measures.

3

The transition to renewables will be cheaper than our current energy system.

The proposed energy transition outlined would require an investment globally of an additional \$1.1 trillion per year, factoring in approximately \$400B/yr in savings from reduced fossil fuel extraction and processing in the 2020's, which grows to approximately \$900B/yr savings in 2030's and \$1.1T/yr savings in the 2040's. While this represents a significant investment, it pales in comparison to the vast subsidies governments currently provide

to prop up the fossil fuel industry, estimated at more than \$4.7 trillion in 2019 by the International Monetary Fund.⁹ Taxpayers are unwittingly funding the climate crisis, and that needs to stop. The research tells us that we could create a clean energy future for less than one-third of what we're spending now, while improving health outcomes, energy access and sustainable livelihoods in both developed and developing countries.

4

The transition will create more long-term energy sector jobs.

Though a rapid transition in line with the 1.5°C target will require significant investments, in the end it will contribute positively to the recovery of the global economy, reducing climate risk and pollution-related illness, while increasing job opportunities in a new, clean economy. The overall number of energy-sector jobs increases – with 48.1 million energy jobs in 2025, 53.8 million energy jobs in 2030, and 47.8 million energy jobs in 2050. The renewable energy sector is projected to account for 86% of all energy jobs in 2025 and 89% in 2030, with solar PV having the greatest share, followed by biomass, wind, and solar heating. There will be a net increase in jobs in the 2020's, with the highest number of jobs being plant and machine operators and assemblers, followed by electricians, and technicians (including electrical, mechanical, civil, and IT technicians). The largest percentage increase will be among laborers, engineers, electricians, and construction trades. Jobs created in wind and solar PV alone will be enough to replace all jobs lost in the fossil fuel industry.

5

Overall energy demand is greatly reduced through efficiency measures.

Despite an increasing need for heat, power and transport as the global population grows, total energy demand will actually decrease in the 1.5C model – from 355,000 PJ in 2020 to 284,000 PJ in 2030, 257,000 PJ in 2040, and 253,000 PJ in 2050. This is accomplished through an array of energy efficiency and demand reduction measures. Transportation will become 75% more efficient than the BAU scenario due to electrification and reduction of powertrain losses for road vehicles, aerodynamic improvements for high-speed transport, and reduction of vehicle mass. Heating of buildings will become 40% more efficient, accomplished through low-energy building codes and retrofit programs that incentivize highly efficient building envelopes, passive cooling and heating systems, low-temperature heating networks, thermal sensors and automated controls. Buildings will increasingly use efficient heat pumps for heating and cooling. Electricity usage will become 50% more efficient, accomplished by increased efficiency of lighting and other appliances as well as greatly reduced losses from smarter power transmission infrastructure and the phaseout of energy related to fossil fuel extraction and processing.

6

Heating demand will be met largely through the use of on-site or district heating sources such as geothermal, solar heating, or sustainable biomass, as well as clean electricity.

Globally, the electrification of heating for both industrial and building sectors will increase from 2% in 2020 to 13% in 2030, 23% in 2040, and 30% in 2050. The remaining heating demand will be met increasingly by direct renewable sources, scaling up from 20% in 2020 to 43% in 2030, 62% in 2040, and 70% by 2050. Geothermal and solar heating will provide more than half of direct heating supply. Estimated investments in renewable heating technologies to 2050 will amount to approximately \$344 billion per year. The largest share of this investment would be for heat pumps – approximately \$5.7T total, followed by investments in solar collectors and geothermal heat use. Energy efficiency plays a major role by keeping consumption relatively flat.

7

The transportation sector will be increasingly electrified, but roughly half of transportation needs will be met through liquid fuels such as hydrogen, sustainable biofuels, or synthetic fuels.

The electrification of transport will greatly increase – from less than 2% in 2020 to 18% in 2030, 45% in 2040, and 50% electrification by 2050. A major increase in electric rail, a reduction in domestic aviation, and energy efficiency measures reduce consumption by 60% from 2020 levels. Approximately 20% of vehicles will be powered by hydrogen, with the remaining 30% from carbon-neutral synthetic fuels and biofuels, which are well suited for aviation and shipping needs. On a global level, internal combustion engines will be almost entirely phased out by 2050. In OECD regions, cars with internal combustion engines that use oil-based fuels will be phased out by 2040, whereas in Latin America or Africa, for example, a small share of internal combustion engine powered cars, fueled with biofuels or synthetic fuels, will still be on the road but will be gradually replaced by electric drivetrains.

8

Not every region will move at the same speed.

Globally, renewables will make up an average of 56% total primary energy by 2030 and 88% by 2040, but targets will vary by region. APCAG takes a “common but differentiated” approach to solving the climate crisis, utilizing 10 Integrated Assessment Modeling (IAM) regions, derived from 72 subregion models, to depict a global transition in which wealthier countries move more quickly, while developing countries proceed more gradually. For this reason, the model is disaggregated into component targets that are specific and actionable for each region.*

*RE Power targets represent renewable shares of final electricity delivered to the end-user. See Chapter 8 in Achieving the Paris Climate Agreement Goals (2019) for shares of renewable electricity generation and installed capacity. See below for topline 2030 and 2040 renewable energy targets by sector and region:

2030 Regional & Sectoral Renewable Energy Targets to Achieve 1.5°C						
Region	Transport	Industry	Buildings	Final Energy	Electrification	RE Power*
North America	59%	62%	73%	65%	39%	84%
Latin America	30%	77%	81%	67%	35%	91%
Europe	50%	54%	60%	56%	43%	74%
Africa	11%	63%	87%	68%	21%	73%
Middle East	13%	26%	39%	28%	30%	58%
Eurasia	22%	48%	47%	42%	27%	66%
India	34%	58%	82%	65%	39%	77%
China	31%	45%	65%	49%	63%	45%
Other Asia	21%	60%	83%	62%	33%	74%
OECD Pacific	42%	51%	53%	50%	48%	68%
WORLD	36%	54%	69%	56%	38%	73%

2040 Regional & Sectoral Renewable Energy Targets to Achieve 1.5°C						
Region	Transport	Industry	Buildings	Final Energy	Electrification	RE Power*
North America	96%	93%	98%	96%	52%	99%
Latin America	96%	96%	97%	96%	55%	99%
Europe	96%	84%	87%	87%	52%	94%
Africa	56%	93%	98%	90%	38%	98%
Middle East	84%	71%	84%	79%	49%	97%
Eurasia	88%	75%	79%	79%	39%	88%
India	91%	88%	96%	92%	58%	96%
China	91%	79%	89%	84%	58%	89%
Other Asia	85%	83%	91%	87%	48%	90%
OECD Pacific	92%	83%	87%	86%	57%	92%
WORLD	88%	85%	91%	88%	52%	94%

Below are the modeled targets and key findings for each of the 10 IAM regions from 2020-2050:



OECD North America 1.5C

- An ambitious energy efficiency program is required.
- Wind and solar power generation will be the backbone of the power supply, supplemented by hydropower and concentrated solar power (CSP).
- There is a high potential for CSP in Mexico and the southern USA.
- There is a high potential for offshore wind to power the coastal regions, supporting the production of hydrogen and synthetic fuels for the transport sector.
- Post-2030 natural gas power plants will switch to renewable-produced methane and/or hydrogen, reusing the natural gas infrastructure.
- Electromobility and hydrogen trucks and buses should enter the market earlier and faster than other regions.
- Biofuels will bridge the gap, providing carbon-neutral fuels until more powertrain technologies dominate the vehicle market.

RE Share	2020	2030	2040	2050
Transport	6%	59%	96%	100%
Industry	17%	62%	93%	100%
Buildings	16%	73%	98%	100%
Final Energy	12%	65%	96%	100%
Renewable Power	24%	84%	99%	100%

RE Share	2020	2030	2040	2050
Transport	6%	50%	96%	100%
Industry	25%	54%	84%	100%
Buildings	27%	60%	87%	100%
Final Energy	20%	56%	87%	100%
Renewable Power	40%	74%	94%	100%

OECD Europe 1.5C

- All member states currently have renewable electricity and energy efficiency targets and policies to implement them.
- Southern Europe has high solar potential and low heat demand for buildings; Northern and Western Europe have high wind potential, especially offshore; Northern and Central Europe have high potential for hydropower and a high energy demand for space heating.
- The European Network of Transmission System Operators (ENTSO-E) can be used as a well-established basis for the further development of an interconnected European grid.
- Large-scale importation of solar thermal electricity from MENA countries via high-voltage lines is a promising long-term option.
- Cars with internal combustion engines using oil-based fuels will be phased out by 2040.
- All European lignite power plants cease operations by 2035, and the last hard coal power plant will go offline in the same timeframe.

Latin America 1.5C

- There is a high potential for efficiency measures and large-scale renewable electrification of heat and transportation thanks to rapid urbanization.
- There is a high overall potential for renewable energy across all sectors, with the largest biomass potential of any region.
- The region also has a long-term deployment of biofuels, especially in Brazil, where bioethanol for transport is already competitive.
- The most important renewable technologies are solar PV and onshore wind, followed by CSP (especially in the Atacama Desert in Chile) and offshore wind.

RE Share	2020	2030	2040	2050
Transport	13%	30%	96%	100%
Industry	48%	77%	96%	100%
Buildings	58%	81%	97%	100%
Final Energy	39%	67%	96%	100%
Renewable Power	69%	91%	99%	100%

RE Share	2020	2030	2040	2050
Transport	2%	11%	56%	100%
Industry	31%	63%	93%	100%
Buildings	81%	87%	98%	100%
Final Energy	57%	68%	90%	100%
Renewable Power	27%	73%	98%	100%

Africa 1.5C

- North Africa currently has a strong dependence on oil, but vast solar potential and a high electrification rate. Africa and Europe are technically in a good position to form an economic partnership for solar energy exchange.
- Sub-Saharan Africa has low urbanization and a lack of access to electricity for two-thirds of its people. Modernizing traditional biomass use could lead to significant demand reduction due to the current prevalence of inefficient cooking and heating methods.
- Africa has significant potential for most renewables, including biomass, hydro, geothermal, solar, and wind.
- A small share of internal combustion engine-powered cars, fueled with biofuels or synthetic fuels, will still be on the road, but will be gradually replaced by electric drivetrains.

Middle East 1.5C

- Despite current oil dependency, the Middle East can be seen as a model solar and hydrogen region, with massive solar potential and excellent conditions for hydrogen production.
- Given very high transport demand, large scale electrification is crucial in this region.
- As water scarcity is a problem, there are opportunities to combine large CSP plants with water desalination to reduce the pressure on water supply systems.
- Scarce biomass must be limited to high-temperature process heat where other renewable sources cannot be used, leading to a high demand for hydrogen or synthetic fuels.

RE Share	2020	2030	2040	2050
Transport	1%	13%	84%	100%
Industry	5%	26%	71%	100%
Buildings	7%	39%	84%	100%
Final Energy	4%	28%	79%	100%
Renewable Power	11%	58%	97%	100%

Below are the modeled targets and key findings for each of the 10 IAM regions from 2020-2050:



E. Eurasia 1.5C

- Currently, the main energy carrier is natural gas, followed by oil with renewables quite limited to date.
- There are large energy resources in biomass, wind power, solar PV, and also geothermal.
- There is significant potential for energy efficiency measures across all sectors.
- Challenges for this region include high heat demand, large rural areas, major oil and natural gas reserves, as well as an uneven distribution of wealth.

RE Share	2020	2030	2040	2050
Transport	2%	22%	88%	100%
Industry	9%	48%	75%	100%
Buildings	13%	47%	79%	100%
Final Energy	9%	41%	79%	100%
Renewable Power	23%	66%	88%	100%

RE Share	2020	2030	2040	2050
Transport	1%	34%	91%	100%
Industry	20%	58%	88%	100%
Buildings	60%	82%	96%	100%
Final Energy	33%	65%	92%	100%
Renewable Power	23%	77%	96%	100%

India 1.5C

- India has limited CSP potential but possesses a large potential for PV power generation.
- Wind power potential is expected to be limited by land-use constraints, but the technical potential estimated from available meteorological data is large.
- Approximately 815 million people still rely on traditional biomass for cooking. Due to population and GDP growth, increasing living standards and increasing mobility, it is expected that overall energy demand will increase significantly.
- The nation has a large potential for energy efficiency and electrification.
- Under the 1.5C Scenario, new renewables, mainly wind, solar, and geothermal energy, will contribute 90% of the total electricity generation by 2050.

Non-OECD Asia 1.5C

- On average, 77% of Southeast Asia has access to electricity, but this varies widely in the region. Myanmar and Cambodia, for example, have 30% access while Singapore, Thailand, and Vietnam have close to 100%.
- In Southeast Asia, 46% of the population still relies on traditional biomass.
- Even though the outlooks for individual countries deviate widely from the average, the model accounts for the full spectrum of renewable resources and technological development available across the region.

RE Share	2020	2030	2040	2050
Transport	4%	21%	85%	100%
Industry	18%	60%	83%	100%
Buildings	61%	83%	91%	100%
Final Energy	31%	62%	87%	100%
Renewable Power	20%	74%	90%	100%

RE Share	2020	2030	2040	2050
Transport	3%	31%	91%	100%
Industry	12%	45%	79%	100%
Buildings	33%	65%	89%	100%
Final Energy	16%	49%	84%	100%
Renewable Power	30%	63%	89%	100%

China 1.5C

- Economic prosperity has been driven largely by coal power, which provides over two-thirds of primary energy supply today, but there is high renewables potential, especially solar thermal power in the west, onshore wind in the north, and offshore wind in the east and southeast.
- China has pledged to reduce CO₂ emissions before 2030 and already has ambitious renewables targets.
- The expansion of hydropower generation is currently also seen as a major strategy.
- Electrification of heating, manufacturing, and transport in high-renewable areas is being encouraged, including the use of renewable electricity for heating to reduce the curtailment of wind, solar PV, and hydropower.
- China's solar PV and wind power markets are the largest in the world and represent about half the global annual market for solar PV and a third of the market for onshore wind. Under the 1.5C scenario, the current solar PV market doubles.

OECD Pacific 1.5C

- While renewable energy resources are abundant in Australia, they are limited across New Zealand, Japan and South Korea.
- Following the accident at Fukushima and the implementation of feed-in tariffs for renewable electricity, the expansion rates for renewable energies, in particular PV, have risen sharply in Japan.
- Large distances across marine areas prevent physical grid connections for power transmission between countries.
- Hydrogen and synfuels will be used for long-term storage of renewable power and provide an option for balancing the renewable energy supply across borders.
- Cars with internal combustion engines using oil-based fuels are phased-out by 2040 in the model.

RE Share	2020	2030	2040	2050
Transport	1%	42%	92%	100%
Industry	14%	51%	83%	100%
Buildings	15%	53%	87%	100%
Final Energy	11%	50%	86%	100%
Renewable Power	22%	68%	92%	100%

FINDINGS ON LAND USE

Top-level findings: Nature-based solutions and land use

The APCAG 1.5C model is one of the first to combine energy decarbonization with large-scale natural restoration, delivering the carbon removal required to achieve the 1.5°C limit. Restoration of natural carbon sinks through forestry and land use pathways could remove a maximum of 513 GtCO₂ by the end of the century. However, a significant portion of this would be required to offset ongoing Agriculture, Forestry and Other Land Use (AFOLU) emissions, estimated to be 124 GtCO₂ through 2100 in the APCAG model per SSP2, which assumes a gradual phase-out of AFOLU emissions to 2080. Given political realities, realizing 100% of the identified restoration potential is unlikely.

Therefore, deforestation and other forms of land conversion will have to decline much more quickly. In addition, reductions in methane and nitrogen will also need to be achieved in the agriculture sector. Without nature-based solutions the 1.5°C limit is not possible, even with a rapid decline in fossil fuel emissions.

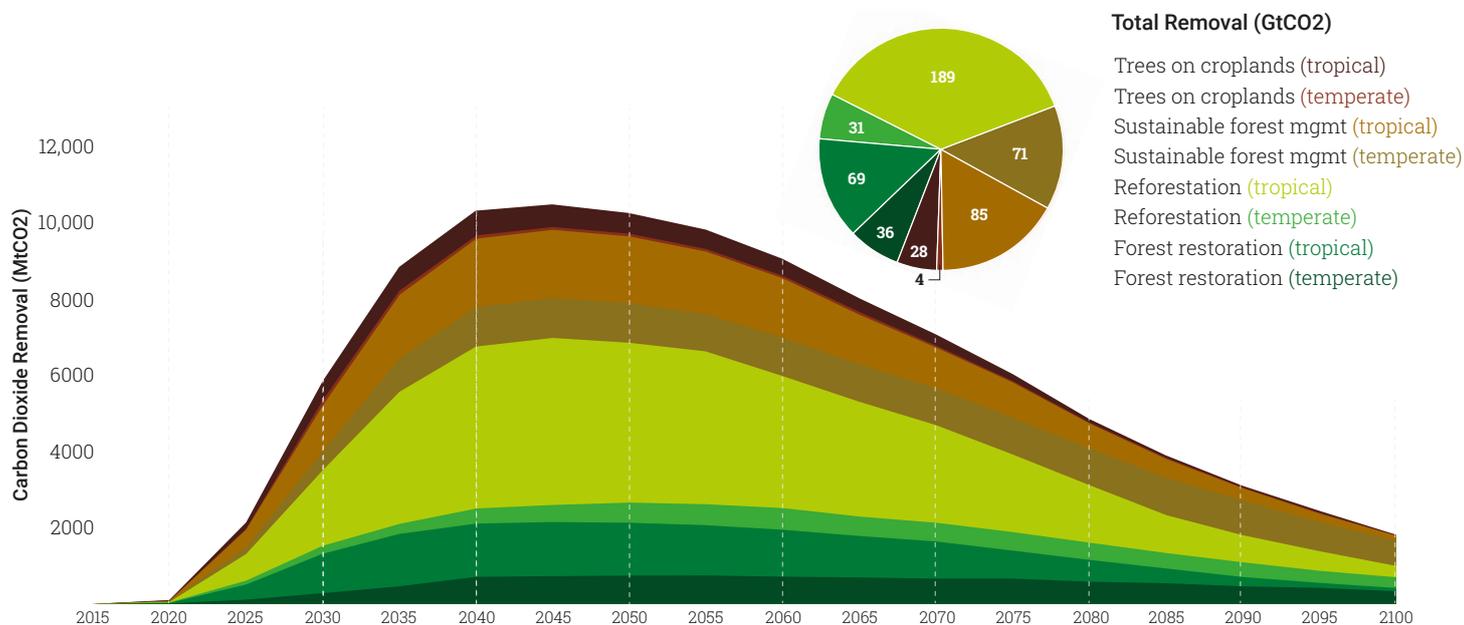
There are four main natural sequestration pathways utilized in the model, divided into temperate and tropical zones – reforestation, natural forest restoration, sustainable forest management, and cropland afforestation (trees in croplands):

“
Citing a growing body of research, we show that using land restoration efforts to meet negative emissions requirements, along with a transition to 100% renewable energy by 2050, gives the world a good chance of staying below the 1.5°C target.
 ”

MALTE MEINSHAUSEN

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 THE UNIVERSITY OF MELBOURNE

Carbon Removal Potential of Land Restoration Pathways 2020-2100



APCAG presents for the first time a statistical analysis (Monte Carlo) of the time horizons and potential cumulative carbon uptake for four major forest restoration pathways, divided in temperate and tropical zones. The chart shows total potential carbon removal of 513 GtCO₂ through these pathways, with a rapid deployment beginning in the 2020s.

Wilderness is vital

Wildlands cover approximately 50% of the Earth's terrestrial area and are vital to the world's carbon cycle, sequestering as much as one-quarter of anthropogenic carbon emissions and storing approximately 450 gigatonnes of solid carbon.¹⁰ Preserving these intact lands and forests is key to maintaining our global carbon sinks, making the 1.5°C limit possible.

An end to deforestation

Today, land use change accounts for more than 10% of global CO₂ emissions, approximately 4 GtCO₂ per year, resulting largely from the clearing of forests for agricultural land or other forms of development. Rapidly phasing out the practice of deforestation would greatly increase the chance of achieving the 1.5°C limit.

Large scale reforestation

The most important sequestration measure identified is large-scale reforestation, particularly in the subtropics and tropics. Under the 1.5C model, 300 Mha of land area is reforested in the tropics, and an additional 50 Mha is reforested in temperate regions.

Natural restoration

The second most important pathway for carbon removal relies upon natural forest restoration or rewilding, increasing carbon density within approximately 600 Mha of existing forests. Reduced logging and better forestry practices on managed forests also significantly contribute to total carbon removal.

The role of agriculture

Even with a rapid transition to renewable energy and a large-scale deployment of natural carbon removal, it is still not quite enough to achieve the 1.5°C limit. We must also reduce net emissions from the agricultural sector. There are four priorities for agriculture:

1. Planting trees on croplands

Tree cropping – a strategy that uses tree planting within croplands – can significantly increase carbon storage on agricultural lands. The model estimates that planting trees on 400 Mha of cropland can achieve approximately 30 GtCO₂ of carbon removal by 2100.

3. Reducing chemical use

The climate model also calls for a reduction of nitrogen emissions by about one-third (from approximately 7 to 4.5 MtN₂O) mostly by reducing agrochemicals and improving agricultural practices.

2. Reducing livestock and meat consumption

The 1.5C model calls for a 50% reduction in methane emissions by 2030 (from approximately 400 to 200 MtCH₄) mostly by reducing livestock and waste emissions. Today, roughly half of the world's agricultural land is used to grow livestock feed and fuel crops. Reducing meat consumption is a key strategy both to solving climate change and increasing food security.

4. Cutting waste

Roughly 30% of produce yields are wasted. Cutting food waste in half will reduce potential landfill emissions, while increasing crop yields and reducing the pressures that lead to deforestation.

Agroecology & other natural climate solutions

There is a growing body of scientific literature that looks at other natural climate solutions – from wetlands and grasslands restoration to agroecological solutions like silvopasture, multistrata agroforestry, covercropping, mycorrhizal applications, and municipal composting. While the APCAG climate model did not factor in these solutions, they do hold promise as a means to remove additional greenhouse gases, thereby further lowering global temperatures. Future versions of the climate model will explore these potential solutions.

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The model shows just how important our natural ecosystems are. Nature is the missing key. While the renewable energy transition is imperative to solving the climate crisis, it isn't enough. Currently, wildlands and oceans absorb one-half of all our CO₂ emissions. As this climate model shows, in order to keep global temperatures below 1.5°C, we have to keep our natural carbon sinks intact, while scaling up restoration efforts to achieve carbon removal.

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KARL BURKART,

MANAGING DIRECTOR OF ONE EARTH

CONCLUSION

The 1.5C model presented in **Achieving the Paris Climate Agreement Goals** is a major development in our thinking about what is possible if we mobilize our resources today.

At a time when COVID-19 has transformed lives across the world, we now get to choose how we will rebuild. Will we continue to subsidize fossil fuels to the detriment of our global climate system, or will we invest in a green future? We now know that we don't need to wait for new technologies or solutions. We can choose to be prepared, to increase resilience, and to unlock huge social and economic co-benefits as we create a climate-friendly future.

The Role of Foundations

1

Advocate
for 1.5°C

G20 countries are responsible for 80% of greenhouse gas emissions, therefore it is their responsibility to lead the transition. However, governments are often constrained by politics and policies. Foundations can help fill leadership gaps by advocating for the 1.5°C limit and increasing the ambition level in Nationally Determined Contributions (NDCs) for both energy and land mitigation under the UN Framework Convention on Climate Change.

2

Fund national and subnational
1.5°C compliant models

Foundations have a crucial role to play in funding cutting-edge science that can inform and inspire decision makers at all levels of government. The 1.5C model was philanthropically funded, and foundations can help drive the next crucial step by funding national 1.5°C compliant models in their own countries, regions, and cities.

3

Invest to increase
resilience

Foundations should invest in line with the 1.5°C pathway, especially as the economic fallout from the COVID-19 epidemic threatens to unwind some of the momentum and progress made in the past few years. Investing in renewable energy infrastructure and the conservation and restoration of ecosystems will help make societies more resilient to the threats of environmental degradation and climate change.

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Foundations and philanthropy can play a key role in these challenging times. We need ‘all hands on deck’ and foundations represent an important cross sectoral group. F20 convenes foundations and philanthropic institutions that are indeed willing to take a stand in that regard. With more than 60 partners, mainly from the G20 countries, the F20 platform can contribute to making our societies more resilient and help shift G20 politics into that direction. F20 can also help to build bridges between civil society, the business and the financial sector, think tanks and politics.

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STEFAN SCHURIG,

F20 SECRETARY GENERAL

Learn more

If you would like to examine the complete 1.5°C model, the book is available as a [free download](#). Also feel free to visit [One Earth](#), for high-level explanations of the various solutions pathways.

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- 4 Teske, Sven (Ed.) (2019). Achieving the Paris Climate Agreement Goals – Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C. Available at: <https://www.springer.com/gp/book/9783030058425>
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- 7 World Health Organization (2016). Mortality and burden of disease from ambient air pollution – Situation and trends. Available at: https://www.who.int/gho/phe/outdoor_air_pollution/burden_text/en/
- 8 Naicker, P.R. (2011). The impact of climate change and other factors on zoonotic diseases. Available at: https://www.researchgate.net/publication/287523149_The_impact_of_climate_change_and_other_factors_on_zoonotic_diseases
- 9 Coady, David; Parry, Ian; Le, Nghia-Piotr; Shang, Baoping – IMF Working Paper (2019). Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates. Available at: <https://www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-Large-An-Update-Based-on-Country-Level-Estimates-46509>
- 10 Erb, Karl-Heinz et al. (2017). Unexpectedly large impact of forest management and grazing on global vegetation biomass. Available at: <https://www.nature.com/articles/nature25138>



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