Climate Vulnerable Forum

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PURSUING THE 1.5°C LIMIT
BENEFITS & OPPORTUNITIES

2016
LOW CARBON MONITOR

SURVIVE THRIVE | #1.5C

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UNDP

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SURVIVE THRIVE #1.5C

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On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany

PURSUING THE 1.5°C LIMIT

BENEFITS & OPPORTUNITIES

ACKNOWLEDGMENTS

We would like to thank the governments of Philippines and Ethiopia as Chairs of the Climate Vulnerable Forum who enabled this independent report to be developed and to see the light of day. Thanks also goes to the designated national focal points and expert advisory group of the Forum who reviewed the drafts and to senior topic specialists at the United Nations Development Programme (UNDP) for expert advice, in addition to UNSP's Administrator Helen Clark for her support of the project.

Thanks also goes to Red Constantino of the Institute for Climate and Sustainable Cities, to GSCC, the Climate Action Network and to Purpose/Here Now for technical advice and assistance in publishing and communicating the report.

THE EDITORIAL TEAM

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> "Carbon-intensive modes of production established in 19[fox] Century Europe will incur enormous social and economic cost in the medium- and long-term, whereas shifting to a carbon-neutral future based on green technology and low-carbon energy creates wealth, jobs, new economic opportunities, and local co-benefits in terms of health and reduced pollution; Convinced that those countries which take the lead in embracing this future will be the winners of the 21st Century."

First Male' Declaration of the Climate Vulnerable Forum
November 2009

Mirrors and tower of the 11 megawatt PS10 (Planta Solar 10) operating near Seville, Spain. The world's first commercial concentrating solar tower power plant.
© raulbaenacasado

FOREWORD

2015 was a once-in-a-generation opportunity to transform sustainable development. The Paris Climate Change Agreement, alongside the Sustainable Development Goals (SDGs), Addis Ababa Action Agenda for Financing Sustainable Development and the Sendai Framework for Disaster Risk Reduction launched a new era of collective action on some of the world's biggest challenges.

To achieve the SDGs, we must address climate change. The Paris Agreement clearly states that our collective goal should be to hold the global temperature rise to well below 2°C and pursue efforts to limit this increase to 1.5°C. Pursuing efforts to limit warming to 1.5°C is absolutely critical so that all countries take strong and ambitious action on the ground. This global threshold will guide our efforts for decades to come and shape our achievement of the goals we agreed to within the Paris Agreement.

What's important about this report is that it suggests that working to achieve 1.5°C might just make it easier to meet several of the SDGs too. Renewable energy and the potential it has to plug off-grid power gaps, for example, may be indispensable to achieving universal energy access. Reducing vulnerability of food systems can help to end hunger and malnutrition around the world.

We also learn in the report that global and local priorities can and do intersect. That happens, for instance, when building a waste-to-energy plant instead of a coal station not only cuts future emissions but also brings jobs to a community while protecting local water and biodiversity. Above all though we learn that global cooperation–North-South, South-South, and even South-North–will be what gets us there in the end, lowering the barriers and costs for all concerned.

The Intergovernmental Panel on Climate Change (spell out) will release its own special report on 1.5°C in 2018 ahead of the planned facilitative dialogue on progress towards the Paris Agreement long-term goal. As a prelude to that contribution, this report is a welcome addition to the global discussion, promoting ambitious actions that align with the Paris Agreement and will achieve results on the ground.

UNDP was therefore very pleased to collaborate on this report. I urge leaders, policymakers and analysts alike to consider the evidence for opportunities presented by ambitious climate action as detailed here. I also wish the Forum well in taking forward these findings at national, regional and international levels.

Magdy Martinez Soliman
Assistant Secretary-General, Director of the Bureau for Policy and Programme Support
United Nations Development Programme

"Despite the insignificance of our individual contributions to climate change, we have also committed to domestic low emission development pathways given the unacceptable outcomes carried by business-as-usual courses of development. In doing so we are improving our competitiveness and believe action on climate change can be configured to boost socio-economic development."

Costa Rica Action Plan of the Climate Vulnerable Forum
October 2013

Lights of Asia, Middle East & Europe
© NASA

PREFACE

Vulnerable countries have insisted on limiting warming to 1.5°C as a matter of survival.

Why survival? 2012 Superstorm Sandy, Typhoon Yolanda in 2013 or Super Cyclone Pam in 2015, and this year's Hurricane Matthew, are all lethal reminders that extreme weather already far exceeds our abilities to deal with it.

If we pass 1.5°C not only will we witness new weather extremes but the world's oceans will also be sure to ultimately submerge countries like Kiribati, the Marshall Islands and the Maldives, as well as large and populated low-lying territories in places as diverse as Bangladesh, Egypt, the United States and Vietnam.

Half a degree does matter. As you will see here, going beyond 1.5, even to 2°C of warming, means committing to the virtual disappearance of the world's coral reefs within the lifetime of most people. It would also increase heatwave duration for most regions by an entire month each year and raise risks of crop yield losses for key breadbasket areas by 10-15% in just the coming decades.

Acknowledging dangers of this nature, all nations agreed to pursue efforts to limit warming to 1.5°C as the goal of the Paris Agreement forged in December last year. The first comprehensive international climate regime, it has also entered into force with unprecedented speed– the clearest possible signal to society at large that we, the governments, do mean business on climate change.

Despite this landmark success, we all know that actual policies currently in place continue to fall far short of achieving our ambitious target. Making up for lost time, however, is also an opportunity, as well as a vehicle for climate justice and social justice.

Polluted air that emissions controls aim to tackle, for instance, already cause more deaths than alcohol or tobacco do, with the bulk of this human toll concentrated in emerging economies and among poor children who die of pneumonia triggered by soot inhalation from indoor fires.

We have also learned that producing energy from coal or oil creates the least possible jobs, whereas sustainable biomass or renewable hydro energy have among the highest employment contributions. 1.5°C policies could thereby create double the amount of jobs come 2050– the energy plan we would choose.

Current policies, moreover, would still leave over one billion people without electricity by 2030, although the international community has committed, with the Sustainable Development Goals, to achieve universal access to energy by that time. To reach this target, 60% of new energy must come outside of grids where the logistical and infrastructure advantages of renewable energy are plain for all to see.

It cannot be done, some say. Well, Costa Rica has gone more than 200 days in the past year with 100% of its energy production derived from renewable sources. The world economy already grew by more than 3% in the past few years while overall global emissions did not even rise.

What is more, according to new research presented with this report, keeping to a 1.5°C limit could raise growth economic output by as much as 1% by the 2040s, since so many of the devastating impacts associated with higher levels of warming would be avoided.

Taken together, it all means that concern over the costs of emissions controls is really a thing of the past. Today's priority instead is to access the largest possible share of the benefits of the low carbon transition, and as quickly as possible.

That's not a zero sum game, either. We are also reminded here of the plain fact that the world's carbon fuel resources are concentrated in just a few countries, whereas renewable energy supplies are hugely abundant worldwide. It means your energy policy choices are also choices of balance of payments between exposure to volatile, globally commoditised imported fuels versus investment in local jobs and industries.

If our transition is to work at 1.5°C speed and scale though, countries that were not participants in the past system of high carbon wealth creation will need help from those that were. The least developed, low and middle income developing countries still require assistance to access new and clean energy technologies they don't yet have, to bridge investment shortfalls when they leave the well-trodden carbon path, and to develop the skills and know-how that are still far more widespread in large and advanced economies.

Shiferaw Teklemariam
Minister of Environment, Forest and Climate Change, Ethiopia

Loren Legarda
Senator and Chair, Permanent Committee on Climate Change, Philippine Senate

Edgar Gutierrez
Minister of Environment and Energy, Costa Rica

With the whole world working together, the costs of low emissions technology and infrastructure will fall for everyone. Renewable energy costs are already substantially lower than just a few years ago and are competing at cost with carbon intensive energy in a low-price oil market still distorted by hundreds of billions of dollars of subsidies for fossil fuels. If all embrace low emissions development, renewable energy could be five times cheaper or more by 2050– that is a vision of a low cost energy future we believe everyone wants and should get.

In the Climate Vulnerable Forum too, we are committed to helping each other. We are learning and sharing and building institutions and networks to equip ourselves together in this climate fight. Commissioned by our Forum, this report is also another independent new contribution to the knowledge base and we thank UNDP, Climate Analytics and our other partners for their efforts on it.

1.5°C can and must be done. We will make it happen not just to survive but also to thrive.

EXECUTIVE SUMMARY

INTRODUCTION

Following the enshrining of a 1.5°C temperature limit as a part of the objective of the 2015 Paris Agreement, this first edition of the Low Carbon Monitor report (LCM), commissioned by the Climate Vulnerable Forum (CVF), aims to further understand the risk reduction and growth opportunities arising from a faster transition to low-carbon, sustainable development. This report specifically reviews the evidence for eight major development themes, identifying the implications and possible global or regional benefits of delivering on a limit to global warming of 1.5°C above pre-industrial levels. In a number of areas, national and local benefits and opportunities are also explored as examples of broader trends.

The scientific community has a strong body of knowledge supporting the feasibility of limiting global temperature increase to 1.5°C, a level of warming understood as both safer and still feasible to achieve by the 5[fox] Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCCs Structured Expert Dialogue of the 2013–2015 Review of the 2°C goal. The present report assesses the extent to which the 1.5°C limit would not only reduce risks but also lead to a range of other benefits for all or most regions and countries.

Global emissions have essentially not increased since 2013-14 despite world economic growth exceeding 3% per year[1]. This new pattern undermines traditional views that stringent emissions reductions would curtail economic development. This report also draws on world leading climate analysis to illustrate the potential benefits of clean, green and climate resilient forms of development, and shows that sustainable development is already achievable, given the success and price effectiveness of renewable energy.

POLICY CONTEXT

Despite the recent trend in decoupling economic from emissions growth, past development patterns show that the growth in global populations and their wealth has occurred alongside a dramatic increase in global greenhouse gas emissions. Based on currently implemented policies worldwide, it is likely that global temperatures will increase by up to 4°C this century above the pre-industrial levels, propelled by continuing emissions.[2]

The 2015 Paris Agreement pledges to alter these policies to achieve more significant emissions cuts would lower warming to 3°C, provided all governments fully deliver on their intended contributions.[3]

Despite this, temperature increases between three and four times the 1°C temperature increase that was first surpassed (temporarily) in 2015 would entail catastrophic consequences for the environment, people and the world economies.

Most affected, however, are tropical and sub-tropical developing countries, particularly Least Developed Countries and small island nations. These countries characteristically have the combination of low incomes with high concentrations of national wealth and labour markets reliant on the weather-dependent agricultural sector, and comparatively limited institutional and technological capacities.

These factors tend to amplify the harmful repercussions of global environmental change. A growing wealth of scientific evidence indicates that even 1.5°C of warming would severely compromise overall development prospects especially for this group of countries.

KEY FINDINGS

Limiting warming to 1.5°C will bring increased safety for people and the environment, and an improved economic outlook of at least 10% higher levels of global GDP by 2050. Limiting warming to 1.5°C:

› Substantially lowers the risk of inundation of the world's lowest-lying nations and territories as a result of multiple meters of long-term global sea level rise, with the Greenland ice sheet (equivalent to raising sea levels by 7 metres) facing irreversible decline most likely around 1.6°C of warming

› Preserves at least 10% of the world's coral reefs, as opposed to higher levels of warming that all cause their virtual disappearance

› Reduces by one month the length of heatwaves experienced each year in tropical developing countries by mid-century, compared with warming levels of 2°C and above, protecting lives, health, water and agriculture

› Limits risks of reductions of yields in crops such as wheat in key developing regions by 10-15%, also by mid-century, when compared with 2°C of warming, safeguarding food security (for more information on avoided physical impacts, see Chapter 2)

A development scenario consistent with 1.5°C would also observe:

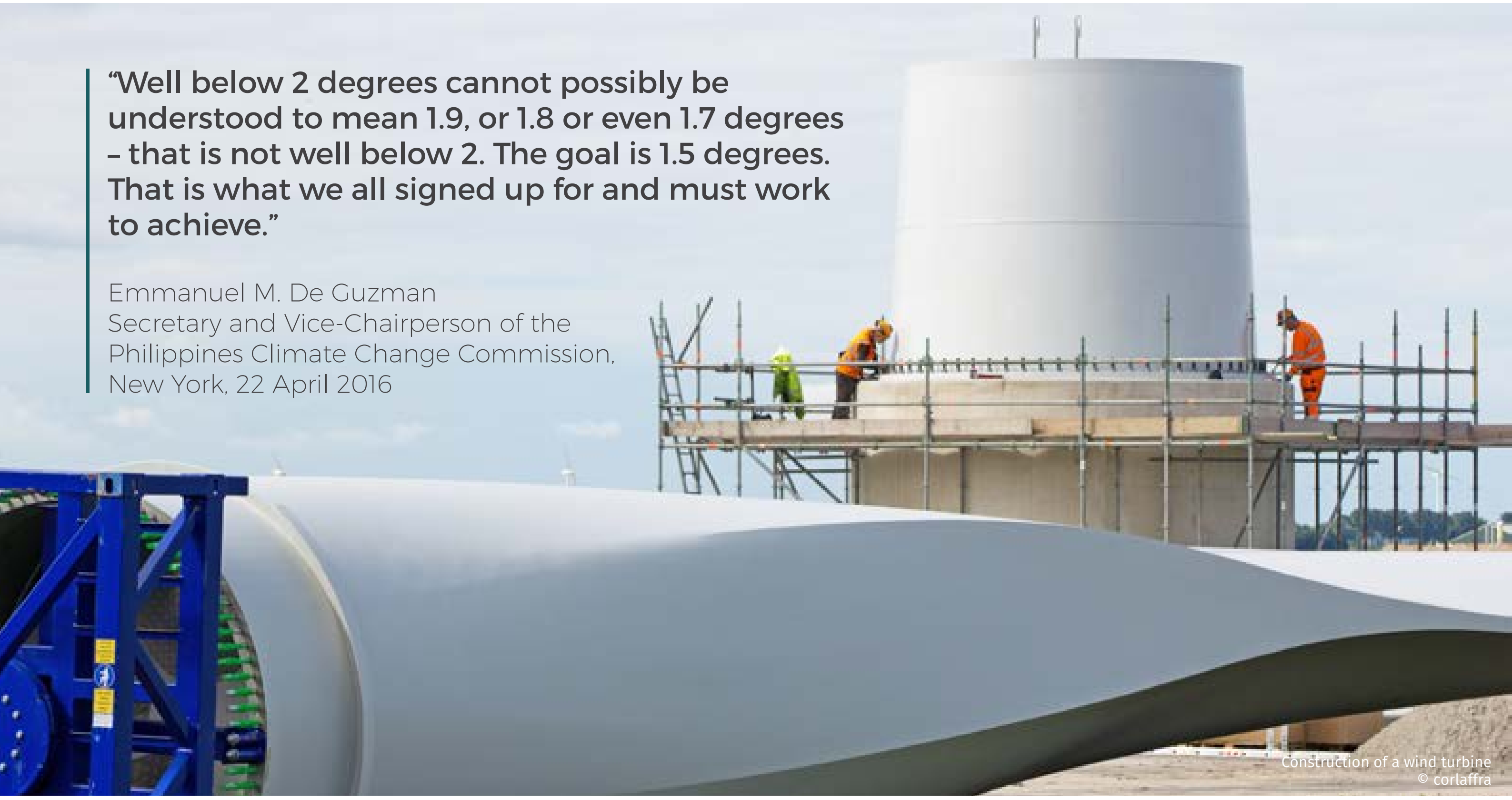
› Higher investment needs for reducing emissions faster and more substantially, leading to a cost measured as annualised consumption growth rates in a 2°C warming pathway reduced by 0.06 percentage points from 1.6-3% (on average over the 21st century), while the costs of a 1.5°C pathway are 1.5-2 times higher. This equates to a two-year delay in reaching equivalent wealth levels in 2100 in the case of 2°C and 4 years in the case of 1.5°C, neglecting, however, the benefits of climate action (for more information see Chapters 1 and 3)

› Significantly reduced investments in adapting to climate change resulting from the lowest possible severity and frequency of climate change impacts, while increasing the likelihood of successful attempts to adapt and facilitating efforts to address loss and damages (for more information see Chapter 3)

› Major health, agricultural and economic benefits from reduced air pollution, as emissions are rapidly reduced, helping to fight a leading global cause of death that already claims 7 million lives per year–more than either alcohol or tobacco (for more information see Chapter 4)

Accelerated and early climate action to achieve the 1.5°C limit would also:

- Speed up the drop in costs of climate change mitigation technologies, or emissions controls. For example, renewable energy costs are set to fall to approximately one fifth of current levels as total global installed capacity expands and lower marginal costs of reducing emissions are achieved earlier, as a result of wider global action required to achieve a more stringent temperature target (for more information see Chapter 9)
- Increase global flows of finance and technology to developing countries to enable and accelerate the globalisation of climate action (for more information see Chapter 9)
- Provide an unparalleled contribution to achieving universal modern-energy access given the reduced renewables costs per unit of energy as total global installed capacity expands and logistical advantages of renewables in providing energy to populations outside of conventional grids that constitute over 60% of the energy poverty challenge to 2030 (for more information see Chapter 8)
- Create approximately double the number of jobs by 2050 than current policies, since the share of low-emission power generation, which has the highest employment ratio per watt of energy produced, would need to grow at a far quicker pace (for more information see Chapter 5)
- Improve energy independence, as almost all countries have 20-80+ times more renewable energy potential than current consumption needs (for more information see Chapter 6)
- Reduce risks for nations reliant on fuel imports which for most countries make up 5–35% of the total value of imports. Limiting reliance on imports also limits exposure to price volatility, as well as inflationary and political risks associated with sourcing power from commoditised global markets supplied by very few countries (for more information see Chapter 7)



"Well below 2 degrees cannot possibly be understood to mean 1.9, or 1.8 or even 1.7 degrees – that is not well below 2. The goal is 1.5 degrees. That is what we all signed up for and must work to achieve."

Emmanuel M. De Guzman
Secretary and Vice-Chairperson of the Philippines Climate Change Commission, New York, 22 April 2016

Construction of a wind turbine
© corlaffra

HALF A DEGREE MATTERS

A DIFFERENCE OF 0.5°C IN GLOBAL TEMPERATURES HAS ENORMOUS REPERCUSSIONS FOR THE WORLD'S PHYSICAL ENVIRONMENT AND FOR THE FREQUENCY AND SEVERITY OF CLIMATE CHANGE IMPACTS

Fundamental physical changes to the global ecosystem are already taking place with the approximate 0.85°C of long-term warming to date (and the short-term spike of warming reaching 1°C above pre-industrial in 2015). The level of warming experienced during the lifetime of most people alive today has already fundamentally altered the Earth's climate. It has, for example, amplified the occurrence and intensity of weather extremes, increased the number of hot days and nights per year, triggered widespread coral reef bleaching events, and led to a global retreat of glaciers and a rising propensity of coastal flooding. A multi-year United Nations Framework Convention on Climate Change (UNFCCC) scientific review concluded that the 2°C goal could not be considered a safe guardrail and significant climate impacts are already occurring at the current level of global warming. Additional magnitudes of warming will only increase the risk of severe, pervasive and irreversible impacts.

As compared with 2°C of warming, limiting the temperature increase to 1.5°C would reduce expected heatwave spells for tropical developing countries worldwide by about one third, amounting to approximately a one-month reduction in extreme heatwaves per year.

It would also lower the risks of reduced yields of key crops such as wheat, and substantially reduce the forecasted increase in extreme rainfall downpours and associated flooding. While sea levels are projected to continue to rise over centuries as the planet warms, the rate in sea level rise would already slow down by the end of the 21st century in a 1.5°C world, greatly reducing adaptation pressure and preventing multi-meter long-term sea level rise. A 1.5°C limit would also reduce the risk of triggering irreversible changes in the Greenland and Antarctic ice sheet.

Even 2°C of global warming results in far more significant medium and long-term changes to the planet, and environmental costs, including the virtual disappearance of the world's reefs and the certain long-term inundation of low-lying island nations and coastal areas around the world. Ensuring temperatures do not exceed 1.5°C would also substantially reduce risks posed by extreme heat for health, labour productivity and agriculture.

THE ECONOMIC BENEFITS OF KEEPING WARMING TO A MINIMUM ARE TREMENDOUS

These changes to our physical environment are likely to exact huge economic costs in a 2°C scenario, with the increase in intensity and frequency of climate-related disasters destroying assets and livelihoods as well as worsening situations of food and water. Under current climate policies — or in a 4°C warmer world — developing countries are particularly exposed to the intensification of impacts due to such levels of warming, with countries such as Bangladesh, China, India and Indonesia, for example, projected to experience an annual GDP growth reduction of 50% by the 2040s. Overall, the current policy trajectory is set to reduce global GDP by about USD30 trillion by mid-century.

It is clear that every incremental increase in temperature results in significantly greater economic losses, as evidenced by historical patterns of economic growth in response to temperature fluctuations.

Limiting the rise to 1.5°C results in the least economic losses of all potentially achievable levels of warming, avoiding a loss of USD $12 trillion (approximately 10 % of global GDP) to the global economy by 2050. Stringent mitigation action would also reduce losses by approximately 1% by the 2040s in developed countries, including for the United States, Japan and Germany.

Across all the sectors explored in this report, there are substantial co-benefits – in terms of employment, health, economic and political stability – that countries embracing a 1.5°C world can take advantage of that would further benefit developed and developing economies in addition to the avoided losses.

Economic losses due to future global warming are complex to predict. The new results presented in this report focus on direct effects of a temperature rise and do not factor in climate change losses induced for example by sea level rise or extreme flooding events, or deliberate additional adaptation measures that would incur further costs but could decrease losses.

CLIMATE ACTION WILL BENEFIT PUBLIC HEALTH, SUPPORT AGRICULTURE, AND SAVE LIVES

Air pollution kills 7 million people a year, more than tobacco or alcohol. 3 million premature deaths can be attributed to outdoor ambient pollution of the air, mainly from power plants, vehicles and industry, and the remainder due to indoor pollution, mainly from cooking fires, with developing nations in Asia accounting for the majority of these deaths. Without a significant change in current policies, outdoor air pollution deaths are expected to grow by 50%, reaching 4.5 million per year by 2040. Crop yields are likely to decrease by 5% due to air pollution alone by 2050, and associated economic losses could total 1% of annual world GDP by 2060.

Limiting warming to 1.5°C requires the rapid phase out of coal and fossil fuel power generation in favor of renewable energy in the power and transport sectors, significantly reducing ambient air pollution. In the context of rapid urbanisation, limiting the temperature rise to 1.5°C will result in a dramatic decrease in respiratory diseases, while creating new opportunities for a growing population. Savings associated with reduced mortality will offset a large portion of the cost of stronger climate policies — such as the increase of renewable energy sources, urban transport policies focussing on public transportation, pedestrian and cycling options, the reduction of industrial smokestack emissions or the improvement of cooking stoves. There is a particular opportunity to address indoor air pollution using low carbon and renewable energy technologies which would at the same time contribute to improved outdoor and indoor air quality.

DEPLOYING AND MAINTAINING RENEWABLES CREATES JOBS AND IMPROVES EMPLOYMENT CIRCUMSTANCES

Medium to long-term job creation is one of the key advantages of tackling climate change, as the employment concentration and occupational intensity of low-emissions energy production is higher on average than for more polluting alternatives. Based on employment factors alone, oil and gas have the lowest required manpower per megawatt (MW) of energy produced while the highest ratios are enjoyed by biomass energy, hydropower and nuclear.

A renewable energy policy consistent with the 1.5°C limit would trigger an estimated 68% increase in jobs relating to energy operations and maintenance, manufacturing, construction, and installation by 2030, compared to current policies. This estimate is already accounting for initial job losses stemming from the economic disruption of legacy energy systems. By the 2050s, it is estimated that there would be approximately twice the number of jobs created if warming is kept below 1.5°C than is currently expected.

For countries with high proportions of outdoor work and large agricultural sectors, the effects of rising heat on the productivity of employees as well as the productive capacity of businesses are already emerging as a major impediment to economic growth and overall welfare.

The expansion of the renewable energy sector, which must grow at the fastest rate to limit temperatures to 1.5°C, not only creates stable, high-quality, gender-unbiased job opportunities, but also catalyses improvements in occupational skills and education with employees facing less hazardous working conditions than for conventional energy production.

LOW-EMISSION DEVELOPMENT IMPROVES ECONOMIC STABILITY AND ENERGY INDEPENDENCE FOR MOST ECONOMIES

Most of the world imports 20% or more of its domestic energy needs, while most industrialised nations importing more than 40% of their energy needs from overseas. Fossil fuel resources are highly restricted in their geographical availability: 75% of the world's oil resources are held by the 14 OPEC countries, while half of all natural gas belongs to just three countries (Iran, Russia, and Qatar).

In contrast, renewable energy is globally abundant and this report shows that virtually every country is self-sufficient in renewable energy with the majority of developing and industrialised nations possessing 20–80+ times their current level of energy needs in potential renewable energy capacity from sources such as solar, wind and hydro power.

Fossil fuels are global commodities whose prices are subject to significant fluctuations that are associated with important economic, and political, costs for both exporting and importing nations. Energy imports in the form of fossil fuels account for 5-35% of total imports for most countries, including 15% of EU imports and around 10% for Climate Vulnerable Forum countries in their aggregate. Oil, in particular, is such a crucial resource that the dependence of GDP on oil supplies amounts to as much as 5-15% in many major economies, including for the EU, South Korea and the Philippines.

Limiting warming to 1.5°C means clean sources of energy should dominate power production by mid-century at the latest with countries refocusing their energy supply on domestic resources. This means countries cutting oil dependence and improving environmental and economic resilience, reducing exposure to political and resource risks.

The rising populations and incomes across the developing world will create a high demand for new energy infra-structure to supporting this high demand's new energy requirements. Countries investing in exploiting their domestic potential of renewable energy sources is the safest and most sustainable way of securing the amount of energy required for their growth.

ACCELERATING UNIVERSAL ACCESS TO ENERGY TO PROPEL SUSTAINABLE HUMAN DEVELOPMENT

Action consistent with 1.5°C carries great potential for closing energy poverty and access gaps. Energy poverty affects 2.4 billion people, 1.2 billion of which have no access whatsoever to electricity. Energy is a key development challenge that affects the availability of time for work or leisure, and has an impact on education, health as well as limiting commercial activities that require power. Women and girls are particularly disadvantaged by the lack of access to electricity because of the traditional role of women in many societies in cooking and household tasks including fuel collection.

Remote communities and landlocked countries pay some of the highest prices for fossil fuels due to logistical costs which are often three times higher. Small island nations likewise face serious challenges in ensuring energy access, with island geography making national grids impractical and the transporting of fuels very costly.

As a result, many small island states have among the lowest electrification rates in the world, such as Papua New Guinea at around 13% or

Vanuatu at approximately 27%. By 2030, current policies would see only a fractional reduction in energy poverty, as expected energy systems based on concentrated production and grid distribution would continue to fail in addressing the commercial and logistical challenges to powering the world's poorest and most remote communities.

To deliver on the international community's commitment to universal energy access by 2030 with the Sustainable Development Goals, 60% of energy would need to be provided outside of conventional, large-scale or national power grids. Renewable energy has inherent logistical advantages because it does not require a constant supply of fuel to produce energy, making these sources far more suitable for distributed generation, mini-grids, and off-grid applications.

Renewables have the most off-grid potential of any fuel: 100 million people worldwide already benefit from off-grid solar energy, while China alone has 50,000 decentralised power stations, most of which are small-scale hydro plants. The high price of fuel in remote communities means that renewables are already cost competitive with diesel-based generators, a trajectory that will only accelerate as renewables become more widespread.

1.5°C REQUIRES GLOBAL ACTION THAT CREATES A POSITIVE FEEDBACK LOOP TO LOWER THE COSTS OF CLIMATE ACTION FOR ALL

Global power generation is still dominated by high-emission technologies, with coal alone meeting about 40% of current electricity demand. However, renewable energy is already competing with conventional forms of power: 90% of new electricity capacity installed in 2015 was from renewable sources.

Renewable energy costs have already fallen by more than half over the past five years as a result of their increasing use, and are expected to become roughly five times cheaper by 2050 as a function of expected increases in renewable energy power generation capacity across a range low-carbon scenarios. The overall costs of mitigation are also lowered through the globalisation of clean energy, since marginal costs of reducing emissions tend to be lower in developing versus advanced economies.

Based on the current scientific knowledge, 1.5°C is the most ambitious, technologically feasible warming limit and its achievement requires stringent and concerted global action and relies therefore on global cooperation and participation in emissions controls. The aggregation of national climate actions consistent with this target would therefore accelerate the penetration rate of renewable energy technologies, increasing the benefits resulting from economies of scale and technological progress. This would further reduce the costs of mitigation technologies, and adaptation, for every individual country worldwide.

Above all, addressing the risks of dangerous climate change requires swift and collective action. The co-benefits covered in each chapter of this report are substantial particularly for developing countries; implementing a range of 1.5°C consistent policies will compound these benefits and create a positive feedback loop across multiple sectors. In order to capture the full spectrum of opportunities, the international community must act collectively and cohesively to accelerate the transition to a low-carbon world.

Table E-1 summarises how this range of benefits can be realised for one example country, the Philippines.

CATEGORY	1.5°C BENEFITS VS. 2°C AND ABOVE
Chapter 2 **Physical Impacts**	• Lowest risks of extreme weather of any temperature limit considered feasible, protecting populations and infrastructure • Avoids much of the virtual (99%) disappearance of coral reefs at 2°C, and associated marine ecosystem and coastal livelihoods crises • Reduces heatwaves by approximately one month per year versus 2°C of warming • Lessens the increase in extreme precipitation for SE Asia from 10% to 7% compared with 2°C
Chapter 3 **Economic Risks**	• Avoids 0.4% of losses to annual GDP growth of the Philippines economy by 2040s versus current policies
Chapter 4 **Air Pollution**	• SE Asia has 1.63 million annual deaths related to air pollution that more stringent 1.5°C consistent emissions controls would help address • Reduces toxic stresses for key crops, such as rice, from ground-level air pollution, boosting agricultural production and resilience
Chapter 5 **Employment**	• Minimises losses caused by extreme heat to total national work hours of 1% compared to 2% at 2°C. • Doubles the level of job creation between now and 2050 compared with a 2°C scenario because of higher employment intensity of renewables, while adding more higher quality jobs
Chapter 6 **Energy Independence**	• Takes advantage of the high domestic energy self-sufficiency of the Philippines on renewable energy resources for power, which exceeds total primary energy requirements by up to 20%
Chapter 7 **Balance of Payments & Price Stability**	• Reduces an up to 17% of GDP inflationary exposure to oil, the primary internationally commoditised and price-volatile fuel that represents as much as 20–30% of the total value of all imported goods and services into the Philippines (1960s-2014)
Chapter 8 **Energy Access**	• 1.5°C scenarios have greatest emphasis on renewables with off-grid advantages for accelerated provision of electricity to 21 million people or 21% of the population with no access (UNEP: 2013)[4]
Chapter 9 **Globalising Climate Action**	• Expands and internationalises renewable energy capacity, which will further reduce the costs of installations globally following radical cost reductions for renewables, now competitive on cost with all other forms of energy production, despite persistent fossil fuel subsidies on a significantly larger scale than total international climate finance[5] • Enhanced international cooperation towards a higher climate goal of 1.5°C accelerates globalising access to emissions abatement opportunities at attractive marginal costs in developing countries with deforestation prevention and land-use change potential, including SE Asia and Philippines

Table E-1 | Benefits of 1.5°C vs 2°C and above in the context of the Philippines and the benefits focused on in this report

Figure E-1 | Philippines led the Climate Vulnerable Forum at the Paris climate talks that forged the Paris Agreement and spearheaded the #1o5C campaign for a strengthening of the UNFCCC's long-term goal to 1.5°C. Pictured is Secretary de Guzman delivering the Philippines CVF Chair closing statement at the plenary session of COP21, Salle Seine, Le Bourget, Paris (12 December 2015); Source: CVF/UNDP; Licence: CC

CAN WE REALLY ACHIEVE A TEMPERATURE LIMIT OF 1.5˚C?

The short answer is yes. A complex array of considerations do however need to be factored in. For instance, global temperatures over the past 20 years were already at approximately 0.85°C, with mean temperatures in 2015 even at a short-term spike exceeding 1°C above pre-industrial levels. This has thrown into question the feasibility of achieving a 1.5°C limit. The IPCC Fifth Assessment Report, the 3-year UNFCCC Review of the 2°C goal, and recent scientific research (e.g. Schleussner et al 2015) all demonstrate that 2°C is significantly riskier than 1.5°C, and do not suggest that 1.5°C is unachievable. It is widely considered to be the most ambitious economically and technologically feasible limit.

FACTS: TRANSFORMATION IS HAPPENING

› Global emissions remained stable since 2013-14 despite world economic growth exceeding 3% per year (IEA, 2016). This illustrates that strong economic growth is possible with significant reductions in emissions per unit of production.

› A number of countries already have the capacity to run on 100% renewable energy for extended periods of time. For example, in 2015 Costa Rica ran on a combination of hydroelectricity, geothermal, wind and solar for 285 days in total[6] while continuing to experience economic growth.[7]

› Renewable energy is expected to become increasingly cost competitive with fossil-fuel based energy, as dramatic decreases in the cost of renewable energy are observed. For example, from 2010 to 2015, photovoltaic energy costs reduced from $4155 USD/kWh to $1848 USD/kWh. This is despite global fossil fuel subsidies being significantly higher than global climate finance – for example, in 2014 fossil fuel subsidies were 26% higher than global climate finance.

› Renewable energy accounted for 90% of new electricity generation in 2015

ENERGY-ECONOMIC EMISSIONS SCENARIOS ANALYSED IN THE IPCC'S FIFTH ASSESSMENT REPORT SHOW THAT 1.5°C IS BOTH ECONOMICALLY AND TECHNOLOGICALLY FEASIBLE[8]

› Both 2°C and 1.5°C pathways need to peak global emissions as soon as possible and no later than around 2020 before beginning a rapid decline, reaching zero global CO_2 emissions by 2050 for 1.5°C and 10-20 years later for 2°C.

› Limiting warming to below 1.5°C by 2100 generally requires similar transformations in the energy system as holding warming to below 2°C during the 21st century, but the decarbonisation of the energy system needs to be faster and more pronounced, and there is a greater urgency to act and less margin for free-riding – a greater need for global participation.

ECONOMIC FEASIBILITY

› The earlier the better: any delay now raises the total costs over the full 21st century if the 1.5°C limit is to be achieved. The costs of the sharper global decrease in emissions later on, to compensate for delayed near-term action, will be higher than avoided costs in the near term.

› The additional costs of pursuing a 1.5°C pathway versus 2°C are very limited. The same wealth levels in a 2°C scenario in the year 2100 are achieved just two years later in a 1.5°C scenario. And this is without accounting for any of the added co-benefits and benefits of limiting warming by another half a degree.

TECHNOLOGICAL FEASIBILITY

- The scenarios that limit warming to below 1.5°C are characterised by (1) immediate mitigation action; (2) the rapid upscaling of the full portfolio of mitigation technologies; and (3) development along a low-energy demand, high efficiency trajectory.
- A major distinguishing feature of the 1.5°C pathways is that emissions need to drop faster, and reach zero approximately 10 to 15 years earlier than in the 2°C pathway. This means that renewable energy technology, energy efficiency, and other emissions reduction options need to be introduced faster than in the 2°C pathway.
- In order to compensate for the insufficient emissions reductions realised to date, negative CO_2 emissions technologies will be needed in the mid to long-term for both 1.5°C and 2°C pathways. Very rapid upscaling of negative emissions initiatives over the 2030-2050 period would be required in both 1.5°C and 2°C pathways.
- In the energy-system models used for developing emissions scenarios, negative emissions are primarily assumed to occur by combining bio-energy with carbon capture and storage (BECCS).
- Well-informed choices of bioenergy crops and dedicated policies can avoid much of the risk of competing land uses. Key conditions that must be met are integrated land-use management and use of second- and third-generation biofuels (as opposed to first-generation biofuels that would require large amounts of land that compete with food production).
- Any remaining risks of bio-energy in terms of trade-offs with other land uses must be considered in light of the alternative of high risks to ecosystems, food and water security under higher levels of warming than 1.5°C or 2°C. IPCC AR5, for example, suggests the negative effects on food prices of large-scale deployment of BECCS by 2050 would be much lower than from (avoidable) impacts of climate change.

UNDERSTANDING 1.5°C

- Climate differs from weather, in that climate is measured over periods of multiple decades, not individual years or even months. Within such multi-decadal periods, global-mean temperatures swing up and down relative to long-term means or trends. These swings are driven by natural fluctuations, such as those related to El Niño and La Niña events. Such events shift heat around between oceans and the atmosphere, giving rise to anomalously high, or low temperature spikes locally and in the global mean, without changing the long-term total energy input of the Earth System, like anthropogenic emissions of greenhouse-gases do. For example, the years 1997-98 and 2015-16 saw powerful El Niños, causing spikes in annual global-mean temperatures far above the long-term trend. Individual month in early 2016 have for example exceeded the long-term warming trend by more than 0.5°C.
- To analyse anthropogenic influences on global temperatures, IPCC has adopted 20-year long-term means for projecting anthropogenic warming, to distinguish from shorter-term natural fluctuations. Given that the IPCC is the major scientific basis leading to the adoption of the long-term temperature goal of the Paris Agreement, this goal is understood as global-mean temperature increase above pre-industrial levels, averaged over a period of at least 20 years. If the 20-year averaged temperatures were to rise by another 0.5°C, 1.5°C would be exceeded in individual years or month, although long-term warming will still not exceed this level.
- Long-term temperature limits such as 1.5°C or 2°C have been adopted as the result of risk assessments of future climate impacts, thereby factoring in the effects of natural fluctuations from one year to the next. To avoid the exceedance of global mean warming levels of 1.5°C or 2°C even for annual (or even monthly) values, the 20-year average limit has to be substantially lower than these levels, implying much stronger mitigation efforts.

THE GLOBAL GOAL

the aim of the Paris Agreement is to hold warming "well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels"

December 2, 2015: The Eiffel tower is lit up in green for the UNFCCC COP 21 climate talks in Paris.

1 THE 1.5°C PARADIGM

The central aim of the Paris Agreement is a long-term temperature goal to limit warming to **“well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels”**.

Dating back to at least 2009, vulnerable developing countries including the Small Island Developing States (SIDS), [1,2] the Least Developed Countries (LDCs)[3] and the grouping of countries drawing from a broader constituency under the Climate Vulnerable Forum (CVF)[4] called for a 1.5°C limit on global temperature increase. Based on the available science, these countries argued that a temperature increase of 2°C above pre-industrial levels would threaten the survival of many island nations and low lying countries around the world and pose major risks to livelihoods and sustainable development, particularly in the Least Developed Countries.
During the negotiations in Paris, these countries sustained their political and science-based campaign to bring the 1.5°C limit into the purpose of the Paris Agreement, and to ensure a clear “line-of-sight” between the long-term temperature goal of the Agreement and its legally binding obligations.

There is a strong scientific case that the 1.5°C limit is very likely to avoid some of the most severe climate change impacts. Avoided impacts relate to the inundation of low-lying coastal and island territories in different regions of the world, the survival of coral reefs, the failure rate of crops, as well as the frequency and severity of extreme weather, among other environmental, health and safety, and social and economic risks.

Risks and dangers at 1.5°C of warming will still be significant, but when compared with a 2°C scenario there are important reductions in loss of life, decreased infrastructural and environmental damages and greatly reduced adaptation costs and risks.

This report assesses the extent to which the 1.5°C limit would not only reduce risks but also lead to a range of benefits for all or most regions and countries. It highlights compelling trends, such as the observation that strong world economic growth of 3% per year since 2013-14 has been possible despite emissions remaining at largely the same level during this same period.

A SHORT HISTORY OF THE 1.5°C LIMIT
In 2005 the EU heads of government adopted the 2°C limit[5]. At the international level, this limit figured in the Copenhagen Accord developed in 2009 and was formally adopted in the Cancun Agreements in 2010 where it was expressed as an aim “to hold the increase in global average temperature below 2°C above pre-industrial levels”.[6] Recognising the concerns of vulnerable countries, in 2010 the UNFCCC established a review process to evaluate whether the long-term global temperature goal of holding warming below 2°C was adequate to avoid dangerous climate change consequences. It also considered “strengthening the long-term global goal on the basis of the best available scientific knowledge, including in relation to a global average temperature rise of 1.5°C”. This process ended in 2015 with the final report of its scientific arm (Structured Expert Dialogue) concluding that a warming of 2°C cannot be considered safe (UNFCCC, 2015), ultimately supporting the enshrining of the strengthened long-term temperature goal language in the Paris Agreement.

The Paris Agreement goes well beyond the UNFCCC’s earlier 2°C limit and aims to hold warming to *well* below 2°C and to pursue efforts to *limit temperature increase to 1.5°C above pre-industrial* levels. The former 2°C temperature goal and the Paris Agreement 1.5°C temperature limit carry quite different implications for long-term emissions levels and for the implementation of the Agreement's long-term emissions goals, with deeper reductions by 2050 and an earlier achievement of zero global greenhouse gas emissions for the 1.5°C pathway. Both the 2°C and 1.5°C pathways require that global greenhouse gas emissions peak no later than 2020, however the 1.5°C pathway requires that emissions drop substantially faster than for 2°C and reach zero emissions 10 to 15 years earlier.

In more detail:

- The 2°C temperature limit[7] implies that global greenhouse gas emissions need to be reduced by 40-70%[8] below 2010 levels (or by 35-55% below 1990 levels) by 2050 and **reach globally aggregated zero emissions by 2080-2100.** Globally, IPCC scenarios also indicate that energy and industry CO_2 emissions[9] would need to be reduced by 35-80% below 2010 levels by 2050 (or by 10-70% below 1990 levels), reaching zero around 2060-2075.

- The Paris Agreement long-term temperature goal[10] requires global emissions are reduced faster and deeper than in the 2°C temperature limit case. A full range of scenarios that meet different interpretations of the Paris agreement[11] is not yet available. The scenarios assessed in this report limit warming to 1.5°C by 2100, but have an overshoot period, where global mean warming lies above 1.5°C for some decades. However, many vulnerable countries interpret the Paris agreement as meaning global mean warming should not exceed 1.5°C.[12] Scenarios that meet this interpretation are in development, but not yet in the peer-reviewed literature. Notwithstanding these limitations, warming to 1.5°C will require reductions of at least 70-95%[13] of GHG emissions below 2010 levels by 2050 (or by 65-90% below 1990 levels), **and reach globally aggregated zero emissions at least by 2060-2080.** Global energy and industry CO_2 emissions will need to be reduced by 95-120% below 2010 levels by around 2050 (or 95-125% below 1990 levels), and **globally aggregated zero CO_2 emissions around 2045-2055**.[14]

ECONOMIC AND TECHNOLOGICAL FEASIBILITY OF THE 1.5°C LIMIT

Present day global warming is already at 0.85°C above pre-industrial levels, with a short-term spike at 1°C in 2015, which begs the question, is a 1.5°C limit achievable? Energy-economic emissions scenarios analysed in the IPCC's Fifth Assessment Report show that 1.5°C is both economically and technologically feasible.[15] Both 2°C and 1.5°C pathways need to peak emissions as soon as possible and no later than 2020 before beginning a rapid decline. A distinguishing feature of the 1.5°C pathways is that emissions need to drop faster, and reach zero earlier than in the 2°C pathway. This means that renewable energy technology, energy efficiency, and other emissions reduction options need to be introduced faster than in the 2°C pathway.

REACHING THE 1.5°C GOAL REQUIRES THE SAME TECHNOLOGIES AS 2°C, DEPLOYED FASTER

A wide range of technologically and economically feasible scenarios that limit warming to below 2°C, or return warming to below 1.5°C by 2100 has been published in the scientific literature.[16,17,18,19] The scenarios that limit warming to below 1.5°C are characterised by (1) immediate mitigation action; (2) the rapid upscaling of the full portfolio of mitigation technologies; and (3) development along a low-energy demand trajectory. These are also important aspects for 2°C pathways.

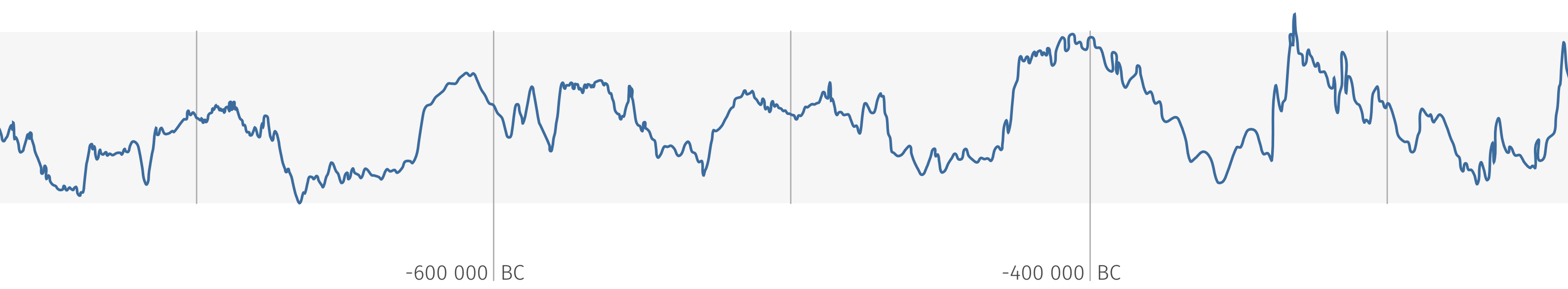


Figure 1-1 | Long term historical CO_2 concentrations from approx. 800 000 BC to 2015 AD & separately for the last 1000 years from 1015 AD to 2015 AD in parts per million (ppm). Blue line depicts data taken from ice cores and the orange line is data from direct measurements taken at Mauna Loa, Hawaii from 1959 - 2015. Source: US EPA 2016, Climate Change Indicators (epa.gov).

BENDING THE CURVE

GETTING GLOBAL AGGREGATE EMISSIONS DOWN TO ZERO

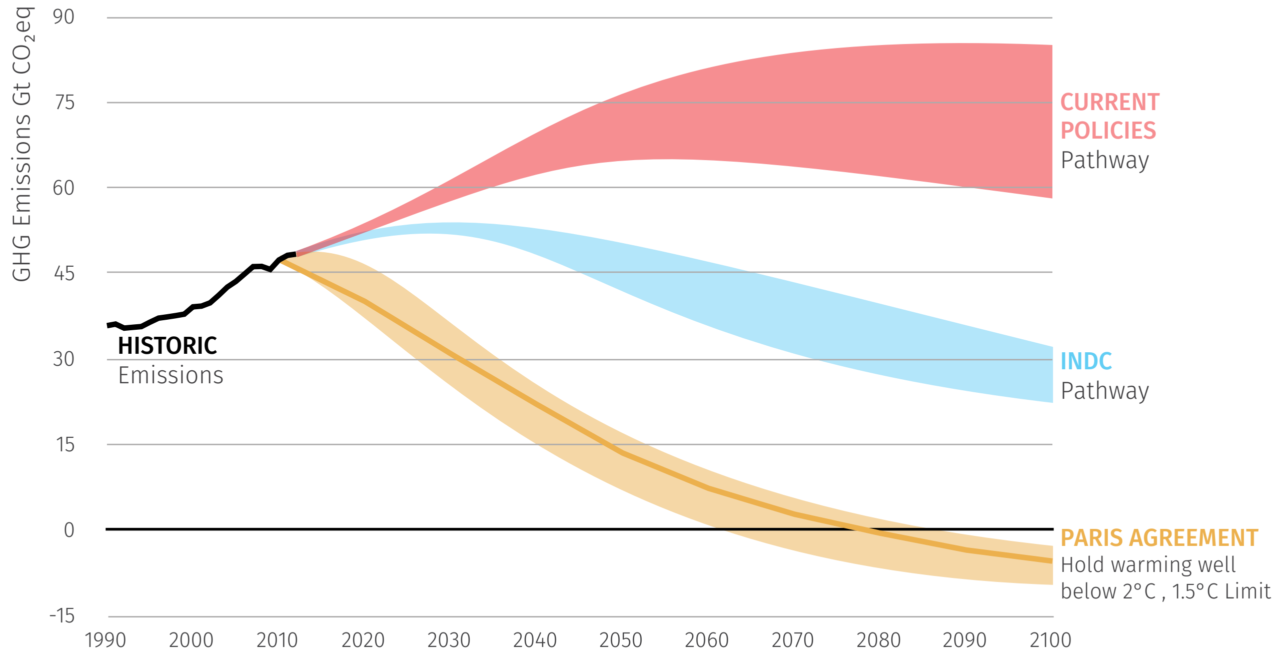


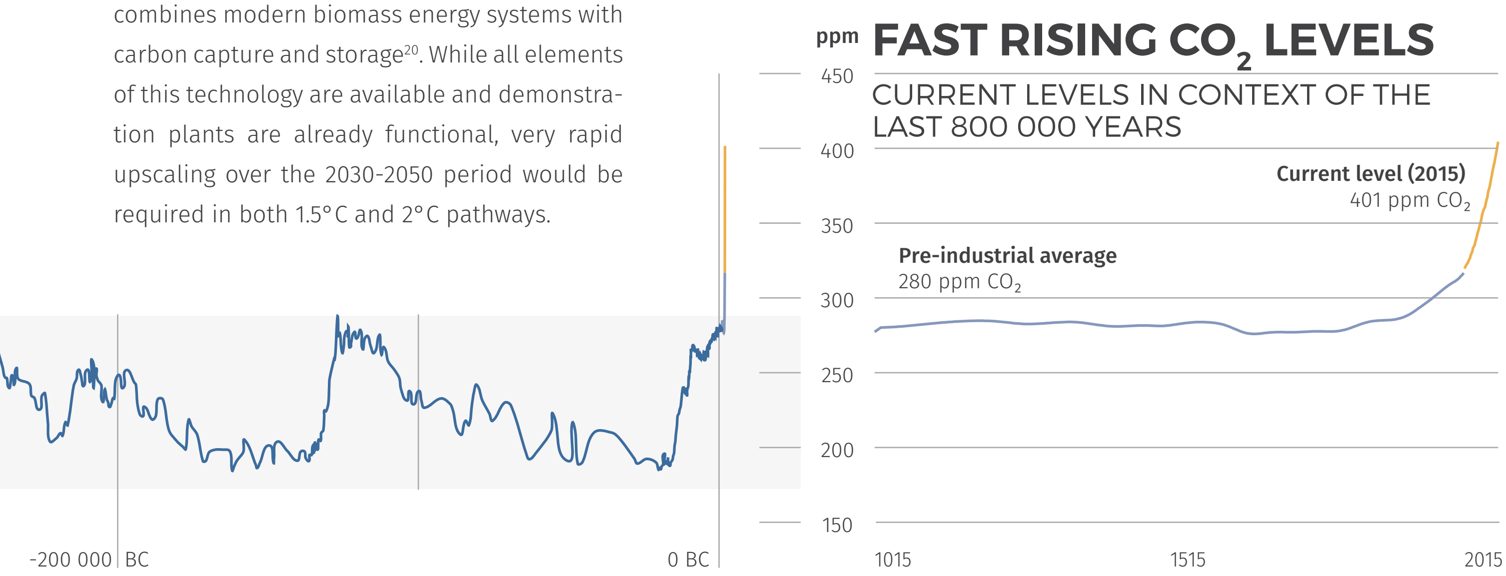
Figure 1-2 | Global emissions pathways to 2100 which show the historical and projected annual level of GHG emissions based on current policies, emissions reduction pledges and (I)NDCs under the Paris Agreement and what is required to meet the 1.5°C limit of the Paris Agreement in gigatonnes per year. Source: Climate Action Tracker (climateactiontracker.org).

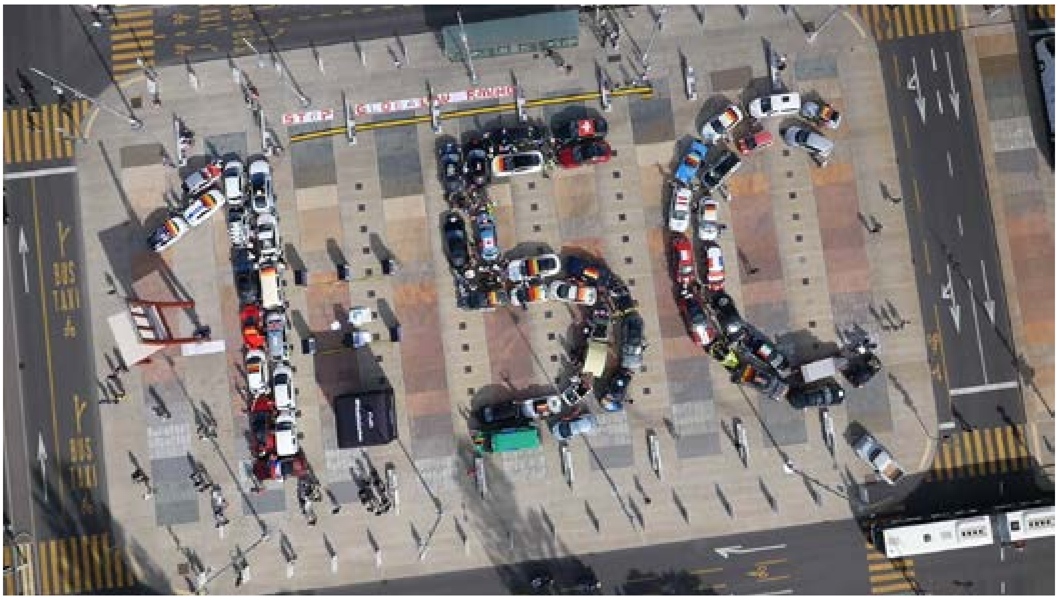
NEGATIVE CO_2 EMISSIONS TECHNOLOGIES NEEDED IN MID TO LONG-TERM FOR BOTH 1.5°C AND 2°C PATHWAYS

Negative CO_2 emissions measures and technology are considered important both for below 2°C and for 1.5°C pathways, with the latter requiring typically a 15% higher amount of total CO_2 removed from the atmosphere by end of century. Such measures and technology are necessary to compensate for the insufficient emissions reductions realised to date. The need to employ negative emissions initiatives also relates to experts' expectations for realistic rates of emissions cuts in the near future. At this moment, the option that is seen as most likely to achieve large-scale negative emissions combines modern biomass energy systems with carbon capture and storage[20]. While all elements of this technology are available and demonstration plants are already functional, very rapid upscaling over the 2030-2050 period would be required in both 1.5°C and 2°C pathways.

REACHING THE 1.5°C GOAL WILL REQUIRE SIMILAR BIOENERGY SUPPLY LEVEL AS 2°C

Bioenergy refers to energy carriers extracted, among others, from woody biomass, agricultural and forestry waste, or dedicated arable crops. Presently available scenarios show that bioenergy demand in the long term for a 1.5°C limit is not higher than for a 2°C limit, but bioenergy use does need to be introduced faster. It is important to note that, while growth of bioenergy use is faster under tighter temperature limits, all energy-economic scenarios, even without these temperature limits, see a rapid growth of bioenergy, due to an anticipated continued competitive development of modern





Cars form giant '1.5C' to support the goal of the 2015 Paris Agreement as part of the 2016 World Advanced Vehicle Expedition (WAVE) rally held outside the gates of the UN European headquarters in Geneva. Photo: CVF / UNDP

bioenergy options, technologies and infrastructure. Large-scale deployment of bioenergy is therefore not unique to 1.5°C and 2°C scenarios and in all cases the related socio-economic and environmental issues associated with large-scale bioenergy deployment must be resolved via integrated land-use management and sustainability requirements, while energy systems must rely primarily on "second generation" options derived from agricultural and forestry residues, dung and organic waste, to minimise conflicts with food security, if the Paris Agreement aims, which also protect food security, are to be respected. Comprehensive policies can safeguard against any remaining risks. However, in any consideration of food security, it must never be ignored that even present-day climate extremes pose very large risks to food security in many countries, due to crop losses and spikes in food prices, and that these risks are set to increase with temperature increases under 1.5°C and more rapidly so with 2°C or higher.

GLOBAL MITIGATION COSTS ARE MODEST, BUT GREATER INTERNATIONAL FINANCIAL FLOWS AND LOW-CARBON INVESTMENTS ARE REQUIRED ESPECIALLY FOR DEVELOPING COUNTRIES

The scenarios in the scientific literature provide mitigation cost estimates for achieving temperature limits. Global emissions reductions can be attained at lowest cost, if action to reduce emissions intensifies immediately: the longer the delay, the more difficult and expensive action will be to meet a certain temperature limit, such as 1.5°C or 2°C. This is because accelerated deployment required to make up for lost time does increase costs. At some point it also becomes impossible to keep warming below a given temperature limit, which is why the scenarios in IPCC's assessment peak global greenhouse-gas emissions by no later than 2020.[21]

IPCC assessed the average global mitigation costs over the whole of the 21st century and its reported estimates are modest compared to expected economic growth. For example, under a cost-effective approach, to meet the 2°C limit with a 'likely' chance (hold warming below 2°C with at 66% chance) is estimated to lead to an average annual cost of about 0.06 percentage points per year (range 0.04-0.14 percentage points estimated as a reduction of global consumption growth). This can be compared to a baseline increase of consumption over the 21st century projected at 1.6-3% per year.[22] Without accounting for the benefits and co-benefits of mitigation (see below) therefore, mitigation costs may reduce consumption growth from 2.30% to 2.24% per year, leading to as little as a two-year delay in reaching the same level of global consumption over the period from 2010 to 2100 come the end of the century.

Meeting a 1.5°C limit is more expensive, although costs are still estimated to be modest. Over the

21st century, limiting warming mitigation costs for 1.5°C by 2100 are about 1.5-2 times higher[23], implying consumption growth could be reduced from 2.30% to roughly 2.20% per year, equal to a four-year delay in reaching the same level of global consumption over the period from 2010 to 2100.

International cooperation is required to cost-effectively reduce greenhouse gas emissions. Cost-effective mitigation will not be achieved if individual agents advance their own interests independently. In particular, for developing countries, international collaborative action is essential to mobilise financial flows towards low-carbon investment in developing countries. A range of economic, institutional and capacity-related factors mean many developing countries carry higher risk environments for investors, which can penalise new forms of investment including into areas that contribute to reducing emissions. The United Nations Development Programme and other international and national organisations have developed programmes aimed at derisking investment in renewable energy projects for this reason[24].

MITIGATION COSTS NEED TO BE WEIGHED TOGETHER WITH AVOIDED DAMAGES, VARYING ADAPTATION COSTS AND CO-BENEFITS OF EMISSIONS CONTROLS.

Not included in the above-mentioned cost estimates are the benefits of avoided risks and damages, nor the co-benefits of climate change mitigation, such as energy independence, the reduction of air pollution, or the resulting beneficial effect on public health and agriculture. The monetised value of co-benefits differs significantly across different studies. For example, the co-benefits of globally avoided mortality through the reduction of air pollutants by climate change mitigation have been estimated[25] to be in the range of USD $50-380/t$CO_2$. Taken together, these co-benefits including sectors such as agriculture, can themselves be of a magnitude comparable to the costs of emissions controls in many regions. A recent study by the Climate Action Tracker indicates that including the economic cost of only air pollution damages, the co-benefits of mitigation down to a 1.5/2°C pathway in 2030 would substantially reduce the overall cost of mitigation.[26]

It is equally important to consider the implications for different levels of warming in terms of the costs that will be required to adapt to climate change. Higher levels of warming do require more resources to manage[27], prevent and address the more significant economic, environmental, health and infrastructure damages associated with a far warmer planet. By comparison, lower levels of warming require lower costs since damages are limited together with limits to warming. The 1.5°C limit would therefore require less adaptation costs than for higher levels of warming.

Press conference at COP21 with national ministers of the High Ambition Coalition contributing to the push for the inclusion of 1.5°C as the limit of the Paris Agreement. Photo © Takver / Flickr

Flags of delegations at the 2015 United Nations Climate Change Conference COP21. Photo © Jmdigne / Wikimedia Commons

It should be noted that IPCC in its recent Fifth Assessment Report explicitly refrains from a cost-benefit analysis, noting that "Analytical methods of valuation cannot identify a single best balance between mitigation, adaptation and residual climate impacts. Important reasons for this are that climate change involves extremely complex natural and social processes, there is extensive disagreement about the values concerned, and climate change impacts and mitigation approaches have important distributional effects. Nevertheless, information on the consequences of emissions pathways to alternative climate goals and risk levels can be a useful input into decision-making processes."[28]

This report focuses on estimates of the benefits and co-benefits of achieving the 1.5°C limit. Only a few elements are represented in monetised terms, such as avoided macroeconomic damages, while others will be presented in physical terms, such as reduced mortality as a result of improved air quality.

COSTS OF RENEWABLE ENERGY ARE DECLINING RAPIDLY

Apart from benefits and co-benefits that are not included in the IPCC cost estimates, very recent key economic and technological developments might not be well represented in the energy-economic models underlying the scenarios and cost estimates. Costs of renewable energy have declined dramatically over the last years and much faster than previously expected and also much faster than what is currently considered in the scientific assessments of the feasibility of 1.5°C and 2°C. Hence the mitigation costs might be overestimated in the assessments discussed above. Several renewable energy technologies have already achieved market competitiveness, to varying extent across the wide variety in national, economic and resource circumstances globally. It is safe to say that these recent trends only add certainty to the already robust findings on the technical and economic feasibility of 1.5°C.

CURRENT POLICIES ARE HEADED TOWARDS 4°C, AND CLIMATE PLEDGES TOWARDS 3°C

Whilst there is strong scientific information on how the 1.5°C limit is technologically and economically feasible, and under which conditions it is feasible, achieving this goal requires strong political support and engagement of civil society and the private sector.

Nationally Determined Contributions (NDCs) are the means by which governments describe how they will contribute to fulfilling the aims of the Paris Agreement in terms of emis-

sions cuts. NDCs specify countries' emissions reduction contributions and relate to periods up to 2025–2030. NDCs are based on the *Intended* Nationally Determined Contributions that almost all Parties to the UNFCCC submitted before the climate conference in Paris in December 2015. It is clear now that the **(I)NDCs in aggregate fall substantially short of what is necessary to put the world on a pathway in line with the 1.5°C limit, leading in aggregate to a temperature increase of about 2.7-3°C**.[29,30,31,32] Policies currently in effect (before translation of Paris Agreement contributions into policy and action) however, would lead in aggregate to up to 4°C of warming by 2100, with greenhouse gas concentrations at such high levels by 2100 committing the world to further warming post-2100.

The Paris Agreement requires countries to prepare, communicate and maintain successive NDCs, every five years. Combined with other "ambition" elements, the Agreement is designed to **pave the way for the mitigation efforts and ambition of emissions reduction targets to be progressively improved**. In fact, the Decision that adopts the Agreement[33] specifies that much greater emissions reduction efforts will be required to close the emissions gap between the estimated aggregate greenhouse gas emissions levels resulting from NDCs and emissions consistent with the long-term temperature goal of the Paris Agreement.

Over three reports, the World Bank 'Turn Down the Heat' series has looked into the consequences the world would face under 3-4°C of warming above pre-industrial levels.[34,35,36] Their findings are clear and show that the consequences of a 3-4°C warming are severe. While every region of the world will be affected, the findings of these reports are clear that the poor and most vulnerable would be affected most. The president of the World Bank in his foreword called on the global community that ''a 4°C world can, and must, be avoided.''[37]

THE RISKS OF CURRENT POLICIES

Below is a summary of the major impacts and risks associated with levels of warming in line with currently implemented policies worldwide:

- Small islands and low-lying coastal cities and regions would be at a severe risk of inundation with a projected sea level rise of up to 1m by 2100 and a multi-meter rise in the centuries to come.

- Risks for food production would increase dramatically on the global scale and in particular in tropical regions, including across Sub-Sahara Africa where already a warming of 2°C would pose substantial risks to food security.

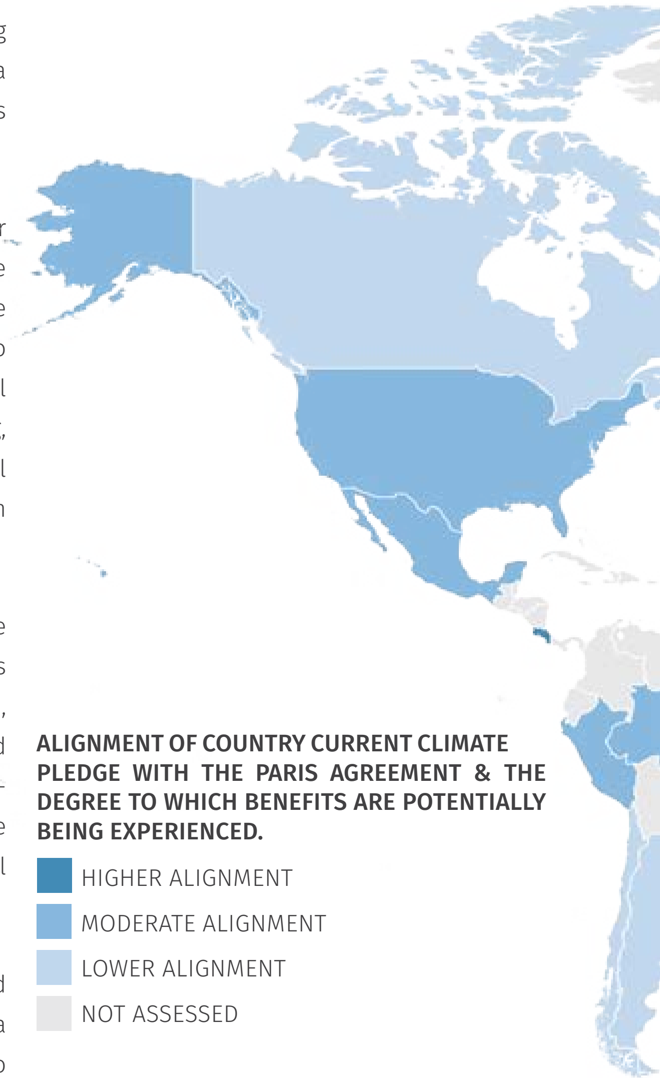
- Substantial glacier loss is projected under 4°C warming with tropical glaciers in the Central Andes projected to disappear in the 21^{st} century and Central Asian glaciers to shrink by up to 80% indicating substantial risks of glacier lake outburst and flooding, but also reduced river flow for agricultural production and livelihoods that depend on glacier water as a key freshwater source.

- Water availability is projected to decline sharply, particularly in subtropical regions such as Central America and the Caribbean, South and North Africa, the Middle East and parts of Central Asia exceeding a 20% reduction in most places and 50% in some. These regions will also experience a substantial increase in drought risks.

- Extreme precipitation intensity is projected to increase globally by about 20% under a 4°C temperature increase, but even more so related to extreme monsoon precipitation e.g. in South Asian countries.

- Unprecedented heatwaves would be the new norm in tropical regions, with widespread and detrimental effects on human livelihoods, health and labour productivity but also on ecosystems.

- Increased frequency of high-intensity tropical cyclones is projected as well as irreversible loss of biodiversity, including coral reef systems. In addition, emerging science projections indicate a trend towards more extreme El Niño Southern Oscillation conditions under increased warming. An increase in extreme El Niño as well as La Niña conditions would lead to more extreme flood or drought conditions in tropical regions and also strongly affect regional sea level rise.



ALIGNMENT OF COUNTRY CURRENT CLIMATE PLEDGE WITH THE PARIS AGREEMENT & THE DEGREE TO WHICH BENEFITS ARE POTENTIALLY BEING EXPERIENCED.

HIGHER ALIGNMENT
MODERATE ALIGNMENT
LOWER ALIGNMENT
NOT ASSESSED

SOME COUNTRIES ARE FRONT RUNNERS

The benefits of the 1.5°C limit are well recognised especially among early adapting and innovative countries, who were the first to capitalise by setting ambitious targets and making climate change policy a cross-cutting issue spanning across sectors and industries. Countries such as Costa Rica, Ethiopia and Morocco were early movers in implementing and designing ambitious and inspiring policies, paving the way towards a 1.5°C world. Already in 2013, 88% of electricity in Costa Rica was generated from renewable sources and it aims to use 100% renewables year-round by 2021.[38] Likewise, Morocco is currently building the world's largest solar power plant, which will provide electricity for 1.1 million people upon completion in 2018 and Ethiopia aims to increase access to electricity (which in 2012 was at 26.6%) through renewable energy, striving to become a net carbon neutral middle income manufacturing hub by 2025.[39]

COUNTRY EMISSIONS COMMITMENT ALIGNMENT WITH THE 1.5˚C GOAL

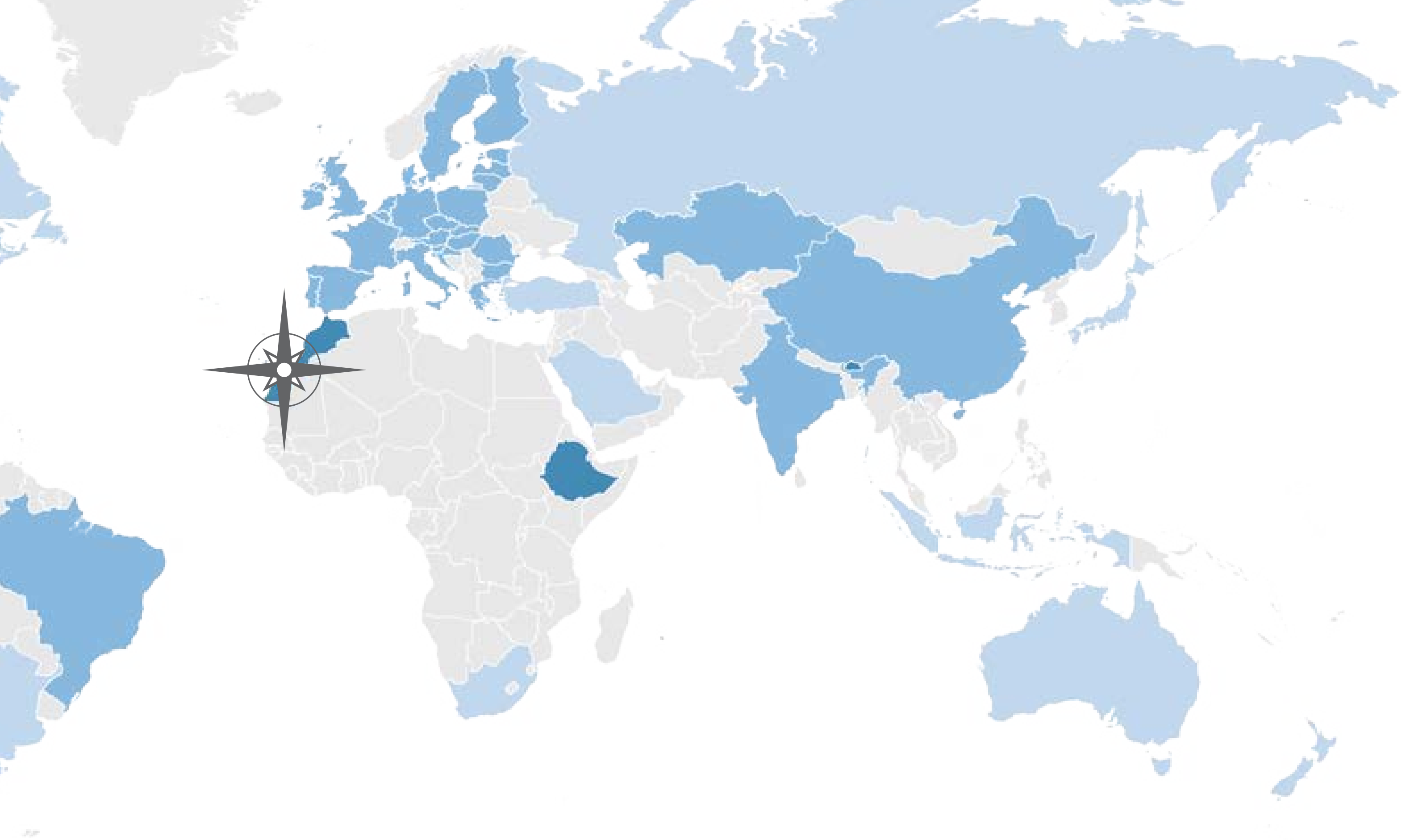


Figure 1-3 | Alignment of countries' climate pledges with the Paris Agreement & the degree to which benefits are potentially being experience. Lighter shading indicates countries with a large gap between current climate pledges and a pathway to achieve 1.5°C who could realise a higher degree of benefits if policies were improved. Darker shades indicate countries that have stronger & more ambitious climate pledges and are potentially already realising the benefits of climate action (Grey depicts countries that were not assessed). These ratings were based on ratings from the Climate Action Tracker (climateactiontracker.org).

Other countries are also recognising the benefits of taking stronger actions towards a 1.5°C limit, although these countries could take advantage of significant further benefits through even stronger climate action (see Table 1-1).

There are also nations, such as Japan, South Africa and Turkey, that are yet to mobilise and utilise their national potentials fully in order to realise the benefits of a 1.5°C world. The transition of the energy sector from solid fuels towards renewable energy sources offers a low carbon future with a multitude of benefits that remains yet to be fully operationalised in these countries.

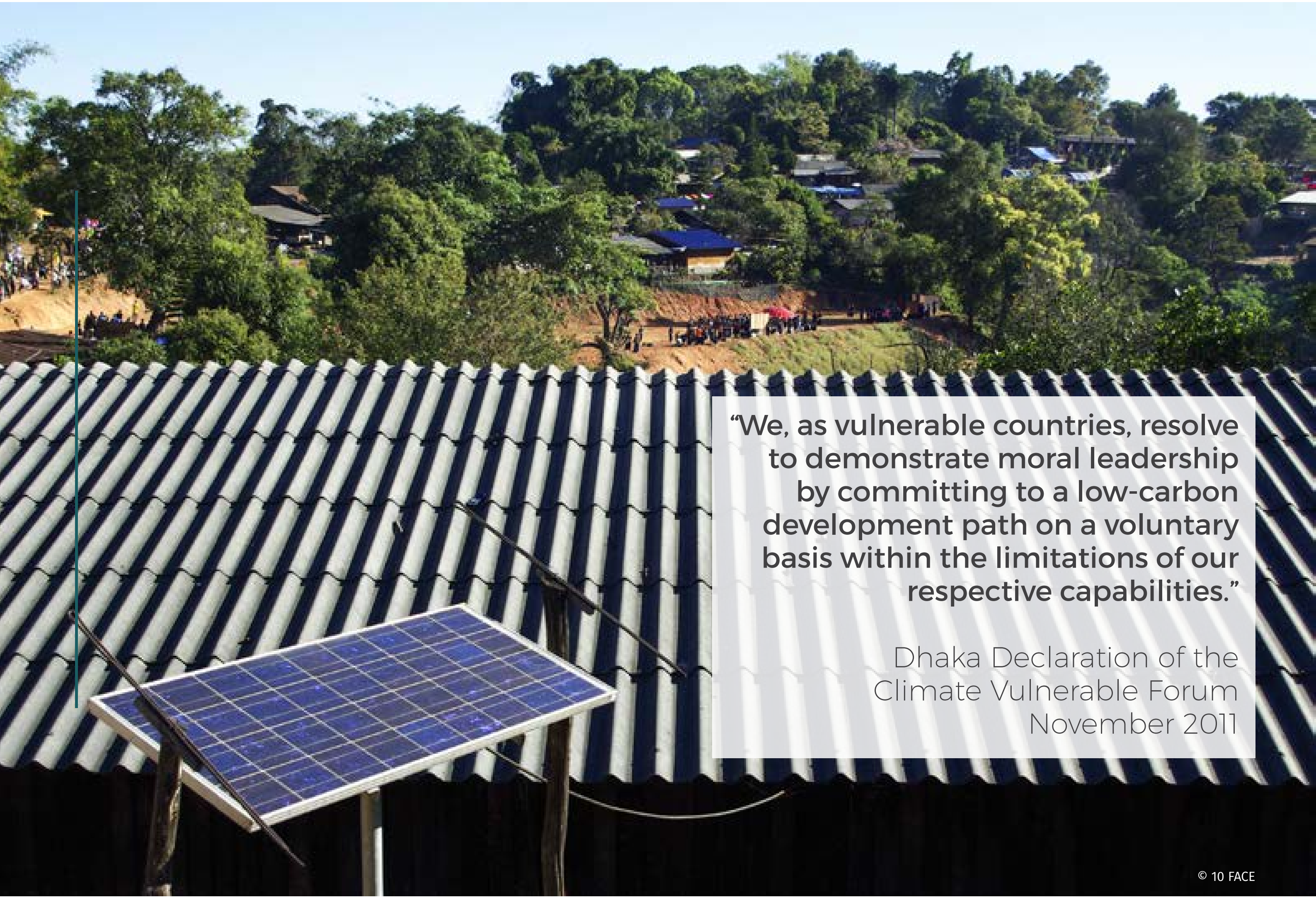
Regardless of the varying degree of uptake towards a 1.5°C world, in Paris in December

Table 1-1 | Notable countries who are also recognising the benefits of taking stronger actions towards a 1.5°C limit, but could also take advantage of significant further benefits through even stronger climate action

COUNTRIES TAKING STRONGER ACTION TOWARDS A 1.5°C LIMIT
The Philippines is currently reviewing its energy policy with an expectation that it will ramp up its climate policy aspirations and revise its INDC to be in line with the 1.5°C long-term temperature goal.[40]
China and the US, the two biggest emitters and economies in the world have demonstrated leadership through joint statements and action areas, such as developing fuel efficient standards for heavy-duty vehicles, working towards the phase-out of hydro fluorocarbons and the introduction of energy efficiency standards for buildings and cities.[41]
China is set to peak its CO_2 emissions from energy use around 2025, achieving both climate goals and reducing air pollution substantially.
The EU, as a long-standing climate champion, continues to have one of the most comprehensive climate packages worldwide. In June this year, the European Electric Vehicle Rally in Geneva stamped 1.5°C at the UN Gates, highlighting the potential the electrification of the transport sector has to contribute towards a low carbon future - a window of opportunity that remains yet to be fully tapped.

2015, 195 countries jointly agreed in Paris to pursue efforts to limit temperature increase to 1.5°C and thereby pave the way towards a low carbon future.

The agreement was adopted to a standing ovation and marked the Launchpad for the global community's actions on climate change. In the years ahead, the speed of transition and strength of climate change policies will be crucial in order to achieve a safer 1.5°C limit to global warming. The current transition in policies is not quick or strong enough, we are approaching a dangerous 4°C world, so that the need and opportunities for global action have never been clearer.



"We, as vulnerable countries, resolve to demonstrate moral leadership by committing to a low-carbon development path on a voluntary basis within the limitations of our respective capabilities."

Dhaka Declaration of the Climate Vulnerable Forum November 2011

BENEFITS TO NATIONS TAKING ACTION TOWARDS A 1.5°C LIMIT

With a strong climate agreement on the table ensuring wide participation, the world is now in the unprecedented position to seize the opportunity and start bending the curve of emissions downward. The world has a once-in-a-generation opportunity to benefit from the significant advantages of taking action towards a 1.5°C limit. The following chapters of this reports step through these different opportunities and advantages in greater detail, and some of the key findings that characterise a 1.5°C pathway are summarised below:

> AVOIDED CLIMATE IMPACTS

The climate change impacts that will be experienced by citizens and the natural environment will be significantly reduced

> SAFEGUARDING ECONOMIC GROWTH

Under the strong global climate Agreement achieved in Paris, large savings in avoided damage to economic growth and productivity will be experienced globally with earlier, stronger action on climate change

> CLEANER AIR

The health of citizens and their surrounding ecosystems, including agriculture, will experience great benefits

> BOOSTING EMPLOYMENT

High levels of job creation with workforces experiencing lower occupational health risks and being more productive

> MORE ENERGY SECURE & INDEPENDENT

Transitioning from fossil fuel based energy to renewable energy sources enables most countries to take advantage of localised energy wealth, reducing reliance on potentially risky supplies of imported fuels that can affect the balance of trade

> IMPROVED BALANCE OF PAYMENTS

Increasing opportunities to take advantage of renewable energy to ensure smooth and reliable long-term growth, decoupling their economies from the price volatility of fossil fuels

> ENHANCING ENERGY ACCESS

Accelerated progress towards universal energy access because of the logistical advantages of renewables while enhancing promotion of human and gender development without loading more pressure on the climate system

> GLOBALISING CLIMATE ACTION

Renewables grew to 90% of new electricity generation in 2015, showing that declining renewable costs, and cooperation on technological transfer across different nations could significantly lower the cost of emissions controls[42]

LOCALISED BENEFITS

Across that wide range of opportunities and benefits, this report identifies a few compelling reasons for specific countries to start taking more substantial climate action:

- Annual GDP growth per capita for developing countries such as Bangladesh, China, India and Indonesia would be cut at least in half by as early as the 2040s as a result of expected global warming when compared to GDP projections not accounting for climate change damages.

- For the United States, Japan, Germany, for example, expected global warming lowers annual GDP growth by 1% before mid-century in line with global estimates, and even leading to negative per capita growth for these economies.

- China is understood to have some of the worst air pollution in the world. In 2015, Beijing experienced a 16% reduction from the previous year's concentration of deadly air pollutants as a result of bold emissions reductions policies and rapid implementation. This trend would only be intensified with more significant emissions reductions.

- Morocco is currently positioning itself to reduce its energy dependence on foreign sources through the development of domestic projects, through the state's embracing of solar and wind as pillar of the country's energy policy.

- In aligning its policies with the 1.5°C limit, the Philippines contributes to reducing emissions locally and globally and improves its chances of enjoying the benefits of low-carbon development which are multiple in the case of Philippines: this would prevent a loss of 0.5 percentage point in GDP growth per capita by the 2040s compared to a high-warming world, prevent reduced labour productivity due to heat in the work place, investing in renewable energy would improve economic stability and independence in the country.

- Regional results:

  - Heat and tropical regions: an increase of 2°C would cause parts of the world, particularly the Tropics, which already experience the most extreme heat conditions, to enter uncharted territory in terms of heat extremes and heatwaves that remain more subdued with half a degree less warming.

  - Food security and Asia: most acutely for this highly populous and agriculturally intensive emerging region, emissions controls will benefit agriculture as well as health, in particular due to emissions controls linked to factories, power plants and transportation that reduce concentrations of ground level, or 'tropospheric', ozone which is highly toxic for plants and can significantly reduce crop yields and diminishes food security.

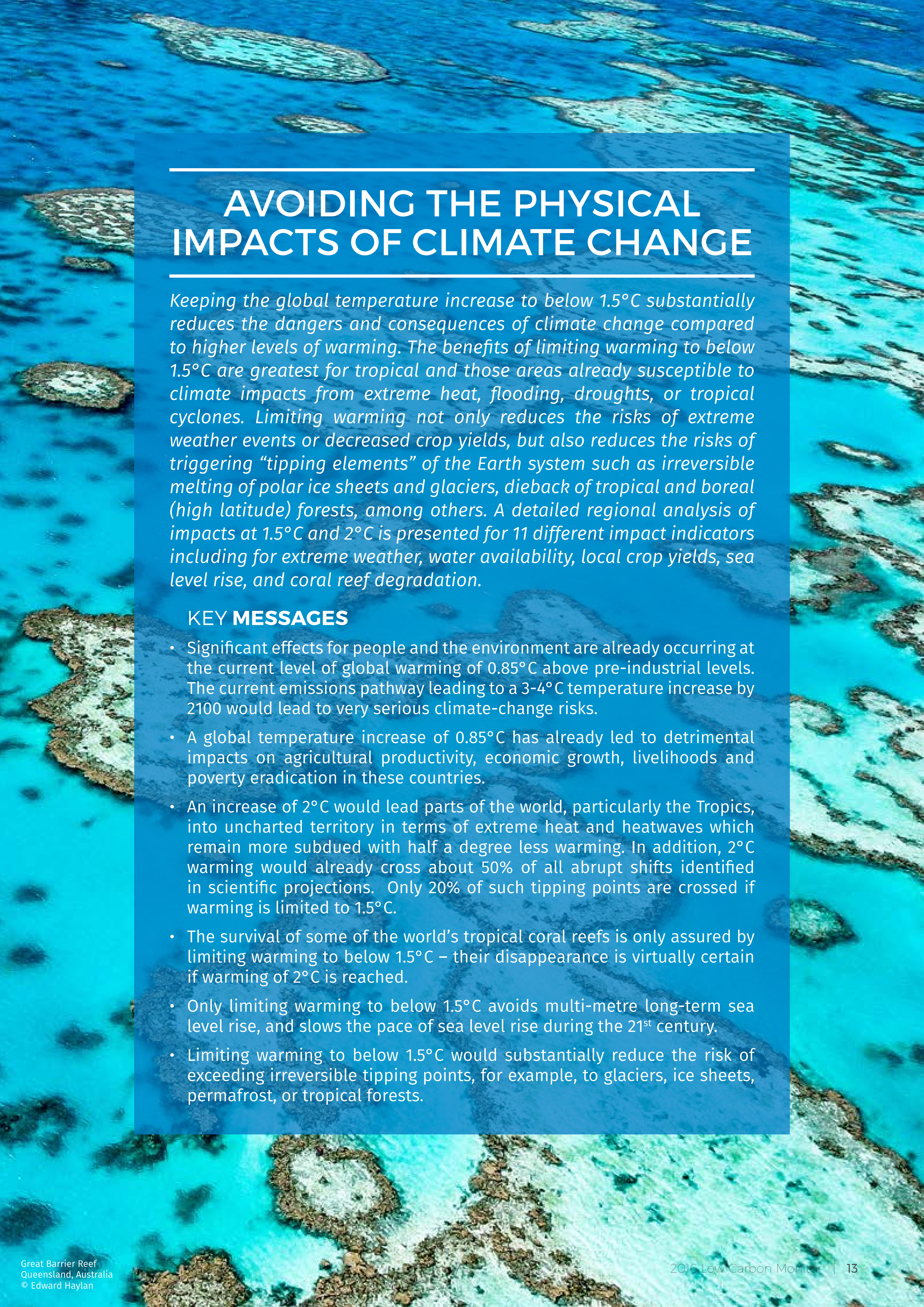
> **"Convinced of the compatibility of the most ambitious forms of action to address climate change with the most ambitious forms of human development and poverty reduction efforts, environmental protection, and robust economic growth that are both inclusive and sustainable, and therein the largely untapped and potentially unprecedented transformational potential for climate action to provide a new opportunity to enhance the prosperity of our most vulnerable countries and of the world."**
>
> Manila-Paris Declaration of the
> Climate Vulnerable Forum
> November 2015

AVOIDING THE PHYSICAL IMPACTS OF CLIMATE CHANGE

Keeping the global temperature increase to below 1.5°C substantially reduces the dangers and consequences of climate change compared to higher levels of warming. The benefits of limiting warming to below 1.5°C are greatest for tropical and those areas already susceptible to climate impacts from extreme heat, flooding, droughts, or tropical cyclones. Limiting warming not only reduces the risks of extreme weather events or decreased crop yields, but also reduces the risks of triggering "tipping elements" of the Earth system such as irreversible melting of polar ice sheets and glaciers, dieback of tropical and boreal (high latitude) forests, among others. A detailed regional analysis of impacts at 1.5°C and 2°C is presented for 11 different impact indicators including for extreme weather, water availability, local crop yields, sea level rise, and coral reef degradation.

KEY **MESSAGES**

- Significant effects for people and the environment are already occurring at the current level of global warming of 0.85°C above pre-industrial levels. The current emissions pathway leading to a 3-4°C temperature increase by 2100 would lead to very serious climate-change risks.
- A global temperature increase of 0.85°C has already led to detrimental impacts on agricultural productivity, economic growth, livelihoods and poverty eradication in these countries.
- An increase of 2°C would lead parts of the world, particularly the Tropics, into uncharted territory in terms of extreme heat and heatwaves which remain more subdued with half a degree less warming. In addition, 2°C warming would already cross about 50% of all abrupt shifts identified in scientific projections. Only 20% of such tipping points are crossed if warming is limited to 1.5°C.
- The survival of some of the world's tropical coral reefs is only assured by limiting warming to below 1.5°C – their disappearance is virtually certain if warming of 2°C is reached.
- Only limiting warming to below 1.5°C avoids multi-metre long-term sea level rise, and slows the pace of sea level rise during the 21st century.
- Limiting warming to below 1.5°C would substantially reduce the risk of exceeding irreversible tipping points, for example, to glaciers, ice sheets, permafrost, or tropical forests.



Great Barrier Reef
Queensland, Australia

2 AVOIDING THE PHYSICAL IMPACTS OF CLIMATE CHANGE

The inclusion of the 1.5°C limit in the Paris Agreement reflected on-going discussion and evaluation of the adequacy of long-term global temperature goals to avoid dangerous climate change. In 2010, the United Nation Framework Convention on Climate Change (UNFCCC) established a review process of the below 2°C goal following concerns in the scientific community and by the leaders of nations particularly vulnerable to climate change about the consequences of such warming. This review concluded that warming of 2°C cannot be considered safe[2]. In December 2015, the Paris Agreement goal of a long-term temperature limit of "well below" 2°C (inclusive of efforts to limit warming to 1.5°C) recognised the strengthened target would **"significantly reduce the risks and impacts of climate change".**[3]

This chapter gives an overview of how the physical impacts of climate change would be reduced at 1.5°C warming, compared to higher levels. Currently observed impacts of climate change are outlined and risks of irreversible impacts at different warming levels are discussed. A detailed regional analysis of impacts at 1.5°C and 2°C is presented for 11 different impact indicators including for extreme weather, water availability, local crop yields, sea level rise and coral reef degradation based on a recent study by Schleussner et al.[4] The economic and social impacts of climate change are discussed in the next chapter.

Table 2-1 | Comparison of avoided impacts at 1.5°C vs. 2°C based on a detailed regional study by Schleussner et al.

	1.5°C WORLD	2°C WORLD	
HEATWAVES			
Tropics	~ 2 months	~ 3 months	While 1.5°C is at the brink of present day natural variability, 2°C would imply a new climate regime in tropical regions where current heatwaves will be the new normal. This indicator is based on the warm spell duration index, a proxy for heatwave length.
ANNUAL WATER AVAILABILITY - RISK OF REDUCTION UP TO			
Central America	20% reduction	30% reduction	Increases in drought length of up to 10% for Central America, South Asia and South East Asia at 2°C, with risks reduced most strongly for Central America at 1.5°C. This indicator is based on total annual runoff, a proxy for annual water availability both for human use and ecosystems.
EXTREME PRECIPITATION			
South East Asia	7% increase	10% increase	Increases in South Asia are likely connected to extreme monsoon precipitation. This indicator is based on annual maximum precipitation on five consecutive days.
SEA LEVEL RISE BY 2100			
Small Islands in the South Pacific and Caribbean and South East Asia	40 cm	50 cm	Sea levels will continue to rise over centuries to come. But only under a 1.5°C scenario will the rate of sea level rise decline during the 21st century to about 30% lower than for 2°C by the end of the century. The long-term sea level commitment arising from a 1.5°C warming is much lower than for 2°C. This indicator is based on global mean sea level rise estimates for stylised 1.5°C and 2°C scenarios and shows the median increase.

Figure 2-1 | Map showing Climate Vulnerable Countries regions and key physical impacts differences under 2°C and 1.5°C warming limits. An explanation of the icons used in the map and the degree of these impacts are detailed in Table 2-1.

EFFECTS OBSERVED TODAY

The effects of observed warming of 0.85°C above pre-industrial levels are already felt globally with consequences especially pronounced for developing countries, such as the member states of the Climate Vulnerable Forum. Atmospheric CO_2 levels are the highest they have been in millions of years[5] and global and regional temperatures and sea levels are rising.[6] Extreme weather events are increasing in intensity and frequency,[7] with already detrimental effects on agricultural yields, which are experienced most acutely in developing regions.[8,9] Severe implications for marine life, including

	1.5°C WORLD	2°C WORLD	
WHEAT YIELDS - RISK OF REDUCTIONS UP TO			
West Africa	**45%** reduction	**60%** reduction	Projected yield reductions are largest for tropical regions, while high-latitude regions may see an increase. The numbers given include the positive effects of CO_2-fertilisation, which remains highly uncertain. Projections not including this effect predict reductions for all crop types of about 10% globally already at 1.5°C and further reductions at 2°C.
East Africa	**25%** reduction	**35%** reduction	We assess changes in local yields over the present day agricultural area (not total aggregated yields). Crop yield projections are highly uncertain due to biophysical and socioeconomic uncertainties. Here we pursue a risk approach by giving the reduction at the upper end of the 66% uncertainty range assessed in the underlying study.
Central America	**25%** reduction	**40%** reduction	
OCEAN ACIDIFICATION AND CORAL REEF LOSS BY 2050			
Small Islands in the South Pacific and Caribbean and South East Asia	**90%** reduction [50;99]	**98%** reduction [86;100]	Already under a 1.5°C warming, coral reefs are under extreme risk, but some window for ecosystem adaptation may remain. Under 2°C there will be little chance for coral reef survival. Fraction of coral reef cells at risk of long-term degradation defined as experiencing at least one bleaching event every five years. Projections based on stylised 1.5°C and 2°C scenarios. Median estimate and 66% uncertainty range given [in parenthesis].

erosion and mass bleaching of tropical coral reefs, are the consequence of higher ocean temperatures and acidity resulting from absorption of CO_2.[10] During the 2015-2016 El Niño event, which added a short-term warming spike on top of the long-term human-induced warming, mass bleaching affected vast parts of tropical coral reefs globally.[11]

In light of these impacts, a recent assessment of the risks of global warming with increasing temperatures under the UNFCCC found that **"significant climate impacts are already occurring at the current level of global warming and additional magnitudes of warming will only increase the risk of severe, pervasive and irreversible impacts".**[12]

LONG-TERM RISKS FOR IRREVERSIBLE IMPACTS

Limiting warming not only reduces the risks of extreme weather events or decreased crop yields, but also reduces the risks of triggering "tipping elements" of the Earth system such as irreversible melting of polar ice sheets and glaciers, dieback of tropical and boreal (high latitude) forests, permafrost collapse leading to methane releases that further amplify heating, Eastern Sahel vegetation shifts adversely affecting human livelihoods and ecosystems, and the total disappearance of Arctic sea-ice.[13] Based on the IPCC fifth assessment report (AR5) foundations, a recent study indicated that 2°C warming would already cross about 50% of all tipping points identified in scientific projections.[14] Only 20% of key tipping points are crossed if warming is limited to 1.5°C.

There is also a risk that large parts of the Antarctic and Greenland ice sheets could be 'tipped' by the effects of climate change leading to multi-metre sea level rise over thousands of years. Assessments of historical sea level evidence from Earth's history and state-of-the-art modelling results indicate a multi-millennial average sea level rise of about 2.3m per degree celcius of warming.[15]

There is growing evidence that parts of the West-Antarctic ice sheet may already be in irreversible retreat. Uncertainties are still large, but sustained warming in this region could eventually lead to the loss of the full West Antarctic ice sheet, which would release enough ice to generate at least 3m of sea level rise on average globally.[16] For the Greenland ice sheet that contains an equivalent volume to raise sea levels by 7m, researchers have identified 1.6°C warming as the best estimate for its tipping point.[17] Thresholds in terms of global mean temperature increase for these large ice sheets are highly uncertain, but it is clear that risks are greater with every increase in warming.

SAFEGUARDING ECONOMIC GROWTH

Limiting global warming to 1.5°C will avoid large-scale economic losses and associated harmful consequences for society during the first half of the twenty-first century. Socio-economic impacts from climate change depend on both the type, intensity and frequency of climatic shock experienced, as well as the vulnerability of communities. The degree of economic damages avoided through strong climate action therefore varies significantly from country to country. The latest research is presented here on the economic damages associated with a high warming scenario that reflects current policies, versus keeping to the 1.5°C limit. Based on the latest IPCC climate models and historical patterns of GDP and temperature fluctuations, the clear pattern projected for most economies, large and small, is a significant negative wealth correction by mid-century, unless more stringent emissions cuts are realised. This further strengthens the case for limiting warming to 1.5°C.

KEY **MESSAGES**

- Annual GDP growth per capita for developing countries such as Bangladesh, China, India and Indonesia would be cut at least in half as early as the 2040s as a result of expected global warming if a 1.5°C limit is complied with as compared with current policies.
- Major reductions in economic prospects are also projected for developed countries as a result of expected warming. For the United States, Japan, Germany, for example, the estimated warming associated with current policies would lead to negative total per capita growth for these economies by mid-century.
- If global mitigation actions are not strengthened substantially, climate-related damages would reduce annual GDP by 2050 by $33 USD trillion for the developed and developing countries assessed here, compared to USD21 trillion in a scenario with strong global mitigation action and low warming consistent with a 1.5°C target. Across the 2015-2050 period, the economic penalty of high versus low warming scenarios would cumulate to approximately USD75 trillion.
- This report's economic damage findings relate only to effects directly linked to temperature fluctuations, meaning that the full spectrum of impacts caused by climate change would reduce growth further than has been presented here, data limitations acknowledged.
- Strong climate-change mitigation reduces the rate and magnitude of warming, which reduces adaptation costs and **increases the timeframe to implement adaptation measures** against adverse effects.
- In contrast, delayed mitigation action increases substantially the need for disaster management and adaptation investments, and combines with greater economic losses derived from higher temperatures.
- Strengthened climate change action will enhance global prosperity and allow for the most significant contribution to the achievement of the Sustainable Development Goals, including by lessening economic penalties that are most severe for the world's poorest groups, from the available development choices facing countries today.

2003 Hurricane Isabel
© NASA

3 SAFEGUARDING ECONOMIC GROWTH

Low income nations and Small Island Developing States, are the most vulnerable to climate change impacts[1]**.** Characterised by factors such as high employment in agriculture and low economic capacity to adapt, the negative impacts of climate change could have severe consequences for the development of these nations.[2]

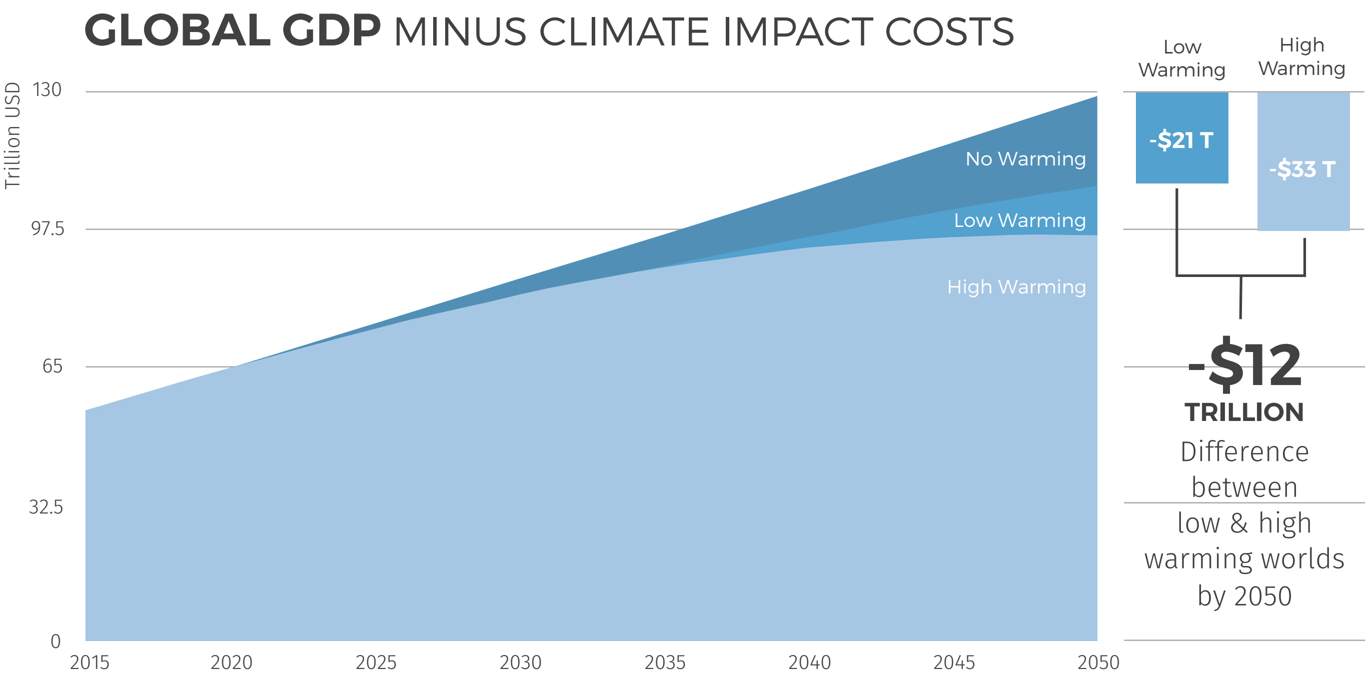
Climate-related shocks result in increased likelihood of "natural disasters that destroy assets and livelihoods; waterborne diseases and pests that become more prevalent during heatwaves, floods or droughts; crop failure from reduced rainfall; and spikes in food prices."[3] Without mitigation and increased levels of adaptation, these impacts can reduce global incomes by significant amounts.[4]

While chapter 2 provided an impression of biophysical impacts associated with different levels of warming, this chapter estimates the macroeconomic impacts associated with climate change and demonstrate that strengthened climate action avoids significant economic losses at the global level (illustrated in Figure 3-1). Figure 3-2 shows reduced annual GDP growth per capita by 2050, as a result of continued climate change, for a selection of countries, based on a methodology adapted from Burke et. al [5]. Two scenarios are assessed here. The low warming scenario reaches 1.75°C by 2050 and represents a typical 1.5°C scenario, with a temporary overshoot above the 1.5°C limit around mid-century. The high warming scenario reaches 2.5°C by 2050 and represents a continuation of current climate policies without strengthened climate action over the next decades. The calculations here are based on temperature change patterns only, from the same climate models underlying the results in chapter 2.

AVOIDING ECONOMIC DAMAGES

If global mitigation actions are not strengthened substantially, climate-related damages would reduce annual GDP by 2050 by USD33 trillion for the countries assessed here, compared to USD21 trillion in a scenario with strong global mitigation action and low warming. Across the 2015-2050 period, the difference between low and high warming scenarios would cumulate

Figure 3-1 | Global macro-economic impacts of climate change between 2015 and 2050 in the low and high warming world compared to a world without further climate change. Authors'calculations.



IMPACTS IMPACT GDP
AVERAGE ANNUAL PER CAPITA GROWTH RATES

NO WARMING
based on IPCC-SSP2

LOW WARMING
based on IPCC-RCP2.6

HIGH WARMING
based on IPCC-RCP8.5

Figure 3-2 | Projections of annual growth rates of GDP per capita (in percentage per year) for the World and a set of countries, in three scenarios: a counterfactual baseline scenario not accounting for climate change impacts on development based on IPCC SSP2 (No warming), a low warming scenario based on IPCC RCP2.6 (Low warming) and a high warming scenario based on IPCC RCP8.5 (High warming). Authors'calculations

AVERAGE ANNUAL PERCENTAGE LOSS OF PER CAPITA GDP OF A HIGH WARMING WORLD COMPARED TO A LOW WARMING WORLD (% OF GDP)

COUNTRY	2020s	2030s	2040s	COUNTRY	2020s	2030s	2040s
World	0.0	-0.3	-0.8	Viet Nam	-0.1	-0.3	-0.5
Ethiopia	-0.1	-0.3	-0.7	China	0.0	-0.3	-0.9
Morocco	0.0	-0.1	-0.2	India	-0.1	-0.3	-1.0
Costa Rica	-0.2	-0.2	-0.3	Indonesia	-0.1	-0.3	-0.7
Dominican Republic	0.0	-0.2	-0.6	Germany	0.1	-0.1	-0.9
Sao Tome and Principe	-0.1	-0.2	-0.6	Japan	0.2	-0.2	-1.2
Bangladesh	0.0	-0.5	-1.2	USA	0.0	-0.2	-1.2
Philippines	0.0	-0.2	-0.4				

Table 3-1 | The changes to the average annual rate of per capita GDP (in percentage per year) from a high warming world compared to a low and a no warming worlds. Percentages are shown for the 2030s and 2040s. Authors'calculations.

to about USD75 trillion. It is also worth noting that warming levels in the scenarios start deviating after the 2030s, explaining the yet limited difference in macroeconomic losses between the low and high warming scenarios. The spread between these scenarios sharply increase between 2050 and 2100.

While GDP per capita growth in the Philippines is projected on average at 3% per year by the 2040s in a GDP scenario not accounting for future climate-change damages (IPCC-SSP2), this decreases to 2.5% per year under a high warming scenario. For the low warming scenario, the decrease is limited and GDP per capita growth still reached 2.8% per year by the 2040s. Likewise, in the high-warming scenario in Bangladesh, GDP per capita growth would decrease from 6% per year in a no-climate-change reference scenario, to only 4%, and annual growth for China would be reduced from 2% to 0.5% per year.

The contractions in India and China alone may have large implications specifically on the growth of neighbouring countries in the region, as well as the world economy. These reductions in macroeconomic outputs induced by climate-change impacts could therefore pose a very serious challenge to poverty eradication efforts in the developing world. In rich countries like Japan and the USA, climate-change damages might flip the GDP projections from a modest annual growth to a potential annual decline, in the absence of adaptation.

The biophysical impacts of changing climate on different regions vary, and the economic impacts depend on the type, intensity and frequency of climatic shock experienced by a specific region, as well as the capacity of communities to adapt to and recover from these shocks. For instance, higher warming levels also increase the frequency of El Niño events, which affect ecosystems, agricultural production, patterns of tropical cyclones, increased drought, likelihood of bushfires, and flooding in different parts of the world.[6] Flooding, extreme precipitation and

sea level rise equate to major capital costs resulting from damage but also from heightened adaptation infrastructure costs. Similarly, reductions in crop yields will lead to increases in food prices and decreasing food security (Table 3-2).

The global impacts of climate change, therefore, are difficult to estimate and can vary significantly depending on certain economic and biophysical assumptions like the inclusion or exclusion of tipping points (see chapter 1), the long or short-term effects on the macroeconomic development trajectory of the countries, among other factors.[7] The calculations in this chapter are based on historical sensitivities of economies to changes in temperatures only, and therefore do not account for additional impacts from variations in other climate variables that are uncorrelated with temperature, particularly flooding events. Phenomena not linked to annual progressions in temperature measured annually, such as coastal damages relating to sea level rise and storms are also not adequately accounted for. Additional data collection and research is required to account for these. As a result, the estimates presented here are not fully representative of the economic ramifications of climate change, estimates of the full consequences of which would be greater than what is indicated here. Table 3-1 below provides a qualitative overview of the link between various climate-change impacts and the resulting socio-economic impacts.

The large majority of the members of the Climate Vulnerable Forum have GDP per capita below the global median. This illustrates that CVF nations are not only highly exposed to some of the most potentially catastrophic risks associated with rising temperatures but also have lower than average economic capacity to adapt and respond effectively to those risks.

In this context, developing countries would particularly benefit from avoided risks and economic losses derived from ambitious mitigation actions.

Flooding in Thailand. Economic costs are both direct from water related damage and indirect from lost economic activity. Photo: © ATIKAN PORNCHAIPRASIT

	IMPACT	MOST AFFECTED REGION	ECONOMIC IMPACTS
1	Heatwaves	All CVF countries	Occupational health risk, Loss of lives, Lower labour productivity
2	Annual water availability	Central America	Lower labour productivity, Loss of lives, Food inflation, Food insecurity
3	Extreme precipitation	South East Asia	Flooding, Physical capital destruction, Interruption to production value chain Spread of disease, Lower labour productivity
4	Risks for wheat yield reductions	West Africa, East Africa, Central America	Food inflation, Food insecurity
5	Risks for rice yield reductions	All CVF countries	Food inflation, Food insecurity
6	Ocean acidification and coral reef loss	Small Islands in the South Pacific and Caribbean, South East Asia	Threat to fisheries livelihood, Threat to tourism industry
7	Sea level rise	Small Islands in the South Pacific and Caribbean, South East Asia	Reduction in productive and non-productive land area, Community displacement, Lower labour productivity, Loss of lives

Table 3-2 | From climate impacts (introduced in Chapter 2) to economic impacts: Which regions are most affected? Sources: Schleussner et al. (2016); Parsons(2014); UNDP(2016)[9]; Hallegatte et al. (2016)

COST SAVINGS IN ADAPTATION

Historically, human societies have adjusted with varying degrees of success to changes in the climate, and it is expected that they will continue to do so in the future through modern means of adaptation such as investment in disaster risk management measures, including the introduction of climate-resilient agriculture practices and the improvement of water resource management. However, strengthened mitigation action will reduce the impacts of climate change in coming years and the need of investment in costly adaptation measures[10]. Furthermore, there are limits to the effectiveness of adaptation measures, especially for low probability but high impact consequences.[11]

Ambitious climate action towards a 1.5°C limit aids adaptation measures by lower needs for adaptation, extending the time-span required for the implementation of the measures to avoid unmanageable damages, and making economies more resilient to unforeseen future warming impacts. The synergies of ambitious adaptation and mitigation actions reduce the risk of higher economic impacts and support socially inclusive growth through environmentally sound policies that ultimately contribute to the achievement of the Sustainable Development Goals.

REDUCING AIR POLLUTION WITH CLIMATE ACTION

Moving towards a 1.5°C world will not only avoid the most dangerous impacts of climate change. Reductions in fossil fuel emissions will also reduce concentrations of toxic pollutants in the atmosphere. As a consequence, strengthened action addressing climate change will also bring numerous benefits in terms of public health, agriculture, and sustainable livelihoods for populations around the world.

KEY **MESSAGES**

- Fossil and combustible fuel use is one of the major sources of air pollutants globally, both in cities and in many rural areas.
- The latest estimates from the World Health Organization attribute 7 million premature deaths to indoor and outdoor air pollution annually – more than one-in-every-eight deaths worldwide – making it the largest single current environmental health risk and more deadly than either alcohol, claiming 3 million lives a year, or tobacco, which kills 6 million each year.
- Ambient, or outdoor, air pollution accounted for 3 million of these deaths, and this figure is expected to grow to 4.5 million by 2040. Asia and the Western Pacific account for almost 90% of these premature deaths.
- The majority of deaths however are currently attributed to indoor air pollution resulting from indoor fires and stoves, which claimed as many as 4.3 million lives in 2012, half of which are children whose death are attributable to pneumonia triggered by soot inhalation from indoor fuel combustion.
- Air pollution is already a serious health concern even for lower income developing countries. In at least 25 Climate Vulnerable Forum countries for instance, over 75% of the population is exposed to dangerous levels of PM2.5 particulates, exceeding World Health Organisation guideline values.
- There is a close, quantitative relationship between exposure to high concentrations of small particulates (PM10 and PM2.5) and increased mortality or morbidity, both daily and over time. Reduced air pollution lowers the risk of mortality from air pollution-related illnesses, and both chronic and acute respiratory diseases, which impose significant economic impacts on national health care systems and economies.
- Economic losses associated with outdoor air pollution could total roughly 1% of global GDP by 2060 – around USD 2.6 trillion annually.
- Sulphur and nitrogen oxides lead to pollution of fresh water and soils, threatening agriculture and biodiversity. A 5% reduction in crop productivity by 2050 could be avoided by improving air quality through strong climate action over the coming decades. This has substantial benefits for food security, particularly in developing nations.
- A large portion of the cost of stronger climate policies — such as the increase of renewable energy sources, urban transport policies focussing on public transportation, pedestrian and bike actions, the reduction of industrial smokestack emissions or the improvement of cooking stoves — will be offset by savings associated with reduced mortality.[5,6]

Haze of air pollution over Bangkok, Thailand
© Silentgunman

4 REDUCING AIR POLLUTION WITH CLIMATE ACTION

The perceived costs of mitigation are one of the strongest obstacles facing nations that are otherwise willing to pursue strong action on climate change. The less tangible long-term - such as the economic cost of premature deaths on workforce productivity or public health burdens - are however rarely reflected in policy making.

This chapter discusses some of these 'co-benefits' and how, when they are weighed into the equation, stronger and earlier climate change action makes a lot more sense. Among the most valuable co-benefits that will be experienced at a 1.5°C limit are those relating to reductions in ambient and indoor air pollution and the associated economic and health consequences, economic benefits of more robust and longer living workforces, and the improvements to food security and agriculture.

3M+
OUTDOOR

7+ MILLION
DEATHS PER YEAR

4.3M+
INDOOR

AMBIENT AND INDOOR AIR POLLUTION CAUSE MORE THAN 7 MILLION [7] DEATHS PER YEAR

In 2012, an estimated 3 million premature deaths occurred due to ambient (or outdoor) air pollution, primarily from traffic, industrial sources, waste burning or residential fuel combustion.[8] Given the economic burden of premature mortality, the United States EPA since 2013 has incorporated global health co-benefits of climate action into its estimations of the public value of emissions controls. In at least 25 Climate Vulnerable Forum countries, over 75% of the population is exposed to dangerous levels of PM2.5 particulates, which exceeds World Health Organisation guideline values.

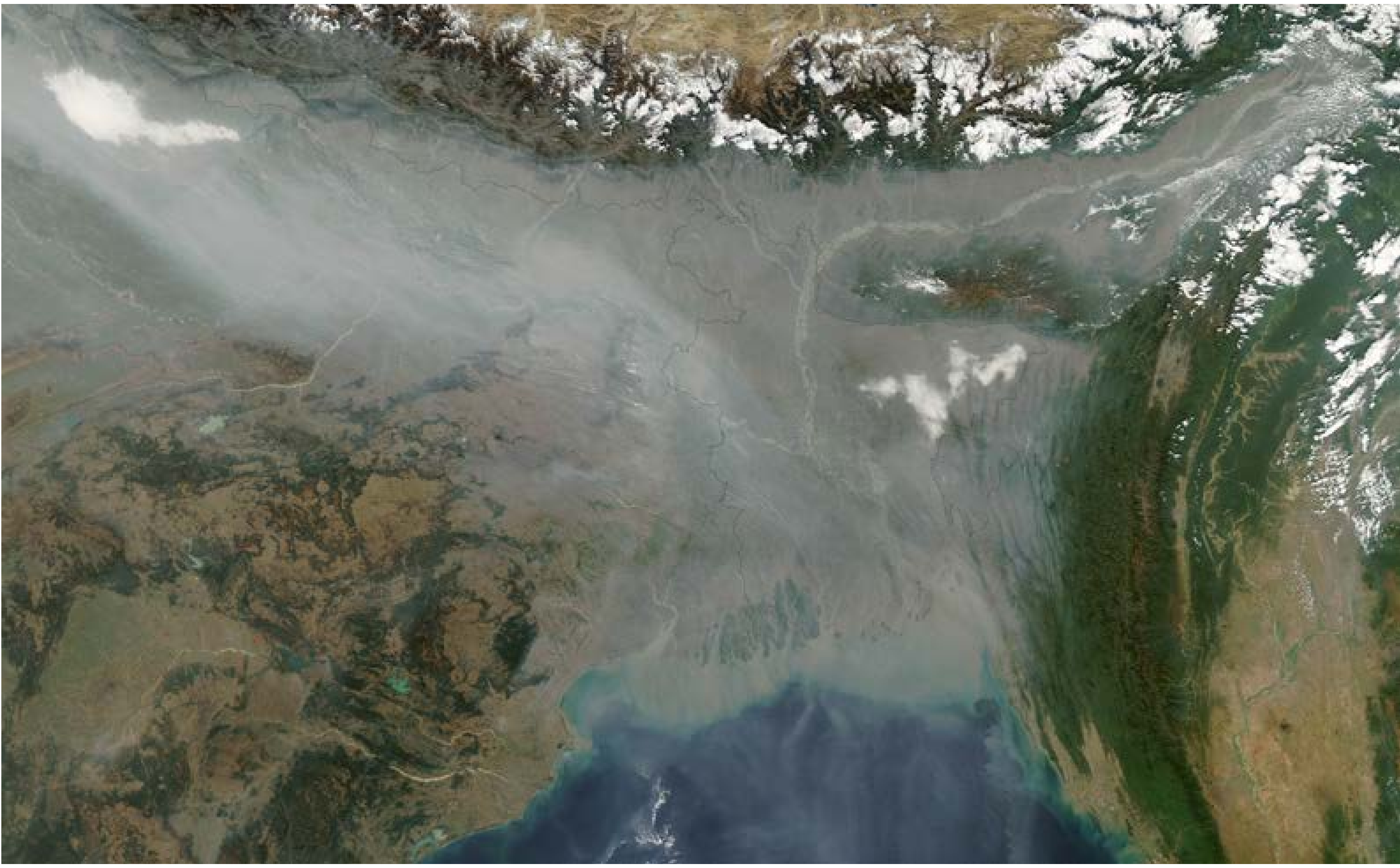
The situation is particularly severe in low-income cities – 98% of cities in low and middle-income countries with more than 100,000 inhabitants do not meet WHO air quality guidelines.[9,10]

Moreover, about 3 billion people worldwide cook and heat their homes using solid fuels such as wood, charcoal or coal.[11] The IEA estimates that by 2040, 1.8 billion people will still not have access to clean cooking devices. High levels of indoor air pollution were responsible for **4.3 million deaths in 2012 (through diseases such as acute lower respiratory disease, chronic obstructive pulmonary disease, ischaemic heart disease, stroke or lung cancer), heavily concentrated in low- and middle-income countries.**[12] This is equivalent to 7.7% of global mortality, which is more than the toll from malaria, tuberculosis and HIV/AIDS combined.[13] It also exceeds deaths from alcohol (3.3 million) and tobacco (6 million). **Particularly affected are the South East Asia and Western Pacific regions, with 1.69 and 1.62 million indoor air pollution deaths respectively.**[14]

STRONG CLIMATE POLICIES ARE ACCOMPANIED BY DIRECT ECONOMIC BENEFITS

Reduced air pollution lowers the risk of mortality from air pollution-related illnesses that would otherwise impose significant economic impacts on national health care systems and economies. **Global economic losses associated with outdoor air pollution could total USD $2.6 trillion annually – roughly 1% of global GDP – by 2060.**[15] These economic losses could be avoided in a world of strong climate policy and mitigation actions in line with limiting warming to 1.5°C, phasing out unabated fossil fuel use.

Directly reducing indoor air pollution, through improved cooking stoves for example, offers a multitude of benefits, including improved health of the population. The key challenge is to address this issue without resorting to



fossil fuels (LPG, kerosene), but instead benefiting from mobilising economies of scale (lower prices) of renewables as well as other low carbon alternatives.

Example projects can increase the visibility of low-carbon solutions to indoor air pollution and also help in overcoming technical difficulties that would otherwise prevent people from switching to low-carbon instead of fossil fuel based solutions. One example project carried out by the German Atmosfair initiative, offers customers the opportunity to offset flight emissions and then invests the money into mitigation projects. These projects include biogas plants for household energy in Nepal, which can save roughly 150.000 tCO_2 in four years. Other examples include efficient cook stoves that can save up to 80% of energy use and lead to improved air quality and reduced deforestation. In Nigeria and Cameroon, efficient cook stoves reduced energy expenditures and CO_2 emissions by about 30,000 and 10,000 tonnes of CO_2 per year, respectively.[16]

In many countries, such as Ethiopia, solar home systems are replacing kerosene lamps, reducing the risk of respiratory diseases. This also leads to additional job opportunities for installation and maintenance of solar powered lamps.[17] A solar mirror for rice cooking is another promising technology. Countries including India are adopting this technology to reduce emissions and improve indoor air quality. This also leads to emissions reduction ranging from 10-200 tCO_2 per facility per year.[18]

Despite these promising technologies, and their associated co-benefits, most of the countries remain conservative when defining their mitigation plans. The current level of ambition of (I)NDC ((Intended) Nationally Determined Contribution) is not sufficient to prevent dangerous global warming. If this level of ambition remains the same, emissions are likely to peak around 2030, and slowly decrease thereafter, phasing out at the end of the century.[23] In comparison, a 1.5°C world requires stronger reductions of carbon dioxide emissions, and

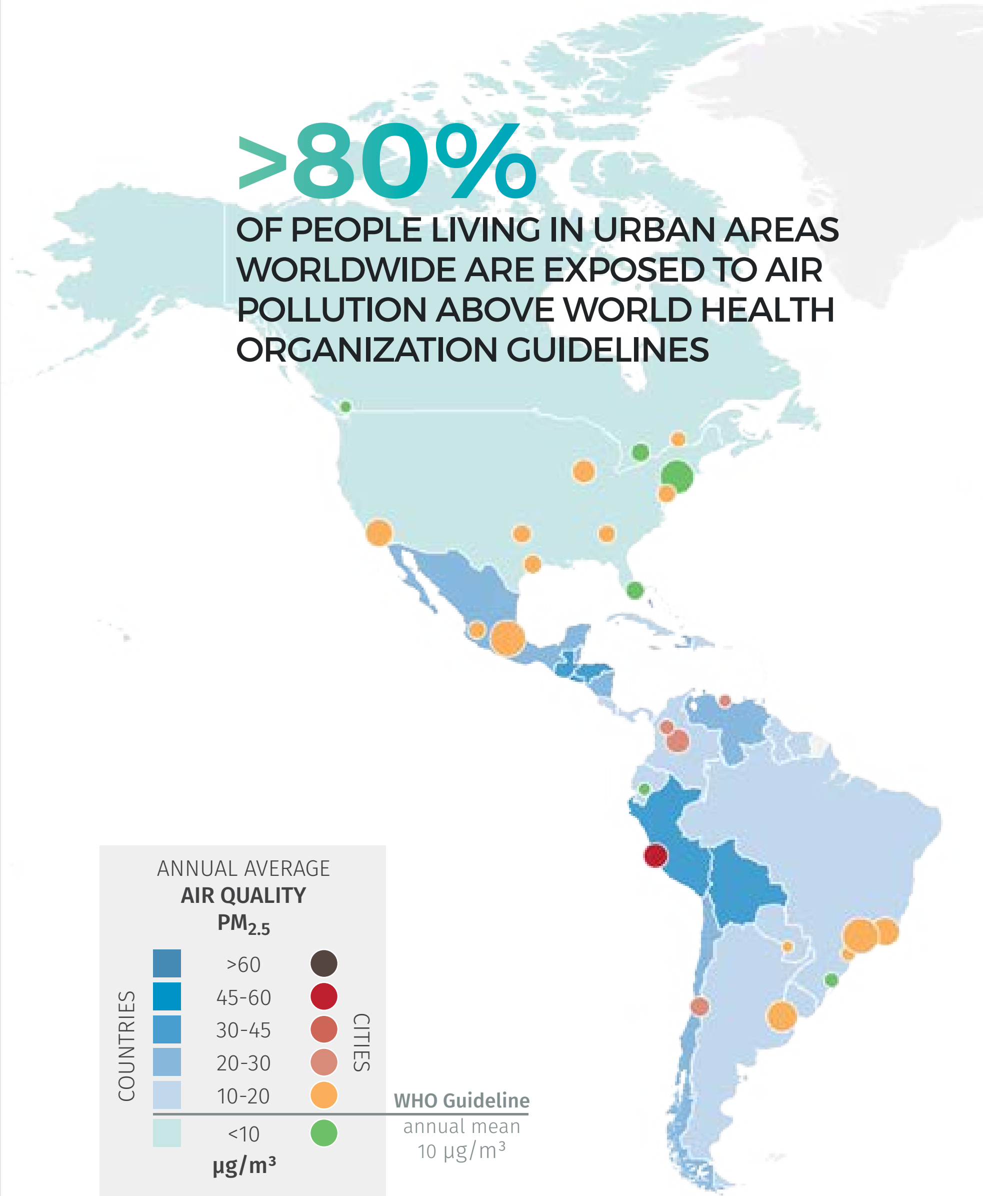
A thick river of haze over northern India and Bangladesh on January 10, 2013, as it hugs the Himalayas and spills out into the Ganges delta and Bengal Sea. The haze likely resulted from a combination of urban and industrial pollution, agricultural fires, and a regional meteorological phenomenon known as a temperature inversion where cold winter air traps the warmer air close to the surface where the pollution it contains can have a big impact on human health. Photo: NASA image courtesy Jeff Schmaltz, LANCE MODIS Rapid Response.

CHINA
A WAR ON POLLUTION

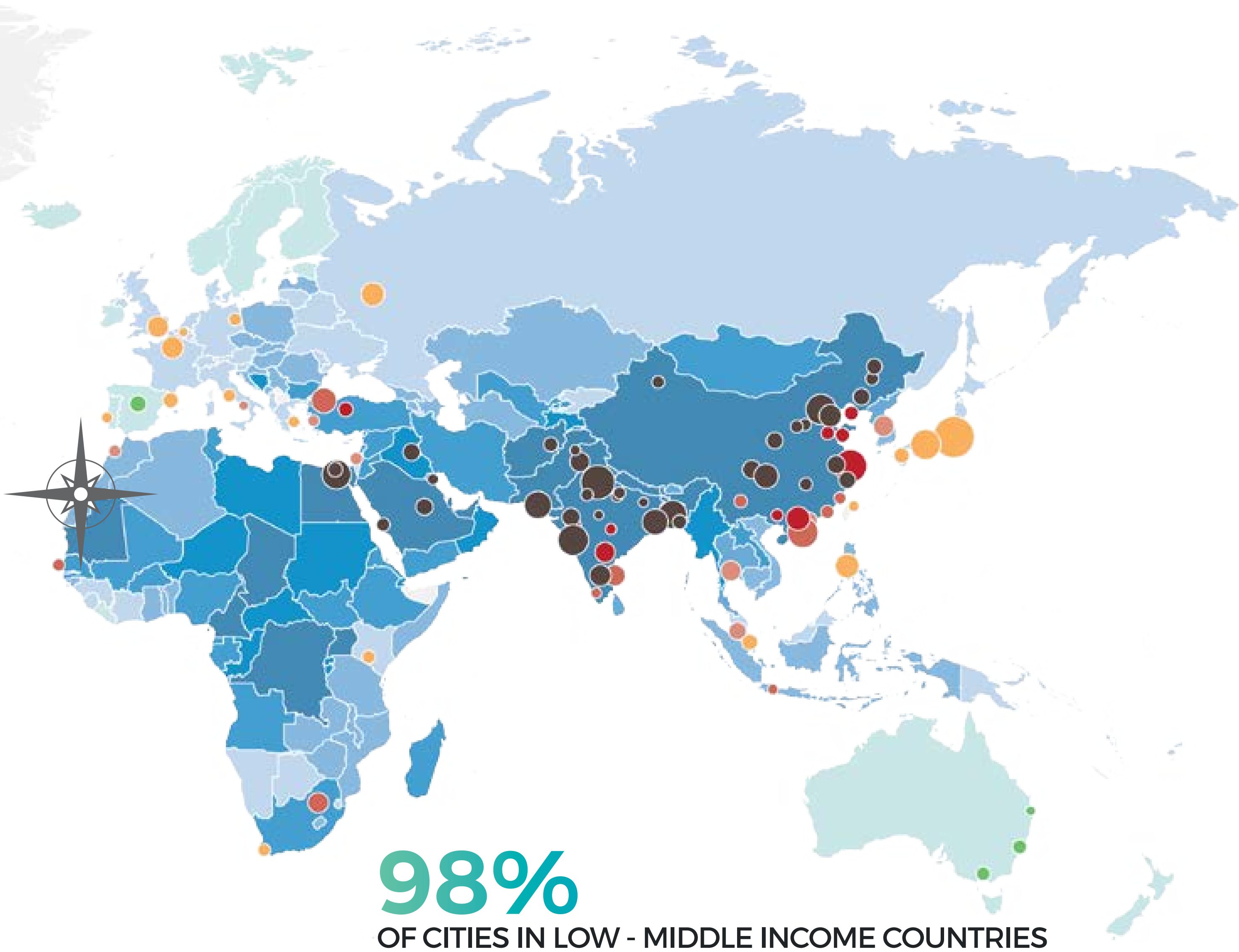
China is commonly understood to have some of the worst air pollution in the world. Less known however are the improvements in air pollution in China over the past few years since Chinese Premier Li Keqiang declared a 'war on pollution' in 2014.[19]

In 2015, Beijing experienced a 16% reduction from the previous year's concentration of deadly air pollutants, according to an analysis by the Paulson Institute and Greenpeace from data collected at the US Embassy. The data is slightly skewed given the gains were recorded during the summer and early fall, however 2015 still equated to being the cleanest year since the embassy began publishing data in 2008.[20] The improvements were mirrored by results from studies taken in other parts of the country that also indicated significant reductions in air pollution.[21]

How such significant reductions have been experienced in such a short period is testament to bold emissions reductions policies and rapid implementation. Whilst it is worth noting that China is spending as much as the US and Europe combined on clean power, its coal-fired power stations are state of the art and China is also now the largest wind power market in the world, having increased its renewable electricity share from practically zero ten years ago to over 25% today.[22]



Traffic in heavy smog on December 25, 2015 in the Guomao area of Beijing, China. More than 200 flights were cancelled at the Beijing International Airport due to excessive air pollution where levels of $PM_{2.5}$ exceeded 500 µg/m³ for the entire day.
Photo: © testing / Shutterstock.com



98%

OF CITIES IN LOW - MIDDLE INCOME COUNTRIES DO NOT MEET WORLD HEALTH ORGANIZATION AIR QUALITY GUIDELINES

hence of co-emitted pollutants such as black carbon over the next decades, until complete phase out is achieved early in the second-half of the century. Such measures would rapidly and substantially reduce risks associated with air pollution.

In the near term (up to 2030), there are also strong immediate and domestic economic incentives to undertake climate mitigation actions to limit global warming to 1.5°C.[24] The Climate Action Tracker (see Figure 4-2) showed that a large portion of the cost of stronger climate policies — such as the increase of renewable energy sources, urban transport policies focussing on public transportation, pedestrian and bike actions, the reduction of industrial smokestack emissions or the improvement of cooking stoves — will be offset by savings associated with reduced mortality.[25,26] The emissions gap between governments' current emissions reductions pledges and the 1.5°C temperature limit is approximately 23 $GtCO_2e$ by 2030. If health costs are accounted for, China, the EU, India, Japan and Russia could strengthen their currently pledged emissions reductions and jointly close this gap by 4.6-7.8 $GtCO_2e$, or 20-34%, without imposing any additional cost burdens on their economies. Similar dynamics between emissions controls and health and economic costs apply to a wide range of developed and developing countries. Climate action not only benefits the environment; by decreasing health costs from air pollution, increasing worker productivity and extending life expectancy, it is also a positive influence for economic development.

Figure 4-1 | Map based on Particulate Matter $PM_{2.5}$ derived from ambient air pollution data from the World Health Organization - WHO. Shading for the countries indicates the annual average level of $PM_{2.5}$ in all urban areas for that country. Circles represent individual cities with the size proportional to the population and the colour on average annual $PM_{2.5}$ levels. Statistics are from WHOs 2016 update to the database.

CLIMATE & AIR QUALITY

COSTS FOR CLOSING EMISSIONS GAP CAN BE LARGELY OFFSET BY AVOIDING ECONOMIC COSTS OF DEATHS BY AIR POLLUTION

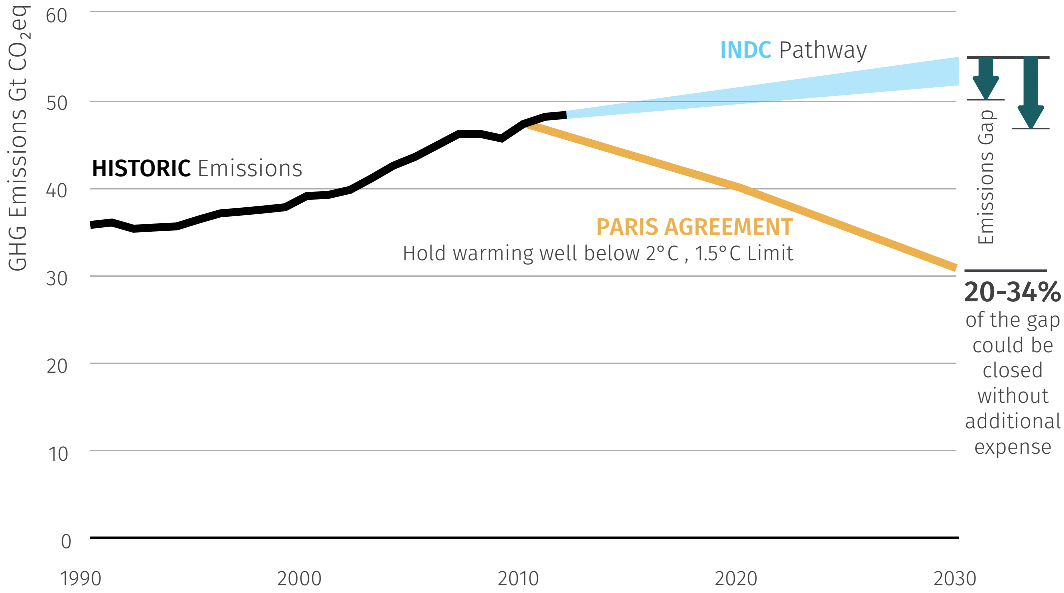


Figure 4-2 | Figure indicates the emissions gap in 2030 from current country climate pledges ((I)NDC Pathway) and a pathway compatible with achieving the Paris Agreement 1.5°C limit. This gap could be closed with policies that would also significantly improve air quality. The savings from health related damages could make closing 20-34% of this gap cost neutral.

EMISSIONS CONTROLS ALSO BENEFIT AGRICULTURE

Human activities leading to fossil fuel combustion release large quantities of environmentally harmful substances.[27] Sulphur and nitrogen oxides lead to pollution of fresh water and soils, threatening agriculture and biodiversity. Coal is a significant source of mercury and other toxic metals harming ecosystems. Ground level, or 'tropospheric' ozone is an air pollutant that is increasing, particularly in Asia. It significantly reduces crop yields and diminishes food security.[28] In India the annual cost of ozone pollution to agriculture has been estimated at around 3.5 million tonnes of foregone wheat production and 2.1 million tonnes of rice, which could have fed over 90 million people.[29]

Along with reductions in CO_2, global emissions reductions in line with 1.5°C, in particular replacing fossil fuel based systems with renewables, bring along reductions in co-emitted pollutants such as nitrous oxide. Similar to methane, such pollutants exacerbate tropospheric ozone, if unmitigated. A recent study[30] showed that over the next decades, strong climate action reduces such pollutants and avoids a negative effect on global crop production of over 5% by 2050, hence avoiding a substantial risk for food security, in addition to averting the direct detrimental effects of climate changes on agriculture, explained in chapter 2.

BOOSTING EMPLOYMENT THROUGH CLIMATE ACTION

Investing and harnessing domestic renewable energy potential promotes employment and also results in more highly skilled jobs in the energy sector. Preventing rapid global temperature increases also helps to avoid significant health risks for the global workforce and productivity losses for workers, businesses and economies.

KEY **MESSAGES**

- Global warming has already increased risks for the health of workers given the significant increases in the number of hot days and nights. These effects are particularly severe for tropical and sub-tropical developing countries where outdoor work is most prevalent and heat already regularly exceeds levels that can cause harm for human health.
- Extreme heat also has broader implications on productivity, economic output, and incomes. Those that will be most affected are employees working in non-climate controlled or air conditioned environments. Reducing warming would also lessen these effects, particularly for smallholder farmers in developing countries, in turn strengthening poverty reduction efforts.
- Detailed analysis has predicted the percentage work hours lost due to heat under current policies and is approximately halved when a 2.7°C warming level is achieved. Further reductions in global warming have similar impact: the difference between 2°C and 1.5°C to India's workplace heat impact is a reduction from a 6% loss to 4%, and in the Philippines it halves from 2% to 1%. Work hour losses do represent similar scale reductions in national GDP.
- Mitigation policies that achieve a low-warming scenario of 1.5°C, namely a transition away from fossil fuel based energy and transport systems, will help to mitigate the negative impacts to workers' health and workforce productivity.

Maintenance workers on the blades of a wind turbine
© Diyana Dimitrova

5 BOOSTING EMPLOYMENT THROUGH CLIMATE ACTION

Low-emission energy systems, such as renewables, have greater occupational intensities (more workers with higher skills are needed) than high emissions energy alternatives. Accelerated climate action therefore provides a new opportunity to promote employment growth through development of the clean energy sector. For example, employment in the energy sector estimated in this analysis shows a sharp increase in employment opportunities starting in 2030, following the shift in energy mix consistent with a 1.5°C and 2°C pathway. The transition to renewable energy from fossil fuels also provides safer and cleaner working conditions, and helps to reduce economic losses, most notably at the worker and family levels.

A lower global temperature increase also helps to reduce occupational health risks and improve productivity. Occupational health risks due to workplace heat were first mentioned in the IPCC 4[fox] Assessment Report (AR), and reiterated further in the 5[fox] AR. Rising temperatures have made extreme temperature conditions that are adverse to human health far more common. This not only affects workers' health, but also has strong implications on productivity, output, and incomes needed to maintain or increase welfare. The employees most affected by these concerns are those working in environments that are exposed to weather and heat, such as agriculture, construction, mining, and other activities, which are particularly prevalent in developing nations.

Limiting warming would reduce the ramifications of rising heat in the workplace and contributes to the Sustainable Development Goals (SDGs) for 2030, in particular with respect to eliminating poverty (SDG1), zero hunger (SDG2), health and well-being (SDG3), quality education (SDG4), gender equality (SDG5), decent work and economic growth (SDG8), reduced inequalities (SDG10), sustainable cities and communities (SDG11), and climate action (SDG13).[2]

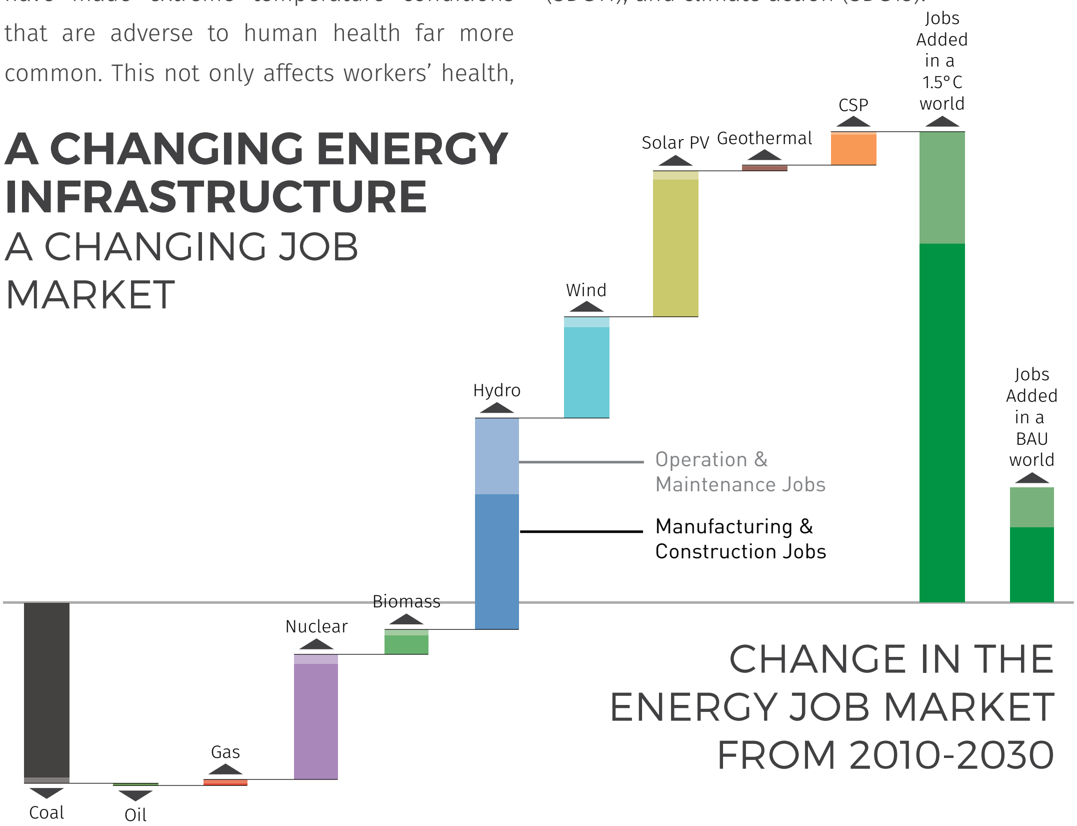


Figure 5-1 | The change in both operational and construction categories of jobs for the various technologies in the energy job market from 2010 to 2030 under the low warming scenario. This scenario combined change is also compared against the same time period under the business as usual (BAU) scenario as well as the total number of energy related jobs in 2030. Authors' calculations.

MORE RENEWABLE ENERGY MEANS MORE JOBS

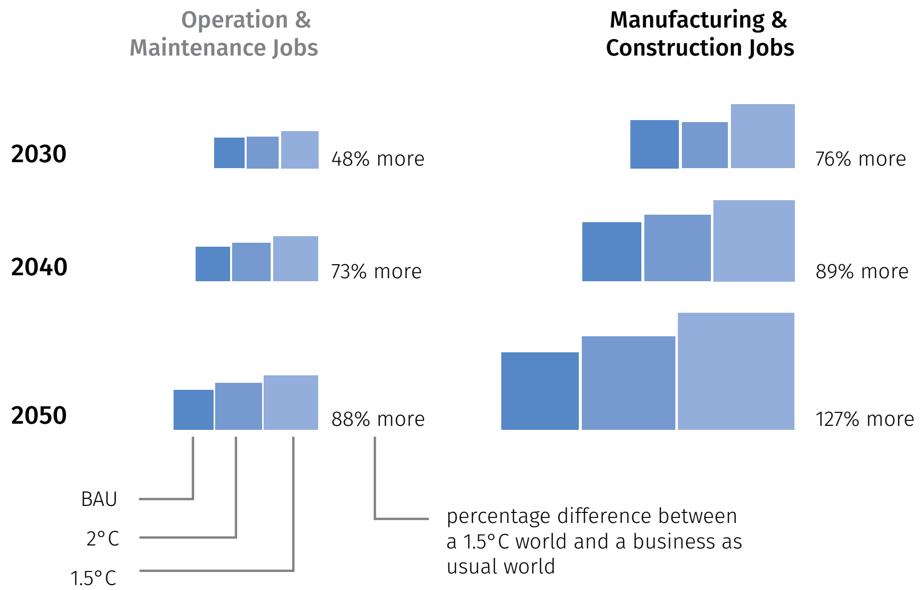
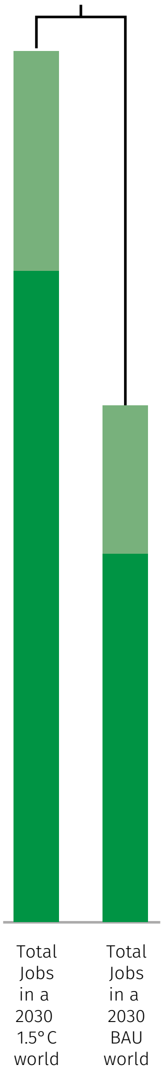


Figure 5-2 | Percentage difference between low-warming and business as usual (BAU) scenarios for various types of energy related jobs. Authors'calculations.

IN 2030 THERE WILL BE A TOTAL OF **68%** MORE ENERGY RELATED JOBS IN A 1.5°C WORLD COMPARED TO A BUSINESS AS USUAL WORLD



OPPORTUNITIES FOR EMPLOYMENT

Increased potential employment in cleaner technologies is a significant co-benefit of moving to a lower-emissions pathway. Moreover, these co-benefits are an incentive even for low-carbon emitting countries to foster growth of domestic low-carbon technology investment. This is because the expansion of the renewable energy sector directly influences the volume and the quality of jobs created. Jobs related to renewable energy production generally have less hazardous working conditions and require higher skills than the traditional energy sector. Some solar energy technology, for instance, can be produced locally, therefore maximising the use of available labour supply, as well as the potential to include vulnerable groups in the labour market, such as women and youth, through targeted training.[3] Indirect benefits of lower dependency on fossil fuels also include the avoidance of adverse effects of global oil price shocks, which have caused economic instability and inflationary pressures, leading to current account imbalances but also to higher rates of unemployment (see also chapters 4 and 7).[4]

An estimation of potential direct employment from different energy transformations consistent with 1.5°C, 2°C, and baseline warming scenarios by 2100 is computed from the employment multipliers of Rutovitz & Harris (2012), energy output and installed capacity

PHILIPPINES
100,000 NEW JOBS

Since the passing of the Climate Change Act of 2009, the Philippines has been working to mainstream climate resilience in its national and sectoral plans. The Renewable Energy Act of 2008 put the country on the path to increased use of renewable energies, with its target of raising the renewable energy capacity from the current level of around 5 gigawatts (GW), to 15 GW by 2030.

These commitments demonstrate the country's impressive progress and ambition, and already the share of renewable energies in its electricity sector (29%) surpasses those of neighbouring countries and the European Union. As of April 2016, more than 1,000 MW of renewable energy projects had been completed under the Feed-in Tariff System (FIT) of the Renewable Energy Act. Almost all of the 1,000 MW installed renewable energy capacities have been completed within the last two-and-a-half years. In addition to installations under the FIT, approximately 2,500 kW have been installed under the net metering mechanism. The construction and subsequent operations of the renewable energy plants has created approximately 100,000 jobs, according to conservative estimates.[5,6,7,8]

derived from the IIASA MESSAGE Model and the International Energy Agency's World Energy Investment Outlook.[9]

Projections from the MESSAGE model show that energy policies consistent with low warming scenarios have lower primary energy production, but higher electricity generation, thereby achieving higher conversion efficiency (see Appendix). More electricity generated through renewables allows for a wider coverage of access within countries, and supports economic growth and poverty reduction targets.

Corresponding to the increase in electricity generated, estimates show a major increase in employment growth starting from 2030 onwards between the warming scenarios. Prior to 2030, the employment benefits of different scenarios are less pronounced. Nevertheless, for the years leading to 2030, Figure 5-2 shows that employment manufacturing, construction, and installation (MCI) activities and operations and maintenance (OM) activities in the 1.5°C scenario reaches up to 76% and 48% more than the baseline scenario, respectively. The increase in the 1.5°C scenario, compared to 2°C and baseline, will be driven by the construction of facilities for nuclear, hydro, wind, and solar energy that more than offset the reduction in construction of new coal and gas plants. Similarly, the increase in facilities also increases the opportunities for regional employment for operations and maintenance activities, particularly for wind onshore in Sub-Saharan Africa and the Middle East and Northern Africa, solar PV in Latin America and the Caribbean, geothermal energy in the OECD and Central and Eastern Europe and Eurasia, and CSP in the OECD.[10]

Employment factors from Rutovitz & Harris (2012) show that oil and gas have the lowest job/MW required, while Nuclear, Biomass, and Hydro power have the highest.

LOWER WARMING PATHWAYS REDUCE OCCUPATIONAL HEALTH RISKS

The rapid increase in global temperatures caused by climate change is adding significant stress to working conditions that reduce work capacity and labour productivity in two ways. First, climate-related disasters, such as storm surges, floods, landslides, droughts and forest fires, cause deaths and permanent injuries, including mental health effects, which incapacitate individuals from performing productive tasks.[11] This is not to mention the time needed for local and national recovery and rebuilding before work can resume. Second, changes in temperatures beyond levels of acclimatisation reduce productivity, which impacts potential income and overall welfare.

Natural protection to heat includes taking more breaks or limiting hours of work, and are, therefore, often associated with lower productivity levels and output. For most vulnerable populations with employment income is output-based, this means lower pay, more limited spending capacity, and higher risk of falling into poverty.

Previous studies show that there is a window of temperature variations – between 21°C and 25°C – that does not significantly affect productivity; but once temperature reaches 26°C and beyond, work speed sharply decreases. A linear relation done by Seppänen, Fisk, & Faulkner (2006) shows a 2% productivity loss for every degree of temperature increment above 25°C. In the study of Sahu, Sett, & Kjellstrom (2013), the estimated hourly labour productivity is reduced by a third when heat increases from 26°C to 31°C. Kjellstrom, Kovats, Lloyd, Holt, & Tol (2009) estimate more than 2% of work hours lost in 10 regions in Asia, Africa and Latin America by 2030, and the worst affected regions to be South Asia and West Africa. Temperatures above 35°C experienced in the workplace cause occupational health risks such as heat exhaustion that, in turn, cause workers to perform slower, incur more errors, and increase the risk of accidental injuries.[12] The risk is, therefore, higher for sectors in the economy where heat is poorly controlled, such as in agriculture, construction, other industrial work, and services that require high levels of physical exertion.[13] In order to avoid dangerous health risks, the body needs to maintain a core temperature of 37°C.[14]

An increase in thermal conditions directly affecting the working environment that is not remedied by adaptation measures (for example, establishing worker rehydration regimes, infrastructure that protects workers from direct heat, building insulation and air conditioning) can lead to more serious health problems such as heat stroke, chronic kidney disease, cardiovascular diseases, and even death. Acclimatisation requires weeks to develop, meaning increasing temperature extremes make adaptation to higher heat levels unmanageable, leading to losses and damages.[15,16,17,18] Such limitations suggest that emissions controls and mitigation action is vital to preventing occupational risks linked to increasing temperatures going far beyond adaptive capacities.

Because of differences in temperature regimes, warming and workplace exposure vary greatly across the world, and the rate of possible losses is increasing. Compared to 1995, the estimated productivity loss will double by 2025. The largest potential annual daylight work hours lost for work in 2025 is expected to be experienced in Asia and the Pacific region, as well as West Africa. This would particularly affect countries such as Pakistan (5.22%), Cambodia (4.24%), and India (3.61%) in Asia; and Burkina Faso (3.56%) in Africa. The losses could be twice as high for very intensive physical work (400W). These losses take a toll on both the worker in terms of income from reduced output per period of time, or a reduced leisure or family time for increasing work hours to meet the same amount of output; as well as for the employer, whose total output delivered is reduced due to hotter conditions.[19] In terms of economic effects, the greatest losses impact the agriculture sector. For the past 10 years in the Climate Vulnerable Forum member countries, an average of 40.3% of total employment has been engaged in the

India: A Calcutta man attempts to cool off during a heatwave where temperatures touch 39°C on June 10, 2015. Photo: © Saikat Paul / Shutterstock.com

agriculture sector. [20] These direct economic consequences have significant implications on development and the achievement of poverty reduction targets.

Detailed analysis shows the percentage work hours lost due to heat for a 'business as usual' scenario would be approximately halved when a 2.7°C warming level is achieved (this would mean approximately halving the values presented in Table 5-1 below). On a regional level, the same study observes that as the global average temperature increases from 1.5°C to 4°C, different regions will experience an increased likelihood of health and productivity problems. South America, northern India and parts of South East Asia will move from 5-15% likelihood of health and productivity problems to 20-40% (and even greater in some countries).

Importantly, there are also significant differences between the impacts of 2°C and 1.5°C scenarios. For example, India's workplace heat impact for a 2°C and 1.5°C scenario are 6% and 4% respectively, and in the Philippines, it halves from 2% to 1%. [21]

Table 5-1 | Losses of labour productivity as a percentage of annual daylight hours for various countries. Based on a business as usual scenario from modelling consistent with national mitigation policies presented at COP21 (RCP6.0) and work conducted in the shade at a moderate work intensity (300W). Source: Climate Change and Labour: Impacts of heat in the workplace (UNDP et al, 2016).

COUNTRY	WORKING AGE POPULATION	PERCENTAGE LOSS IN WORKING HOURS		
Asia and the Pacific	**Million People (2015)**	**1995**	**2025**	**2055**
Bangladesh	98.65	1.06	2.53	4.61
Cambodia	9.51	1.82	4.24	6.54
China	892.11	0.32	0.68	1.12
India	817.16	2.04	3.61	5.22
Indonesia	164.23	0.33	1.23	2.56
Kiribati	0.06	0.59	1.95	4.31
Maldives	0.12	0.42	1.90	4.52
Nepal	19.7	0.61	1.27	1.98
Pakistan	109.88	3.73	5.22	7.00
Philippines	61.92	0.32	1.03	2.07
Vietnam	60.55	0.80	2.08	3.44
Africa	**Million People (2015)**	**1995**	**2025**	**2055**
Burkina Faso	10.25	1.90	3.56	5.59
Ehtiopia	51.55	0.14	0.28	0.43
Ghana	17.34	0.64	1.71	3.49
Kenya	29.57	0.05	0.17	0.32
Morocco	21.02	0.01	0.04	0.08
Nigeria	109.4	0.96	2.18	3.86
Tanzania	33.57	0.04	0.15	0.35
Tunisia	6.89	0.29	0.69	1.14
Americas	**Million People (2015)**	**1995**	**2025**	**2055**
Barbados	0.18	0.05	0.34	0.78
Colombia	30.48	0.21	0.63	1.22
Costa Rica	3.14	0.28	0.65	1.19
Honduras	5.3	0.07	0.32	0.67
Mexico	74.94	0.33	0.69	1.15
USA	208.12	0.15	0.43	0.73
Europe	**Million People (2015)**	**1995**	**2025**	**2055**
France	40.56	0.00	0.00	0.01
Germany	52.17	0.00	0.00	0.00
Greece	7.38	0.00	0.02	0.06
Spain	30.69	0.01	0.04	0.08
Switzerland	3.56	0.00	0.00	0.00

STRENGTHENING ENERGY SECURITY & INDEPENDENCE

Limiting warming to 1.5°C prompts early and accelerated adoption of low-emission forms of energy. Renewable energy in particular presents significant advantages for securing stable, reliable and local sources of power. While most nations are rich in resources for renewable energy – such as solar and wind – few possess fossil fuels in the same quantities. Therefore, nations reliant on fossil fuels are dependent on the economic and political dynamics of trade partners and global market forces. If such countries instead realised their full renewable energy potential, they would become increasingly energy independent and secure.

KEY **MESSAGES**

- For some countries, more than two thirds of domestic energy consumption are fulfilled using imports, including Japan, Turkey, Italy, Spain and Morocco. With growing populations and income levels, developing countries would likely follow similar development pathways without policies that encourage investment in domestic renewable energy production.
- However, countries are increasingly utilising domestic renewable energy sources as nations move towards becoming energy independent; the current relationship between fossil fuel producers and consumers is collapsing.
- Most developing economies have rising populations with growing income. They face the challenge of building up energy systems capable of meeting rapidly increasing energy demands. This requires investments in new energy infrastructure, and it is crucial that this infrastructure is built in line with the 1.5°C limit to avoid stranding assets.
- Renewable energy sources, notably solar and wind are abundant worldwide and currently retain much more potential than fossils. Renewable energy has become increasingly more attractive, as prices dropped sharply over the last decade. The renewable energy potential of developing countries such as the members of the Climate Vulnerable Forum is extremely high. Low-carbon transformation and shifting towards renewable energy sources represent an opportunity, rather than a challenge.
- Compared to current levels of energy demand, an oversupply of renewable energy sources is available in most countries.

Men installing panels at a solar farm near Nha Kok, Samut Sakhon, Thailand in August 2015
© jShep / Shutterstock.com

6 STRENGTHENING ENERGY SECURITY & INDEPENDENCE

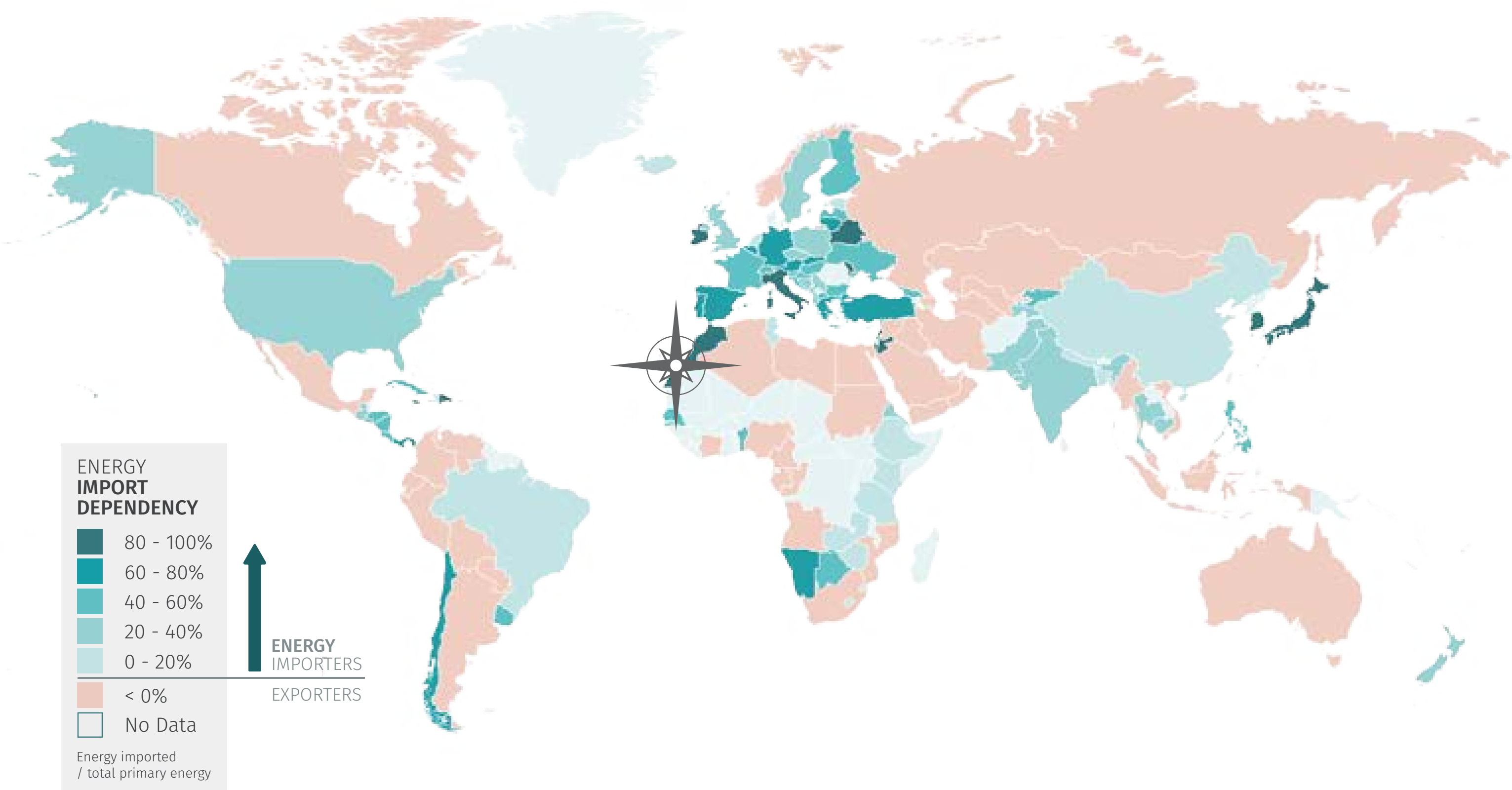
Energy security is defined as the "uninterrupted availability of energy sources at an affordable price".[1] If a country's own supply of primary energy carriers such as coal, oil or gas are not sufficient to fulfil demand, it has to import these. Securing energy through international trade carries a number of implications for the domestic economies of energy importing countries:

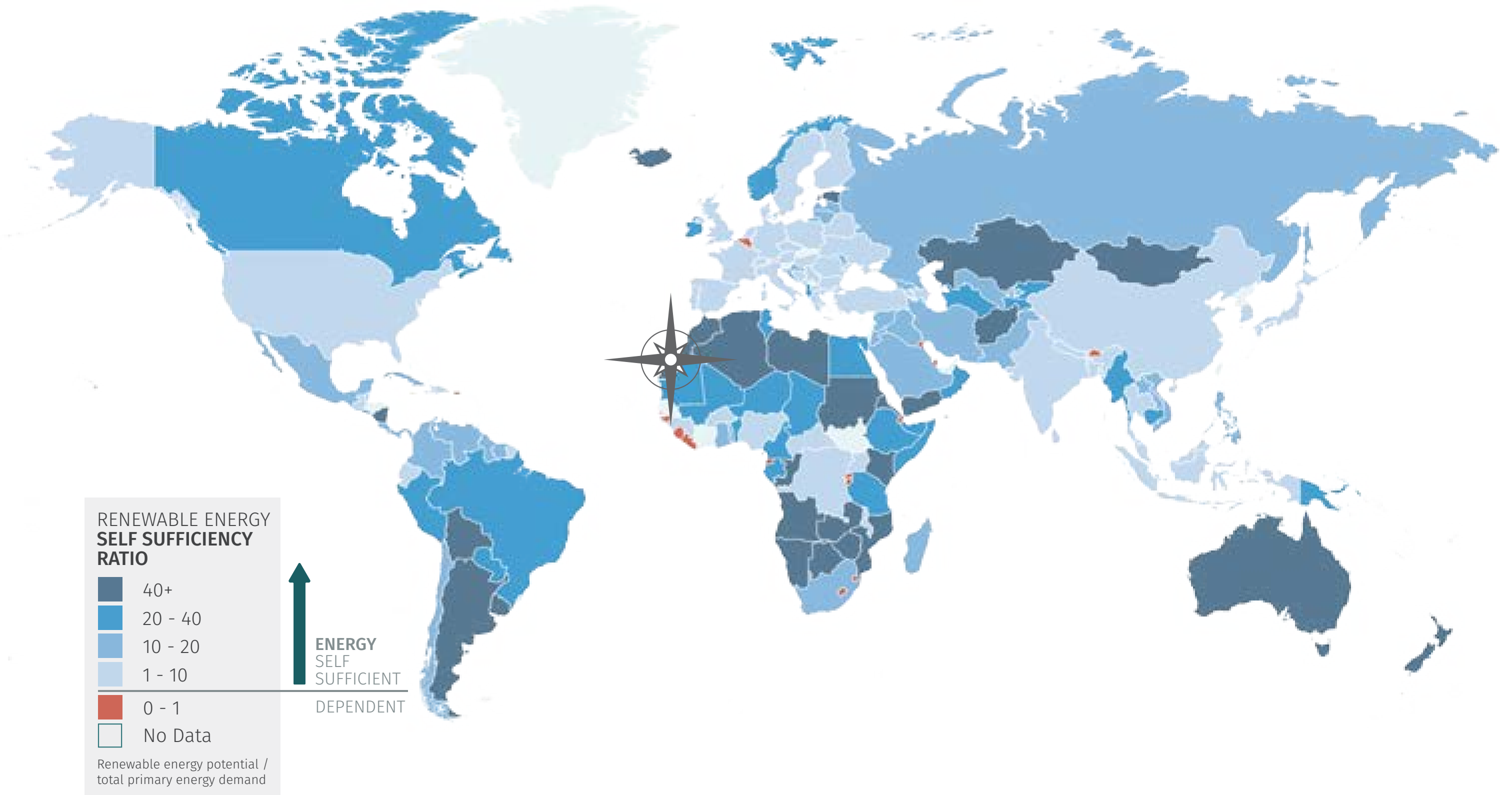
- **Money outflows to foreign economies.** When energy is procured from international markets, rather than through domestic production, income generated inside the country flows to other economies, rather than being reinvested domestically.

- **Fossil fuels are traded in global markets that are dominated by a small number of producers and are subject to demand fluctuations in major economies**. Oil and gas – and to a lesser extent coal – are concentrated in only a handful of countries. The OPEC countries hold 75% of global proven oil reserves and 56% of gas reserves are located in Russia, Iran and Qatar.[2] In this way, global energy markets and prices for fossil fuels are shaped by the production trends of a few countries. On the consumer side, domestic policy and economic cycles in major economies directly affect market prices globally; surging demand in large countries such as the USA or China can drive up global prices and have negative implications for low-income countries. Among the seriously affected during oil price spikes are the Commonwealth Independent States (CIS) and Heavily Indebted Poor Countries (HIPC), of which, 30 of 40 are net oil importers.[3] Conversely, a slump in oil prices has recently led oil-exporting countries such as Saudi Arabia, Russia, Iran and Kuwait to explore alternative sources such as wind and solar power for domestic electricity supply.[4]

- **Dependence on energy imports increases vulnerability to external influence**. If a coun-

Figure 6-1 | Map showing the level of energy import dependency, based on the share of energy that is imported compared to total primary energy consumption (2010 values). Countries shaded in red are energy exporters and have values less that 0%. Source: WDI (2015), authors' calculations.





try needs to import a substantial portion of its energy, trade partners can strategically influence the flow of energy, especially when an energy importer is strongly dependent on a single energy exporter that exports to several other countries. The Ukraine and Lithuania demonstrate this dynamic, as both are dependent on oil and gas from Russia and pay political rather than market prices for their imports.[5]

Figure 6-1 demonstrates the share of energy that is imported by country. Many large countries with low population densities such as Russia, Canada, Australia and the countries of North Africa and the Middle East export more energy than they use themselves. However, many others, including those with large populations (China, India, Europe and Eastern Africa) are importing large quantities of energy. For some countries, more than two thirds of domestic energy consumption are fulfilled using imports, including Japan, Turkey, Italy, Spain and Morocco. With growing populations and income levels, developing countries are likely to follow similar development pathways without policies that encourage investment in domestic renewable energy production.

INVESTING IN ENERGY PRODUCTION CONSISTENT WITH A 1.5°C WORLD ALSO ACHIEVE ENERGY INDEPENDENCE

Limiting global warming to 1.5°C requires greater emissions cuts and a swifter departure from the world's reliance on fossil fuel energy than for higher global warming targets. The 1.5°C compliant scenario, for instance, indicates the need for emissions from coal to be phased out[6] globally in the 2030s[7] and from oil by 2050, with clean energy sources dominating the energy mix by 2050.[8]

Renewable energy sources, notably solar and wind, are vastly abundant worldwide (see Figure 6-2) and remain far from being exploited to their full potential. Renewable energy has become increasingly more attractive, as prices dropped sharply over the last decade[9]. As countries exploit more of their domestic renewable energy sources they will begin to rebalance the globalised nature of energy supplies and strengthen energy independence.

Figure 6-2 | Potential renewable energy self-sufficiency index. This is calculated as the ratio of total renewable energy potential (solar, wind and hydro power) over present day primary energy demand. A value greater than 1 (blue shading) indicates that a nation can fulfill its present (2012 data) primary energy demand from domestic renewables sources potential and a value smaller than 1 (red shading) indicates that a nation cannot fulfill its present primary energy demand from domestic renewables sources potential.

RENEWABLE POTENTIAL

RENEWABLE ENERGY POTENTIAL AGAINST HISTORIC ENERGY DEMAND

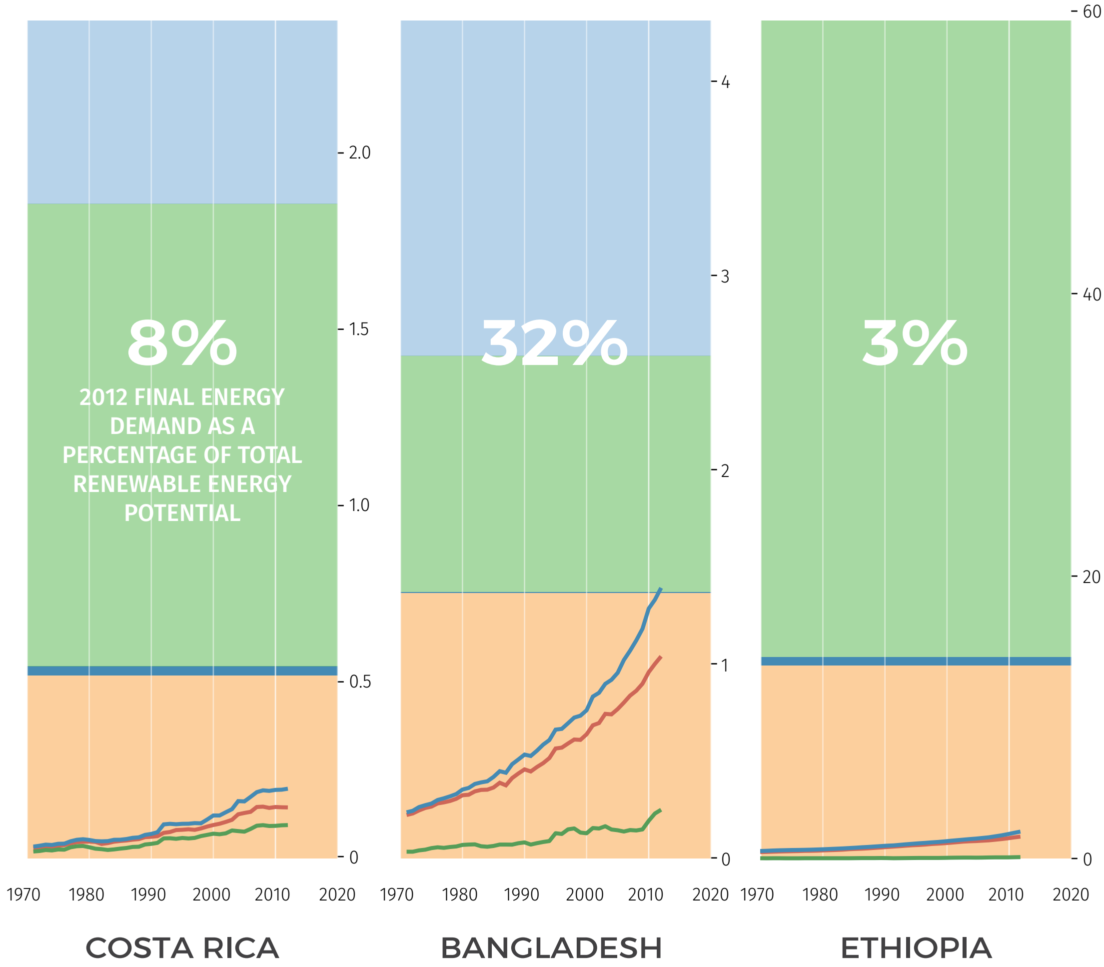


Figure 6-3 | Potential for renewables to provide energy self-sufficiency. The shaded background area corresponds to the potential of wind, solar and hydro (note hydro potential is often relatively small and thus appears more as a narrow horizontal blue line). The red, blue and green lines correspond to historical figures for primary energy demand, final energy demand and net imports respectively. All countries shown have the potential to be net energy positive through renewable energy. Based on data from NREL.

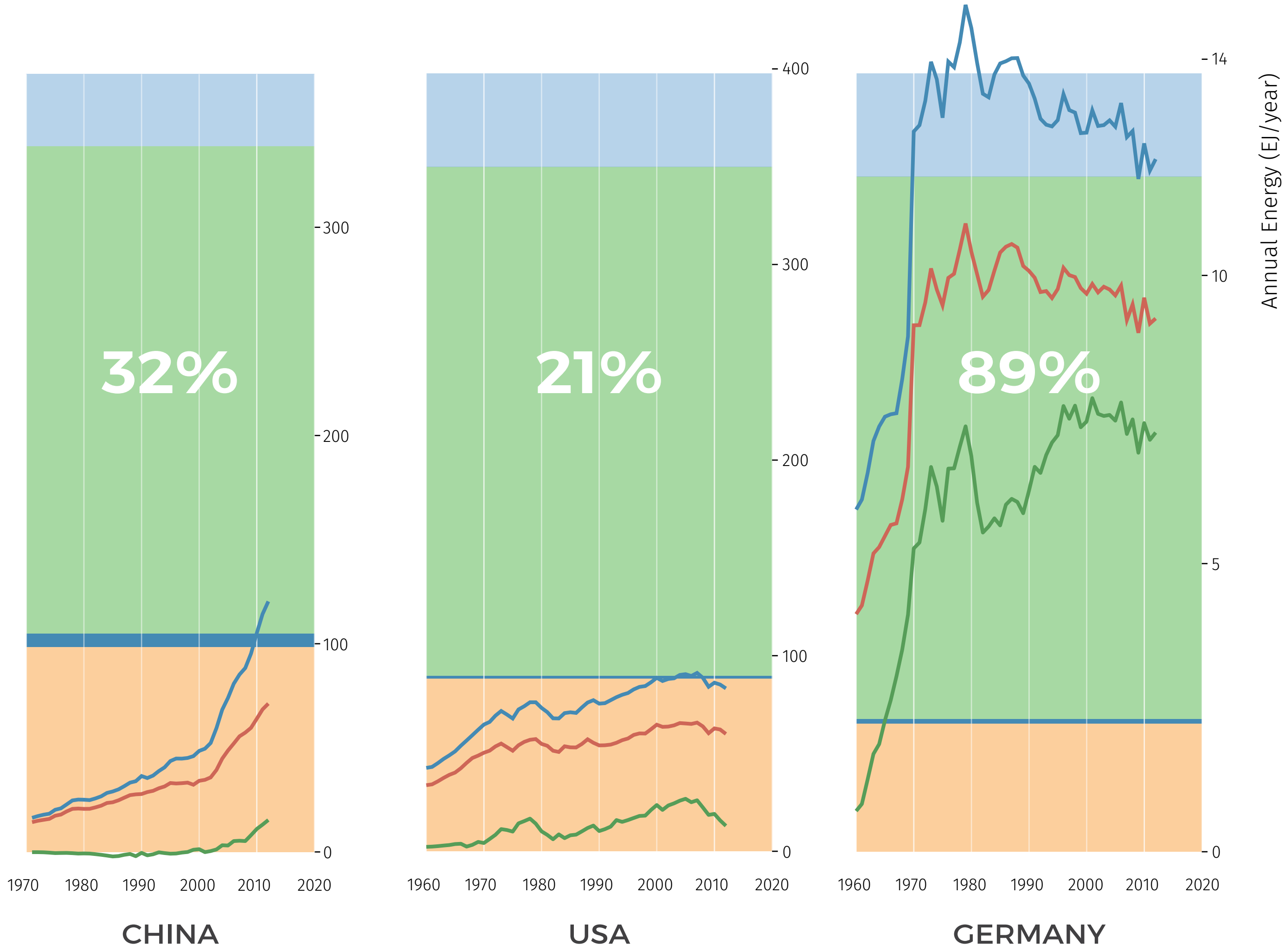
EXPLOITING RENEWABLE ENERGY SOURCES IS OF PARTICULAR INTEREST FOR DEVELOPING COUNTRIES

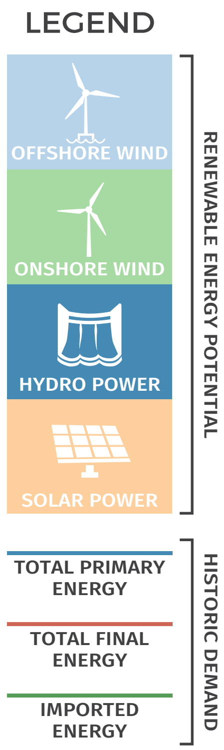
Most developing economies have rising populations with growing income. They face the challenge of building up energy systems capable of meeting rapidly increasing energy demands. This requires investments in new energy infrastructure, and it is crucial that this infrastructure is built in line with the 1.5°C limit to avoid stranding assets.

While for some countries a low-carbon transformation and shifting towards renewable energy sources may represent a challenge, for the majority of countries this represents an opportunity. Figure 6-3 compares yearly renewable energy potentials for solar, wind and hydro energy with historical and current energy demand levels for some developing (Bangladesh, Ethiopia and Costa Rica – upper panel) and some industrialised (USA, Germany, China – lower panel) countries.

Global renewable energy potential is extremely high. The yearly renewable potential identified for most developing countries would be largely sufficient to not only sustain current levels of energy demand (both primary and final),[10] but also far higher levels of energy consumption. For example, final energy demand in Bangladesh could more than triple and the country would still remain entirely energy self-sufficient. This is despite not assuming improvements in energy efficiency on both energy supply and demand that are usually a by-product of a more renewable based energy system. The renewable potentials in Ethiopia and Costa Rica are even greater.

While this is a common picture among developing nations, this pattern is also common among industrialised countries. For example, renewables potential is far greater than primary and final energy demand in the USA and in China, even if demand would rise strongly for several decades – which is unlikely, given the stagnating population and the cap on coal use in China. In Germany, access to renewable energy supply





may be limited, however this country also has a stagnating population and has been successful in decoupling its economic growth from energy demand, so the demand is not expected to grow from current levels.

WHAT IS THE RENEWABLE POTENTIAL WORLDWIDE?

For a general picture of global renewable energy potential, Figure 6-2 compares present day primary energy demand levels with annual renewables potential within individual countries, by calculating the ratio between these two values. The assessment does not account for the potential from sustainable bio-energy production, which could be very significant for large countries with low population densities and abundant arable land, such as Russia, Canada, Brazil or Argentina. For a few smaller and/or densely populated countries coloured in red, current primary energy demand surpasses their yearly renewable potential (ratio below 1). This indicates that these countries may face difficulties in fulfilling their present day and future energy demand from domestic renewable sources. Darker shades of green indicate a higher ration of renewables potential over present day demand. For some of these countries – coloured in light green, which indicates a ration of between one and ten, large growth in energy demand in the future could potentially mean that they could not rely solely on their own renewable energy potential. However, **for the vast majority of countries in the world, the potential for renewable energy surpasses present day energy demand by more than ten-fold,** which could mean that they would have no need for further investment into fossil fuels.

This potential oversupply of renewable energy sources is a fact for most countries in the world. No large country is in a situation of renewable energy scarcity, while the few renewable energy insecure countries are characterised by a relatively diminutive territorial extent versus population. Many of these countries are not wealthy in fossil energy supplies either and could procure power from renewable abundant neighbouring countries.

MOROCCO
SHIFTING DIRECTION

Morocco is one of the most energy dependent countries in the world, with over 91% of energy coming from abroad.[11] Rapid electrification and the increasing standard of life will further increase energy demand. Most notably, electricity consumption is projected to grow at around 5-7% per year during the period 2020-2030.[12] Should heavy reliance on fossil fuels continue, Morocco would spend an increasing share of its GDP on energy imports thus restraining the country's potential for economic growth.

To limit this burden, Morocco is currently positioning itself to develop its plentiful domestic energy sources. Whilst some of these include recently discovered fossil fuel energy reserves, the state's embrace of solar and wind has become a pillar of the country's energy policy, and has also seen Morocco become a regional leader in renewable energy development.[13]

The government has facilitated the investment of USD $13 billion for the rapid expansion of wind, solar and hydroelectric power generation capacity. This significant investment has been backed by the creation of a series of new energy policies and regulations and a commitment to achieve a very ambitious target of 42% of the country's electricity generation capacity to be provided by renewable energy sources by 2020.[14] Morocco's ultimate goal of 52% of installed capacity to come from wind, solar and hydro sources by 2030 places it substantially ahead of its regional peers in its share of renewable capacity - even higher than many European nations.

Morocco has already made progress towards this target. In 2015, the country ranked 3rd in investment in renewable power and fuels per unit of GDP and 1st in terms of investment in Concentrated Solar Thermal Power (CSP) (REN21). With plans to expand its Noor CSP plant to 350 MW by 2018, Morocco will also be home to the second largest CSP complex in the world. To reduce Morocco's dependency on fossil fuels in the transport sector the government decided to significantly reduce subsidies on diesel fuel in late 2013 and early 2014.[15] With 17% of the country's investment budget financing energy subsidies, this measure helps to increase energy independence and free up resources for other public expenditure priorities. Butane subsidies could also be phased out to reduce energy dependency and GHG emissions.[16]

Rows of 150 metre long curved parabolic trough solar mirrors being cleaned at The Ain Beni Mathar ISCC Integrated Thermo Solar Combined Cycle Power Plant. The facility was commissioned in 2011 and is located near Ain Bni Mathar within Jerada Province in north-eastern Morocco. Photo: © Dana Smillie / World Bank

IMPROVING BALANCE OF PAYMENTS & PRICE STABILITY

Because of the price volatility of fossil fuels and the economic impact of rapid price changes linked to such volatility, countries have increasing incentives to take advantage of renewable energy to ensure smooth and reliable long-term growth. Accelerating the addition and proportion of renewable energy capacity in the national energy mix of most countries when striving to contribute to limiting warming to 1.5°C will therefore strengthen economic resilience.

KEY **MESSAGES**

- Fossil fuel prices are unpredictable, presenting uncertainties for investors. Price volatility, as well as the scale and magnitude of the required import costs, impose significant burden on economies around the world. The current large scale of reliance and investments in fossil fuels lead to additional and unnecessary costs.
- Expanding renewable energy infrastructure makes economies more resilient against international price volatility, especially in oil and gas, while oil-exporting countries can also benefit from diversification.
- In Climate Vulnerable Forum countries, energy represents 5%-35% of total imports expenditure, depending on varying country-specific reliance on fossil fuels and status of international energy prices.

Electric car being charged
© Matej Kastelic

7 IMPROVING BALANCE OF PAYMENTS & PRICE STABILITY

The prices of fossil fuels, and oil in particular, have proven to be increasingly volatile in recent years.[1] The volatility of the price of oil has either led to economic crises, or made existing economic crises more severe. This volatility has had serious impacts on the economies of developing countries, particularly those relying substantially on oil imports.

This chapter discusses the current over-reliance of many economies on fossil fuels and looks at the risks experienced by fossil fuel importers and exporters. It also discusses the benefits in investing in renewable energy sources.

THE FOSSIL FUEL BURDEN

Current economies are heavily reliant on fossil fuels. To enhance energy access, governments often subsidise conventional sources of energy (such as gasoline, kerosene etc.) for consumers, which increases this reliance and diverts significant portions of public budgets. Reducing the dependency on fossil fuels among countries spending a large share of their GDP on energy imports decreases the potential impact of such volatility on economies. Oil-exporting countries can benefit from decarbonisation by diversifying their economy whilst promoting sustainable economic growth, which is explained in more detail below.

Figure 7-1 | Percentage of fuel Imports compared to total imports vs Oil prices. Colored lines refer to fuel imports, as percentage of total imports (authors' calculations based on WDI 2015). Blue patch depicts historical oil prices (in 2011USD/ Barrel).

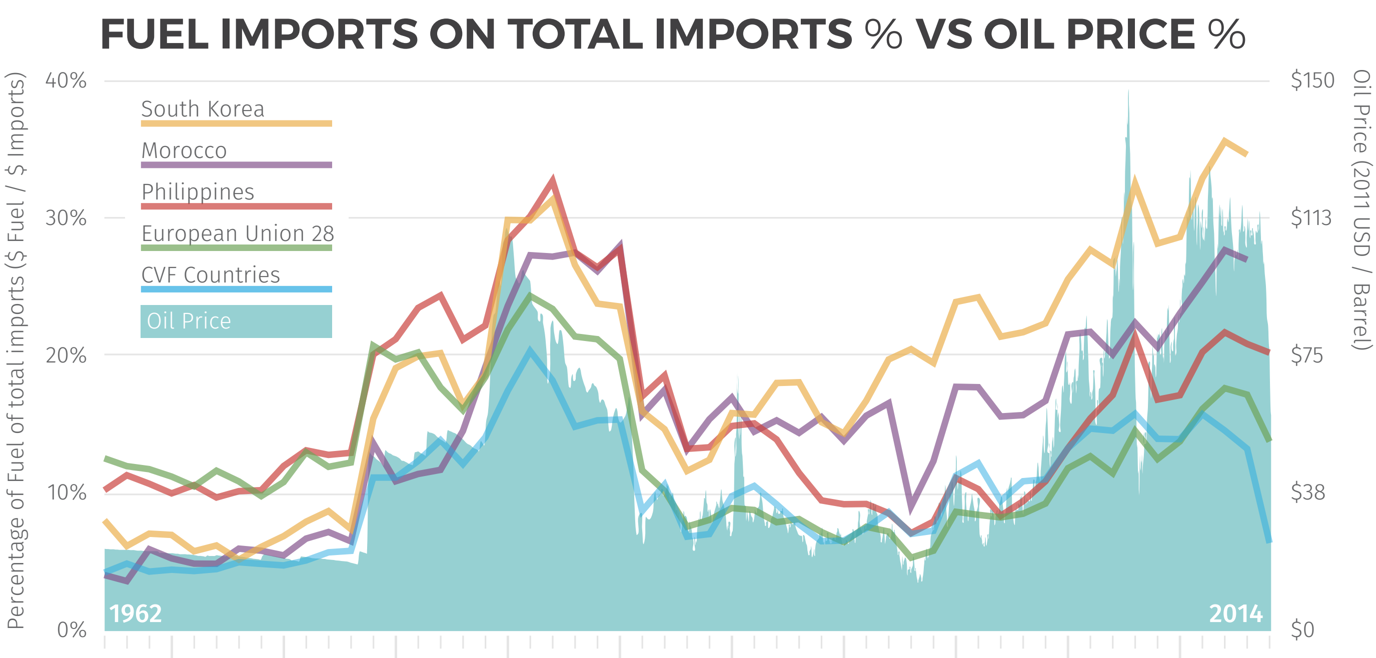


Figure 7-2 | History of oil prices from 1946 to 2016 with annotations of major price movements

OIL DEPENDENCE % OF GDP

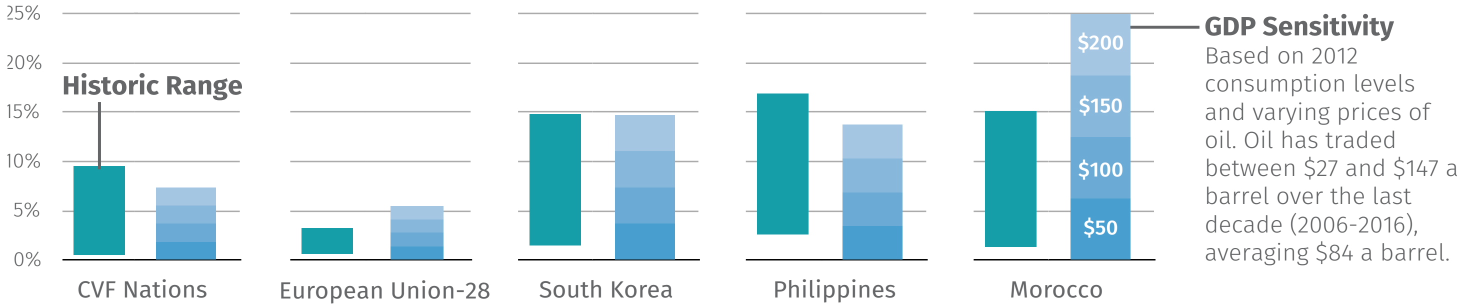


Figure 7-3 | Oil import Expenditures, as percentage of current GDP (2014 data and historical range)

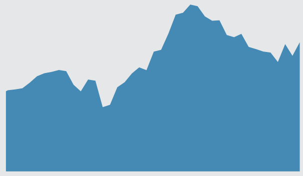
In the global oil market, both oil supply and demand are not sensitive to changes in oil price in the short term. This is particularly clear in countries where oil is subsidised. Large changes in the oil price cause only small variations in consumption. As a result, possible unbalances between supply and demand might lead to large swing in the oil prices and therefore high volatility. Other factors such as market fundamentals and speculation also contribute to high volatility[2]. Higher oil prices will generally lead to increased rates of inflation, affecting both economic growth and unemployment.[3]

In developed countries such as Ireland, energy expenditures accounts for around 5% of the GDP.[4] This burden is higher for many developing countries. In Climate Vulnerable Forum countries, energy represents 5%-35% (own analysis, Figure 7-1) of total imports expenditure, depending on varying country-specific reliance on fossil fuels and status of international energy prices. During historical periods of high oil prices, for example when the oil price increased rapidly

PRICE DYNAMICS IN THE PHILIPPINES

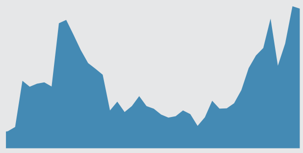
OIL IMPORTS BARRELS

Oil demand has historically been linked to the size of the economy and the policies it pursues, particulary in the transport sector.



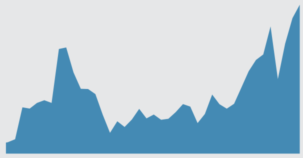
OIL PRICE $ / BARREL

The cost of oil is determined by the world market and is largely out of the hands of national governments.



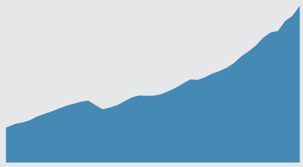
OIL IMPORT COSTS $

The combination of these two factors determines the flows of money out of the country and demand reduction can be difficult in the short term.



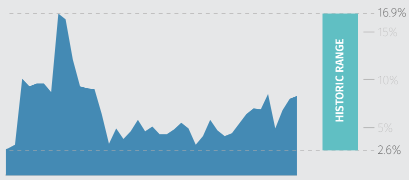
ECONOMY $GDP

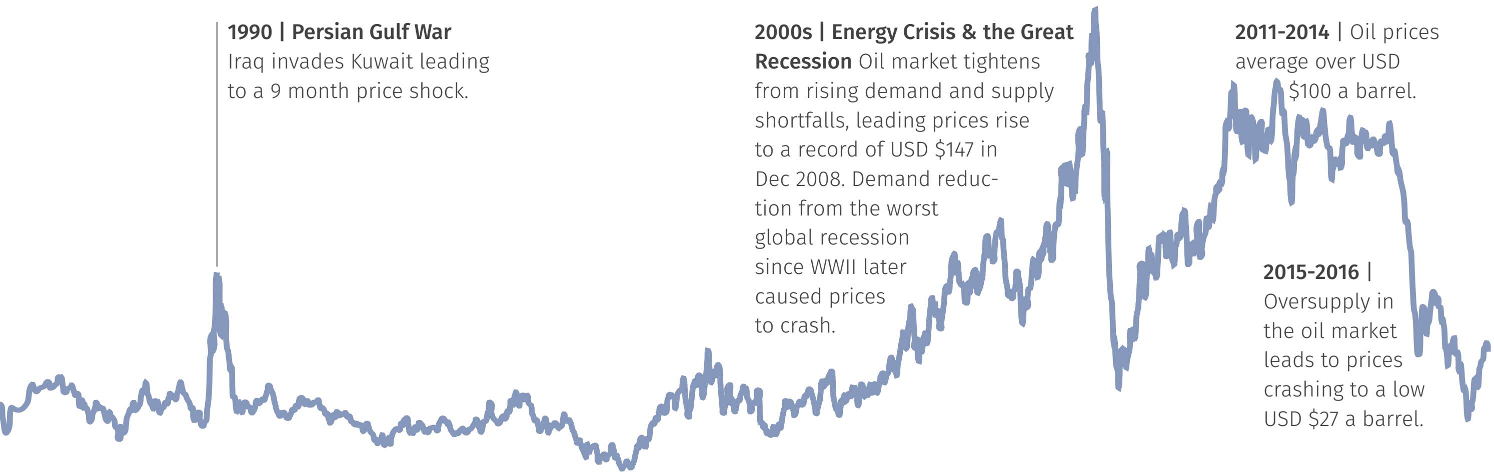
As oil is embedded in so much of economic activity, high oil prices lead to inflation and higher overall costs for consumers.



OIL DEPENDENCE $OIL / $GDP

High levels of oil dependence is an economic risk that can cripple economies when prices rise. A sweet spot in price can foster energy efficiency.





as it did between 2004 and 2007, Morocco spent almost 15% of GDP on energy imports (Figure 7-3), three times higher than in low price periods.

Energy represents a large share of total merchandised imports (Figure 7-1). During the oil crisis in the early 80s and the subsequent spike in the energy prices, energy accounted for more that 20-30% of total imports in many Climate Vulnerable Forum countries. This share flattened during the 90s, when the price of energy was relatively stable. The oil price escalation during the last decade, again led to an increasing share of energy imports in all Climate Vulnerable Forum countries. In 2012, this share registered a new record in Morocco, and also in other non-CVF countries like Korea, where it exceeded the level reached during the oil crisis three decades ago. The most recent slump in oil prices again caused a decline in share of imports.

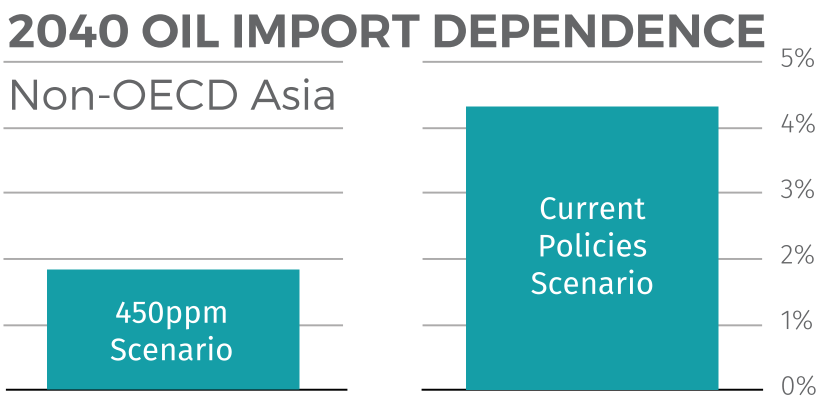


Figure 7-4 | Oil import Expenditures as % of GDP, in Non-OECD Asia in 2040: Current Policies and 450 Scenarios (own analysis based on WEO 2015 scenarios and WDI data).

The high reliance on oil is a problem for oil-exporting countries as well.[5] The hydrocarbon sector accounts for over 40% of the GDP in Saudi Arabia, Qatar and Iraq.[6] This makes these countries extremely vulnerable to oil price dynamics. When the oil price drops, there are serious consequences not only on GDP growth but also on public deficits and debts. For these and other reasons, the scientific literature shows mixed evidence for oil production fostering long-run economic growth in oil-exporting countries.[7,8,9,10]

It has even been shown that these economies could benefit from a low-carbon world where the revenues from a global carbon market exceed revenues from oil market.[11,12]

A low carbon world will enhance the economic stability of nations in two different ways: first, low-carbon transformation requires a phase out of oil and stronger reliance on clean sources of energy; second, lower demand in oil will likely lead to lower oil prices.

For example, according to WEO 2015, in non-OECD Asia, in a world without enhanced climate action (scenario in line with currently implemented policies), oil import expenditures could remain as high as 4% of the GDP in 2040 on average (Figure 7-4). Continued price volatility would cause strong variations around this average level. By contrast a low carbon (450ppm) scenario would halve these average expenditures (Figure 7-3), and as a consequence these countries would be less exposed to the negative effects of price volatility and its economic repercussions.

CONCLUSIONS

Fossil fuel price volatility poses major uncertainty for investors. Higher oil prices lead to increasing inflation rates that ultimately affect economic growth and job creation. A major shift towards renewable energy would progressively eliminate such uncertainties given its relative price reliability. This would likewise enable more reliable GDP growth in the long term.

Investing in renewables could emerge as a positive strategy for oil-exporting countries as well. This is due to an expected decline in global oil demand along with an increasing need for diversification. Investors can take further advantage of declining renewable costs, which are projected to fall by 60% by 2025,[13] compared to 2015 levels (see Chapter 9).

ENHANCING ENERGY ACCESS

Lack of access to modern forms of energy is a major contemporary development challenge that affects billions of people. By 2030 a business-as-usual evolution in global energy supply would see only a fractional reduction in those affected by so-called 'energy poverty'. It is often assumed that increasing access to energy services would lead to a proportional rise in emissions from energy generation. However, global climate action consistent with a 1.5°C limit to global warming allows for improved energy access and reduced energy poverty while contributing little to emissions increase. In particular, energy technologies that are emissions neutral, especially solar power, offer significant access and logistics advantages over carbon intensive energy systems. An accelerated diffusion of low-carbon technologies would hasten closing the energy access gap in developing countries and speed development progress.

KEY **MESSAGES**

- Conventional energy systems dependent on capital-intensive grid-based power production and transmission are poised to fall far short of achieving the Sustainable Development Goal 7's target of universal energy access by 2030.
- Over 1 billion people lack access to the electricity grid globally, but could benefit from the off-grid advantages of distributed renewable energy technologies, promoting the reduction of poverty, increasing human welfare and empowering women who are frequently disadvantaged by the inaccessibility of energy in the world's poorest communities.
- Renewable energy sources are not only climate friendly, they also remove requirements for a continuous supply of fuel, overcoming a critical access and logistical challenges to power generation.
- Advantages are most pronounced for developing island nations, Sub-Saharan Africa, and other remote and land-locked developing countries that face a combination of geographical and socio-economic challenges in meeting basic energy needs.

A solar panel sits on top of a Berber hut in the Sahara desert of North Africa.
© Mieszko9

8 ENHANCING ENERGY ACCESS

With approximately 1.4 billion people living without electricity across the planet, the challenge of ensuring universal energy access is far from overcome.[1] According to the International Energy Agency, 95% of people lacking electricity access live in Sub-Saharan Africa and Asian developing countries, while over 80% live in rural areas outside of towns and cities.[2] In addition 2.7 billion people rely only on the burning of solid fuels like wood or charcoal for their cooking needs, including 840 million people in India alone. In a number of Sub-Saharan African countries, households are nearly entirely dependent on wood fuels, including Burundi (99%), Madagascar (99%), Malawi (98%), Rwanda (98%), Somalia (99%), and Tanzania (96%).[3]

1.4
BILLION PEOPLE
WITHOUT ACCESS TO ELECTRICITY

This chapter discusses the importance of energy access given the extent of contemporary energy poverty and the flow on effects of poor energy access to population's education and health. The economic, social and other advantages of low carbon development pathways are illustrated, as well as the specific positive changes that will be felt by small islands states, remote communities and women.

ENERGY POVERTY

Electricity is an essential input to a wide range of socio-economic activities, and energy is considered central to virtually all aspects of human welfare.[4] In the absence of energy, powered utilities such as lights, telephones, refrigeration, heating, mechanical operations and cooling, basic business functions are inhibited. For people living in energy poverty, it can be a daily struggle just to keep homes adequately warm, to have lighting at night, or to cook food.[5]

Education and health are also directly affected. Limiting homework or reading books to daylight hours alone can impede educational advancement. 90% of children in Sub-Saharan Africa attend primary schools without electricity, and many health facilities in developing countries are entirely devoid of electricity: 58% in Uganda (2011) and 50% in Tanzania (2012).[6] [7] According to the WHO "unreliable electricity access leads to vaccine spoilage, interruptions in the use of essential medical and diagnostic devices, and lack of even the most basic lighting and communications for maternal delivery and emergency procedures."

80% IN RURAL AREAS

Energy poverty has a variety of causes, especially economic, geographic and also cultural, and is also a function of both availability and affordability. Electricity is "available" if a household is "within the economic connection and supply range of the energy network or supplier."[8] Energy is considered affordable when a household is able to pay up-front connection and energy usage costs or if a household's energy expenditures are below certain disposable income thresholds (e.g. 10%).[9]

LOW EMISSIONS ACCESS ADVANTAGES

Energy suppliers often find it difficult, time-consuming and expensive to develop distribution channels to reach remote or rural areas.[10] The majority of grid connections are in urban areas and, in particular for middle and lower income countries, the additional costs for each kilometre of grid extension rarely pay off because there are few consumers with adequate disposable incomes in rural developing regions.[11] Unless there are shifts in energy policies, by 2030 the number of people living without electricity is expected to still exceed of 1 billion, while 2.5 billion would go without modern forms

Zambian student Christopher finishes his homework by the light from a portable solar charged lamp on September 22, 2013. Photo: Patrick Bentley / SolarAid

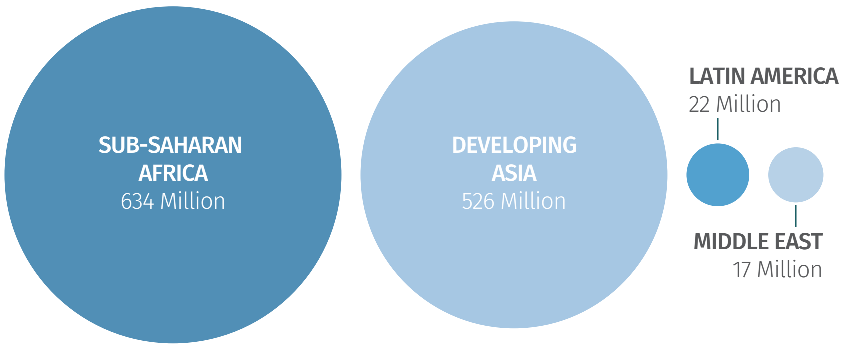
or energy for cooking.[12] Conventional, capital-intensive grid infrastructure distribution systems that dominate the global energy supply today are therefore expected to fail the international community's ambitious energy access objectives. This includes ensuring "universal access to affordable, reliable and modern energy services", the primary target of Sustainable Development Goal 7.[13]

In order to provide universal access to energy by 2030, the International Energy Agency estimates that around 60% of new energy access would need to be created via supplies outside of centralised grids.[14] Until recently the most often utilised decentralised source of power were diesel generators: currently there is approximately 400 gigawatts (GW) of diesel power capacity not integrated in grid transmission networks. However, off-grid carbon-based energy production requires a constant supply of fuels that also present costs and encounters logistical challenges in remote, rural and island regions so that replacing such diesel generation is already an important market opportunity for renewables.[15] It is also susceptible to price hikes in fossil fuels.[16]

Low carbon, renewable forms of energy, such as hydro and concentrated solar thermal plants, can supply gigawatt scale capacity for conventional grid systems.[17] Renewable forms of energy also offer truly independent power supplies that do not require continuously furnishing fuels. Renewable energy advantages are growing together with technological and infrastructure advances such as energy demand management and battery design that help to address inherent challenges for solar and wind energy, in particular an intermittent supply of power. A growing number of energy independent installations, including over 10,000 network towers for mobile phones, are, for instance, powered by renewable energy. This is a strong indication of logistical advantages and future potential. Currently, the supreme off-grid energy tech-

Figure 8-1 | Regional breakdown of the population with no electricity access. Source: International Energy Agency WEO 2015.

POPULATION WITHOUT ACCESS TO ELECTRICITY



nology is solar, which already powers 20 of the 26 million households with off-grid renewable energy that benefit some 100 million people.[18] Small-scale wind, geothermal (i.e. together with heat pumps) and hydro systems are additional alternatives as is the coupling of existing diesel generation systems, or electricity, with renewables in hybrid applications.[19] China alone already has 50,000 decentralised power generators most of which are small-scale hydro units.[20] There is also a growing network of "mini-grids", or small-scale grids that are disconnected from national power networks, including over 10,000 solar photovoltaic (PV) modules or hybrid village scale grids now powering communities around the world.

A group of African women learning to be solar technicians. "I never imagined that technical knowledge like this would be open to women who were illiterates, like us," a student reflected at the end of her training in Tilonia, in the state of Rajasthan. "But coming to Tilonia has given us this confidence that we can learn about new things and make our lives better." The women plan to return to their home villages and electify them for the first time. Photo: UN Women / Gaganjit Singh

BENEFITS FOR SMALL ISLANDS, REMOTE COMMUNITIES AND WOMEN

The benefits of decentralised and distributed power generation from renewables will be most pronounced for those groups particularly challenged with the supply of conventional energy, which includes island nations, remote and landlocked territories, as well as women and girls.

Island nations, for instance, experience some of the highest costs of energy services in the world due to outlays required to transport fuels between islands.[21] Indeed, 90% of energy use in many of the SIDS (Small Island Developing States) comes from imported oil[22] with over 67 million USD per day for oil in 2008.[23] Island geography also makes national electrical grids impractical. In the Pacific island nation of Kiribati for instance, some 80,000 people are distributed across 33 widely scattered islands.[24] Such challenges are also reflected in the low electrification rates of many SIDS, for example Papua New Guinea at ~13%, Solomon Islands at ~20%, Vanuatu at ~27%.[25] Many islands with populations up to 100,000 inhabitants are reliant on diesel generators for the production of electricity.[26] Decentralised energy systems that do not require transportation of energy from one place to another eliminate these logistical costs. In fact, according to the International Renewable Energy Agency (IRENA), renewables already compete on cost with diesel generators in most island contexts.

Land-locked and remote regions also face similar challenges and stand to benefit substantially from increasing off-grid, renewable installations. For remote areas with low road density in particular, fuel transportation poses a challenge and investments in transport networks would add to the marginal costs of electrification, as well as to the overall emissions of the transport sector.[27] "A recent World Bank study shows that, on average, it costs USD $3,040 (£1,900) to export a standard container of cargo from a landlocked developing country, whereas a coastal neighbour spends about USD $1,268. Likewise, a country such as Burundi pays USD $3,643 to import a similar container of merchandise compared with USD $1,567 for its coastal neighbours in east Africa."[28] Additionally, landlocked and other remote regions rely on neighbouring areas to facilitate trade and transport; these areas may face challenges if there are turbulent political relationships with surrounding areas, which may lead to energy price and access volatility.[29,30]

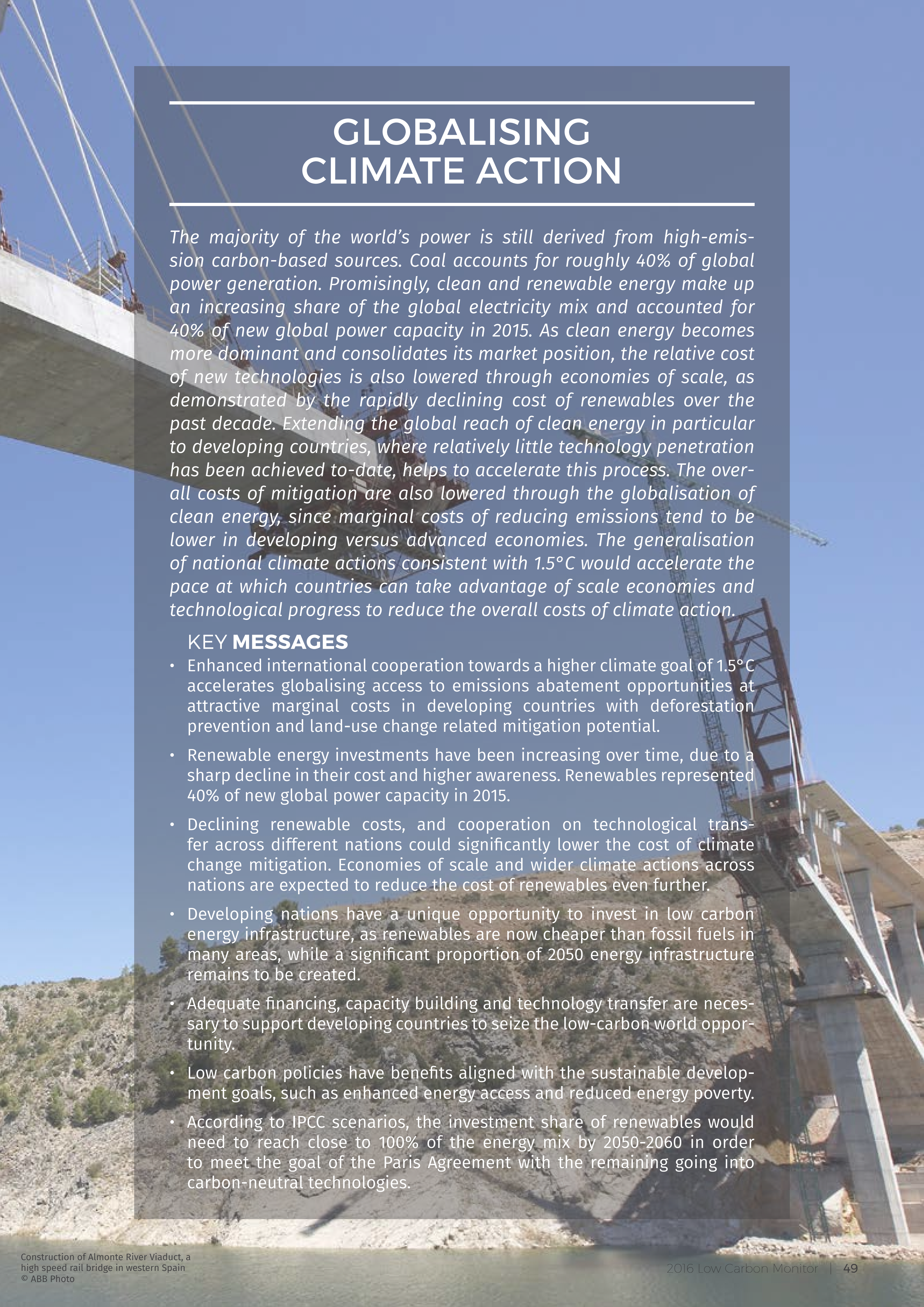
Accelerating off-grid energy access also presents particular benefits for increasing gender equality given the importance of the role of women and girls in collecting biomass fuels.[31] Without energy to pump water there is often a need to carry it over long distances.[32] Collecting and transporting biomass for energy or water limits engagement in education, employment and leisure while the journeys can incur safety risks for women as well as physical strain and stresses to health.[33]

GLOBALISING CLIMATE ACTION

The majority of the world's power is still derived from high-emission carbon-based sources. Coal accounts for roughly 40% of global power generation. Promisingly, clean and renewable energy make up an increasing share of the global electricity mix and accounted for 40% of new global power capacity in 2015. As clean energy becomes more dominant and consolidates its market position, the relative cost of new technologies is also lowered through economies of scale, as demonstrated by the rapidly declining cost of renewables over the past decade. Extending the global reach of clean energy in particular to developing countries, where relatively little technology penetration has been achieved to-date, helps to accelerate this process. The overall costs of mitigation are also lowered through the globalisation of clean energy, since marginal costs of reducing emissions tend to be lower in developing versus advanced economies. The generalisation of national climate actions consistent with 1.5°C would accelerate the pace at which countries can take advantage of scale economies and technological progress to reduce the overall costs of climate action.

KEY **MESSAGES**

- Enhanced international cooperation towards a higher climate goal of 1.5°C accelerates globalising access to emissions abatement opportunities at attractive marginal costs in developing countries with deforestation prevention and land-use change related mitigation potential.
- Renewable energy investments have been increasing over time, due to a sharp decline in their cost and higher awareness. Renewables represented 40% of new global power capacity in 2015.
- Declining renewable costs, and cooperation on technological transfer across different nations could significantly lower the cost of climate change mitigation. Economies of scale and wider climate actions across nations are expected to reduce the cost of renewables even further.
- Developing nations have a unique opportunity to invest in low carbon energy infrastructure, as renewables are now cheaper than fossil fuels in many areas, while a significant proportion of 2050 energy infrastructure remains to be created.
- Adequate financing, capacity building and technology transfer are necessary to support developing countries to seize the low-carbon world opportunity.
- Low carbon policies have benefits aligned with the sustainable development goals, such as enhanced energy access and reduced energy poverty.
- According to IPCC scenarios, the investment share of renewables would need to reach close to 100% of the energy mix by 2050-2060 in order to meet the goal of the Paris Agreement with the remaining going into carbon-neutral technologies.



Construction of Almonte River Viaduct, a high speed rail bridge in western Spain
© ABB Photo

9 GLOBALISING CLIMATE ACTION

This chapter reviews the benefits that would emanate from the globalisation of efforts to reduce emissions, in particular through wider participation in low emissions development among developing countries. It looks once more at the emissions gap between current domestic emissions policies and the 1.5°C goal agreed in Paris, and discusses the crucial role that developing nations could play in contributing to this goal, with sufficient international support. The additional benefits of wider climate action and their importance in considering the overall value of actions towards a 1.5°C world is then discussed.

THE EMISSIONS GAP

Current policy projections lead to global average temperature increases of around 3°C by the end of the century (chapter 1). Achievement of the Paris Agreement long-term temperature goal will require a deep transformation of the energy sector,[1] which accounts for the majority of GHG emissions at the global level. This equates to a phase out of fossil fuels and transition into low-carbon energy production.

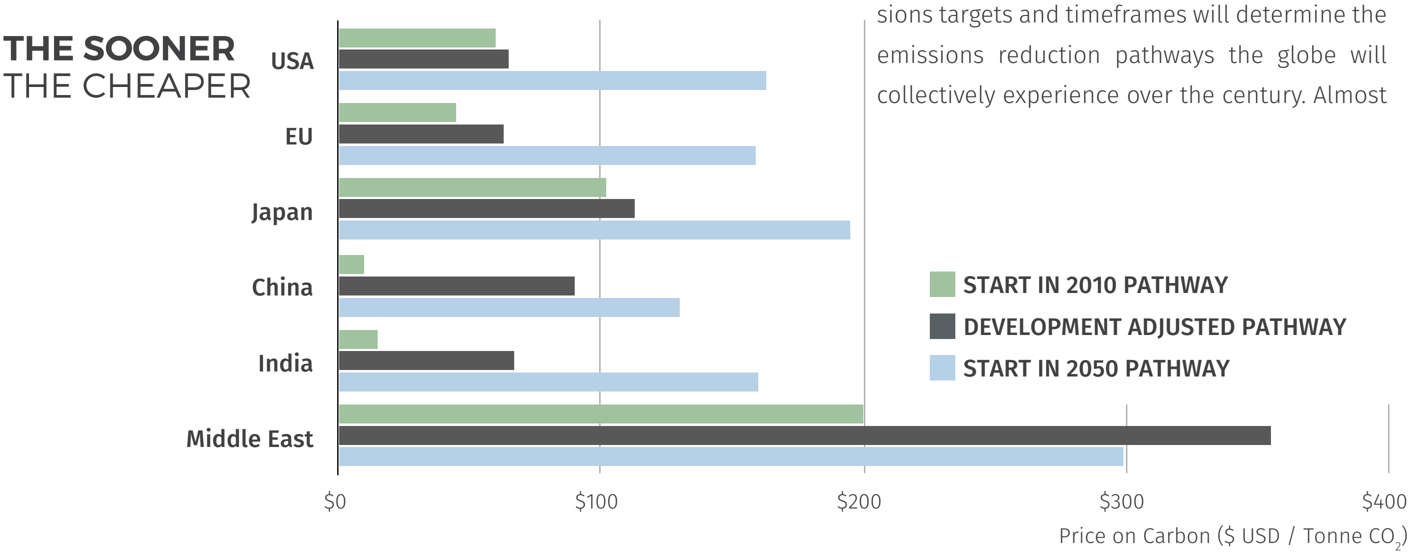
The introductory chapter explained the clear and growing gap between currently implemented policies and the long-term goal of the Paris Agreement. The global level of ambition of NDCs and of domestic policies to meet those NDCs must be enhanced, to ensure consistency with a 1.5°C compatible pathway. This is only possible with wider action on climate change encompassing the vast majority of countries, which would bring down the overall costs of low-carbon transformation as rapidly as possible.

As the introductory chapter also noted, only a small number of countries are front-runners in this respect. If a significant number of countries continue to lag behind on climate action overall costs of holding warming below 2°C could be increased by 30-45% over the 2030-2050 period (noting this variation would depend on the magnitude of global emissions by 2030).[2] Yet more serious implications of lagging behind would hold for the 1.5°C limit. A coordinated action in climate change requires a fast reform on fossil fuel subsidies (currently totalling USD $ 500 Billion)[3], and elimination of these as early as possible would make a large contribution towards closing the emissions gap.[4] Fossil fuel subsidies are implemented in many countries, especially oil-exporting countries,[5] and provide counter-productive incentives to energy investors.

THE PATH OF LEAST RESISTANCE

The choices we make as individual nations or through global agreements regarding emissions targets and timeframes will determine the emissions reduction pathways the globe will collectively experience over the century. Almost

Figure 9-1 | Price per tonne of CO_2 for a 50% reduction in carbon emissions for three different scenarios for a selection of countries. [6]



regardless of region, there is a clear relationship between emissions reduction policy, cost and implementation timeframe that shows early emissions reduction is significantly more cost effective.

Figure 9-1 shows the price per tonne of CO_2 for a 50% reduction in carbon emissions for three different scenarios. We observe that for all countries, the case in which emissions reductions start in 2010 is the least costly emissions reduction pathway. By 2050, this scenario has achieved substantial investment in clean technology and has achieved policy that allows for strategically purchasing emissions reductions for lowest cost abatement. The Development adjusted path, in which developed nations implement 50% reductions in carbon emissions from 2010 and undeveloped nations begin in 2025, shows a significant increase in cost per tonne of abatement as a less stringent emissions reduction pathway relative to 2010. In a scenario where emissions reductions are not initiated until 2050, carbon intensive capital stocks exist and there is no incentive in earlier years for clean technology investments and there has been no build-up in the capacity to install cleaner advanced technologies, leading to the highest cost of abatement.[7]

The correlation between early climate action and lower cost abatement is clear across multiple regions. Whether it be in developed, developing, vulnerable or resilient nations, collec-

GLOBAL EMISSIONS BUDGET **COAL**

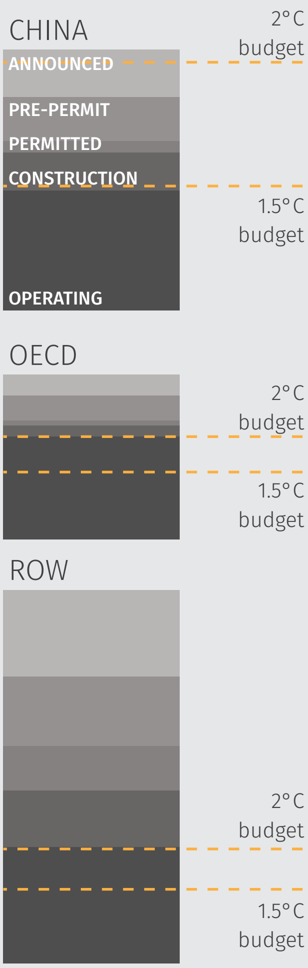


Figure 9-2 | Lifetime carbon emissions of coal plants operating, under construction and planned compared to emissions budgets for 2°C and 1.5°C for China, the OECD and the rest of the world (ROW).

Limiting warming to 1.5°C requires the rapid phase out of fossil fuel power generation in favour of renewable energy in the power sector. Coal accounts for roughly 40% of global power generation and the transition from coal to renewable energy sources presents one of the greatest opportunities for reducing global emissions.

Coal is the fossil fuel with the highest carbon content, meaning that for each unit of energy used, a relatively high amount of CO_2 is emitted, compared to other fossil fuel, such as oil or gas. Whilst the transition from coal to renewables cannot happen overnight, a fast and complete transition must be made over the coming decades in order to achieve the Paris Agreement 1.5°C goal (Climate Action Tracker, 2015).

Integrated Assessment Models (IAMs) have been used to inform optimal investments pathways in line with temperature goals of 2°C and 1.5°C over the course of the 21st century. These IAMs compute indicative scenarios for optimal energy system transitions given a certain climate goal – where optimal here means with minimal global cost. The remaining emissions budgets for coal use are shown in Figure 9-2 for three major global regions: The OECD countries, China and all other countries (Rest of the World - ROW). The figure also shows the emissions that would result from currently operating coal power plants as well as plants that are in different stages of development.

It is clear that only for the OECD countries are coal emissions roughly in line with the Paris Agreement. This is predominantly because of the fact that many of the OECD nation's power plants are ageing and coal fired substitutes are generally not planned.

The situation is very different for China, where even using the many existing – and relatively young – coal power plants over their remaining lifetime would already result in emissions nearly three times the global coal emissions budget.

Coal power plants require a relatively long time to pay back the initial investment and begin generating returns for investors. The economic lifetime of coal-based power plants is over 40 years, which poses significant concerns for more immediate reductions in global GHG emissions. Additional fossil fuel investments turn out to be highly unproductive, as science shows these would need to be shut down for achieving 1.5°C pathways before they will start to generate their anticipated revenues.

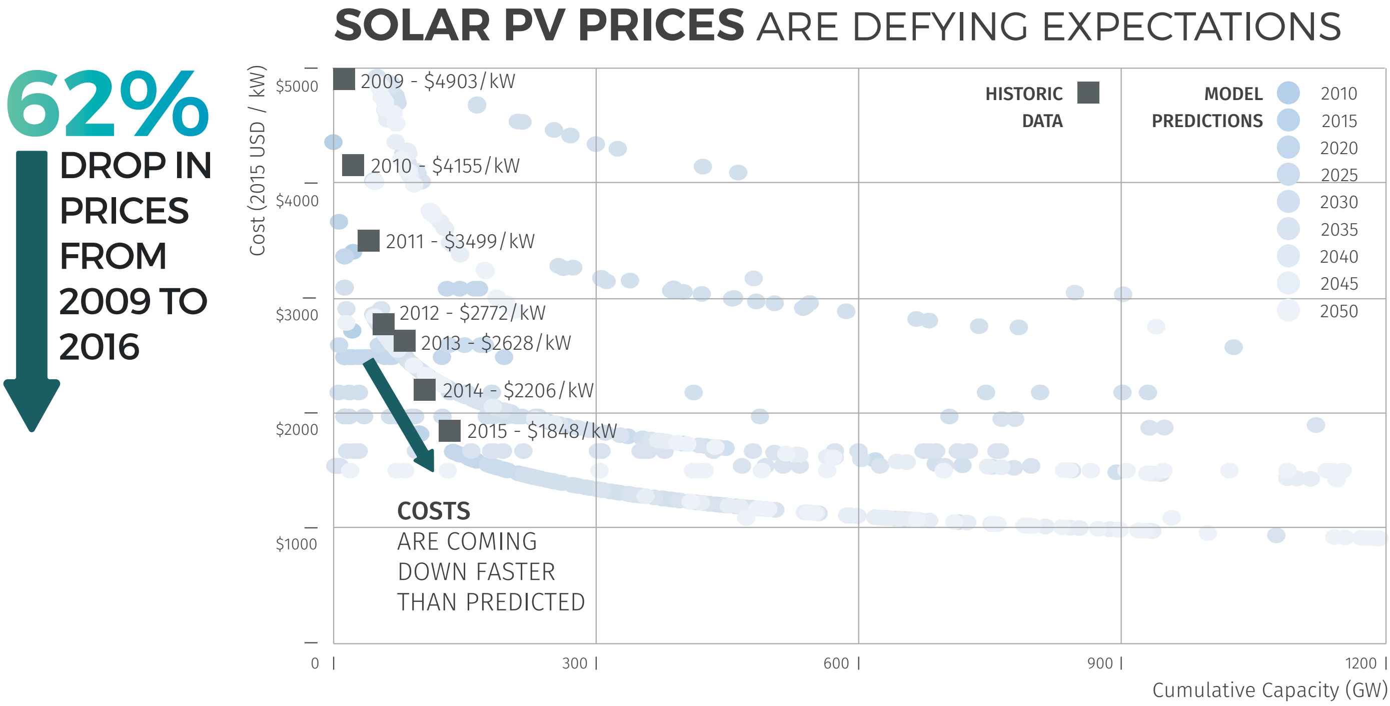


Figure 9-3 | Solar PV cost vs installed capacity: 2009-2015 data and cost projections from energy-system models (2005-2100). Various symbols indicate different models. Own analysis based on Ampere Database and IRENA 2016

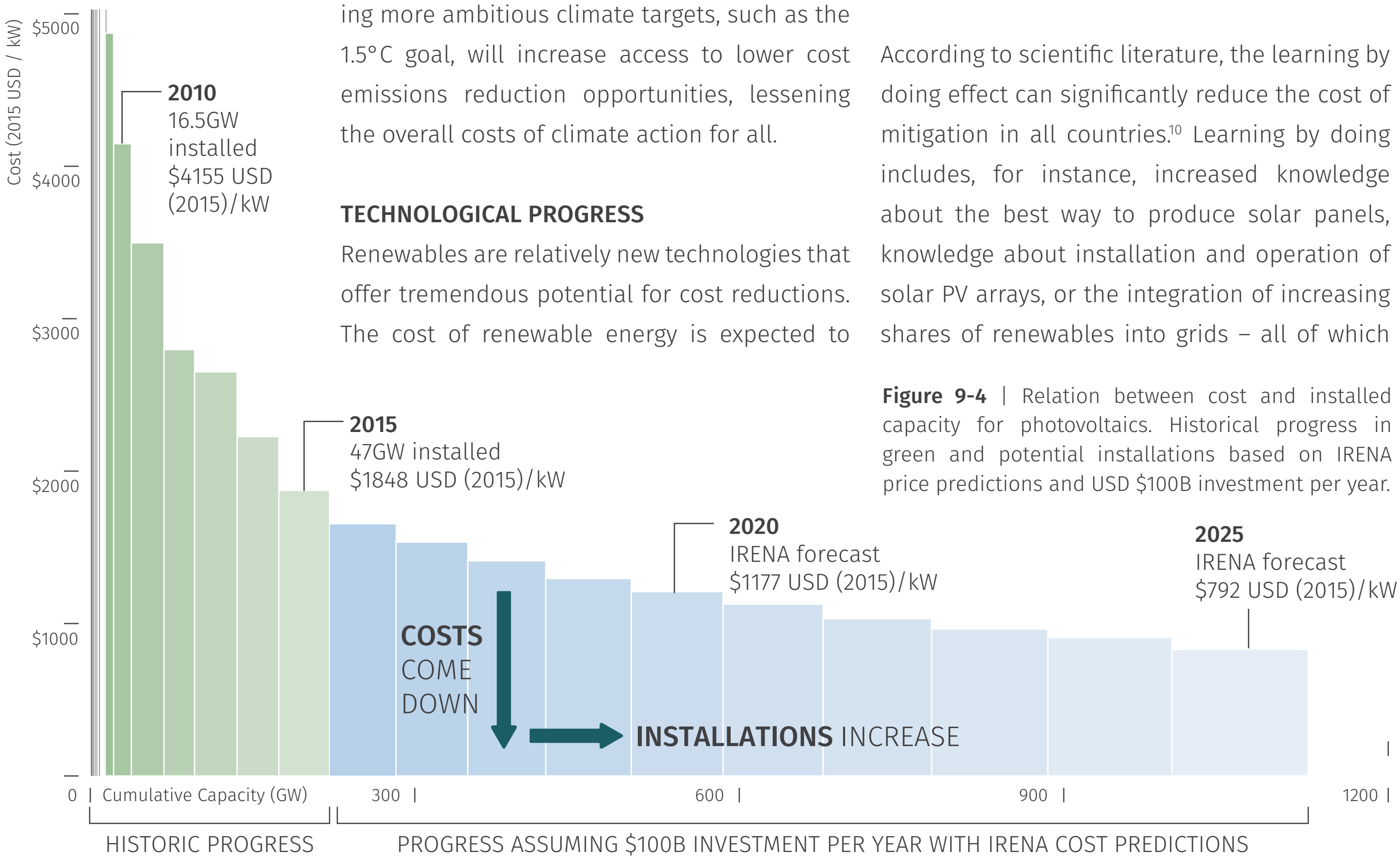
tive and early action will result in lower costs for the reduction of global emissions in the atmosphere. Studies of emissions abatement opportunities have indicated that a significant proportion of cost-attractive or economically beneficial emissions reductions can arise from the prevention of deforestation and other land-use related policies and initiatives.[8] Such opportunities are more abundant in developing countries and therefore the expansion of international cooperation necessary to achieving more ambitious climate targets, such as the 1.5°C goal, will increase access to lower cost emissions reduction opportunities, lessening the overall costs of climate action for all.

TECHNOLOGICAL PROGRESS

Renewables are relatively new technologies that offer tremendous potential for cost reductions. The cost of renewable energy is expected to decline the more capacity is installed. Reasons for this are the development of new, cheaper production technologies and also accumulated knowledge about more efficient ways to install and use capacities and integrate them into existing grids. Figure 9-3 and Figure 9-4 illustrate these so called *learning by doing* effects on costs for solar photovoltaics. Depending on the extent of actual global renewables installations, the cost of renewables could fall by 59% by 2025 compared to 2015 levels.[9]

According to scientific literature, the learning by doing effect can significantly reduce the cost of mitigation in all countries.[10] Learning by doing includes, for instance, increased knowledge about the best way to produce solar panels, knowledge about installation and operation of solar PV arrays, or the integration of increasing shares of renewables into grids – all of which

Figure 9-4 | Relation between cost and installed capacity for photovoltaics. Historical progress in green and potential installations based on IRENA price predictions and USD $100B investment per year.



leads to efficiency gains and reduction in costs. Put simply, cost reduction through learning by doing is mainly driven by the speed of technological deployment. As a result, concerted actions on climate change will provide larger economic benefits for all, as all countries can benefit from lower renewable and mitigation costs. It is also a difficulty for economic models to calculate competing energy costs over time far into the future. If, for instance, the current trend of falling costs of renewable energy continues, it would already begin to invalidate the cost assumptions of many economic models, and the implication would be less costly mitigation. Further and scaled-up generalisation of renewables through wider global uptake of these technologies will almost certainly perpetuate the trend of falling costs, even if economic models struggle to represent the pattern (see Figure 9-3). The long-term goal of the Paris Agreement requires a rapid decarbonisation of the energy sector. It is critical to prevent installations of new fossil fuel generation assets to avoid lock-ins of emissions. Additional fossil fuel investments now would likely lead to an early retirement before their initial investments pay off. This is the reason why delaying climate action increases the overall mitigation costs, and lowers the probability of reaching the long-term goal of the Paris Agreement.[11,12,13,14,15,16]

Notably, the time for technological diffusion across regions has been reduced drastically by globalisation. For example, new technologies are now capable of reaching 80% of the world's countries in the next 20 years, whereas it would have taken more than 100 years in the 1800s. Mobile phones, for example, took only 16 years to cover 80% of world's countries.[17,18,19,20]

THE BROAD BENEFITS OF LOW CARBON DEVELOPMENT

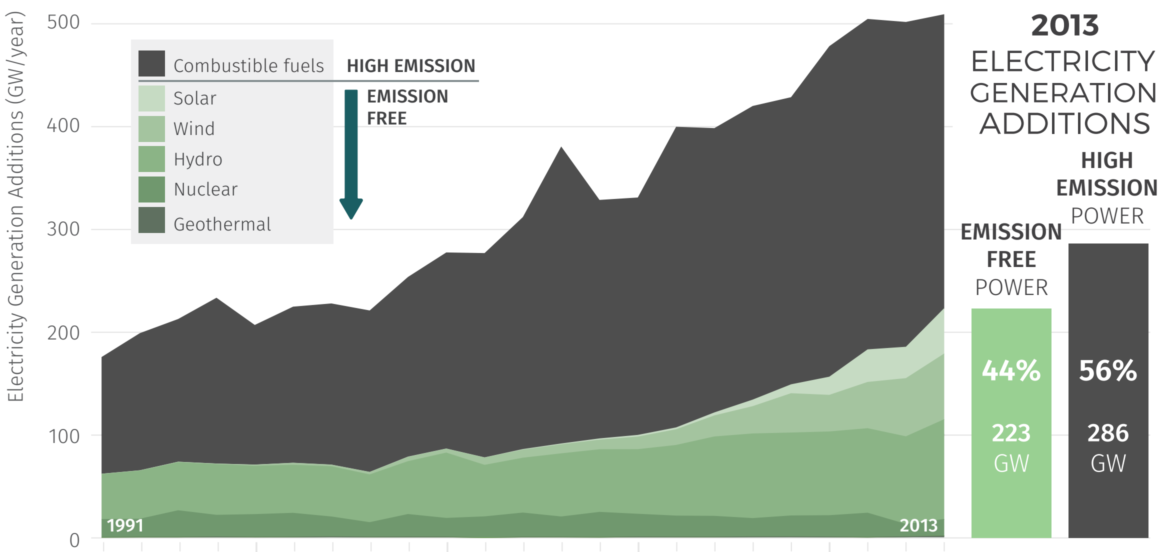
In 2015, renewables represented 40% of new capacity installed in the power sector. This share has been growing after 2005 when investments into solar and hydro started in earnest and added to the relatively constant investments into hydroelectricity. According to IPCC scenarios, the investment share of renewables would need to reach close to 100% of the energy mix by 2050-2060 in order to meet the goal of the Paris Agreement with the remaining going into carbon-neutral technologies.

Renewable sources of energy are now competitive in most rural and remote areas in Africa[21,26] and capable of overcoming the challenge of lack of electricity access[30,22]. Notably the cost of reaching universal access to energy is estimated at USD $35 Billion per year, which is well below the cost of global fossil fuel subsidies, estimated at around USD $500 Billion per year[3,23].

Figure 9-5 | Global additions to electricity capacity per year by energy source. Source: UNdata, authors calculations.

GRID ADDITIONS

RENEWABLE ENERGY INVESTMENT IS CATCHING UP BUT INVESTMENT IN FOSSIL FUELS STILL HIGH



Damage from Typhoon Haiyan (Yolanda) that struck Tacloban in the Philippines on November 8, 2013. It was one of the strongest tropical cyclones ever recorded and impacted large portions of Southeast Asia, in particular the Philippines where it killed at least 6,300 people, making it the deadliest Philippine typhoon on record. Photo: © ILO / Marcel Crozet

The overall mitigation potential in Africa is huge and also relatively cheap if compared to other regions[24]. For this reason, many African countries – including Ethiopia, Gabon, Liberia, Gambia and Morocco – have put forward renewables targets in their national development plans.

Renewable energy emerges as cost-effective technologies also in many other countries. This is the case in Nepal and Bhutan where mountain and steep terrains hinder the deployment of power grids and makes centralised power plants costlier.[31,25]

Developing countries have the opportunity to skip older conventional technologies and make their initial primary investments into low carbon technologies such as renewables.[26,27] This might also entail significant 'first-mover' advantages and technological leadership, if a robust regulatory environment supports investors. Environmental regulations, energy efficiency standards and pollution control measures can facilitate the transition to low-carbon energy infrastructures. Further investments in general education and specific training can facilitate the absorption rate of renewables. A participatory, renewables-based energy system can trigger huge co-benefits, especially in terms of improved general education levels. From the perspective of this report, higher education levels increase the economic capabilities and general wellbeing of people, *and* have the co-benefit of increasing the absorptive capacity for high-tech solutions like renewables.

Renewable energy also offers additional co-benefits that are difficult to quantify in monetary terms. Often scientists rely on Integrated Assessment Models (IAMs) to inform policy makers. However, those models focus on mono-objective, cost-optimal investment pathways to meet the long-term climate targets.[28] IAMs do not take into consideration economic co-benefits such as improved air quality (Chapter 3), job creation (Chapter 4), and energy security (Chapter 5), and the detrimental economic effect of fossil fuel reliance (Chapter 6).[29] For this reason, the literature suggests actual policy be guided by an alternative multi-objective framework[30] as a basis for decision-making. Notably there is a significant overlap between energy efficiency investments, the United Nation's Sustainable Development Goals and other domestic plans.[3132] For example, a higher level of ambition is likely to enhance energy access,[333435363738] and to reduce air pollution,[39,40,41,42,43,44,45] especially in China.[46] Notably, many of these objectives would require the support of the broader international community to be achieved.[47] Capacity building, access to adequate financial support and technology transfer are indeed prerequisite to the low-car-

bon transition in developing nations. Moreover, the deployment of clean energy sources in developing countries represents a huge opportunity to attract climate finance investment resources,[48] which in turn will create economies of scale that will increase the affordability of advanced technologies.

CONCLUSIONS

Energy demand is very likely to grow even more in the future, especially in developing countries. Where this demand is fulfilled using renewable energy sources, this will guarantee that no new emissions will be locked-in over their lifetime. Developing countries can take advantages of cutting-edge renewable technologies and skip investments in conventional carbon intensive energy already in global phased out given the recent surge in renewables capacity coming online. Globalisation is accelerating the diffusion rate of renewables and the low carbon sector is growing rapidly. In such a context, countries are presented with opportunities to become technological leaders in a growing low-carbon sector. Governments can facilitate this process, via public investments, and policy and fiscal incentive, including subsidies, feed-in-tariffs or similar measures. Enhanced information and investments in education and in training and skills can also accelerate the process of increasing the share of renewables in energy generation. Such measures may also attract other forms of finance, such as international carbon finance from investors aiming to promote transformational change in the context of the Paris Agreement.

PHILIPPINES

THE PEOPLE'S SURVIVAL FUND

The People's Survival Fund (PSF) was established in 2012 by the Government of the Philippines upon enactment of a law legislating the country's first legislated adaptation funding mechanism dedicated to support the adaptation action plans of local governments and community organisations. It became operational in 2015. With an initial PhP2 billion (approximately USD44 million) allocation sourced from the 2015 and 2016 national budgets, the PSF is intended to support resilience-building activities such as natural resource management, public health, disaster risk and resiliency programs, and as risk guarantee for farmers, agricultural works and other sectors vulnerable to the effects of climate change[49].

As of mid-2016, the PSF has already received over 38 proposals for grassroots funding submitted by local governments, community organisations, international NGOs and private citizens[50]. In the first round of submissions, 9 projects totalling roughly PhP450 million have already been shortlisted for submission to the PSF Board[51].

However, the fund hopes to further expand access to climate finance in the poorest and most disaster-prone areas. Conversely, local governments in these districts often do not have the capacity to submit highly technical applications for funding. With support from the UNDP, the Philippine Climate Change Commission has established a comprehensive training and awareness program in order to increase the quantity and quality of submissions from local government units. A key takeaway from this experience has been the importance of awareness and capacity-building within these vulnerable districts and designing clear criteria for assessing proposals, in order to ensure that national funds such as the PSF can find and support the most vital and impactful climate projects.

Developing and strengthening such initiative across the developing world could contribute to decrease the short- to long-term detrimental consequences of climate-related disasters on macroeconomic indicators, supporting developing countries attain their Sustainable Development Goals.

ANNEX & TECHNICAL NOTES

SAFEGUARDING ECONOMIC GROWTH

The results are derived from a two-step method. The first step relies on a non-linear econometric model, adapted from a publication by Burke et. al[1], whose objective is to **infer climate analogues for different levels of intensity of temperature extremes, called climate-economy elasticity, from historical data for the period 1980-2015.** Regressions are performed in pooled panels for developed and developing countries. The best fitting sets of elasticities per panel are selected using a Monte-Carlo based randomisation-filtering method. In the second step, an ensemble of 5 models from the CMIP5 database, in two different warming scenarios representative of 1.5-2° C (RCP2.6) and roughly 4° C (RCP8.5) warming trajectories, is used to compute future country-level exposure to temperature intensity. The losses experience by the countries are assumed to be permanent – growth effect. The results are consistent with the estimates from Burke et. al[2].

STRENGTHENING ENERGY SECURITY & INDEPENDENCE

Of course, the most compelling case for renewables is that the stock of fossil fuels is finite, whilst renewable energy resources are infinite. However, we should also consider the primary energy content of fossil fuels compared with their electricity output. In general, fossil fuels have to go through conversions before the energy stored is actually put to use.

- Coal is mostly used for the provision of electricity, which is provided with an efficiency of about 40%, i.e. 60% of the energy stored in the coal is lost as heat.

- Oil is mainly used to produce liquid fuels like gasoline, diesel, jet fuel, heavy fuel oil, etc. which are used in the transport sector. Apart from losses in the conversion from crude oil to fuel, additional losses on a scale similar to the case of coal appear e.g. in combustion engines of cars and trucks.

- Natural Gas is the fossil fuel type which can be used with the highest efficiency for a multitude of purposes: providing electricity with a higher efficiency than coal, cooking, heating or fueling cars with combustion engines.

The conversions necessary for fossil fuels mentioned above lower the effective energy output that can be put to use significantly – with the highest losses occurring for coal and the lowest for gas.

Electricity as provided by both fossil power plants and renewable energy technologies can be used for all purposes. When coming from renewables, it requires costly storage to smoothen intermittent electricity output from solar panels or wind turbines. In general, it is difficult to use electricity for individual mobility since the required high-energy density battery systems are still relatively costly.

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THE 1.5°C PARADIGM

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