DIGITAL SOLUTIONS FOR CLIMATE ACTION

USING ICT TO RAISE AMBITIONS ON CLIMATE ACTION IN LOW- AND MIDDLE-INCOME COUNTRIES

GeSI ENABLING DIGITAL SUSTAINABILITY

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The Global Enabling Sustainability Initiative (GeSI) is an inclusive and open multi-sectoral, multi-stakeholder organization embracing a challenging agenda, driven by leading visionary and committed global corporations. GeSI holds the firm belief that responsible business, with digital sustainability at its core, will make for the most successful companies in the years to come.

GeSI is comprised of diverse and international members and partnerships, representing some of the world's leading ICT companies, global businesses and multiple international organisations, such as the International Telecommunication Union (ITU), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Environment Program (UNEP), the International Chamber of Commerce (ICC), the World Business Council for Sustainable Development (WBCSD), the Carbon Disclosure Project (CDP), global asset management firm Arabesque, and the World Resources Forum Association (WRFA).

GeSI works with a range of international stakeholders committed to ICT sustainability and supports member initiatives in developed and developing nations which tackle: climate change, energy/resource efficiency, privacy and security, digital literacy and digital divide, people's rights, as well as foster collaborative and innovative approaches, ideas and joint initiatives.

With these partnerships, GeSI is able to work towards its global vision of a greater evolution of the ICT sector to best meet the challenges of sustainable development. For more information, see www.gesi.org

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CONTENTS

FOREWORD

2020 is a pivotal year for climate action and sustainable development. Countries are set to submit Nationally Determined Contributions (NDCs); their national climate action plans under the Paris Agreement. We've already seen some progress. To date, 114 countries have already announced they will enhance their national plans and 121 countries have committed to achieving carbon neutrality by 2050. Yet, much more work remains.

This report sets out in detail how the world's low and middle-income countries can leapfrog polluting and inefficient technologies with the help of ICTs when designing and implementing their NDCs, and fully grasp the opportunities in areas ranging from smart grids to precision agriculture.

To be successful, the Paris Agreement needs the full support of *all* non-Party stakeholders. It is therefore encouraging to see that the ICT sector is fully on board in helping governments transition to zero carbon and greater resilience. I am pleased that this report puts a strong emphasis on how digital technologies can assist countries not only cutting greenhouse gas emissions but adapting to the inevitable impacts of climate change. I also commend the fact that the report clearly addresses the issue of finance and capacity building that low and middle-income countries require to implement ICT for climate action. The best NDCs of these countries can only be effective if the required support outlined in the plans is delivered. I am confident that going forward, the ICT sector will play a key role in helping countries design ever more ambitious climate action plans, which are crucial to avert the worst impacts of climate change and to fully grasp the multiple opportunities of the zero-carbon economy.

PATRICIA ESPINOSA

EXECUTIVE SECRETARY OF THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

FOREWORD

As the United Nations specialized agency for information and communication technologies (ICTs), the International Telecommunication Union welcomes this report, which comes at a time we are faced with the greatest global challenge facing our planet – climate change. At the same time, our world is being disrupted by a digital revolution, driven by the emergence of frontier technologies which are transforming, at unprecedented speed and scale, our economies, the way we live, consume, produce and work.

Although we know ICTs are a contributor to greenhouse gas emissions given their rapid growth since 2007, their impact is much more in terms of its mitigating effect on the highly energy intensive and polluting sectors such energy generation, transportation and buildings, and in helping efforts to adapt to climate change. The latest ITU study forecasts also show that growth in the sector will be balanced out by energy efficiencies and greater use of renewable power.

The question before us then is how can we leverage this digital transformation into effective climate action, one that contributes effectively to the implementation of the Paris Agreement and deliver on the 2030 Agenda and Sustainable Development Goals (SDGs), in particular for low- and middle-income countries most exposed and vulnerable to the impacts of climate change.

The use-cases and digital technologies analysis and insights in this report give clear illustration of the potential carbon abatement opportunities afforded by digital solutions, which can serve as good practice recommendations to be considered to support countries in meeting the nationally determined contributions (NDCs).

At ITU, we have also been working with the ICT industry to develop international standards that minimize the digital ecosystem's growing carbon footprint, and set out the 1st ICT sector-specific science based pathway to meet the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement's goal of limiting global warming to 1.5°c above pre-industrial levels.

I thank GeSI and sponsors for this important contribution of how digital technologies can assist in accelerating climate action. I believe now is the time that we seize the opportunity ICTs are offering and turn today's digital revolution into an environmental development revolution.

MALCOLM JOHNSON

DEPUTY SECRETARY-GENERAL OF THE INTERNATIONAL TELECOMMUNICATION UNION

FOREWORD

Together with its members and partners, GeSI has been driving for the last 20 years, the global transformation to a smarter, more sustainable world in 2030 with digital solutions at its core. We support our member initiatives in developed and developing nations which tackle climate change, energy/resource efficiency, privacy and security, digital literacy and digital divide, people's rights, as well as foster collaborative and innovative approaches, ideas and joint initiatives. With these partnerships, GeSI works towards its global vision of a greater evolution of the digital sector to best meet the challenges of sustainable development. GeSI holds the firm belief that responsible business, with digital sustainability at its core, will make for the most successful companies in the years to come. We support efforts that ensure environmental and social sustainability because they are inextricably linked in their impact on society and communities around the globe. GeSI is committed to sustainability actions and outcomes. We use collective knowledge and experience to identify opportunities and develop solutions for improving energy and resource efficiency, reducing carbon emissions and footprints, ensuring sustainable good practices in the supply chain, encouraging access to sustainable technologies, and supporting worldwide digital enabled transformation across all industries.

As the world continues to face unprecedented climate-related challenges, GeSI presents its latest report, "Digital Solutions for Climate Action: using ICT to raise ambitions on climate action in low- and middle-income countries." This report underlines the abatement opportunities afforded by digital technologies in specific contexts, understanding that the "endeavour to reach the furthest behind first[1]" is critical to support countries most exposed to the impacts of climate change. Ultimately, we believe that urgent action is needed as closer cooperation between business and policy makers is necessary to curb down carbon emissions at a faster pace. We believe that digital technology will continue to play a critical role in tackling the world's most pressing issues as this report and previous GeSI research since 2008 show.

GeSI is grateful to the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU) for their support. We do hope that the outcomes of this report can be leveraged to help the analysed countries and others not only meet but also accelerate the achievement of target commitments through digital technologies.

LUIS NEVES
GESI MANAGING DIRECTOR/CEO

EXECUTIVE SUMMARY

AIMS OF REPORT

This report presents mitigation and adaptation potentials that can be achieved with digital technologies by 2030 for seven countries. The current Nationally Determined Contributions (NDCs) and digital readiness of Brazil, Chile, China, India, Kenya, South Africa, and Vietnam were analysed. Four relevant sectors have been analysed for greenhouse gas emissions mitigation: power, transport, manufacturing and construction, and agriculture. Finally, emissions resulting from the use of digital technologies have also been analysed to put the results in perspective.

Achievement of more ambitious NDCs for any given country will require action and innovation on many levels. This report focuses on the technological level; specifically, how digital technologies can assist the achievement of the NDCs of seven show-case countries, taken into consideration their particular circumstances, such as digital infrastructures and existing power sources.

DIGITAL TECHNOLOGIES AND USE-CASES ANALYSED

The main digital technologies included in the assessment are:

- Digital Access: connectivity to the internet via telecommunications infrastructure (fixed or mobile), devices (handheld devices and computers) and software.
- Fast Internet: next generation connectivity that provides speed, capacity and reliability at fundamentally higher levels including high speed fixed broadband, 4G and 5G.
- Cloud: the provision of highly scalable, advanced IT capabilities as hosted services.
- IoT (Internet of Things): the suite of technologies enabling the connection of physical objects to the internet.
- Cognitive: the application of advanced analytics, machine learning (ML) and artificial intelligence (AI).
- Blockchain: digital, distributed ledgers of transactions maintained on multiple computer systems.

The following digital technologies are considered to have a potentially high decarbonising impact:

- Smart grids and buildings, to increase energy efficiency and the management of renewable energy.
  Use of digital communications and other advanced technologies to measure usage at the local level and manage demand and supply accordingly.

- Intelligent transport systems.
  Real-time traffic flow management, improved public transport information, smart logistics and predictive maintenance of infrastructure are all potential ways to help decarbonise the movement of goods and people.

- Industry 4.0 and more efficient manufacturing processes.
  Enabling industry to become more connected, efficient and smart, using digital technologies such as big data, machine learning, IoT and cloud computing.

- Precision agriculture, to improve efficiency in the use of nitrogen-based fertilisers and livestock management.
  Using digital technology to target, for example, the application of fertilisers thus increasing productivity and reducing emissions.

Chapters 5-8 of this report reveal the case studies in more detail, illustrating specific examples of implementation of digital solutions and the carbon abatements potentially achievable.

Carbon abatements potentials were calculated based on previous GeSI reports - especially Smarter2030[2] and Digital with Purpose[3]. This has been modified where necessary to reflect the availability of more up-to-date information and to reflect the circumstances of the countries analysed, and supplemented by relevant latest publicly available data. Two decarbonisation scenarios were used – a reference scenario and an ambitious scenario – the latter assuming a considerably more aggressive decarbonisation approach than current NDCs indicate, alongside an associated higher adoption rate of the assessed digital technologies.

DIGITAL CONTRIBUTION TO THE MITIGATION OF GHG EMISSIONS

The total estimated potential carbon abatement for the seven countries analysed is 1.1Gt of CO_2e in the case of the reference scenario and 2.1Gt of CO_2e in the case of the ambitious decarbonisation scenario. These numbers are significant when seen in context, e.g. the total 2014 baseline footprint for the four sectors analysed across all seven countries was 13.2 Gt of CO_2e and the projected 2030 footprint for the four sectors across all seven countries under business as usual conditions is 21.8 Gt of CO_2e.

The highest abatement potential in using digital technologies (1043 Mt CO_2e in the ambitious decarbonisation scenario) is estimated to be in the Power sector, across both supply and demand intervention points. In the case of China for example, the digitally enabled accelerated decarbonisation abatement of 777 Mt CO_2e is equivalent to decommissioning over 170 average Chinese coal-fired power plants. Significant opportunities for decarbonisation have been identified for energy efficiency gains through smart grids and for increases in distributed renewables, especially through microgrids.

In the Transport sector there is an estimated 394 Mt CO_2e abatement potential in the ambitious decarbonisation scenario using digital solutions supporting car sharing, private and commercial vehicle route optimisation, smart EV charging and facilitating public transport. Digitally-assisted road freight logistics was calculated to make the biggest carbon reduction contribution within the Transport sector with 273 Mt CO_2e of potential abatement in the ambitious decarbonisation scenario.

High-level abatement assessments were also made for adoption of certain digital solutions in the Manufacturing and Agriculture sectors which showed 495 Mt CO_2e and 211 Mt CO_2e abatement potentials in the ambitious decarbonisation scenario, respectively.

The overall potential abatements by country and sector are summarised in the following tables for the reference and ambitious carbon scenarios respectively.

POTENTIAL ABATEMENTS BY COUNTRY AND SECTOR FOR THE REFERENCE SCENARIO

	HEAT AND POWER		TRANSPORT		MANUFACTURING AND CONSTRUCTION		AGRICULTURE		TOTAL
BRAZIL	-6	14%	-12	29%	-5	12%	-19	45%	-42
CHILE	-9	64%	-4	30%	0	3%	0	2%	-14
CHINA	-434	59%	-161	22%	-112	15%	-22	3%	-729
INDIA	-97	37%	-91	35%	-46	18%	-25	10%	-259
KENYA	-2	35%	-1	20%	0	3%	-2	42%	-5
SOUTH AFRICA	-13	64%	-2	11%	-3	13%	-3	13%	-20
VIETNAM	-7	48%	-2	13%	-4	30%	-1	9%	-15
TOTAL	-567		-274		-171		-73		-1085

ALL ABATEMENT FIGURES ARE IN MT CO2E PER ANNUM.
THE (%) FIGURES REPRESENT THE SECTOR PERCENTAGE SHARE OF THAT COUNTRY'S TOTAL POTENTIAL ABATEMENT.

NOTE
Due to rounding, numbers presented may not add up precisely to the totals indicated and percentages may not precisely reflect the absolute figures for the same reason.

POTENTIAL ABATEMENTS BY COUNTRY AND SECTOR FOR THE AMBITIOUS SCENARIO

	HEAT AND POWER		TRANSPORT		MANUFACTURING AND CONSTRUCTION		AGRICULTURE		TOTAL
BRAZIL	-10	10%	-20	20%	-15	15%	-55	55%	-100
CHILE	-15	58%	-8	33%	-1	5%	-1	4%	-25
CHINA	-777	55%	-234	17%	-325	23%	-65	5%	-1401
INDIA	-198	38%	-122	23%	-133	25%	-72	14%	-526
KENYA	-4	31%	-2	13%	0	4%	-6	53%	-12
SOUTH AFRICA	-26	59%	-3	7%	-7	17%	-7	17%	-44
VIETNAM	-14	38%	-5	15%	-13	36%	-4	11%	-35
TOTAL	-1043		-394		-495		-211		-2143

ALL ABATEMENT FIGURES ARE IN MT CO2E PER ANNUM.
THE (%) FIGURES REPRESENT THE SECTOR PERCENTAGE SHARE OF THAT COUNTRY'S TOTAL POTENTIAL ABATEMENT.

NOTE
Due to rounding, numbers presented may not add up precisely to the totals indicated and percentages may not precisely reflect the absolute figures for the same reason.

DIGITAL CONTRIBUTION TO CLIMATE CHANGE ADAPTATION

In addition to assessing the contribution which digital solutions can make to *mitigation* of climate change, this report also assesses how digital solutions can assist in *adaptation* to it in the target countries.

The specific technologies most likely to be the basis of adaptation applications are remote sensors, satellites, GIS (Geographical Information Systems), big data analytics, AI and supercomputers. Such applications include early warning systems for extreme weather events, climate modelling, natural disaster management and recovery, water monitoring and risk evaluation for agricultural communities, mitigating agricultural risk using index-based weather insurance supported by digital tools, control capabilities, such as adjusting water pressure according to availability, and power sector resilience using smart grid technologies. However, there remain considerable barriers to widespread adoption of such adaptation-relevant applications in low- and middle-income countries, including lack of funding, inadequate communications infrastructures, and unstable political environments. On the positive side, there exist also a number of enablers to adoption, some of which should in time act to overcome some of the barriers and thereby facilitate adoption. These enablers include increasing smartphone ownership, improving access to reliable and high bandwidth networks in many currently digitally disadvantaged areas of the world, and the rising willingness to freely share data and information, including open source and other free software, amongst interested parties.

EMISSIONS RESULTING FROM THE USE OF DIGITAL TECHNOLOGIES

Various studies into the carbon footprint of the ICT industry have shown quite disparate results, and caution must be applied when comparing them as the basis of such studies are rarely the same, e.g. differences in the definition of exactly what constitutes ICT, and whether or not upstream and downstream emissions are included.

One recent and comprehensive study, for example, published by the International Telecommunications Union (ITU)[4], estimates that for all data centres, telecoms networks and ICT end-user devices, the 2015 carbon footprint was 740Mt CO_2e including embodied emissions in ICT equipment and network deployment and construction, and electricity grid transmission loses. The study forecasts that this figure will remain similar in 2020, i.e. growth in the sector is balanced out by energy efficiencies and greater use of renewable power.

Future emissions are very difficult to predict due to many uncertainty factors including future energy efficiencies in digital hardware, the extent to which the power grid will decarbonise, and growth rates of digital technologies.

As it is known today, the ICT sector carbon footprint is, and will probably continue to be, dominated by applications such as video streaming, gaming, social media and conventional commercial transactions. In comparison, many of the carbon reducing applications identified in this report will require minimal bandwidth and increases in their take-up are therefore not expected to make any significant contribution to changes in the overall ICT sector carbon footprint.

REPORT RECOMMENDATIONS

To help facilitate and accelerate the adoption of the types of digital solutions covered in the report, and thus maximise their potential for assisting achievement of the NDCs for the target countries, and those of other low- and middle-income countries, the following recommendations are made:

FOR POLICYMAKERS

I INTRODUCE MARKET REGULATION TO INCREASE DIFFUSION WHILE ENCOURAGING DECARBONIZATION IN THE SECTOR

- Investigate regulation designs that focus on efficient investment incentives for electricity grid expansion and smart solutions, allowing new market actors to enter
- Include an obligation in the terms of reference of energy market regulators to achieve levels of decarbonisation in the sector, reflecting the opportunities afforded by digital technologies

II SUPPORT DIVESTMENT AND COAL EXIT EFFORTS THROUGH DIGITAL TECHNOLOGIES

- Develop an open-access database and monitoring tool on companies across the national coal value chain to inform divestment and coal exit strategies

III ESTABLISH A FAIR, BALANCED AND CONSISTENT REGULATORY APPROACH TO ICT SOLUTIONS

- Set general and sector specific standards on ethical and technical levels to ensure trustworthiness and data security

IV INTEGRATE DIGITAL TECHNOLOGIES IN PUBLIC PROCUREMENT CONTRACTS

- Integrate the funding and development of digitally enhanced abatements with carbon reduction and climate change adaptation ambitions

V CREATE INCENTIVES TO INVEST IN BROADBAND INFRASTRUCTURE DEPLOYMENT

- Connect schools and libraries to broadband, increasing digital literacy to drive adoption and raise ICT access and awareness

VI COLLECT AND PROVIDE OPEN ACCESS DATA TO FACILITATE THE DEVELOPMENT AND EXPLOITATION OF DIGITAL APPLICATIONS

- Develop a digital infrastructure that collects real-time data including demand and supply information on power grids; public transport arrival and departure times; traffic congestion etc. Build the data into relevant projects along with the development of open data portals with suitable APIs (Application Programming Interfaces).

VII PROMOTE THE BENEFITS OF SMART HOME AND SMART BUILDING SOLUTIONS

- Establish an engagement plan for end-users by market segment (innovators, early adopters, early majority, late majority, laggards), marketing enrolment through whole-house upgrades
- Partner with industry stakeholders to develop standards and guidelines for: design, functionality, data and privacy, and assessment

VIII CONSIDER ICT WITHIN THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) PROCESS AS A KEY INSTRUMENT TO SUPPORT COUNTRIES IN ACHIEVING THEIR CLIMATE TARGETS

- Develop guidelines on how donor countries and organisations can embed the use of ICTs within climate change mitigation and adaptation programmes

IX UNDERTAKE IN-DEPTH ASSESSMENTS WHICH INVESTIGATE THE ROLE OF DIGITAL TECHNOLOGIES IN AGRICULTURE, INCLUDING RICE CULTIVATION

- As many low- and middle-income countries are rural with vast agricultural diversity, considerations must be made to different regions and the differing potential for impact and trends
- Broader studies can be conducted by strengthening private-public partnerships (PPPs) and engaging civil society across different levels

X UNDERTAKE IN-DEPTH EXAMINATION OF THE IMPACTS OF E-COMMERCE IN LOW- AND MIDDLE-INCOME COUNTRIES

- Focus the case study selection on specific cities and produce recommendations to better understand the impacts through an integrated transport and digital infrastructure

FOR THE ICT INDUSTRY

I SET EMISSIONS TARGETS AT INDUSTRY OR BUSINESS LEVELS

- Deciding to set and communicate its own target and performance will bring greater commitment and transparency

II INVEST IN LOW- AND MIDDLE-INCOME COUNTRIES TO INCREASE ENERGY EFFICIENCY AND DEVELOP LOW-CARBON PARTNERS TO SPEED UP DEPLOYMENTS

- Promote low-carbon economic growth through innovative funding mechanisms through PPPs, safeguarding community-based solutions and ownership

1

INTRODUCTION

For the past few decades, digitalisation has affected every aspect of our lives. Social media has changed the manner and speed at which we communicate, innovations in financial technology (fintech) enable transactions with a click of a button, even governments are testing electronic governance (e-governance) systems to deliver services efficiently and expand inclusivity. While digitalisation is being deployed at different rates in low-, middle-, and high-income countries, there is no denying the important role that it plays in our world today.

While this age of digitalisation has been thriving, we have also been facing humanity's greatest challenge to date: climate change. Deadly heat waves, massive flooding, prolonged droughts, and other natural disasters - these events are occurring at alarming rates across the globe. As a response to the climate crisis, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) 2015 Paris Agreement committed to accelerate and ramp up investments in order to develop a sustainable, low carbon future. Additionally, enhanced capacity building frameworks to support low- and middle-income countries were put in place to help them meet nationally determined contributions (NDCs) and to boost collective efforts.

Being integrated into multiple industries and facets of daily life, the Information and Communication Technology (ICT) sector is well-positioned to help individuals, businesses, and governments work towards the goals of the Paris Agreement. Although sometimes seen as an accelerator of waste and energy consumption, solutions-driven technologies are key for a faster, more efficient global transformation. By analysing the impacts of real-world use cases of digital technologies, this study analyses how digitalisation can offer effective solutions for climate action.

The ICT industry and its stakeholders should work to develop, deploy, and integrate digital technologies to support countries, especially low- and middle-income countries, in raising their NDC ambition and strive for a more efficient, low-emission, more resilient future.

COUNTRIES SELECTED FOR DETAILED ANALYSIS

The carbon abatement opportunities of seven specific countries were selected to offer selected to offer a range of varying:

- Levels of economic development in terms of GDP per capita.
- Geographic spread - with at least one country in each of Africa, Asia and South America.
- Levels of existing climate impact reflecting different extents of fossil fuel and renewable energy availability
- Distributions across four main components of the country's carbon footprint – power and heat, transport, manufacturing and agriculture.
- Levels of urbanisation as reflected in the importance of agriculture in the country's economy and carbon footprint.

The seven countries thus selected were:

BRAZIL
Upper middle income

CHILE
Higher income

CHINA
Upper middle income

INDIA
Lower middle income

KENYA
Lower middle income

SOUTH AFRICA
Upper middle income

VIETNAM
Lower middle income

The report specifically focuses on those digital applications leading to reduced carbon impacts where additional interventions may be required to stimulate take up, rather than applications that might be expected to happen as a natural matter of course.

The calculated abatements are generally before any consideration of rebound effects[5]. Such effects are known to be significant in certain circumstances and, although they have not been quantified, they are discussed in detail throughout out the report

EXISTING GESI REPORTS ON CLIMATE CHANGE

Since 2008 GeSI has published a sequence of reports exploring the role digital technologies can play in the achievement of the SDGs more generally, and climate change more specifically.

- Smart2020: Enabling the Low Carbon Economy in the Information Age (2008)[6]
- SMART Portugal 2020: Reducing Emissions and Increasing Energy Efficiency through ICT (2009)[7]
- Using ICTs to Tackle Climate Change (2010)[8]
- The Broadband Bridge Linking ICT with Climate Action for a Low Carbon Economy (2012)[9]
- GeSI SMARTer2020: The Role of ICT in Driving a Sustainable Future (2012)[10]
- Measuring the Energy Reduction Impact of Selected Broadband-Enabled Activities Within Households (2012)[11]
- The Enabling Technologies of a Low-Carbon Economy: A Focus on Cloud Computing (2013)[12]
- Evaluating the Carbon Reducing Impacts of ICT - an Assessment Methodology Developed by BCG for GeSI (2013)[13]
- ICT Solutions for Sustainable Lifestyles (2013)[14]
- SMARTer2030 ICT Solutions for 21st Century Challenges (2015)[15]
- #SMARTER2030 – ICT can Help Germany and its Climate Targets while Delivering Economic Benefits (2015)[16]
- Carbon Abatement Handbook (2016)[17]
- Digital with Purpose (2019)[18]


2

DIGITAL CONTRIBUTIONS TO THE NDCS OF LOW- AND MIDDLE-INCOME COUNTRIES

2.1 NATIONALLY DEVELOPED CONTRIBUTIONS (NDCS)

The 2015 Paris Agreement provides the overarching framework for global collective response to the threat of climate change by keeping global temperature rise in the 21st century to well below 2˚C (compared to pre-industrial levels) and to pursue efforts to limit temperature increase even further, to 1.5˚C.

According to the Paris Agreement, each Party shall prepare, communicate and maintain successive NDCs that reflect the country's ambition for reducing emissions, taking into account its domestic circumstances and capabilities. Countries shall pursue domestic mitigation measures with the aim of achieving the objectives of such contributions.

Countries committed to review their NDCs every five years, first in 2020. In principle, the updating of NDCs presents countries with significant opportunities to align their climate and development agendas to promote sustainable growth. As the UN Environment Programme's (UNEP) emissions gap report highlights this is urgently required. Released just prior to COP 25 in 2019, the report showed the stretch 1.5˚C goal of the Paris Agreement is "slipping out of reach". Even if existing NDCs are met, emissions in 2030 will be 38% higher than required to meet that target, the report concluded.

The year 2020 is the first opportunity for countries to review their NDCs and submit more ambitious ones. However, the actual requirement is to either "[re]communicate" or "update" the pledges, with no requirement to increase ambition or align to the 1.5C goal and given the outcome of COP25 in Madrid expectations are not high.

Every opportunity should therefore be grasped to help increase NDC ambition levels and the purpose of this report is to investigate how digital technologies can help low- and middle-income countries achieve and strengthen their NDCs.

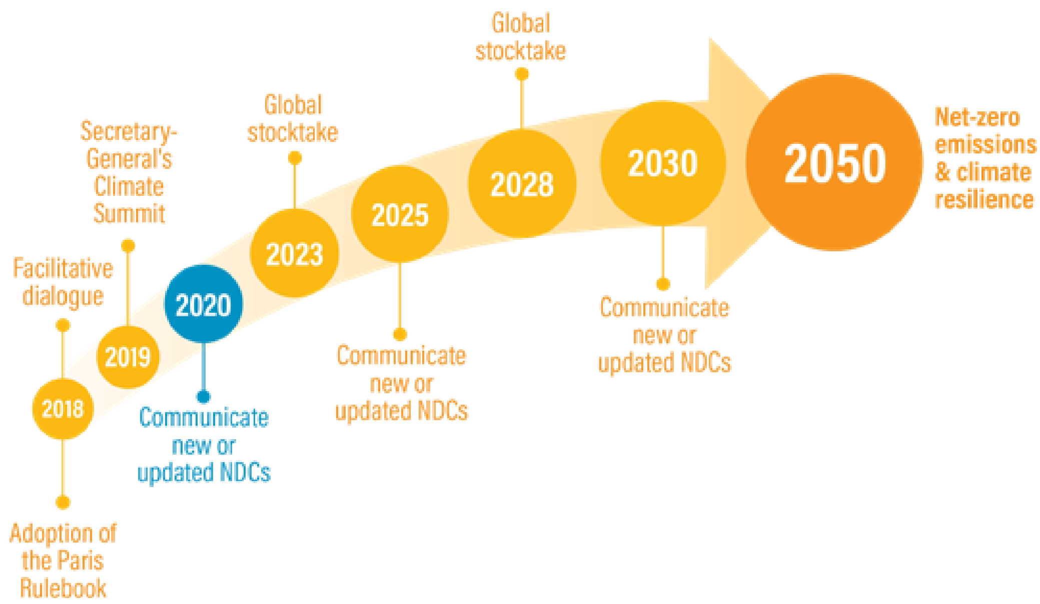


FIGURE 2.1
The NDC roadmap.

2.2 LINKING CARBON EMISSIONS TO ECONOMIC DEVELOPMENT

As low- and middle-income economies grow and people are lifted out of poverty, lifestyles have, historically at least, become more carbon intensive.

Today, for low- and middle-income countries, there will be an inevitability to this trend as new infrastructure is built and individuals achieve their aspiration of more middle-class lifestyles with homes complete with refrigeration, air conditioning, heating, sanitation, energy and water supplies, private transportation etc.

A graph of national carbon emissions per capita against GDP per capita, figure 2.2, demonstrates the general trend.

However, closer inspection of the historic pathways followed by a number of specific countries shows, figure 2.3, that a continuous coupling of carbon emissions per capita to GDP per capita is not inevitable.

Two high income countries, Australia and the UK, have shown very different development pathways. Australia's per capita emissions continued to grow as its GDP per capita grew, whereas the UK demonstrated a distinct decoupling between the two.

CO_2 PER CAPITA VS GDP PER CAPITA

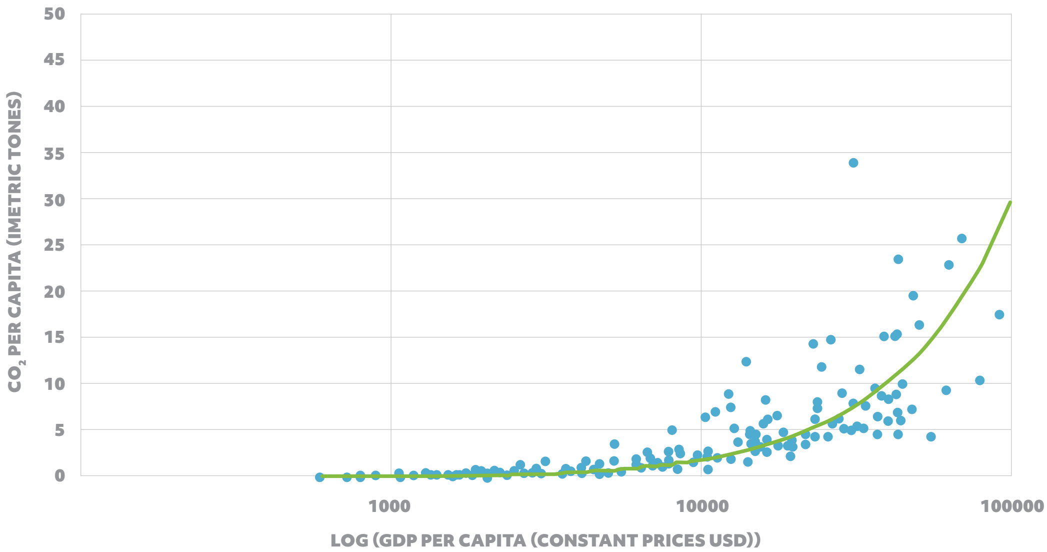


FIGURE 2.2
Global national carbon emissions per capita against GDP per capita. Each point represents a different country.

HISTORIC CARBON PATHWAYS 1950 - 2014

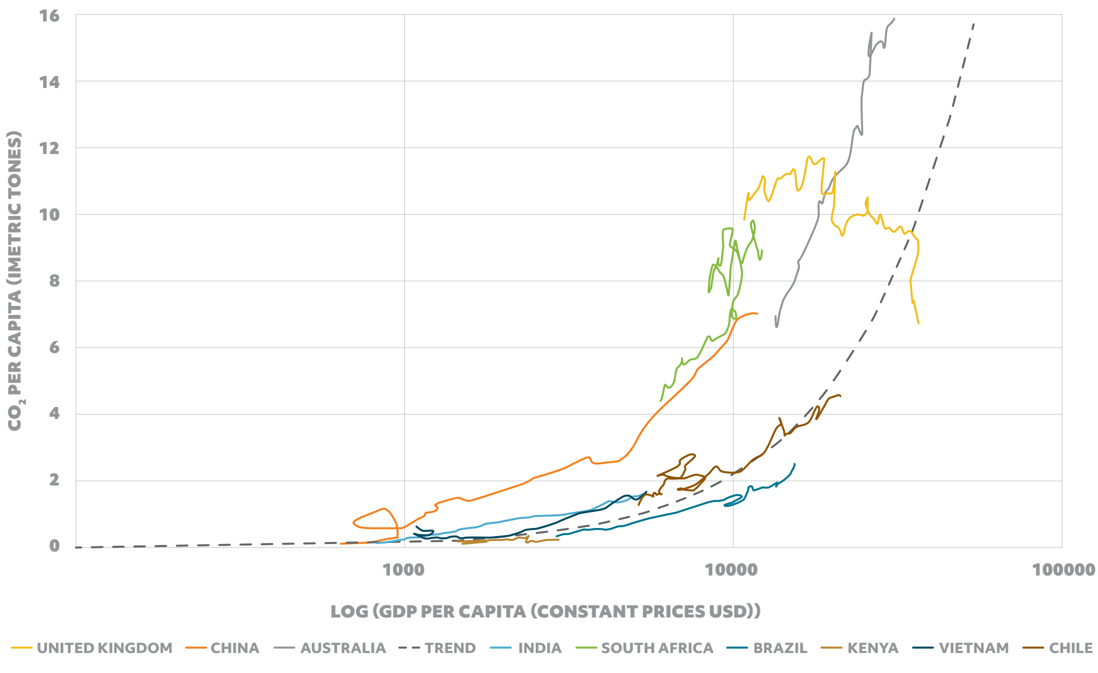


FIGURE 2.3
Historic carbon emissions pathways for selected countries covering the period 1950 – 2014 from left to right.

To some extent the decoupling demonstrated by the UK may be explained by the UK's switch from a manufacturing economy to a service economy. As many high-income economies have made this transition, other, low wage countries such as China, have inherited those emissions. This may explain why China's carbon intensity pathway sits significantly above the dashed trend line.

However, Australia also has a significant service sector, representing 61% of its GDP in 2016[18] compared to 80% of GDP for the UK in 2016[20]. This implies other factors are in play as a comparison of the carbon intensity of electricity generation demonstrates. The UK, which is well on its way to completely eliminating coal fired generation and has installed extensive renewable generation, has a grid intensity of 256kg CO_2e/MWh[21]. On the other hand, Australia continues to generate most of its power from coal and has a grid intensity of 744kg CO_2e/MWh[22].

All seven countries studied in this report have shown increasing emissions as their economies have developed. In 2014, the three low- middle-income countries plus Chile, were close to the trend line, whilst Brazil was below. Chinese and South African emissions per capita and GDP per capita are both roughly where the UK and Australia were in 1950.

2.3 FUTURE CARBON PATHWAYS

All countries are currently preparing for the 2020 five-year update of their NDCs and many economies are at a critical juncture where decisions now will determine whether or not their future trajectories will follow a closely coupled path such as Australia, or a de-coupled path such as the UK.

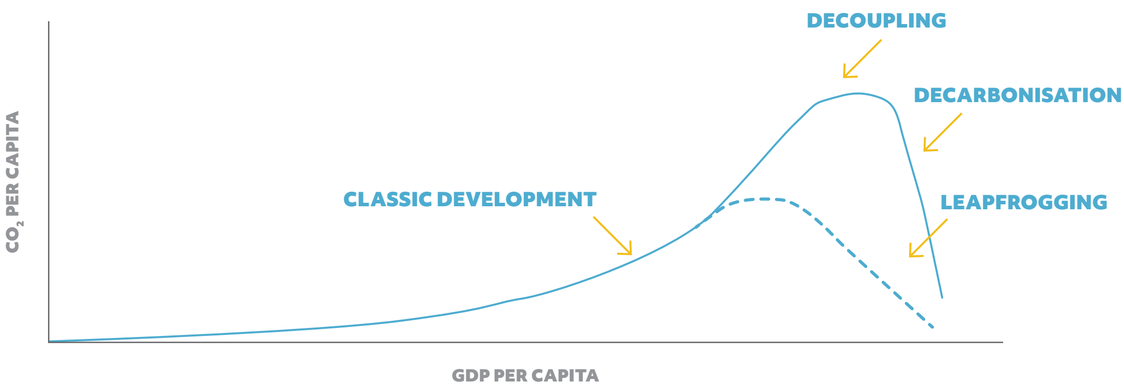


FIGURE 2.4
Schematic diagram showing different possible decarbonisation, development pathways.

As illustrated in figure 2.4, in order to deliver against the Paris Goals, countries about to transition into the higher-income band will need to enter a decoupling phase before then decarbonising rapidly. Countries, lower down the development curve have the opportunity to leapfrog over the standard road of high carbon intensity and, through the application of new low carbon technologies, tunnel through the high carbon hill. Figure 2.5 illustrates where the seven countries under current investigation approximately sit on the development pathway graph.

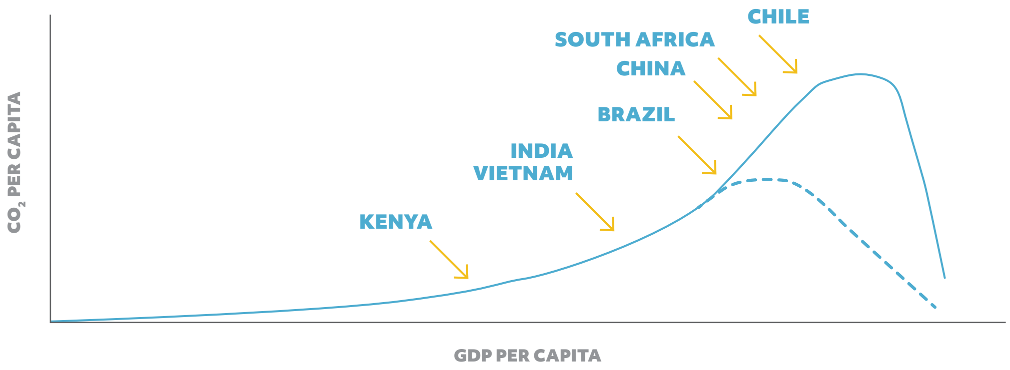


FIGURE 2.5
Current positions of selected countries on the decarbonisation, development pathways.

2.4 DIGITAL TECHNOLOGIES AND THE NDCS

There are many ways in which ICT can reduce global GHG emissions. For this report we have split them into four main categories:

SMART GRIDS AND BUILDINGS, TO INCREASE ENERGY EFFICIENCY AND THE MANAGEMENT OF RENEWABLE ENERGY

Smart electricity grids use digital communications and other advanced technologies to measure usage at the local level and manage demand and supply accordingly. They are essential in coping with the dynamics of energy generation from intermittent sources and are thereby a fundamental enabler of large-scale renewable energy generation.

INTELLIGENT TRANSPORT SYSTEMS

Intelligent transport systems have the potential to reduce emissions from all sizes and types of vehicles. Real- time traffic flow management, improved public transport information, smart logistics and predictive maintenance of infrastructure are all ways that improve the way in which people and goods move.

INDUSTRY 4.0 AND MORE EFFICIENT MANUFACTURING PROCESSES

Industry 4.0 enables industry to become more connected, efficient and smart, and digital technologies are the underlying drivers: big data, machine learning, IoT and cloud computing allow for autonomous and intelligent manufacturing, predictive maintenance, and optimise production and supply chains.

PRECISION AGRICULTURE, TO IMPROVE EFFICIENCY IN THE USE OF NITROGEN-BASED FERTILISERS AND LIVESTOCK MANAGEMENT

Precision agriculture uses digital technology to target the application of fertilisers thus increase productivity and reducing emissions. Targeted sensing can also help control enteric emissions from livestock.

The aim of this report is to evaluate how these potential abatement areas can be attributed in a quantitative fashion to individual low- to middle- income countries and thereby contribute to, and even raise, their NDC ambitions. Each of the four categories is considered in much more detail later in the report with a special focus placed on the power and transport sectors.


3

COUNTRY PROFILES

The following spectrum illustrates a wide spread of grid intensities across the seven countries. The position of the countries on the spectrum shows no specific relationship to the level of economic development but is more indicative of a country's available natural resources – particularly hydro power and coal. The left-hand side of the spectrum represents the highest carbon intensity power generation – typically from coal, whereas the right hand side represents zero carbon generation which may be from either renewable or nuclear sources.

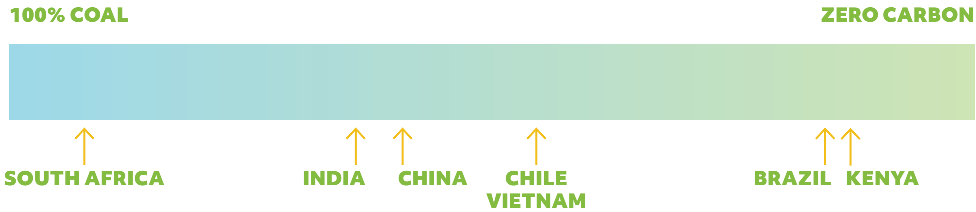
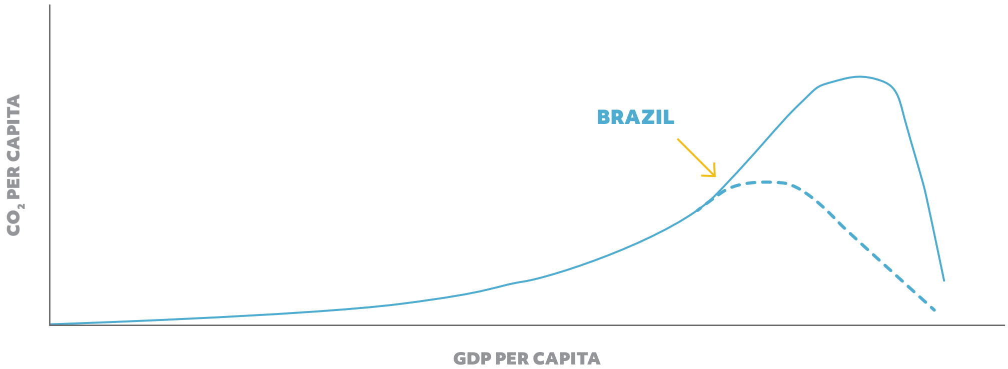


FIGURE 3.1
Existing power sector decarbonisation for the seven selected countries.

For each country a detailed breakdown of carbon emissions by source has been taken from the WRI CAIT Climate Data Explorer[23] and presented as a bar graph.

Country power grid carbon intensities as shown in figure 3.1 have been approximated by taking the power sector generation mix published by the International Energy Agency (IEA)[24] and an estimated emissions factor by fossil fuel source[25].

3.1 BRAZIL



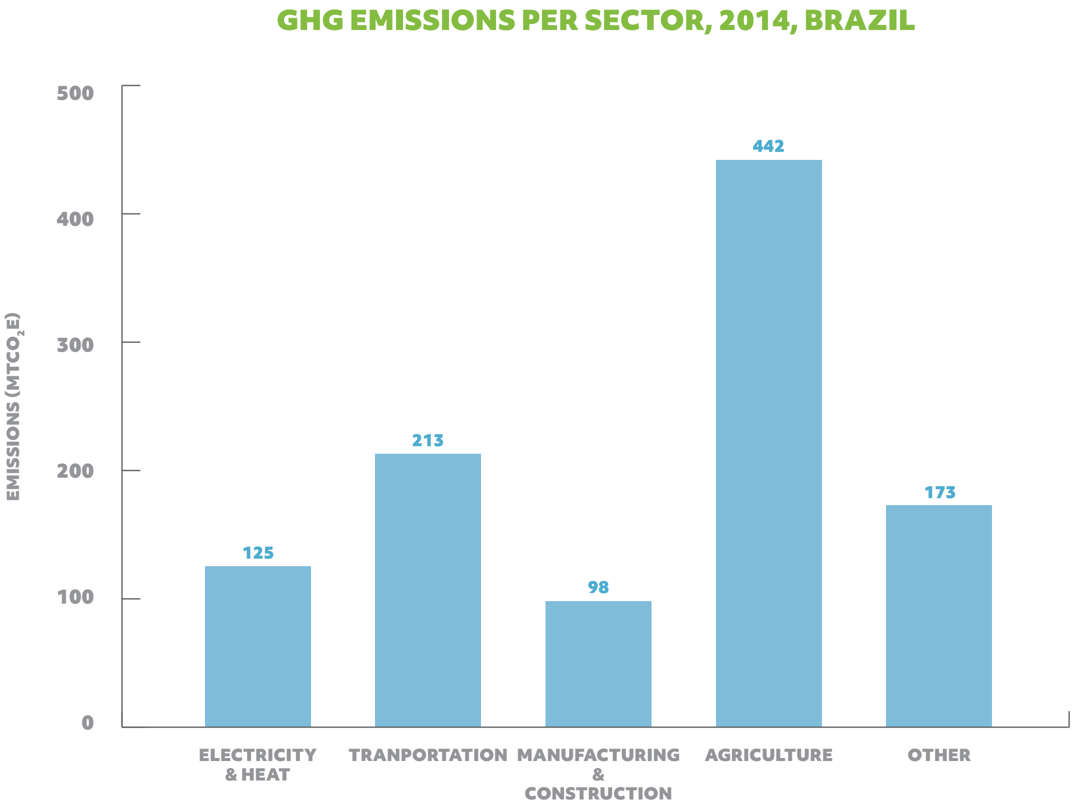


FIGURE 3.2
Brazil: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

Brazil is a high middle-income country rich in natural resources. It has the world's sixth largest greenhouse gas (GHG) emissions. Home to much of the Amazon, its largest source of emissions by far is land-use change and the forestry sector.

Extensive deforestation data collected by INPE, Brazil's National Institute for Space Research confirm that while deforestation rates are very high: more forest has been cleared during the summer of 2019 than in the past three years combined, the number of fires increased by 80% since 2018[26].

Brazil also uses large amounts of biofuels in transport and generates more than 70% of its electricity from hydropower[27].

Brazil's current NDC outlines plans to boost the share of renewables in its overall energy mix to 45% by 2030, up from 40% in 2015. The country indicates around two-thirds of this should come from renewables other than hydro. It also wants to reach 23% of non-hydro renewables in its power mix by 2030, as well as making the electricity supply 10% more efficient[28].

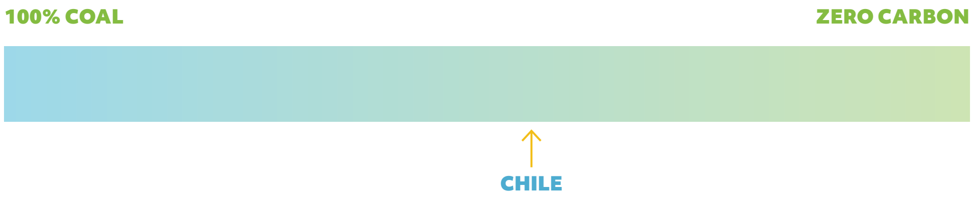
BOOST THE SHARE OF RENEWABLES IN ITS OVERALL ENERGY MIX TO

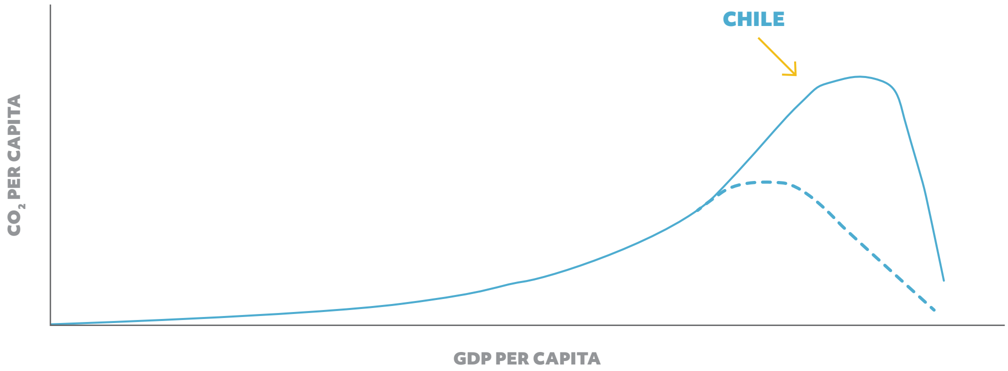
45% BY **2030**

UP FROM

40% IN **2015**

3.2 CHILE





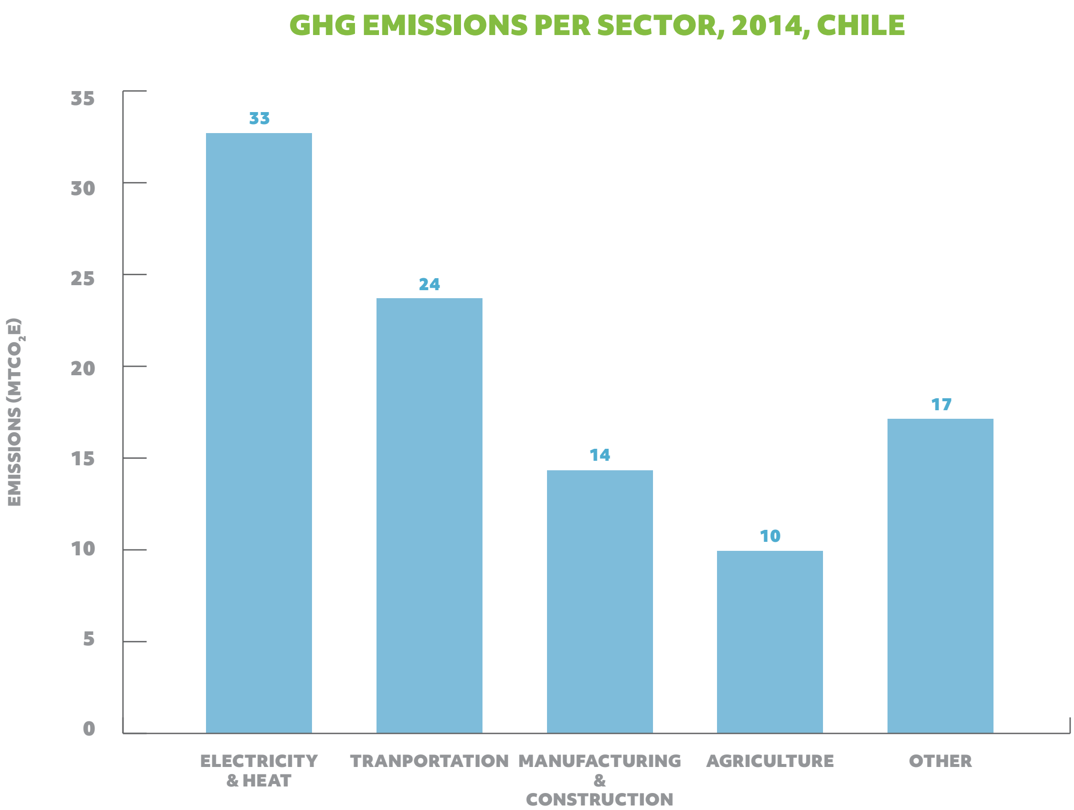


FIGURE 3.3
Chile: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

Chile is a higher income country and has been one of Latin America's fastest growing economies in recent decades. Around 50% of total electricity generated in Chile is from thermal sources (mainly coal), 28% from hydro and 19% from other renewables[29].

In its NDC[30], Chile has committed to two carbon intensity targets, exclusive of Land Use, Land-Use Change, and Forestry (LULUCF):

- to reduce its CO_2 emissions per GDP unit by 30% below their 2007 levels by 2030; and
- subject to IMF grants, reduce its CO_2 emission per GDP unit by 2030 until it reaches a 35% to 45% reduction with respect to the 2007 levels.

LULUCF sector targets are:

- sustainable development and recovery of 100,000 hectares of forest, accounting for GHG sequestrations and reductions of an annual equivalent of around 600,00 CO_2 as of 2030; and
- reforest 100,000 hectares accounting for sequestrations of 900,000 - 1,200,000 annual equivalent tonnes of CO_2 as of 2030.

Chile's key energy strategy – Energy 2050 – contains ambitious plans to reduce dependence of fossil-fuel power generation and rapidly increase renewables capacity. For example, it will not build any new non-CCS coal-fired power plants and will plan, in time, to phase them out completely, and aims to generate at least 60% of its total electricity by 2035, and 70% by 2050, using renewables. In addition, the Energy Route 2018–2022 includes a roadmap for improving energy efficiency, promoting small distributed renewable energy, and for starting the process of decarbonising Chile's energy. As regards decarbonisation of the transport sector, the Electromobility Strategy aims to achieve electrification shares by 2050 of 40% of private vehicles, and 100% of public vehicles[31].

CHILE AIMS TO GENERATE AT LEAST

60%

OF ITS TOTAL ELECTRICITY USING RENEWABLES BY

2035

3.3 CHINA

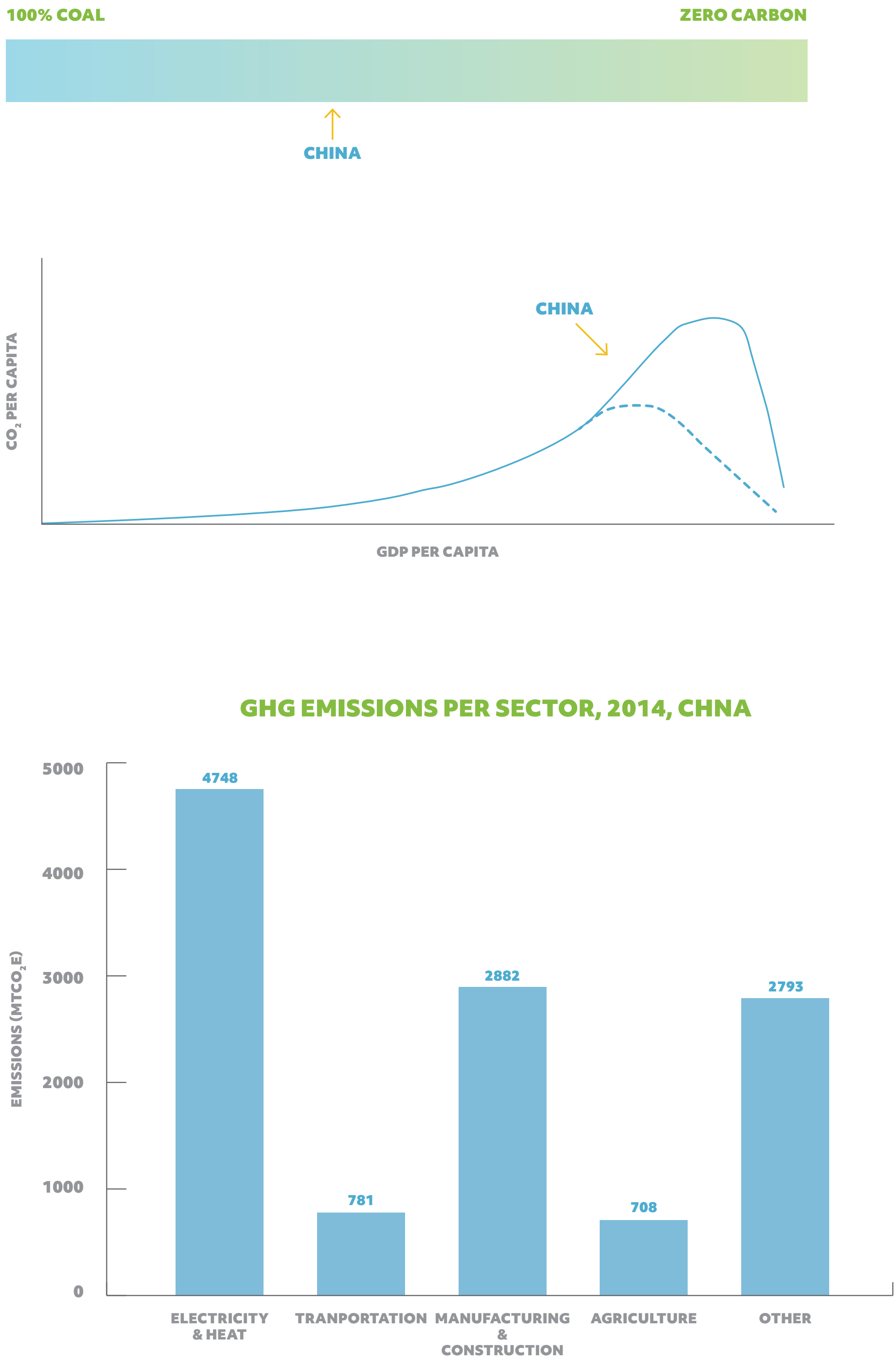


FIGURE 3.4
China: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

China is an upper middle-income country, it is the world's largest GHG emitter, accounting for some 27% of total emissions (excluding LULUCF). On the one hand it is the world's largest consumer of coal, but, on the other, it is also the world's largest renewable energy developer[32]. Currently, fossil fuels are the dominant electricity generation sources, with non-hydro renewables forming a very small share.

In its NDC[33], China commits to, by 2030:

- achieve GHG emissions peak in 2030 and make best efforts to peak earlier
- reduce GHG emissions per unit of GDP by 60 - 65% from the 2005 level
- increase the share of non-fossil fuels in primary energy consumption to around 20%
- increase the forest stock volume by around 4.5 billion cubic meters compared with 2005 levels

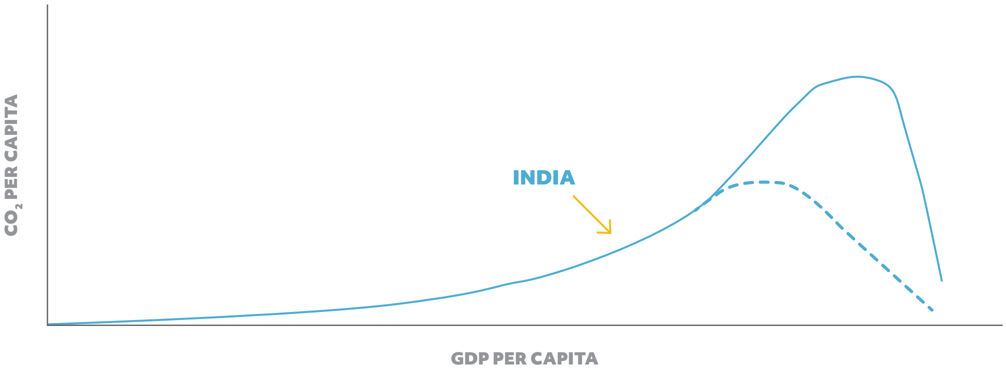
China's 13th Five-Year Plan (covering the period 2016-2020) targets a maximum 58% share of coal in national energy consumption by 2020. China is implementing an emissions trading system, and has also announced a mandatory renewable energy certificate scheme that sets targets for renewable energy for each province individually.

Over 1.25 million electric vehicles were sold in China in 2018—a 2018 market share of 4.2%. China has both subsidies and tax exemptions that apply to new electric vehicles, which are expected to make up 10% of annual sales in 2019 and 12% in 2020, although these subsidies will end in 2020.

China's government has been actively reducing the fuel intensity of road transport, with a new fuel standard implemented for light duty trucks in 2018, and planned standards coming into effect for passenger vehicles in 2020 and heavy-duty vehicles in 2021.

IN ITS NDC, CHINA COMMITS TO INCREASE THE FOREST STOCK VOLUME BY AROUND
4.5 BILLION CUBIC METERS
COMPARED WITH 2005 LEVELS

3.4 INDIA



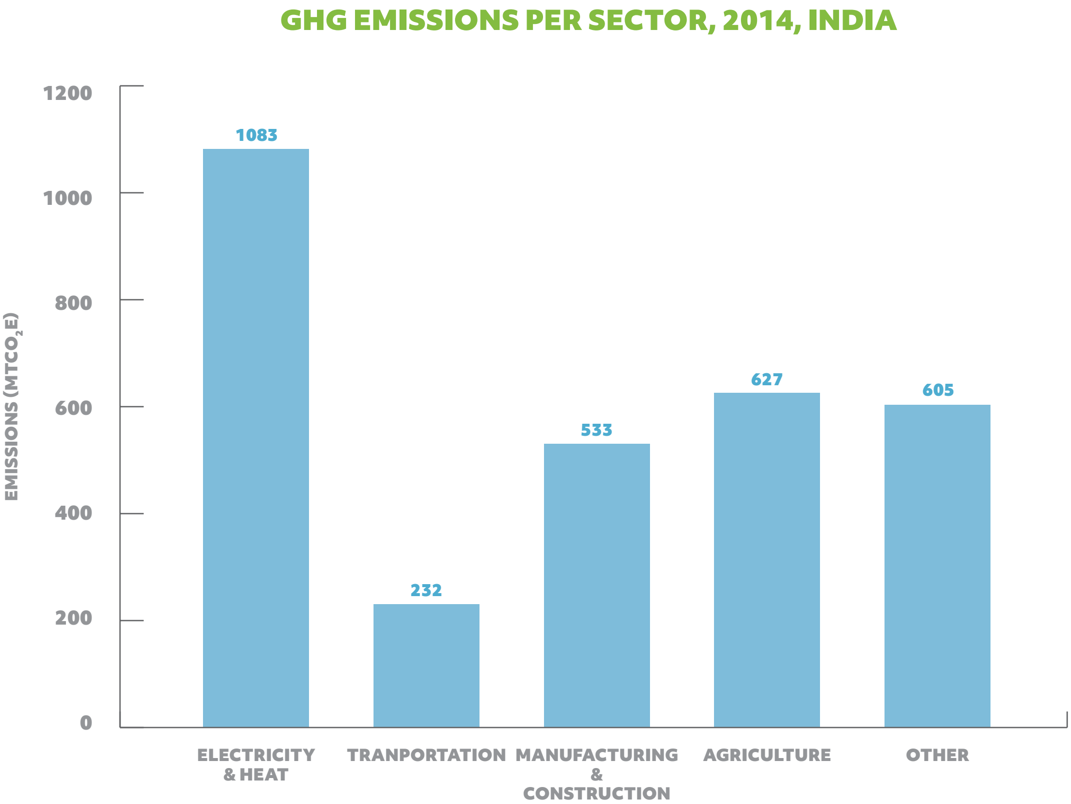


FIGURE 3.5
India: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

India is the world's third largest emitter of greenhouse gases (GHGs), after China and the US. It is intensively populated and intensively farmed, resulting in less than 4% of its emissions associated with land-use and forestry. Coal power plants, rice paddies and cattle are major sources of emissions, which continue to rise steeply, although per-capita emissions remain well below the global average.

India has a national smart grid mission that includes advanced metering, distributed renewables, microgrids and integration with electric vehicles[34].

India currently has the world's fifth largest car sales. These are expected to grow with rising incomes and rapid urbanisation[35]. Emissions from vehicles is a major problem for India that will only increase unless dramatic steps are taken to manage the predicted growth of private car ownership. The World Health Organization reported last in 2018 that 11 of the 12 cities in the world with the most pollution from PM2.5 were in India[36].

Agriculture is responsible for around 16% of India's GHG emissions[37]. Of this, 74% is due to methane produced from livestock – largely cows and buffalo – and rice cultivation[38]. The remaining 26% comes from nitrous oxide emitted from fertilisers[39].

The country has pledged a 33-35% reduction in the "emissions intensity of its economy by 2030, compared to 2005 levels". India also aims for 40% of its installed electricity capacity to be renewable or nuclear by 2030, compared to 16% in 2015.[40]

INDIA AIMS FOR
40%
OF ITS INSTALLED ELECTRICITY CAPACITY TO BE RENEWABLE OR NUCLEAR BY
2030

3.5 KENYA

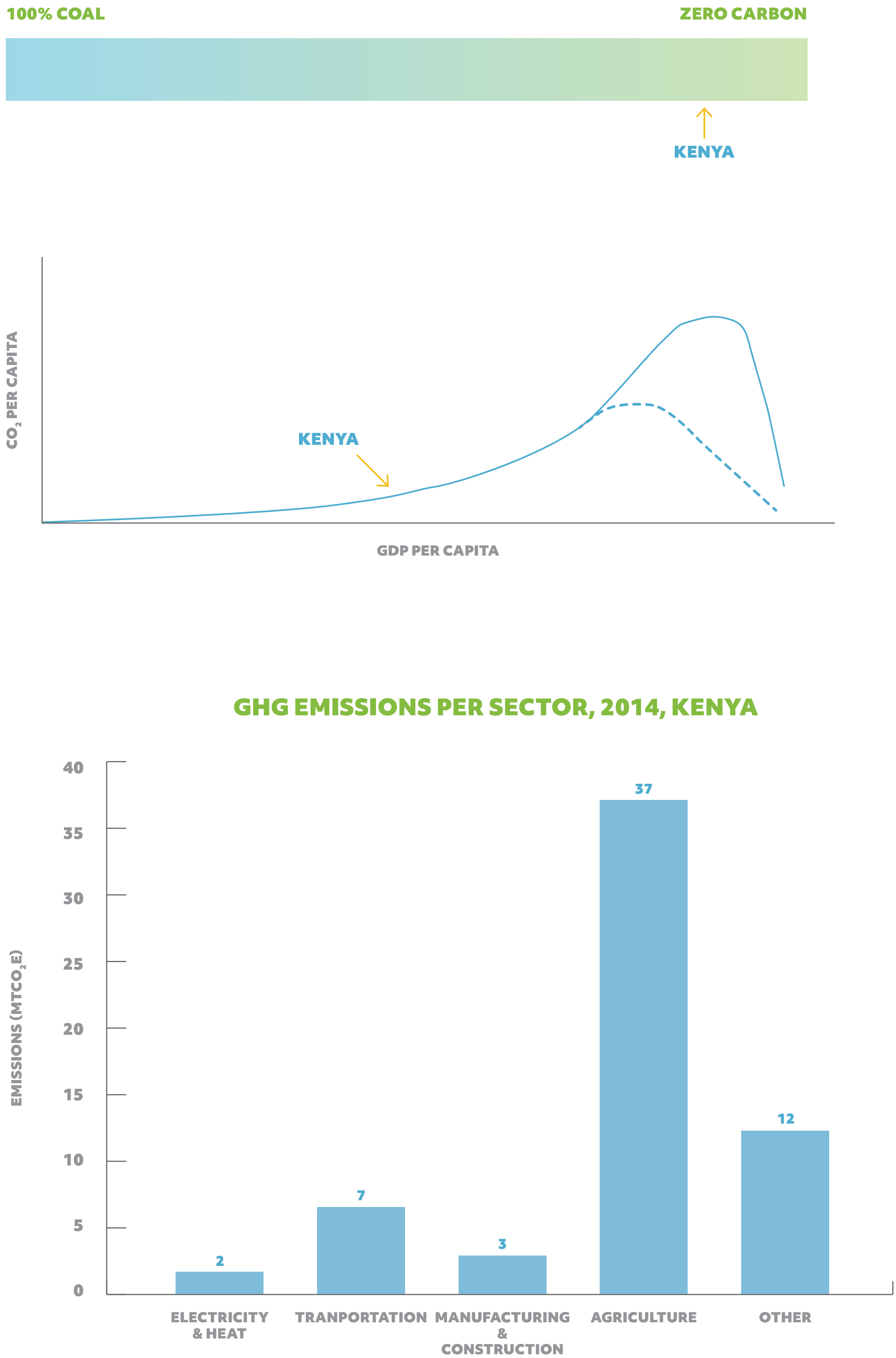


FIGURE 3.6
Kenya: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

Kenya is a lower middle-income country, with a very large agricultural sector, relative to other sectors, from which the vast majority of total GHG emissions originate. Renewable energy makes up 85% (mainly hydro) of its installed electricity capacity and the Kenyan government has stated aims to be powered entirely by green energy by 2020. However, and perhaps paradoxically, there are also plans to extract coal and build one, perhaps two, new coal-fired power stations[41].

Until relatively recently, in common with many African countries, a large portion of the Kenyan population were not served by grid electricity, but the situation is now much improved with almost 75% of the population today on the grid. The Last Mile Connectivity Project of the Rural Electrification Authority aims to make this 100% by 2022[42].

In its NDC[43], Kenya aims to reduce its GHG emissions by 30% by 2030 relative to the BAU scenario of 143 $MtCO_2eq$. This is subject to international support in the form of finance, investment, technology development and transfer, and capacity building.

RENEWABLE ENERGY MAKES UP 85% OF KENYA'S INSTALLED ELECTRICITY CAPACITY, MAKING THE ENERGY SECTOR AN IMPORTANT CONTRIBUTOR TO KENYA'S AIMS TO REDUCE ITS GHG EMISSIONS BY 30% BY 2030 RELATIVE TO THE BAU SCENARIO

3.6 SOUTH AFRICA

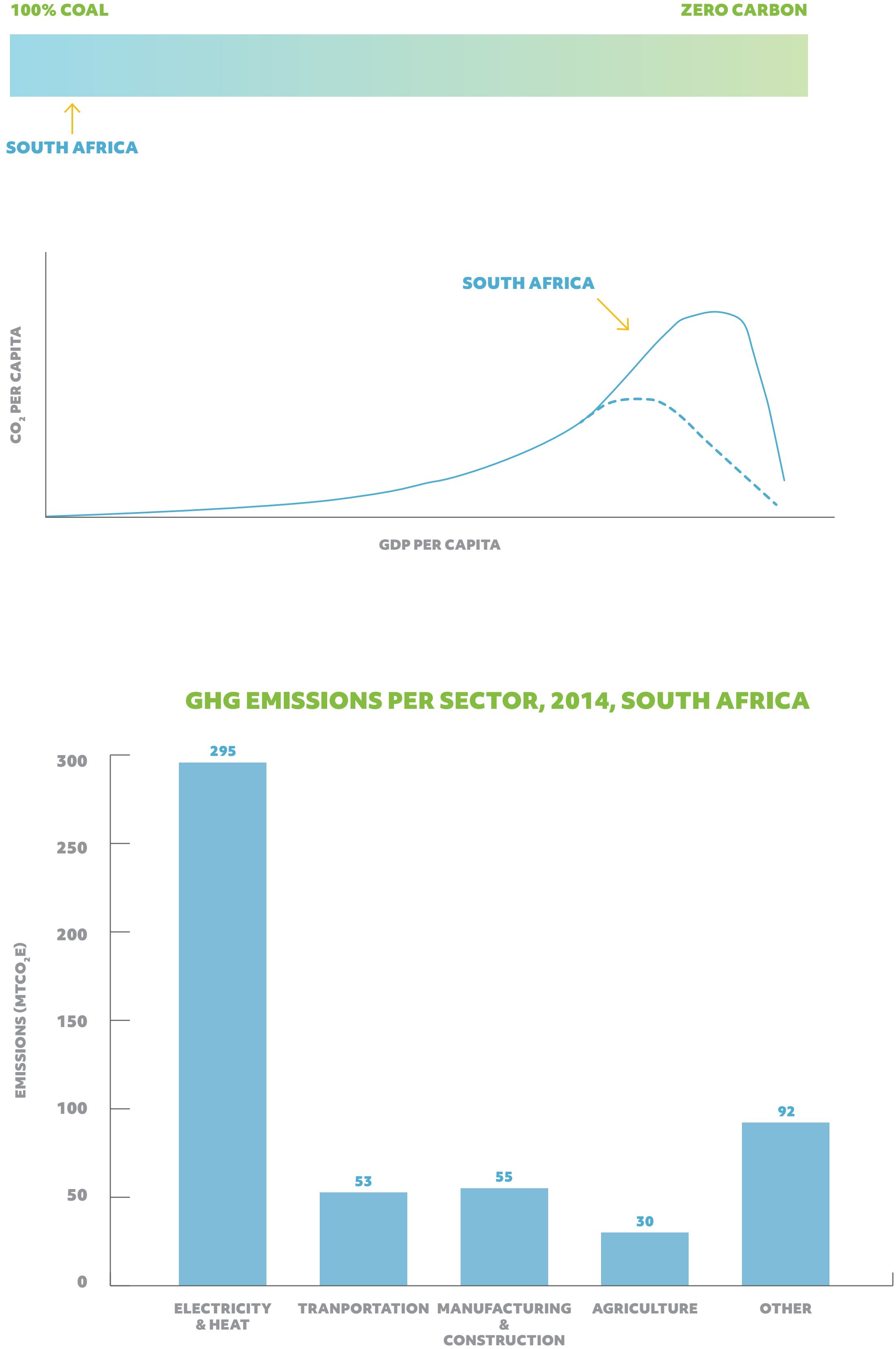


FIGURE 3.7
South Africa: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

South Africa is the world's 14th largest emitter of greenhouse gases (GHGs). Its CO_2 emissions are principally due to a heavy reliance on coal.[44]

South Africa NDC pledges a "peak, plateau and decline" approach, whereby emissions would peak between 2020 and 2025, plateau for roughly a decade, and then start to fall. Emissions during 2020-2025 would be between 398-614MtCO_2e, it says, including land use and all sectors of the economy. This "plateau" would translate to a 14-75% rise above 1990 levels.[45]

South Africa's 2010 Integrated Resource Plan (IRP) included plans for 17.8GW of new renewables capacity (excluding hydro) to be installed by 2030, made up of 8.4GW of each of wind and solar PV, plus 1.2GW of concentrated solar power (CSP). This means renewables capacity in 2030 would be 18.8GW, 21% of all capacity.

The draft 2018 IRP adjusted these 2030 plans to 8.0GW solar, 11.4GW wind, and 0.6GW CSP, totalling 20GW of renewables excluding hydro. Since it also substantially reduces total capacity from all sources, this means renewables would provide 27% of installed capacity in 2030.[46] The 2019 IRP[47] is even more ambitious with 8.3 GW solar, 17.7GW wind, and 0.6GW CSP, totalling 26.6GW of renewables excluding hydro representing 34% of installed capacity in 2030.

SOUTH AFRICA'S 2019 IRP PLANS FOR

26.6GW

OF RENEWABLES EXCLUDING HYDRO REPRESENTING

34%

OF INSTALLED CAPACITY IN

2030

3.7 VIETNAM

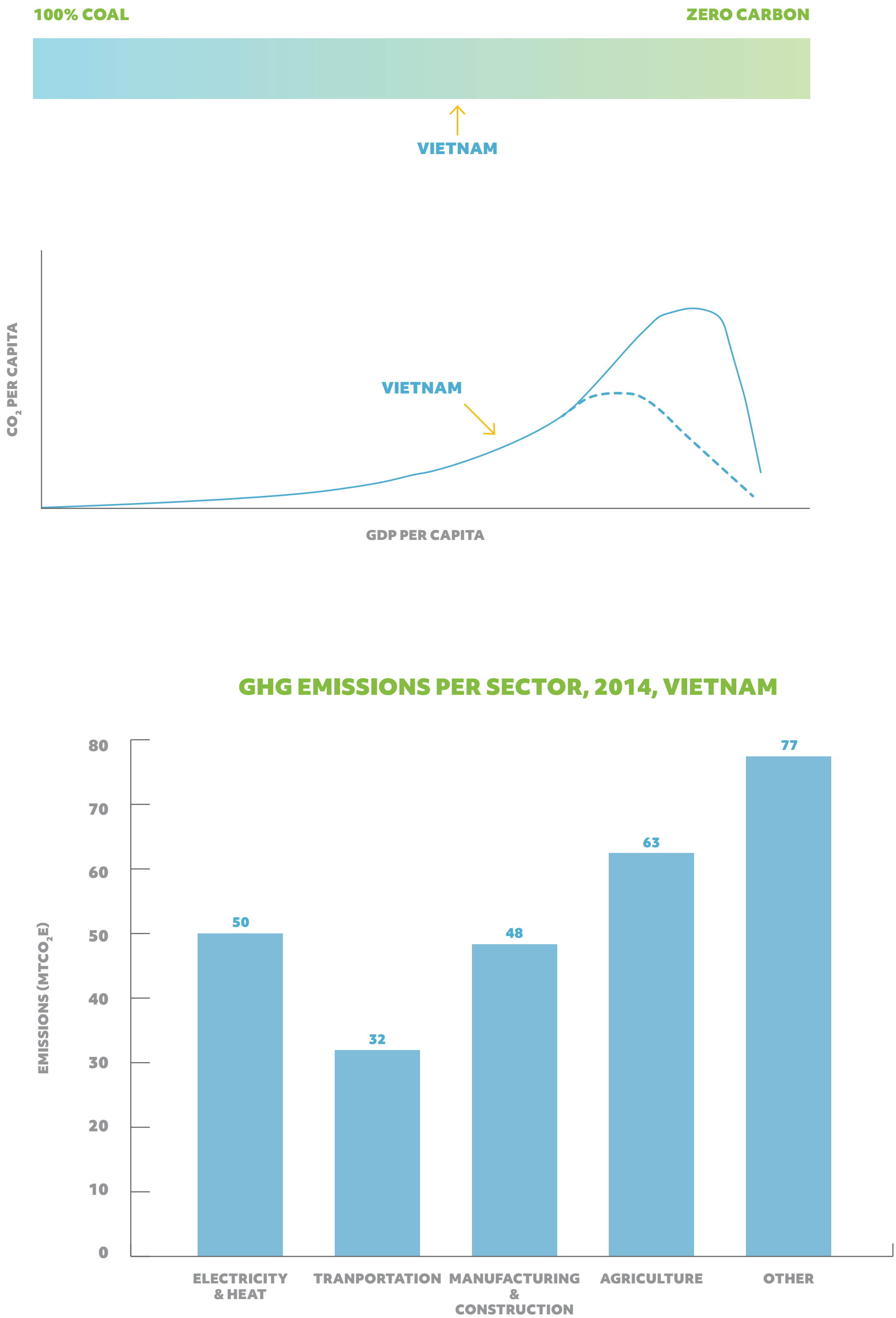


FIGURE 3.8
Vietnam: power sector carbon intensity, position on the development pathway curve and 2014 emissions broken down by sector.

Vietnam is a lower middle-income country. It is Asia's newest 'Tiger Economy' with rapid growth in its economy, population and urbanization, which has led inevitably to high increased energy demand. This has resulted in significant coal-fired power station expansion plans. The current 34% coal share of electricity generation is planned to leap to over 50% by 2030 (and over 65% for all fossil fuels)[48]. Vietnam's GHG emissions grew at the highest rate of any country in the world in 2018[49].

Agriculture is the dominant GHG emissions generating sector (28% of Vietnam's total)[50]. Policies are in place to reduce this.

Industry accounts for the largest sectoral energy consumption (55% of total). The policies for this sector include green growth plans, energy efficiency and reducing cement emissions. However, emissions from industrial processes (mainly cement) are not yet included in the country's NDC target, even though they represent a 13% of share of its 2014 emissions and are growing faster than energy-related emissions. This creates uncertainty when assessing the NDC[51].

In its NDC[52], Vietnam, by 2030, commits to reduce GHG emissions by 8% compared to BAU by reducing the emission intensity per unit of GDP by 20% compared to 2010, and increasing forest cover to 45%.

The above targets could be increased with international support.

VIETNAM'S ECONOMIC GROWTH HAS RESULTED IN COAL-FIRED POWER STATION EXPANSION PLANS. THE CURRENT

34% **COAL SHARE OF ELECTRICITY**

ELECTRICITY GENERATION IS PLANNED TO LEAP TO OVER

50% **BY 2030**


4

STUDY METHODOLOGY

This chapter describes the methodology adopted to derive examples of quantified abatement potential of digital technologies across the seven selected countries.

4.1 DIGITAL TECHNOLOGIES

The world of digital technology constantly evolves, and any precise definition is often quickly out of date. Six digital technologies based on the framework in GeSI's Digital with Purpose report have thus been selected to represent the short- and medium- term evolution of the ICT sector. These technologies are:

- Digital Access: connectivity to the internet via telecommunications infrastructure (fixed or mobile), devices (handheld devices and computers) and software.
- Fast Internet: next generation connectivity that provides speed, capacity and reliability at fundamentally higher levels including high speed fixed broadband, 4G and 5G.
- Cloud: the provision of highly scalable, advanced IT capabilities as hosted services. Typically on-demand and pay-as-you-go and including an ever widening breadth of capabilities including infrastructure, network, storage, computing power, applications and data.
- IoT (Internet of Things): the suite of technologies enabling the connection of physical objects to the internet.
- Cognitive: the application of advanced analytics, machine learning (ML) and artificial intelligence (AI).
- Blockchain: digital, distributed ledgers of transactions maintained on multiple computer systems controlled by different entities and accessible by all participants without the need for intermediaries enhancing accuracy, verifiability and security.

DIGITAL BOUNDARIES

Digital technologies are becoming ubiquitous, entering nearly all aspects of life and integral to many sectors. For example, cars are increasingly 'connected', as are domestic appliances. Cloud and web-based applications often interact with, or even replace, physical world experiences such as shopping and entertainment.

In this report we aim to focus on those digital applications leading to reduced carbon impacts where additional interventions may be required to stimulate take up, rather than applications that might be expected to happen as a natural matter of course.

ICT SECTOR CARBON IMPACTS

The ICT sector has its own carbon impacts and opportunities to mitigate them. It is not, however, the purpose of this report to focus on these apart from considering the impact digitally empowered mitigation applications may have on the ICT sector carbon footprint. This is covered in Section 10.

4.2 CALCULATING EMISSION REDUCTIONS

4.2.1 FUTURE PROJECTIONS

Where they are available, future projections are linked to the IEA's Energy Technology Perspectives (ETP)[53] which comprises four interlinked technology-rich models, one for each of four sectors: energy supply; buildings; industry; and transport. However, the ETP does not include emissions arising from land use changes, forestry and many agricultural processes such as emissions from livestock and fertilisers.

Based on the ETP modelling framework, the IEA scenarios are constructed using a combination of forecasting to reflect known trends in the near term and "backcasting" to develop plausible pathways to a desired long-term outcome.

The ETP outlines three future scenarios:

1. The Reference Technology Scenario (RTS) takes into account today's commitments by countries to limit emissions and improve energy efficiency, including the NDCs pledged under the Paris Agreement. By factoring in these commitments and recent trends, the RTS already represents a major shift from a historical "business as usual" approach with no meaningful climate policy response. Even, the RTS requires significant changes in policy and technologies in the period to 2060 as well as substantial additional cuts in emissions thereafter. The IEA state that these efforts would result in an average temperature increase of 2.7˚C by 2100, at which point temperatures are unlikely to have stabilised and would continue to rise.

2. The 2˚C Scenario (2DS) lays out an energy system pathway and a CO_2 emissions trajectory consistent with at least a 50% chance of limiting the average global temperature increase to 2˚C by 2100. Annual energy-related CO_2 emissions are reduced by 70% from today's levels by 2060, with cumulative emissions of around 1 170 gigatonnes of CO_2 ($GtCO_2$) between 2015 and 2100 (including industrial process emissions). To stay within this range, CO_2 emissions from fuel combustion and industrial processes must continue their decline after 2060, and carbon neutrality in the energy system must be reached before 2100. The 2DS scenario relies on a substantially strengthened response compared with today's efforts.

3. The Beyond 2˚C Scenario (B2DS) explores how far deployment of technologies that are already available or in the innovation pipeline could take us beyond the 2DS. Technology improvements and deployment are pushed to their maximum practicable limits across the energy system in order to achieve net-zero emissions by 2060 and to stay net zero or below thereafter, without requiring unforeseen technology breakthroughs or limiting economic growth. This "technology push" approach results in cumulative emissions from the energy sector of around 750 $GtCO_2$ between 2015 and 2100, which is consistent with a 50% chance of limiting average future temperature increases to 1.75˚C. The B2DS falls within the Paris Agreement range of ambition but falls short of the 1.5˚C ambition.

4.2.2 DIGITAL ABATEMENTS

Digital abatements estimated for this report have been derived using a modified analysis framework drawn from a combination of GeSI's Smarter 2030 and Digital with Purpose reports. Abatements are estimated for both a 'reference scenario' and a more 'ambitious decarbonisation scenario'. The former can be considered to be roughly in line with the IEA World Energy Outlook[54] New Policies and ETP Reference scenarios, whereas the latter is better associated with the World Energy Outlook New Policies sustainable development scenario and the more ambitious ETP scenarios.

A more detailed explanation of the abatement calculation methodologies is given in each of the chapters covering the four specific abatement areas. Further information is also provided in Annex A.

4.2.3 PRESENTATION OF RESULTS

For each of the seven selected countries the above analysis is presented in tabular form for each of the following emission sources:

- Electricity and heat[55]
- Transport
- Manufacturing and construction
- Agriculture

These sources match previous GeSI analyses and can be usefully cross-referenced to the CAIT and IEA data. The table headings are interpreted as follows:

2014 EMISSIONS (CAIT)	Country emissions for 2014 from the CAIT database.
2030 APPROXIMATE HISTORIC PROJECTION	Historic data from 1990 to 2014 extrapolated with best fit approach to 2030.
2030 CURRENT POLICY PROJECTION INCLUDING NDC	When available this is based on the IEA Reference Technology Scenario. For countries where this is unavailable published NDC and other government sources have been used.
2030 REFERENCE SCENARIO DIGITAL ABATEMENT	A BAU digital abatement estimate in line with the ETP reference scenario.
2030 AMBITIOUS DECARBONISATION SCENARIO DIGITAL ABATEMENT	A more ambitious decarbonisation digital abatement estimate according to previous GeSI report methodologies.

TABLE 4.1

4.2.4 DIGITAL CONSIDERATIONS IN THE EXISTING IEA SCENARIOS

In undertaking these kind of abatement assessments there is always a level of subjectivity about the extent one might expect digital technologies to be incorporated into carbon intensive sectors as a matter of course, versus the need for additional intervention. In calculating a specific level of abatement, it is also important to consider the level of abatement that can be attributed specifically to the digital intervention.

For example, the IEA ETP scenarios already include a number of technologies which will be supported and enhanced by digital technologies, for example:

- Demand response in the power sector
- Electricity storage
- Energy efficiencies in the power sector
- Smart charging for electric vehicles
- Energy savings in buildings and industry

Whilst the IEA expect digital technologies to play an important role in these applications they did not make a separate determination of their abatement contribution[56].

4.2.5 ANALYSIS CONSTRAINTS

The analysis presented here has been produced using a combination of existing, published material. As such it is important to emphasise that the resulting digital abatements should be taken as indicative rather than absolute.

Important constraints to note are:

1. There isn't an exact match between the sectoral breakdowns used by the IEA ETP, the WRI CAIT and the previous GeSI work. A best match approach was therefore adopted.

2. Due to a lack of data, current policy projections could not be established for agricultural emissions.

3. Additionally, IEA ETP trajectories are not available for Chile, Kenya and Vietnam so the pathways reflect other sources including the country government policies.

4. In the analysis undertaken for the original GeSI reports, no greater country granularity was generally drawn in terms of the expected level of impact of the digital technologies than a distinction between low-, middle-, and high-income economies. In this report, to avoid such a broad generalisation, the country abatements for each of the four emission categories takes account of published country data and variances.

5. The abatement figures given are before any consideration of the rebound effect. According to the Digital with Purpose report, under the Current Policy scenario there maybe rebounds of up to 50%. This level of rebound may be expected to be substantially reduced under an accelerated decarbonisation scenario in which the socio, economic and regulatory environments are more aligned to achieving sustainability.

Specific rebound effects are covered in more detail later in each of the following four chapters.

5

DIGITAL TECHNOLOGIES IN THE POWER SECTOR

In the case of China for example, the digitally enabled accelerated decarbonisation abatement is **equivalent to decommissioning over 170 average Chinese coal-fired power plants**.

5.1 DECARBONISATION OF THE ELECTRICITY GRID

According to the IEA, currently, 25% of all electricity generated globally in 2017 came from renewable sources[57]. Additionally, the IEA Renewables report for 2019 predicts renewable power capacity will expand by 50% between 2019 and 2024, led by solar PV[58]. This increase of 1,200 GW is equivalent to the total installed power capacity of the United States today.

According to the IEA, in 2019, while renewables are growing rapidly in some parts of the world, coal maintained its position as the world's largest source of electricity with a 40% share, up 2% on the previous year[59]. China, India and other Asian economies led the expansion, while coal power generation fell in Europe and North America.

Traditionally renewable electricity generation came mostly from hydro. However, with tumbling costs, wind and solar PV are where most new investment occurs[60]. Wind generation tends to occur in large scale wind farms. Solar PV is a mix of large-scale solar farms and wide-spread distributed generation within communities. According to the IEA, distributed PV systems in homes, commercial buildings and industry have almost tripled since 2014, transforming the way electricity is generated and consumed[61]. Looking forward, the IEA forecast that renewables will expand by 50% through 2024, with distributed PV alone growing as much as onshore wind.

Whilst the key factors in boosting renewable energy uptake will be the economic and political drivers to move away from fossil fuels, digital technologies definitely have an important role to play in improving the share of renewable energy consumption. In particular they are expected to be highly instrumental in enhancing the next big development wave of decentralized, interconnected and remotely controlled energy systems. The case of micro-grids forms the basis of the use case profiled in section 5.5.2.

5.2 DEMAND SIDE MANAGEMENT, GRID EFFICIENCY AND RESILIENCE

As levels of intermittent, highly distributed generation on a grid increase there comes a point where traditional grid infrastructure is unable to cope. Digitally enabled intelligent, connected control systems become essential, including the dynamic management of demand as well as supply.

Additionally, connected grids, smart buildings and connected homes powered by IoT and AI can improve the efficiency, reliability and operation of networks and reduce home energy usage. Improving energy efficiency is important to improving overall resource efficiency and relieving stress on energy networks, as well as reducing emissions and decoupling economic growth from environmental degradation.

The term 'Smart Grids' covers a combination of applications allowing digital communications and other advanced technologies to detect local changes in usage and generation, thereby enabling improved management of electricity supply and demand. In particular, smart electricity grids allow for real-time recording of electricity consumption and off-grid production using renewable sources via smart meters (i.e. behind the meter production); the optimisation of distribution networks using real-time monitoring, automation and dynamic storage; and, at the transmission level, allows networks to operate at higher capacities, closer to their physical limits.

Smart grids also improve the management of energy by allowing consumers to become 'prosumers' (i.e. consumers are able to supply the grid with surplus energy produced by their own renewable sources). Two ways by which digital technology enables this is through IoT, which can be used to remotely monitor consumption and production, and AI, to automatically control devices.

Further improvement in lowering power sector carbon intensity requires raising awareness and promoting public behaviour change, as well as supporting wider market transformation and making investment and resources available to progress this. As part of this transformation, digital technologies such as blockchain will be important in enabling new business models.

5.3 DIGITALLY ENABLED BUSINESS MODELS

A new and increasingly common digital solar business model in emerging markets is pay-as-you-go (PAYGo) solar. The business model allows customers to pay for their off-grid solar product in small instalments. Particularly in East Africa, companies utilise the ubiquity of mobile phones to allow customers to pay their regular instalments with mobile money, e.g. M-Pesa in Kenya. There is evidence PAYGo solar unlocks benefits for its users beyond access to clean and affordable electricity. People who have never had access to financial services and banks can build a credit history with PAYGo providers.[62]

One of the main obstacles of rooftop PV ramp up is often the disconnect between housing owners and PV investors. Digitalisation can facilitate the connection of both with specialised market platforms. Digitalisation can also contribute to streamline the administrative process to register a rooftop PV system with the local utility. Another example is Impact investment with seed money. Through platforms like Bettervest[63] and Ecoligo[64] individuals from high-income countries can directly support small scale projects in low- and middle-income countries.

Future low carbon business models may also be enabled by blockchain technologies. For example, blockchain has the capacity to allow peer-to-peer energy trading permitting small scale generators to trade their surplus power over the electricity grid to a specific end user. A 'proof of concept' project in Brooklyn, New York, USA used a permissioned blockchain platform, to enable a small group of local energy producers to automatically conduct transactions with local energy consumers in near-real time.[65]

5.4 DIGITAL ABATEMENTS

The following country level digital abatement assessments cover the two main use case areas - Smart Grids and Buildings, and Distributed PV Generation. The abatement estimates generally follow the approach used in GeSI's Smarter 2030 report. Where data were available, improvements were made to better reflect country level historic trends, availability of resources, and government policies, as well as incorporating the latest IEA distributed generation forecasts. More details on the calculation methodologies are provided in Annex A.

The resulting collective abatements are shown in Table 5.1.

	SECTOR EMISSIONS			2030 DIGITAL ABATEMENT	
	2014 BASELINE (CAIT)	2030 APPROXIMATE HISOTRIC PROJECTION	2030 CURRENT POLICY PROJECTION	REFERENCE SCENARIO	AMBITIOUS DECARBONISATION SCENARIO
BRAZIL*	80	112	55	-6	-10
CHILE	33	74	28	-9	-15
CHINA	4748	9300	4870	-434	-777
INDIA	1083	2100	2023	-97	-198
KENYA	2	3	36	-2	-4
SOUTH AFRICA	295	340	265	-13	-26
VIETNAM	50	130	120	-7	-14

***NOTE**
The 2014 Brazil CAIT figures are based on the historic trend to 2012 thus removing an anomalous subsequent rise.

TABLE 5.1
Predicted digital abatements in the power sector. All figures in Mt CO_2e per annum

In most cases, the current policy pathway projections in 2030 for the lower-middle income countries are roughly in line with historic trend projections. However, in the case of Kenya the 2030 current policy figure, which is based on Kenyan government projections, is significantly above historic trend projections and reflects an expectation that recently discovered coal and oil reserves will be exploited.

The 2030 pathways based on current policy for the upper-middle income countries are showing signs of decoupling but not to the levels of ambitious decarbonisation that will be required to meet the Paris Goals.

On the surface these abatements may not appear to be significant. However, they can represent many hundreds of megatonnes of CO_2e. In the case of China for example, the digitally enabled accelerated decarbonisation abatement is equivalent to decommissioning over 170 average Chinese coal-fired power plants[66].

The digitally enabled abatements in the 'ambitious decarbonisation' scenario could be much higher if relevant countries decide to radically move away from generation from fossil fuels, especially coal.

	DECREASE IN POWER PRODUCTION DUE TO SMART GRIDS AND BUILDINGS	INCREASE IN DISTRIBUTED RENEWABLE ELECTRICITY
BRAZIL	-4	-7
CHILE	-2	-13
CHINA	-331	-446
INDIA	-138	-60
KENYA	-2	-1
SOUTH AFRICA	-18	-8
VIETNAM	-8	-5

TABLE 5.2
Split of predicted digital abatements in the power sector ambitious decarbonisation scenario. All figures in Mt CO_2e per annum.

The split of abatements between the decrease in power production due to smart grids and buildings, and the increase in distributed renewable electricity in the case of the ambitious decarbonisation scenario is given in table 5.2.

Abatements for the decrease in power production due to smart grids and buildings have been calculated using the approach used in the Smarter 2030 report which uses adoption rates previously identified by Gartner.

The abatements resulting from digitally enabled increases in renewable generation have been calculated using individual country data and policies, including their NDC commitments. The extent to which these increases are due to distributed generation, as opposed to large scale solar farms, has been derived from the IEA Renewables 2019 Market Analysis and Forecasts report[67].

REBOUND EFFECTS IN THE POWER SECTOR

If energy prices remain relatively stable, then there would be no reason to expect rebound effects resulting from a switch to renewables from fossil fuel electricity sources, or from improving the efficiency of the grid. However, where consumer level energy efficiency measures lead to reduced energy bills a rebound effect is likely to be apparent.

5.5 POWER SECTOR USE CASES

To use cases are presented for the power sector: Grid-Level Management and Control Systems, and Microgrids.

5.5.1 GRID-LEVEL MANAGEMENT AND CONTROL SYSTEMS

A conventional national electricity grid is a combination of:

- large power sources – such as coal, nuclear or gas fired power stations;
- power users – from large industrial plants to individual homes;
- wires to connect them together – from national to local level, with associated substations to transform voltages; and
- a centralised control system to operate it all.

Traditionally, the power flowed in just one direction – from generators to users – and power stations could be fired up at will, albeit taking different times to start up and close down.

Today's grid is undergoing a radical transformation. Renewable generation is creating much higher levels of intermittency of supply and, when co-located with a user, can result in bi-directional power flows. In addition, as extreme weather is becoming more common place, climate change itself is creating the need for additional built-in grid level resiliency.

It is impossible to cope with these new conditions without having a much better understanding of real-time grid dynamics, management and control. For these reasons, the introduction of additional renewable generation is dependent on the digitisation of the underlying grid infrastructure.

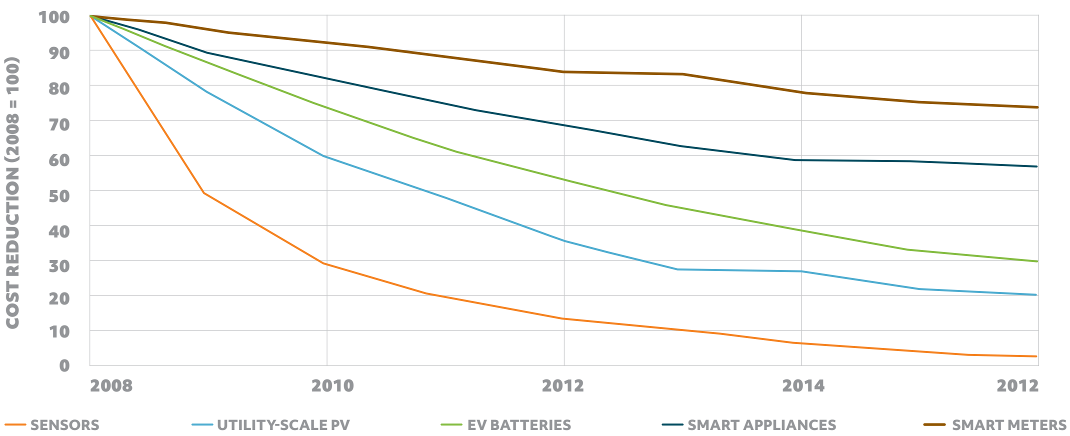
A 'Smart Grid' addresses these challenges and allows digital communications and other advanced technologies to detect local changes in usage, enabling improved management of electricity supply and demand. Smart electricity grids allow for real-time recording of electricity consumption and off-grid production using renewable sources via smart meters (i.e. behind the meter production); the optimisation of distribution networks using real-time monitoring and automation; and at the transmission level allow networks to operate at higher capacities, closer to their physical limits.

Smart grids also allow consumers to become 'prosumers' (i.e. producers and consumers). In such cases, consumers are able to supply the grid with surplus energy produced by their own renewable sources.

Some of the specific components of a smart grid are:

- Integrated Communications providing real-time control, information and data exchange to optimize system reliability, asset utilization, and security. This covers: substation automation; demand response; distribution automation; Supervisory Control and Data Acquisition (SCADA); energy management systems; etc.
- Sensing and Measurement: voltage, frequency, direction and extent of power flow, congestion and grid stability, equipment status and failure prediction, and control strategies support.
- Smart Meters: electronic devices that record consumption of electricity and communicate the information to the electricity supplier for monitoring and billing.
- Smart Power Generation and Consumption: load balancing by matching electricity generation to demand in real time and matching electricity demand to generation in real time.
- Smart Buildings, Vehicles and Appliances: allowing real time interaction between the grid and consumers providing load shedding, dynamic EV charging and real time pricing.
- Microgrids: a group of interconnected loads and generation sources that can connect to the grid but also operate as an island independent of the grid.

The cost of smart grid components has tumbled over the past decade as highlighted by the IEA[68]. For example, the unit cost of small-scale PV has dropped by a factor of five since 2008, sensors by more than 95% and battery storage by more than two-thirds (mostly thanks to the deployment of EVs) (Figure 5.1). The average cost of a smart meter has dropped by about one-quarter, with nearly 600 million smart meters being deployed globally by 2017.



KEY MESSAGE
Technology cost reduction is a key driver enhancing connectivity throughout the electricity sector

TABLE 5.1
Unit costs of key emerging technologies.
On adaptation according to the sources: IEA analysis based on Bloomberg New Energy Finance (2017); Holdowsky et al. (2015); IEA (2017a; 2017b; 2017c); Navigant Research (2017).

CASE STUDY: SMART METERS

Businesses and individuals can use smart meters to measure and understand their energy usage better, allowing them to take steps to reduce consumption. In the UK, research shows that 86% of people take energy-saving actions once their device is installed[69], for example 40% of people install energy-efficient lightbulbs immediately after acquiring a smart meter[70].

Additional benefits of smart meters include:

- Accurate meter data and bills for customers and easier supplier switching
- Providing accurate measurement of electricity export to grid from localised generation,
- Reduced operational costs for suppliers in reading meters and handling disagreements on readings
- Ability to monitor consumption patterns and better manage the electricity network
- Support the development of new services such as time-of-use tariff
- Electricity loading by customers shifting time of demand

Energy Watch[71] identify a number of smart meter successes including:

- China: As of 2017 there were an estimated 469 million smart meters deployed in China, accounting for almost 70% of total worldwide deployment. China's smart meter adoption is intrinsically linked with its wider smart grid targets. It is estimated that smart metering and smart grids could reduce China's need for additional generation capacity by as much as 25%.
- USA: Oklahoma Gas and Electric installed 823,000 smart meters across participant customers. Energy use at peak periods dropped by 33% resulting in a 70MW reduction in the company's load demands. Key to this success was introduction of a 'smart hours' programme, which introduced variable pricing periods for electricity consumption. This policy was complemented by the insight provided by smart meters to customers around consumption time and usage.

CASE STUDY: EMBEDDING IOT IN USA POWER GRIDS

According to the IEA[72] many low- and middle-income countries suffer from a significant lack of detailed, real time knowledge of what is happening on their power networks. In more advanced economies such data are already enabling the power utilities to run their networks in more efficient and reliable ways. According to a recent survey in the USA, many utilities are already using IoT to inform and manage their networks in multiple ways from cybersecurity to supply chain management.[73] The same utilities are also expecting information to be further improved through the use of AI.

From the survey it is found that the following have the greatest potential to reduce carbon emissions:

- Smart metering as described in the preceding case study.
- Energy efficiency has a direct relationship with carbon savings.
- Mobile workforce management can reduce distances travelled through more efficient routing.
- Demand response allows load shedding to avoid running up carbon intensive generators at times of peak demand.
- Small-scale renewables and distributed resources lowers the overall carbon intensity of the grid.
- Smart charging for electric vehicles as described in the next case study.
- Energy storage allows load shifting to further avoid running up carbon intensive generators at times of peak demand.

CASE STUDY: REAL-TIME GRID MONITORING AND APPLICATIONS

The capability of real time monitoring is demonstrated in the UK by the publicly available GridWatch website[74]. This website uses marketplace price balancing and load data from the National Grid and other sources to inform users of the mix of generation types on the country's power grid. A number of regions across the world have similar, publicly available data sets and these have been consolidated by the Danish start-up Tomorrow[75].

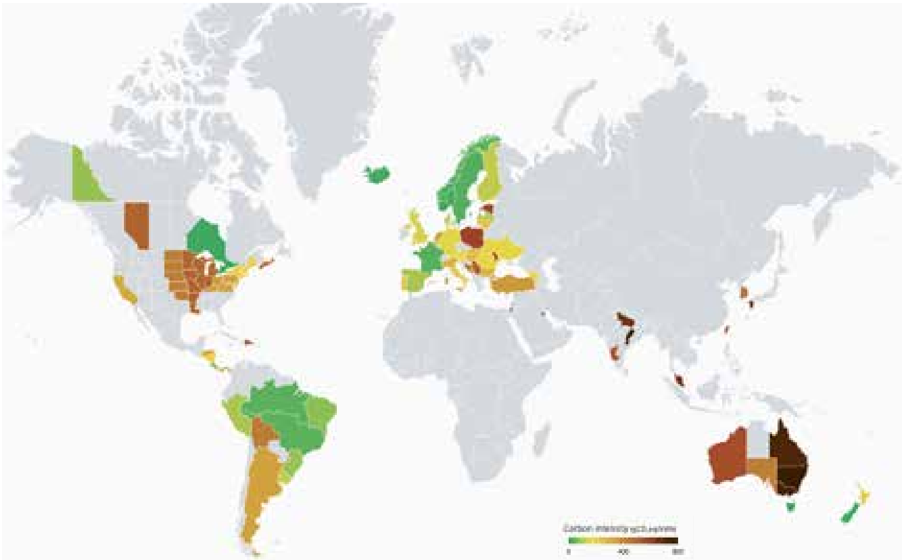


FIGURE 5.2
Real-time electricity map. The colours indicate the carbon intensity of the generated power.

A detailed breakdown of each region is also available providing the generation mix and carbon intensity over the past 24 hours.

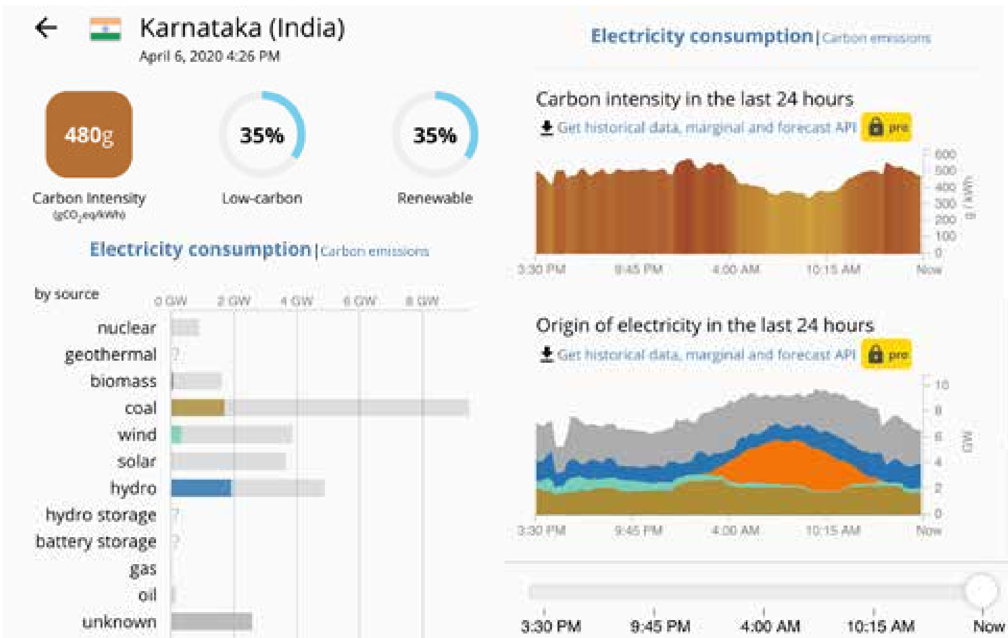


FIGURE 5.3
Detailed electricity information for Karnataka, India from the ElectrictyMap Live website.

This kind of data is essential in enabling a number of the applications from demand side management to smart EV charging.

According to the IEA[76], because of their lower marginal operating costs, times when variable renewables are generating the most often correspond with relatively low (and sometimes negative) prices in electricity wholesale markets. This means that shifting electricity demand to times of low CO_2 intensity can potentially save consumers money on their electricity bills.

Setting different prices for different times of the day (known as time-of-use (TOU) tariffs) can incentivise consumers to shift their consumption to benefit from lower prices. Traditionally TOU tariffs were at fixed times and generally lowest at night, but today some jurisdictions are proposing more responsive pricing regimes.

The rapidly growing market for electric vehicles offers a major opportunity to link their charging to times of low carbon intensity on the grid. In fact, the IEA estimate that smart EV charging could nearly halve related CO_2 emissions from EV's. But to do so requires embedded digital technologies across the electricity system, consumer awareness and supportive regulatory frameworks.

5.5.2 MICROGRIDS

At its most basic level a microgrid is a small version of a large grid with all the same components. In general, all microgrids share two main characteristics:

- a microgrid is a locally controlled system
- a microgrid can function both connected to the traditional grid or as an electrical island.

According to the U.S. Department of Energy Microgrid Exchange Group, the following criteria defines a microgrid:

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.

Microgrids are an important component of a larger smart grid and often an important enabler of renewable energy generation. They offer distinct advantages to customers and utilities including:

- improved energy efficiency
- minimization of overall energy consumption
- reduced environmental impact
- improvement of reliability of supply
- network operational benefits such as loss reduction
- voltage control
- security of supply

CASE STUDY: STONE EDGE FARM, USA

The Stone Edge Farm microgrid[77] is a state-of-the-art installation that demonstrates many different technologies. A mile-long power line connects a network of electrical services and integrates various forms of distributed energy generation (solar, microturbine, hydrogen fuel cells) and storage (batteries and hydrogen) with real time monitoring and control. Like other microgrids, it can operate normally, connected to and importing electricity from the utility grid, or disconnected from the grid, in island mode.

In case of grid failure, a natural gas-fired microturbine provides backup power within three minutes. Various battery systems, with associated inverters, kick in while the microturbine fires up.

For additional energy storage surplus solar-generated electricity is used to generate hydrogen through the electrolysis of water. The hydrogen can be fed into up to twelve 2.33 kW fuel cell hives that effectively reverse the electrolysis process to make water and generate electricity on demand. Enough hydrogen can be made and stored to operate the fuel cells for up to 12 days. The hydrogen is also used to power vehicles and forklift trucks.

In low- and middle-income countries microgrids offer a number of advantages. For example, some microgrids stand on their own, apart from any larger grid, often in remote rural areas. These off-grid microgrids are a relatively cheap and quick way to secure some access to power for people who now lack it, often more quickly than large, centralized grids can be extended.

CASE STUDY: HUATACONDO, CHILE

Huatacondo is a remote Andes Mountains community of 150 residents (mostly miners and their families). Prior to a microgrid installation, the community had its own electric network (operating independently from the macro-grid) operating 10 hours per day with power provided from a single diesel generator. The vision of the microgrid was to continue using that diesel generator but supplement it with distributed energy resources, namely solar PV, wind, and a battery system. Today 60% of the village's electricity is provided from renewable sources[78].

The microgrid includes a 150 kW diesel generator, 22 kW tracking solar PV system, a 3 kW wind turbine, a 170 kWh battery, and an energy management system. The energy management system provides online set-points for generation units while minimizing operating costs, taking into account renewable resource forecast, load, solar tracking, and water consumption.

The Huatacondo project created a so called "Social-SCADA" approach that adapted the usual SCADA outputs to better present the information to users with no technical background to help assist the community members with decision making surrounding the electricity system. With the Social SCADA system in place, the community actively participates in the decision making and maintenance of the system, which allowed the initial project support team (from University of Chile) confidently to hand over the project's ownership and management to the community.

Low- and middle-income countries are vulnerable to extreme weather events and microgrids offer opportunities to improve the resilience of power provision. This benefit was proven when Hurricane Sandy hit New York in 2012. Although much of New York lost power New York University kept its lights on[79]. The university microgrid has drastically reduced NYU's local emissions with an estimated 68% decrease in EPA criteria pollutants (NO_x, SO_2, and CO emissions) and 23% decrease in greenhouse gas emissions.

CASE STUDY: PUERTO RICO

In September 2017 hurricane Maria caused catastrophic damage to the island of Puerto Rico in the Caribbean. The hurricane completely destroyed the island's power grid, leaving all 3.4 million residents without electricity[80]. By the end of January 2018, approximately 450,000 people still remained without power.

In the aftermath of the hurricane it was widely recognised that the magnitude of devastation to the Puerto Rico electric power system presented an unprecedented opportunity to rebuild and transform the system to one that is hardened, smarter, more efficient, cleaner, and less dependent on fossil fuel imports. The Puerto Rico Energy Resiliency Working Group proposed that a transformed electric power system for Puerto Rico should be one designed with the resiliency to withstand future storms and built with modern grid technologies and control systems. This system should deliver increased renewable energy resources, such as wind and solar; incorporate new distributed energy resource technologies, such as energy storage and microgrids; reduce the dependency on fossil fuels; and enable energy to become abundant, affordable, and sustainable to improve the way of life.

Much of the required transition involves the development of microgrids, which in the case of projects in Puerto Rico often involve solar photovoltaics with battery storage to generate and store power on-site. These renewable microgrid systems are able to isolate from the grid, so the lights can stay on when the central grid is down.

Various policy changes have been introduced including Act 17 of 2019, which calls for an efficient and market-led shift toward 100 percent renewable energy and the energy regulator (PREB, the Puerto Rico Energy Bureau) introducing the world's first comprehensive microgrid regulations[81].

Whilst more than 300 energy projects for communities and critical facilities have been completed, there is still much to do.

5.6 SUMMARY

The application of digital technologies in the Power sector analysed within this report, such as smart grids and micro grids, illustrate their significant potential when designing alternatives for centralized fossil fuel-based power generation such as coal or gas fired power stations.

- Smart grids: Integration of decentralised renewable energy sources to the power grid can be realized most effectively when making use of digital communication technology, which for example can detect local changes in usage and enable improved management of electricity supply and demand.
- Microgrids: Especially in remote areas where grid extension is not economically viable, microgrids are an important option to guarantee electricity access. For the technical integration of the components and the administration of payments digital technologies have proven to be an essential ingredient for the success of microgrid systems scale-up.

It is estimated that 568 – 1044 Mt CO_2e can be saved when using the potential of Digital Technologies in the Power Sector in the seven countries studied.


6

DIGITAL TECHNOLOGIES IN TRANSPORT

Smart logistics utilisation in road freight can contribute to a carbon **reduction of about 272 Mt Co2e annually** for all seven countries combined.

6.1 INTRODUCTION

The transport sector worldwide is responsible for around 15%[82] of global GHG emissions and 62% of all oil used[83]. Despite major improvements in fuel efficiency in almost all forms of transport in recent years, decarbonization of the transport sector is happening at a slow pace compared to other key sectors – especially the power sector – and is projected to continue at a similar pace until there is significant electrification of both personal and freight vehicles.

The transport (and logistics) sector is a vital component of any economy and must develop to match the needs of that economy as it develops. Low- and middle-income countries typically have transport and logistics infrastructures and capacities which are inadequate to meet their development plans and the rising expectations of their populations regarding personal mobility. The need to rapidly modernize and expand these infrastructures and capacities creates a conflict for these countries vis-a-vis achieving their carbon and other environmental targets (e.g. as expressed in their NDCs), due to the current relatively high emissions intensity of the transport sector.

Achieving a sustainable transport and logistics sector capable of supporting countries' future development objectives without compromising their environmental objectives, will depend upon on innovations and societal changes in a number of different areas. These include, in no particular order:

- Electrification of the transport infrastructure (at a pace aligned to the availability of cost-effective zero- or low-carbon power)
- Increasing use of bio-fuels
- Further efficiencies in vehicle fuel consumption
- Modal shifts, i.e. private to public transport
- Avoidance of need for travel, e.g. traditional to on-line shopping, tele-commuting
- Car sharing and pooling
- Increasing optimization of freight logistics
- Increasing 'smartness' of traffic systems in cities and on highways
- Self-driving vehicles

Most of the above depend on digital technology in some way, or at least could be assisted and accelerated by digital technology.

Accelerating deployment of digital technologies will allow the sector to optimise traffic and logistics routing and increase the efficiency of journeys, and overall improve the efficiency and sustainability of the sector:

- One solution for sustainable transport is adoption of cleaner fuels and, in countries with low grid carbon intensities, electric vehicles. Digital technologies can accelerate uptake, through digital twin simulations of the needed infrastructure, predictive grid management to manage charging demand, and applications to locate charging facilities or locate shareable options, such as e-bikes.
- IoT sensors, big data analysis and mobile access enable connected and intelligent traffic management and parking space routing.
- Mobile platforms enable carpooling, optimised public transport information, and encourage inter-modality.
- Fleet telematics and cloud enabled smart fleet management and optimised delivery routing.
- Digital technologies such as drone delivery, video conferencing, and VR simulations eliminate the need for transport altogether.

6.2 DIGITAL ABATEMENTS

The country level digital abatement assessments presented here cover the following use case areas and sub-areas:

6.2.1 PRIVATE TRANSPORT

CAR SHARING

Car usage reduction due to use of (normally smartphone-based) car sharing applications. Car ownership rates are rising rapidly in most low- and middle-income countries.

6.2.2 TRAFFIC CONTROL AND OPTIMIZATION

EFFICIENT ROUTES

Implementation of ‘smart’ traffic control systems and increasing usage by vehicle drivers of optimum route finding apps will enable more efficient flow of traffic, less idling, and lower distances travelled per vehicle, leading to fewer GHG emissions and less pollution, especially in congested cities.

ELECTRIC VEHICLES

Implementation of digitally-enabled smart electric vehicle charging infrastructure leading to accelerated take-up and use of electric vehicles.

PUBLIC TRANSPORT ATTRACTIVENESS

Digitally-enabled enhancements to the traffic control and optimization capacities (such as information LED screens, intelligent sensors, real time timetables, etc.) will promote public transport services better, leading to a higher share of travel by public transport and lower by private vehicle, meaning fewer overall GHG emissions.

6.2.3 IMPROVED LOGISTICS

FALL IN TRANSPORT USED - ROAD FREIGHT

Smart logistics could result on a significant reduction in road freight (i.e. tonne-kilometres) due to digitally-enabled capacities such as route optimization, maximization of vehicle capacity (for example, by avoiding empty return journeys), logistics sharing and eco driving.

FALL IN TRANSPORT USED - TRAIN FREIGHT

It is likely that the biggest potential GHG abatements in the freight sector will be in the road freight sector rather than in the rail sector. This is because rail transport tends to currently be a much smaller emitter than road transport, and to the relative sizes of these sectors in low- and middle-income countries. However, smart logistics still could potentially have some positive abatement impact in the rail sector.

These areas were chosen due to sufficiently robust source data being available (for at least for some of the target countries), and because they can be reasonably regarded as being practically implementable in some or all of the target countries.

The abatement estimates generally follow the approach used in GeSI's Smarter 2030 report. Where data were available, improvements were made to better reflect country level historic trends, availability of resources, and government policies.

The estimates are based on projections in the following principal areas:

- electric vehicle penetration rates
- grid electricity decarbonization progress
- relevant digital technology adoption rates (e.g. car sharing apps)
- per capita car ownership levels
- population growth
- annual average distance travelled by cars
- traffic optimization and control adoption rates

For most of the above, a generally lower rate has been used than that used in previous GeSI studies which have focussed mainly on high-income countries, to reflect the fact that the target countries are currently less able to exploit new technologies (e.g. due to having less financial means). Rates vary, however, between the target countries, to reflect their varied development statuses. More details on the calculation methodologies are provided in Annex A.

The aggregate resulting abatements from the use-case areas modelled are shown in Table 6.1

	SECTOR EMISSIONS			2030 DIGITAL ABATEMENT	
	2014 BASELINE (CAIT)	2030 APPROXIMATE HISOTRIC PROJECTION	2030 CURRENT POLICY PROJECTION	REFERENCE SCENARIO	AMBITIOUS DECARBONISATION SCENARIO
BRAZIL	213	365	271	-12	-20
CHILE	24	29	44	-4	-8
CHINA	781	1950	1469	-161	-234
INDIA	232	595	640	-91	-122
KENYA	2	16	21	-1	-2
SOUTH AFRICA	53	70	66	-2	-3
VIETNAM	32	72	41	-2	-5

TABLE 6.1
Split of predicted digital abatements in the transport sector ambitious decarbonisation scenario.
All figures in Mt CO_2e per annum.

As can be seen from the table, by far the highest abatement potential in absolute terms is in China, which is not surprising given the size of the Chinese population and economy. As might be expected, given the differing degrees of development of these countries and other differences, the proportion of projected 2030 emissions for this sector varies considerably between them. However, for all countries the ambitious decarbonisation estimates still indicate worthwhile GHG savings from the adoption of the small subset of digital technologies modelled, i.e. in the range of around 5 – 20%.

The 2030 ambitious decarbonization scenario annual abatement potential in Mt CO_2e per country for each of the six transport and logistics use-cases modelled is shown in Table 6.2

	CAR SHARING	EFFICIENT ROUTES	ELECTRIC VEHICLES: SMART VEHICLE CHARGING	PUBLIC TRANSPORT ATTRACTIVENESS	FALL IN TRANSPORT USED: ROAD FREIGHT	FALL IN TRANSPORT USED: RAIL FREIGHT
BRAZIL	-1.1	-3.4	-0.7	-5.0	-9.8	0.0
CHILE	-0.1	-0.4	-3.7	-0.6	-3.4	0.0
CHINA	-10.0	-24.2	-3.7	-35.4	-156.4	-3.9
INDIA	-2.0	-8.3	-0.7	-12.2	-98.3	-1.0
KENYA	-0.1	-0.1	0.0	-0.2	-1.1	0.0
SOUTH AFRICA	-0.2	-0.4	0.0	-0.6	-1.9	-0.2
VIETNAM	-0.3	-1.2	-0.1	-1.7	-1.9	0.0
TOTAL	-13.8	-38.0	-9.0	-55.7	-272.8	-5.1

TABLE 6.2
Split of predicted digital abatements in the transport sector ambitious decarbonisation scenario.
All figures in Mt CO_2e per annum.

As can be seen, the abatement potential of each of the individual use-case areas varies widely both between countries and between use-cases. The Logistics use-case ‘Fall in transport used: road freight’ in particular shows much potential for carbon reduction, i.e. around 272 Mt CO_2e annually for all seven countries, the vast majority in China and India.

The Traffic Control and Optimisation areas of ‘Efficient routes’ and ‘Public transport attractiveness’ are also projected to generate significant total savings of 38 and 56 Mt CO_2e respectively.

The other use-case areas, while projected to generate somewhat smaller abatements, still make worthwhile contributions.

6.3 REBOUND EFFECTS IN THE TRANSPORT SECTOR

Rebound effects from the adoption of the digital solutions modelled here are many and varied. Indeed, it could be argued that some of these rebound effects may well turn out to be more severe in the low- and middle-income countries than in the industrialised countries, at least in the short to medium term. One reason for this is what might be termed the ‘pent-up demand’ of people in low- and middle-income countries for improved personal mobility and more material goods, i.e. playing catch-up with richer countries. For example, the increased ease with which people and freight can be moved around cities and rural areas, which many of these solutions facilitate, could well lead to more private cars being owned, more journeys being made over longer distances, and more goods being bought, sold and delivered, causing a net increase in GHG emissions.

Quantitively assessing rebound effects of the types mentioned above is a non-trivial task due to the multi-factoral nature of the real-world systems being analysed, and the difficulty in predicting aspects such as future consumer behaviour or societal shifts. It is clearly important however to continue to monitor, at least at a high level, the effects of the adoption of any digital technologies to identify wherever the perceived benefits are being outweighed by ‘hidden’ negative impacts, such as increased GHG emissions. Each country will have its own priorities as regards the relative importance of such negative impacts, and some may regard increased GHG emissions as a ‘price worth paying’ for, say, improved living standards for their citizens.

6.4 E-COMMERCE

Many countries, including some of those profiled in this report, are experiencing a rapid upsurge in e-commerce, both in terms of the purchasing and subsequent delivery of everything from consumer goods and groceries to ‘take away' meals. For example, McKinsey report that in China same-day and instant delivery already make up more than 10% of overall parcel deliveries. This accounts for roughly 3 million daily, same-day items with approximately 400,000-500,000 instant deliveries. These numbers are more than double those of European deliveries, where same-day delivery accounts for only 5% of deliveries so far[84].

This activity is being underpinned by ICT technologies which, on the one hand is avoiding people driving to shops, but on the other hand is increasing the amount of delivery vehicles. According to McKinsey this will resulting in a net increase in emissions unless specific action is taken. This would include electric vehicle (EV) regulation for inner-city areas, permitted delivery times, effective data-based connectivity solutions such as dynamic re-routing and load-pooling, as well as multi-brand parcel lockers and boxes. Such a scenario, McKinsey claim, could reduce CO2 emissions by 30%, congestion by 30% and delivery costs by 25% by 2030 when compared to a “do nothing” baseline.

6.5 TRANSPORT SECTOR USE CASE: SMART LOGISTICS

Smart Logistics is an umbrella term covering the innovative application of technologies and processes to the supply chain cycle, including transport of components and raw materials input to the production process, warehousing and inventory control, and distribution of the finished goods through the wholesale and retail chain. Smart Logistics offers a range of benefits to suppliers, customers, and society compared with more traditional logistics systems. These include reduced costs, faster time to market, and potential societal benefits such as less congestion, improved transport safety, and reduced energy usage and carbon emissions.

Smart Logistics relies upon use of various combinations of many different digital technologies, e.g.

- Cloud computing
- Big Data analytics
- GPS
- 4G networks
- low-energy WIFI networks
- sensors

Four case studies are overviewed below showing how these and other digital solutions can be applied to different aspects of logistics operations with beneficial environmental impact. One (Optitruck) is complex and employs an array of integrated digital solutions. The other three (‘Connected Reusable Pallets', ‘Optimisation Software' and ‘Relay Trucking') are much simpler in concept and demonstrate how simple solutions can yield large benefits.

CASE STUDY: OPTITRUCK[85] PROJECT EU

Optitruck is an EU Horizon 2020 research project aimed at producing demonstrators that bring together the most advanced truck powertrain technologies and intelligent transport systems with the objective of reducing fleet carbon emissions by at least 20%. The integration of a wide array of digital solutions is being exploited to achieve this, including Big Data analytics, cloud computing, predictive algorithms, and embedded software systems. The following diagram gives a high-level view of the Optitruck system concept.

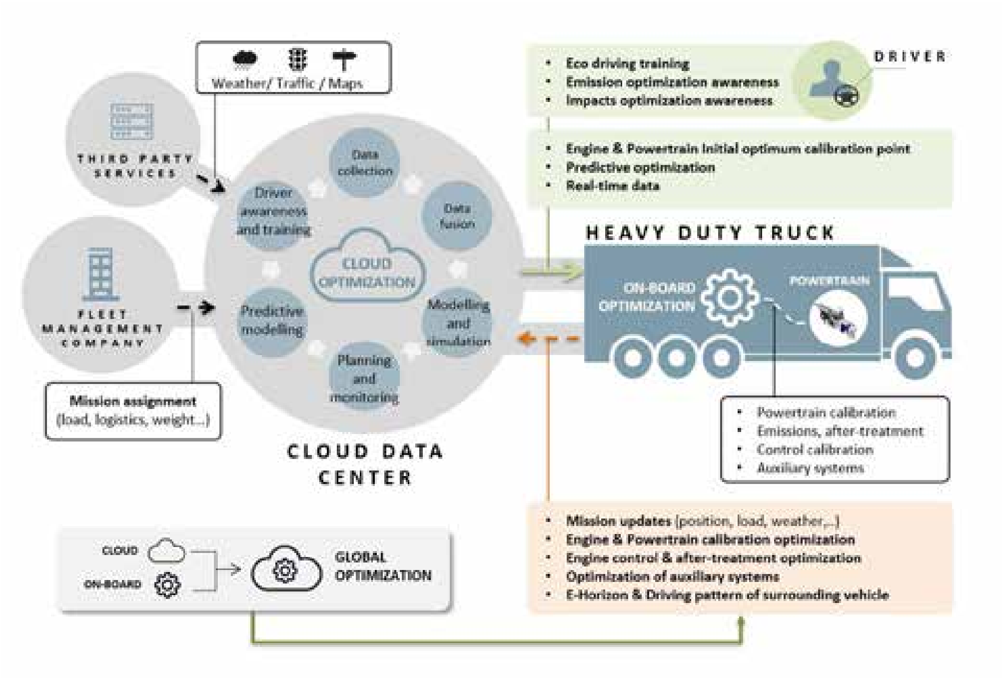


FIGURE 6.1
High level overview of Optitruck

In summary, the system '...develops a strategy for the best route and generates a velocity profile, using the information provided by new-generation navigation systems and big data analytics in the cloud, including predictive traffic and weather information, road topography and road network, and information about the transport mission. Inside the cabin, a smartphone-based interface provides the driver with optimal route and speed profiles, using on-board equipment and the connected Cloud Optimiser.'[86]

Trials so far, conducted on two long-distance routes in Europe, have produced a carbon savings of around 12%. However, Optitruck is still at proof-of-concept stage, and will hopefully, in time, show that the types of solutions integrated into the demonstrators will yield significant benefits to road freight operations in reducing fuel usage and carbon emissions globally, including in low- and middle-income countries.

CASE STUDY: TRUCK DRIVER RELAY MODEL - INDIA

Around 90% of freight in India is transported by road. The road freight sector in India, as in many other low- and middle-income countries, suffers from a number of problems and inefficiencies. One reason for this is that the industry is dominated by very small players - two-thirds of truck companies have less than five trucks – meaning that drivers have to individually spend long periods on the road, goods spend an unacceptably long time in transit, and low-tech inefficient logistics operations are the norm. For example, a truck journey from Kolkata to Mumbai, a distance of just over 2,000 km can take nearly eight days. One obvious result, in the case of perishable goods, is spoiling – up to 40% according to some studies. Another negative consequence is that some goods requiring faster delivery than road transport can provide, and where rail transport is not a viable alternative, are air freighted, increasing carbon emissions and costs.

One solution which has been introduced to address the above issues is the 'Driver Relay Model', whereby a team of drivers is used, in relay, to transport goods long distances. This allows each driver to normally return home each day, improving life quality for him and his family, more efficient use of vehicles (due to less idle time), and faster delivery times. Another positive effect is reduced indirect carbon emissions due to less road to air freight substitution and less wasted goods.

One Indian company pioneering the 'Driver Relay Model' approach is Rivigo[87]. This company relies heavily on digital technology to operate this model. Its vehicles are enabled with not just GPS but various sensors, and it has developed and uses a range of complex algorithms and data analytics, along with location tracking, to monitor the performance of their vehicles and drivers in real-time.

CASE STUDY: CONNECTED REUSABLE PALLETS

While the main focus of digital solutions aimed at improving the environmental efficiency of the logistics sector is in such areas as fleet management, route optimisation, and driver training, there are other areas where the appliance of simple digital solutions can generate substantial carbon savings, which could be applicable to low- and middle-income countries.

One such area is the pallet system, the traditional method for storing and carrying goods in transit. Pallets are typically made of wood and have relatively short lives before needing replacement. One study estimated that around 10 billion wooden pallets are in use globally[88]. One way to reduce both the embedded carbon from pallet manufacture and carbon emitted by trucks in transit is to replace the wooden pallets by reusable, lighter pallets, with RFID sensors attached to them so they can be tracked centrally (e.g. to maximise their reuse capability, and loss rate) – effectively creating a 'pallet Internet of Things'.

A 2017 study[89] carried out by AT&T into the potential carbon savings of implementing a 'connected, reusable pallet' system is summarised here. IoT technology provides a necessary tracking and loss prevention mechanism which can mean that replacement of wooden pallets by modern reusable (normally composite) ones becomes cost-effective for many businesses. Benefits are reductions in freight vehicle fuel consumption (from lighter pallets), wood waste, and use of raw materials needed to produce replacement pallets. The following diagram[90] shows the main benefits of connected reusable pallets:

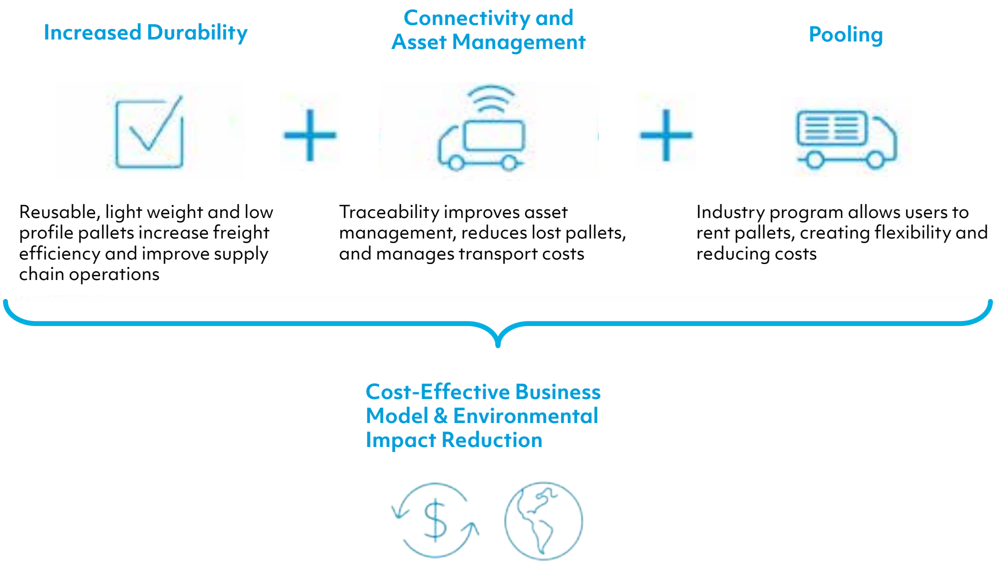


FIGURE 6.2
Schematic diagram of reusable pallet system

It is estimated that each connected, reusable pallet can be used an average of 162 times before replacement (> 5 times that of wooden pallets), leading to per trip cost up to 20% lower than for traditional pallets.

In terms of carbon savings, it was estimated that a company managing one million wooden pallet trips per year could reduce the emissions of these trips by 21%, by switching to connected, reusable pallets. It was further estimated that, if 5% of the 10 billion pallets in use globally were switched the total savings would be 7.3 Mt CO_2e annually.

CASE STUDY: TRANSPORT OPTIMISATION SOFTWARE

Route planning software has helped a number of businesses including Glanbia, a global nutritionals and dairy business group based in Ballitore, Co. Kildare, Ireland.

Glanbia run a dairy operation distribution centre with more than 4,500 weekly deliveries across 136 routes, serviced by nine hauliers and contending with more than 250 individual delivery windows. Glanbia sought to improve the operation and maximise efficiencies through transport optimisation software. As a result, routing efficiencies yielded a 15% gain in vehicle utilisation, a 10% drop in loads per week, and a fuel reduction equating to over 100 tonnes of CO_2 per year[91].

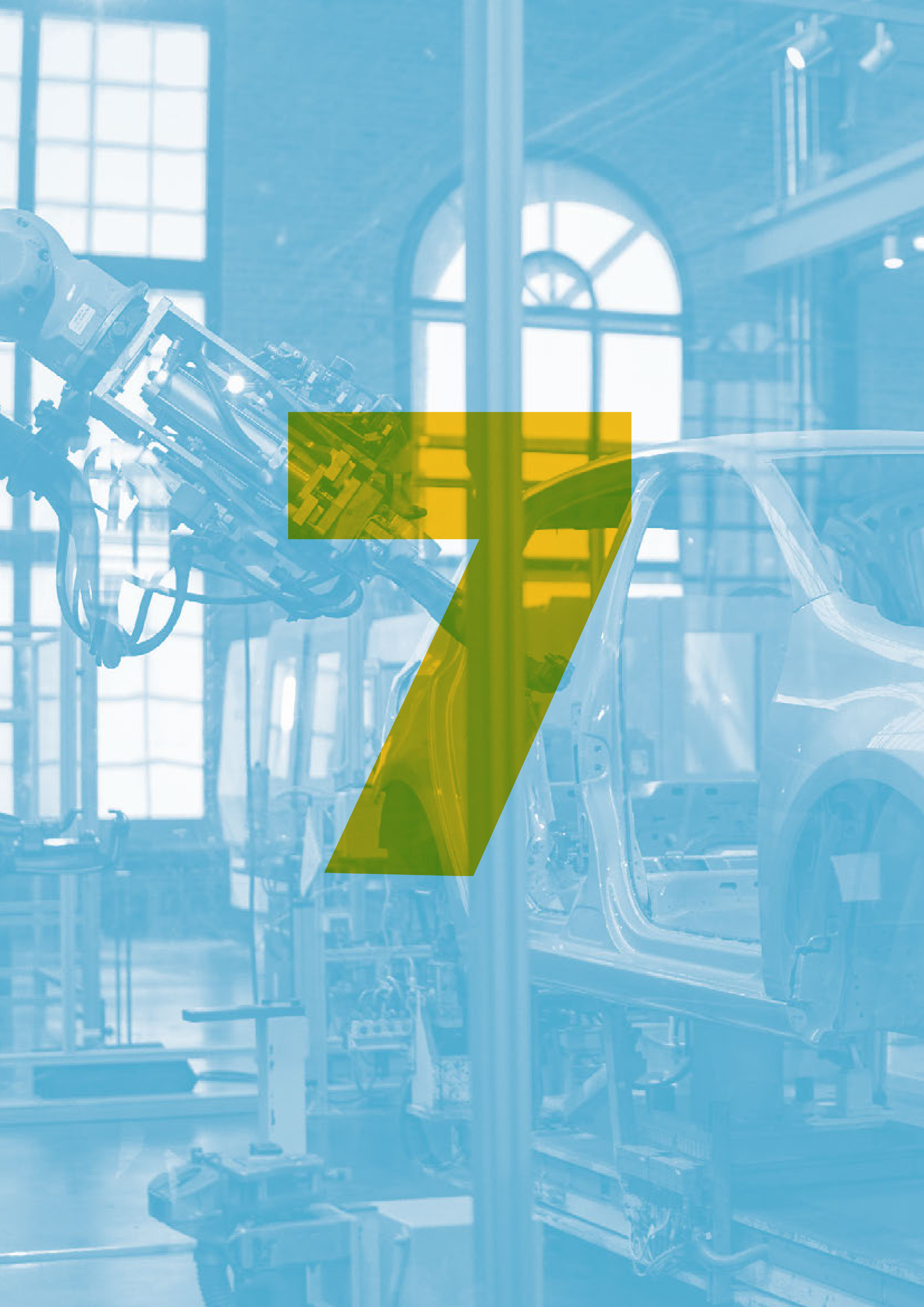
Finding the most efficient route between a number of different locations is a problem that has puzzled mathematicians for two centuries[92]. There is no simple solution to the problem and it is an application that is expected to benefit significantly from Artificial Intelligence (AI). According to Redwood Logistics AI software will collect and learn from data to consistently analyse the best routes for drivers. This will include vehicle trackers and time of day congestion data. The systems are always learning from the data in order to make more predictive recommendations and strategies. In this way it can consider previous routes, historic traffic data, current traffic notices, customer locations, and even the particular driver and truck to determine in real time how the vehicle should proceed.

6.6 SUMMARY

Achieving a sustainable transport and logistics sector capable of supporting countries' future development objectives without compromising their environmental objectives, will depend upon innovations and societal changes in a number of different areas, including electrification of the transport infrastructure, modal shifts, optimization of freight logistics, and 'smartness' of traffic systems in cities and on highways. Digital technologies will play a major role achieving these.

It is estimated that 274 – 394 Mt CO2e can be potentially saved when using the potential of digital technologies in the seven countries studied, in areas such as car sharing, efficient routing and smart vehicle charging, digitized road and train freight. Over 90% of these saving exist across China and India, and are largely in freight. However, for all countries the ambitious decarbonisation estimates indicate worthwhile GHG savings from the adoption of the small subset of digital technologies modelled. This is in the range of a 5 – 20% reduction from the projected 2030 emissions.

It is estimated that **274 – 394 Mt CO2e can be potentially saved when using the potential of digital technologies** in the seven countries studied, in areas such as car sharing, efficient routing and smart vehicle charging, digitized road and train freight. **Over 90% of these saving exist across China and India**, and are largely in freight.


7

DIGITAL TECHNOLOGIES IN MANUFACTURING AND CONSTRUCTION

Industry 4.0 (data-driven, AI-powered, networked smart factories and supply chains) **can save 171 – 495 Mt CO_2e in the manufacturing and construction sector** across the seven countries studied, with over 50% of this in China.

Industry 4.0 is often used to describe data-driven, AI-powered, networked smart factories and supply chains. Such digitally-enabled systems allow for the realisation of smart and connected factories and assets, predictive maintenance, and production optimisation and automation. Industry 4.0 is digitally transforming and optimising manufacturing productivity by enabling the convergence of Operational Technology with Information Technology, allowing for more connected people and things and more efficient, sustainable and data-driven production processes

Widespread adoption of Industry 4.0 in manufacturing is expected to produce substantial productivity gains by 2030. However, there are significant differences between high-, middle- and low-income countries, driven by the varied impacts Industry 4.0 is expected to have and by Industry 4.0 adoption rates. The limited scalability of more advanced technologies in low- and middle-income countries that lack sufficient digital infrastructure could further widen the productivity and value add gap currently observed.

7.1 DIGITAL ABATEMENTS

Digital abatements have been calculated according to the approach used in the GeSI Digital with Purpose Report. Where available, the 2030 projections are based on IEA ETP Reference Scenario and adjusted to align with the CAIT baseline. Where IEA data was not available (Chile, Kenya and Vietnam) projections were calculated using the Digital with Purpose approach and again adjusted to align with the CAIT baseline. More details on the calculation methodologies are provided in Annex A.

	SECTOR EMISSIONS		2030 DIGITAL ABATEMENT	
	2014 BASELINE (CAIT)	2030 CURRENT POLICY PROJECTION INCLUDING NDC	REFERENCE SCENARIO	AMBITIOUS DECARBONISATION SCENARIO
BRAZIL	98	124	-5	-15
CHILE	14	12	0	-1
CHINA	2882	2800	-112	-325
INDIA	533	1149	-46	-133
KENYA	3	3	0	0
SOUTH AFRICA	55	64	-3	-7
VIETNAM	48	34	-4	-13

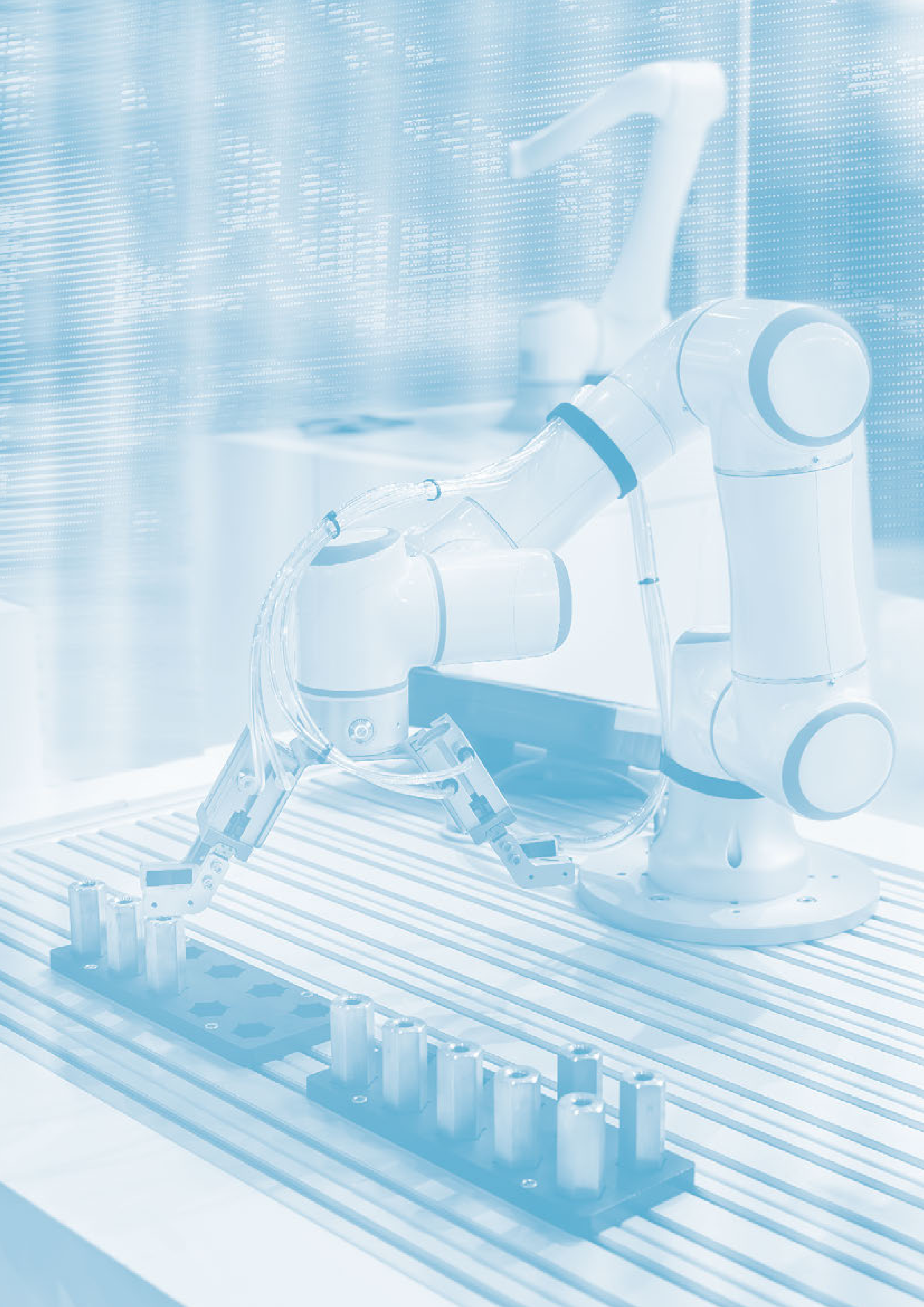
TABLE 7.1
Predicted digital abatements in the manufacturing and construction sector. All figures in Mt CO_2e per annum.

7.2 REBOUND EFFECTS IN MANUFACTURING

Digital technologies potentially have a large role to play in decreasing the carbon intensity of industry. However, in a highly competitive environment, productivity gains may lead to lower product prices and higher consumption, with correspondingly high levels of value-chain rebounds.

7.3 SUMMARY

Industry 4.0 (data-driven, AI-powered, networked smart factories and supply chains) can save 171 – 495 Mt CO_2e in the manufacturing and construction sector across the seven countries studied, with over 50% of this in China.




8

DIGITAL TECHNOLOGIES IN AGRICULTURE

The analysis of **applying digital technologies** in the agricultural sector illustrates a potential to **reduce between 73 – 211 Mt CO2e** across the seven countries studied.

Agricultural yield must increase to feed the world's growing population, but in a resource-efficient way. Agriculture currently accounts for 70% of all freshwater withdrawals and around 20-30% of global carbon emissions. Global nitrogen fertiliser usage has increased by 800% over the past few decades.

The use of digital technologies in agriculture has the potential to drive productivity, ultimately increasing efficiency by reducing the number of inputs required per unit of output. The types of technology used in an agricultural setting will depend on the size of the farm and level of development, though the goal of increasing productivity is the same. For example, a smallholder farm in a middle-income country might rely on mobile phones and data access to provide basic information, whereas a large farm may implement IoT sensors and AI to monitor and automatically react to changes in crop health so as to optimise yields.

The following solutions enable yield and resource-use optimisation:

- IoT sensors or cameras to monitor farm data and crop health in real time, enabling precision farming activities that minimise water, fertiliser and other resource use.
- Digital platforms that collate the above farm sensor data with other data sets, e.g. weather, to enable even more targeted advice.
- Digitally controlled, indoor and vertical farming options should also be explored, as they optimise space and resource utilisation, can be situated closer to cities and are less vulnerable to climate change.

Additionally, the digestive process of livestock, known as enteric fermentation, produces methane that currently equates to around 2100 Mt of CO_2e per year globally. Digital technologies that enable the automated monitoring of livestock using connected sensors to alert farmers to changes could reduce the risk of disease and improve the efficiency with which meat is produced, ultimately reducing total emissions from enteric fermentation.

8.1 DIGITAL ABATEMENTS

The 2030 projections are extrapolations of historic CAIT data. Digital abatements have been calculated according to the approach used in the GeSI Digital with Purpose Report. This covers two main abatement areas: greenhouse gas emissions from the use of nitrogen fertilisers and enteric emissions from livestock. More details on the calculation methodologies are provided in Annex A.

	SECTOR EMISSIONS		2030 DIGITAL ABATEMENT	
	2014 BASELINE (CAIT)	2030 CURRENT POLICY PROJECTION INCLUDING NDC	REFERENCE SCENARIO	AMBITIOUS DECARBONISATION SCENARIO
BRAZIL	442	610	-19	-55
CHILE	10	13	0	-1
CHINA	708	870	-22	-65
INDIA	627	745	-25	-72
KENYA	37	58	-2	-6
SOUTH AFRICA	55	30	-3	-7
VIETNAM	63	86	-1	-4

TABLE 8.1
Predicted digital abatements in the agriculture sector. All figures in Mt CO_2e per annum.

8.2 RICE

Rice is a staple food for roughly half the world's population[93], and growing practices in their current iteration are responsible for 800million tonnes of CO_2e per annum– representing over 10% of global agricultural carbon emissions[94].

Methane is the major contributing greenhouse gas emitted during production, released through anaerobic decomposition of organic material in flooded rice paddies. The water prevents oxygen from penetrating the soil, creating conditions conducive for methane-producing bacteria, which escapes to the atmosphere via diffusion through plants[95].

It has been observed that altering paddy field irrigation strategies through the use of mid- season drainage or alternative wetting and drying processes, has the potential to reduce methane emissions by 75% without detrimental impacts to yields, with estimates suggesting that perfect water management strategies result in 90% CO_2e reductions[96]. These drainage strategies allow the soil time to reoxygenate, and lower bacterial methane production and thus methane.

Whilst it has been well demonstrated that improved management practises will result in significant emissions reductions, the specific role digital technologies can play in reducing these emissions is still relatively un-explored. Sensors can also play a significant role in maximising the precision of these irrigation strategies, but the specific abatement potential of the technology over and above the abatements achieved through improved management practises have not been conclusively proven.

Given the significant GHG impacts associated with rice production and the fact that many of the countries covered by this report are the main producers of rice, it is a recommended area for further investigation.

8.3 REBOUND EFFECTS IN AGRICULTURE

As with the other sectors, the key consideration in determining expected levels of rebound is the extent to which the applied digital technologies result in lower costs of production and thereby increased levels of consumption. If the costs of production post implementation of the technology remain about constant, then minimal rebound might be expected. However, the extent of rebound in the case of a lowering of the cost of production will depend on the extent to which that saving filters through to a proportionate reduction in the cost of the market in the final market. This is likely to be highly dependent on the crop in question but for many food items such as coffee, farmers receive a very small percentage of the retail price[97].

Of course, given the predicted continued growth in world population and the negative impacts climate change may have on food production, it may well be considered that more productive production is a good thing and any reduction in the carbon emissions associated with a unit of production is to be welcomed.

8.4 SUMMARY

The application of digital technologies in the agricultural sector analysed in this report, illustrated their potential to reduce 73 – 211 Mt CO2e across the seven countries studied. This was found to be achieved through greater productivity and increased efficiency, and can be significantly amplified through greater deployment of best practice irrigation strategies. Such digital technologies analysed include IoT sensors / cameras and AI to monitor crop health in real time, enabling precision farming activities that minimise resources. Additionally, IoT sensors which monitor livestock were identified to improve the efficiency with which meat is produced and ultimately reducing total emissions from enteric fermentation. It was also recommended in this report that rice production is further investigated to better understand the roles digital technologies can play in reducing emissions in rice production, which makes 10% of global agricultural carbon emissions [98].


9

DIGITAL TECHNOLOGIES FOR CLIMATE CHANGE ADAPTATION

The Sao Paulo Water Loss Reduction system is able to measure water usage, adjust pressure and improve system awareness to reduce water loss (currently 40%). The Water Operations Management platform securely stores data and optimises operations using mapping functionality.

9.1 INTRODUCTION

Human-induced climate change impacts are already with us, and are predicted to worsen in intensity and frequency in the future. Impacts include:

- Increased risk of severe weather events (e.g. floods, storms, heatwaves), causing humanitarian disasters, crop failures, wild fires, damage to infrastructure, and disruption to economic activities
- Long-term change to weather patterns (e.g. wetter in higher latitudes and droughts in the tropics), creating unsustainability of existing agricultural patterns in some regions, mass people migrations, and biodiversity reduction
- Sea-level rise, causing migrations of people, agriculture, and industry from coastal regions, and increased vulnerability to natural events (e.g. hurricanes/ typhoons, tsunamis)
- Knock-on effects of above to food security, transport infrastructure, health, energy supplies, access to raw materials, natural environment, and forests

Changes in the earth's climate have always occurred naturally, and life on the planet has had to adapt accordingly, or become extinct. However, several factors make adaptation to current climate change different in scale and urgency to that required in the past. For example, it is estimated that the world population has increased from under 200 million to 7.7 billion in the last two millennia[99], making the numbers of those impacted vastly higher than in the past.

The world has also become a very much more connected place, with a complex network of economic, political and other interdependencies now existing between regions, which make disruption in one part of the globe affect other parts also – for example, failure in export crops. It is estimated, for example, that the value of exports and imports as a percentage of world GDP have grown from around 2% in 1500 to around 60% now[100].

Lastly, if current global warming forecasts prove correct[101], then the pace of adaptation required may be far speedier than that needed previously.

While the main focus of this report is on the role of digital technologies in climate change *mitigation*, we must also consider how important that role could be in climate change *adaptation.* This dimension is particularly relevant to the low- and middle-income countries, which are expected to be disproportionately negatively impacted by climate change. Low-income countries, especially in Africa, South Asia, and South East Asia, are likely to be impacted more than high-income ones, as, for example, agriculture is highly climate-dependent and the poorest people have the least available means to allow them adapt to the changing environment.

The NDCs of the target countries for this report reflect this, with their adaptation needs being a mix of those common to many countries and those specific to individual countries or regions depending on factors such as climate (current and predicted), topography, development stage, location in world, and economic profile.

India's NDC, for example, includes a comprehensive adaptation needs assessment, the details of which are largely specific to India but which identifies themes applicable to many other low- and middle-income countries, such as:

- Agriculture e.g. enhancing food security, developing less water-consuming and climate-resilient crop varieties
- Water e.g. more efficient water usage and ensuring access to water for all
- Disaster management e.g. the need for early warning systems, loss and damage responses, and capacity building at all levels
- Health e.g. analysing epidemiological data, identifying vulnerable populations and regions, building knowledge bases and increasing awareness and community participation.
- Bio-diversity e.g. long-term monitoring of the effects of climate-related Himalayan glaciers change on wildlife
- Protecting rural livelihoods e.g. preserving and enhancing the threatened natural resource base (land, water and soil) of rural economies

The digital technologies applicable to each target country, which help meet these adaptation needs, will therefore vary accordingly.

This section overviews the general potential of digital technologies to assist adaptation to climate change, provides some examples of technologies which may be particularly relevant to the low- and middle income-countries, and lists some potential barriers and enablers to their adoption.

9.2 HOW DIGITAL TECHNOLOGIES CAN ASSIST ADAPTATION

ICT offers an array of technologies and applications that can assist adaptation to climate change. No doubt, over the coming decades, many more technological innovations will emerge to solve adaptation problems, the nature of many of which we cannot even guess at today.

The specific technologies most likely to be the basis of adaptation applications are remote sensors, satellites, GIS (Geographical Information Systems), big data analytics, Artificial Intelligence (AI) and supercomputers. These, supported by and integrated with, more widely available technologies, such as smartphones, laptops, tablets, Wi-Fi, mobile broadband, the Internet, social media, and the cloud, can provide extremely powerful, flexible and agile capabilities in a range of adaptation applications. Such applications include:

- Early warning systems for extreme weather events using monitoring satellites and mobile communications channels to rapidly disseminate real-time information and advice to vulnerable communities
- Climate modelling and prediction using satellites, sensors, and supercomputers
- Natural disaster management and recovery using sensors, GIS mapping, big data analytics, and mobile communications channels
- Water monitoring and risk evaluation for agricultural communities using GIS mapping and big data analytics
- Awareness raising on causes and impacts of climate change, using Internet-based e-learning
- Mitigating agricultural risk in low- and middle-income countries using index-based weather insurance supported by ICT tools (such as weather stations, satellite imagery, and weather prediction models)
- Control capabilities, such as adjusting water pressure according to availability
- Remote working access at times of severe weather
- Power sector resilience using smart grid technologies

Digital technologies have long been a key tool in agriculture. They can enable, for example, the provision to farmers of timely and accurate climate and agricultural information, the capability to assess climate change impacts on their local and regional agricultural production systems and environment, better knowledge sharing within the community, and the ability to pool and exploit regional and international research findings.

Many, indeed probably most, adaptation solutions will not have been specifically developed to assist adaptation, but for other reasons, and their adaptation application will be a beneficial by-product. It should be noted also that some digital solutions have the dual benefit of addressing both adaptation and mitigation, e.g. climate modelling, smart grids.

Impacts of 'climate change' are difficult to isolate from those impacts not specifically caused by human-induced climate change. For example, droughts and floods have always existed but climate change may increase their frequency and intensity. This, together with the renewed urgency due to the predicted rapid pace of change, is likely to lead to greater political and market pressure to accelerate the development of adaptation-specific solutions.

In other words, the business case is likely to become much stronger in future, creating a bigger and more developed marketplace through which solutions will emerge.

9.3 EXAMPLE ADAPTATION SOLUTIONS RELEVANT TO LOW- AND MIDDLE-INCOME COUNTRIES

SAO PAULO WATER LOSS REDUCTION SYSTEM[102]

Brazil has 12 – 14% of the world's fresh water but it is very unevenly distributed throughout the country, i.e. 70% of it in the River Amazon, but only 1.6% of it is in the state of São Paulo, where a quarter of the nation's population lives. The Sao Paulo Water Loss Reduction system is able to measure water usage, adjust pressure and improve system awareness to reduce water loss (currently 40%). The Water Operations Management platform securely stores data and optimises operations using mapping functionality. To reduce non-revenue water loss, the utility will be able to manage apparent and real water losses through the algorithms and dashboards provided by the platform.

BURKINA FASO WEATHER FORECASTING APP[103]

This enables intelligent decision making for small farmers by providing customised, highly accurate weather forecasting data, allowing them to stabilize operations, mitigate risks, and maximise profits. Farmers receive, by SMS, a daily 48-hour weather forecast on the probability, timing, and intensity of rainfall, plus monthly and seasonal outlooks. The system sends highly localized forecasts based on GPS location data of the subscribers.

FLOWKIT (FROM FLOWMINDER)[104]

A suite of Open Source software tools designed to enable access and analysis of mobile data for humanitarian and development use cases. e.g. understanding the location of displaced people during humanitarian emergencies is a key factor when assessing the scale and impact of an event and for the management of relief response, as it informs decisions on suitable locations for on-the-ground assessments for initiating relief assistance.

NORTH SUMATRA DISASTER INFORMATION MANAGEMENT SYSTEM[105]

Supports rescue and recovery activities, as well as quick decision making, when disasters occur, offering centralized management of disaster information in North Sumatra, Indonesia. People dispatched to disaster sites can connect to the system and input information about numbers of casualties and damaged structures, and select from twelve different types of disasters, including volcanic eruptions, floods, and landslides, using a proprietary smartphone application to transmit the information to the command centre. The information submitted from disaster-afflicted areas will be displayed in real time on a dashboard map screen, providing insight into the extent and nature of damage suffered.

AQUEDUCT: MAPPING WATER RISK

Many of the impacts from climate change are likely to relate to water in some way, so adaptation strategies will require effective water monitoring and management as a key component. This applies especially to agriculture, but also to urban populations in water-stressed regions. Aqueduct is a big data project run by the World Resources Institute, aimed at measuring and mapping water risk around the world.

9.4 POTENTIAL BARRIERS AND ENABLERS TO ADOPTION OF ADAPTATION SOLUTIONS

While there are clearly many ways in which digital technologies can assist climate change adaptation, there still remain substantial barriers to their adoption, especially in low- and middle-income countries. Whilst specific barriers will vary according to sector, they are likely to include:

- Lack of finance to invest in solutions
- Patchy quality of local supporting infrastructure, in particular communications networks
- Limited awareness of which solutions are available
- Low levels of technical ICT skills
- Lack of supporting regulatory frameworks
- Limited regional or international co-operation
- Weak local or national government
- Unstable or dangerous environments, for instance in war-zones

Moreover, and perhaps paradoxically, increasing dependence on digital technologies in every aspect of our lives might in some respects make adaptation more difficult. This is because ICT systems themselves can be vulnerable to the impacts of climate change. For ICT to play an effective role in adaptation, as well as in all its other roles, it will need itself to adapt appropriately to the changed world. Climate change impacts will necessitate heightened resilience against a range of vulnerabilities, such as:

- Loss of power grids
- Loss of networks
- Loss of data centres
- Unavailability of key support staff

A range of resilience-improving strategies will be required, such as:

- Locating data centres away from places under threat from flood or sea-level rise
- Use more off-grid (and preferably zero-carbon) power sources, e.g. solar, wind
- Data duplication in back-up data centres

On a positive note however, in contrast to the potential barriers to adoption, there are a number of enablers which should facilitate adoption in all countries, including low- and middle-income ones. These include:

- Increasing pervasiveness and affordability of high-quality networks in much of the world
- The near ubiquity of smartphones - almost everyone has (or will have) a computer in their pocket
- Location independence, or physical de-coupling, of interconnected components of digital systems, which can be of particular benefit in certain adaptation applications – such as, natural disaster management – as it means that key components can be located well away from the affected areas, e.g. cloud datacentres
- 'Democratisation of information' i.e. the rising willingness to freely share data and information, including open source and other free software, amongst interested parties. This is particularly useful for low- and middle-income countries, e.g. in facilitating access to expert knowledge and specialist software tools, which may not be otherwise available or affordable
- A strengthening business case as climate change impacts worsen, awareness grows, the scope and intensity of future impacts become clearer, and the richer countries become increasingly impacted, e.g. disrupted access to agricultural products of low- and middle-income countries. These should all add impetus to solution development by vendors, and to implementation.
- Improving confidence in climate change vulnerability assessments, i.e. expected nature, timing, and geographical spread of impacts

9.5 ADAPTATION CONCLUSIONS

The impacts of climate change are increasingly being felt. Knowledge is still evolving regarding the full nature of these impacts over the coming years and decades. It is already clear, however, that, in addition to their role in helping *mitigate* climate change, current digital technologies have a substantial potential to assist the world to *adapt* to a changing climate. The vast majority of adaptation-relevant solutions and technologies would not have been developed specifically to target climate change adaptation but are simply the application of existing technologies and solutions, which have been developed to meet a plethora of real-world requirements, to climate change adaptation. Doubtless, in future, many more digital solutions will be available which can be exploited to tackle climate change impacts.

The low- and middle-income countries are expected to be disproportionately affected, which is reflected in the adaptation needs expressed in their NDCs. Whereas many adaptation-relevant digital solutions would be of great potential benefit to low- and middle-income countries, there remain considerable barriers to their implementation in many of those countries. These include lack of funding, inadequate communications infrastructures, and unstable political environments. However, on the positive side, there exist also a number of enablers to adoption, some of which should in time act to overcome some of the barriers and thereby facilitate adoption. These enablers include increasing smartphone ownership and improving access to reliable and high bandwidth networks in many currently digitally disadvantaged areas of the world.

One might also expect an uptick in the development of adaptation-relevant solutions by the ICT industry as it becomes clearer to the world exactly what impacts to expect, where, and when. This will allow more informed business cases to be made by vendors reducing the risks of investing in developing expensive solutions for which there is only a small market. It might be expected also that the onset of certain impacts in low- and middle-income countries which will in turn negatively affect high-income countries e.g. reduced food production for export, mass migrations to avoid drought - might act as a spur to the ICT companies in high-income countries to accelerate the development of relevant solutions and assist in various ancillary ways, including financially, to facilitate implementation of those solutions in low- and middle-income countries.


10

EMISSIONS RESULTING FROM THE USE OF DIGITAL TECHNOLOGIES

With GHG emissions for the ICT sector in 2020 remaining relatively similar to 2015, **data centres** have great potential in emission reductions by **maximising the use of renewable energies**.

Whilst there have been numerous studies into the carbon footprint of the ICT industry, caution must be applied when comparing them[106, 107, 108, 109, 110,]. It is important to recognise that the published carbon emissions from these studies depend on a number of factors that may not have been evenly applied across all the studies, including:

- The boundary conditions used – that is the specific technology, devices and applications covered by the calculations.
- The extent to which upstream (embodied) and downstream emissions have been included.
- Sensitivity to regional and other technical variations in the carbon intensity of electricity drawn from the power grid.

A comprehensive study, recently been published by the ITU[111], focusses on data centres, telecoms networks and ICT end-user devices. The study found a 2015 carbon footprint of 740Mt CO_2e including embodied emissions in ICT equipment and network deployment and construction, and electricity grid transmission loses. Using up to date data, the same study expects GHG emissions for the ICT sector in 2020 to remain relatively similar to the 2015 value.

Future emissions are difficult to predict, and published papers vary widely. Critical additional factors to consider are:

- Changes (usually increases) in the number and types of services.
- Increases in the number of end-users.
- Increases in the amount of IP traffic.
- The number and complexity of cloud-based compute instances.
- The amount of cloud-based storage.
- Future energy efficiency improvements.
- The extent to which grid electricity will decarbonise.

Some trends can be extrapolated from existing data sets, for example, population and economic growth rates, and account taken of new technologies such as M2M and IoT. However, many trends are open to subjective extrapolations and uncertainties. For example, historic energy efficiency has relied on Moore's Law[112], but there are now concerns that as transistor dimensions approach the atomic level, Moore's Law may well falter.

One thing that is certain is that IP traffic growth will continue to increase rapidly. This is mainly due to the massive uptake of video services as illustrated in the Cisco Visual Networking Index[113].

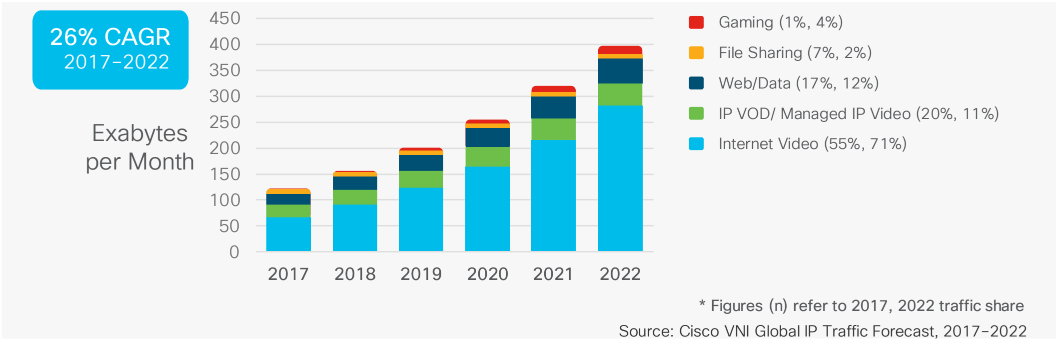


FIGURE 10.1
Breakdown of IP traffic from the Cisco Visual Networking Index

According to the same Cisco white paper, connected home applications, such as home automation, home security and video surveillance, connected white goods, and tracking applications, will represent 48 percent, or nearly half, of the total M2M connections by 2022, showing the pervasiveness of M2M in our lives. Connected cars, with applications such as fleet management, in-vehicle entertainment and Internet access, roadside assistance, vehicle diagnostics, navigation, and autonomous driving, will be the fastest-growing industry segment, at a 28 percent CAGR. Connected cities applications will have the second-fastest growth, at a 26 percent CAGR each.

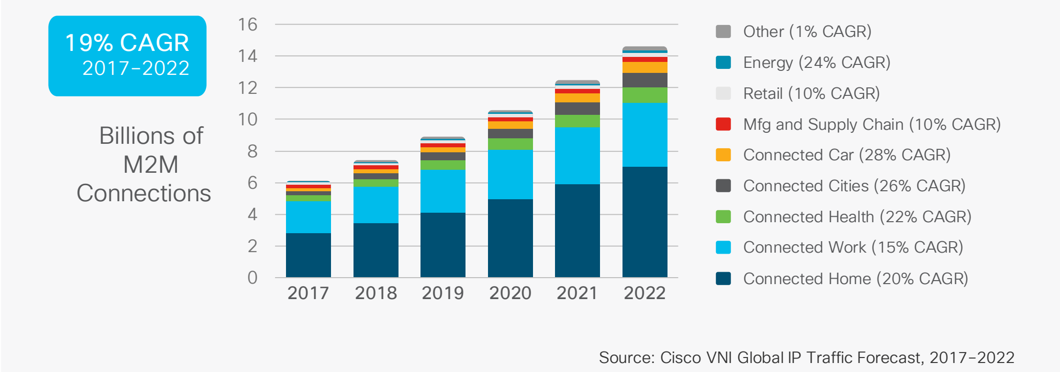


FIGURE 10.2
M2M connections from the Cisco Visual Networking Index

Although some of these applications will have carbon reducing potential, many will not. In fact, the evidence suggests that the ICT sector carbon footprint is, and will continue to be, dominated by applications such as video streaming, gaming, social media and conventional commercial transactions. In comparison, many of the carbon reducing applications identified in this report will require minimal bandwidth and increases in their take-up are therefore not expected to make any significant contribution to changes in the overall ICT sector carbon footprint.


11

CONCLUSIONS AND RECOMMENDATIONS

Meeting the goals of the Paris Agreement requires a dramatic transformation of the world's economies.

As this report demonstrates for seven countries, the appropriate application of digital technologies will be an essential enabler that can underpin and even accelerate, the required levels of decarbonisation across four key sectors: power, transport, manufacturing and agriculture.

To realise the full potential of digital technologies, countries will need to combine their application with a political desire to transition into a low carbon economy. This will need supporting policy and regulatory frameworks. In order to take into account differing ambition levels, digital abatement potentials were assessed for two scenarios. A reference scenario that reflects current country policies including the NDCs, and an ambitious decarbonisation scenario that reflects the country reductions needed to approach the goals of the Paris agreement.

Taken together across all seven countries the level of potential carbon abatement is significant, with 1.1Gt of CO_2e in the case of the reference scenario and 2.1Gt of CO_2e in the case of the ambitious decarbonisation scenario. To place these figures in perspective they can be compared to the total 2014 baseline footprint for the four sectors across all seven countries of 13.2 Gt of CO_2e and the projected 2030 footprint for the four sectors across all seven countries under business as usual conditions of 21.8 Gt of CO_2e.

Unsurprisingly the country abatements naturally vary according to the size of the economy, with China and India showing the largest abatement potentials. The distribution of a country's total abatements also varies between sectors. For example, in the case of Brazil, the abatements in the agriculture sector are 55% of the total, and only 10% for heat and power. Whereas, for Chile agricultural abatements constitute just 4% of the total, compared to 58% for heat and power. These important differences reflect the nature of the different country economies, their levels of development and often the availability of natural resources for power generation. They illustrate how important it is not to draw broad conclusions and that the role of digital technologies must really be considered on a per country basis.

	HEAT AND POWER		TRANSPORT		MANUFACTURING AND CONSTRUCTION		AGRICULTURE		TOTAL
BRAZIL	-6	14%	-12	29%	-5	12%	-19	45%	-42
CHILE	-9	64%	-4	30%	0	3%	0	2%	-14
CHINA	-434	59%	-161	22%	-112	15%	-22	3%	-729
INDIA	-97	37%	-91	35%	-46	18%	-25	10%	-259
KENYA	-2	35%	-1	20%	0	3%	-2	42%	-5
SOUTH AFRICA	-13	64%	-2	11%	-3	13%	-3	13%	-20
VIETNAM	-7	48%	-2	13%	-4	30%	-1	9%	-15
TOTAL	-567		-274		-171		-73		-1085

ALL ABATEMENT FIGURES ARE IN MT CO2E PER ANNUM.
THE (%) FIGURES REPRESENT THE SECTOR PERCENTAGE SHARE
OF THAT COUNTRY'S TOTAL POTENTIAL ABATEMENT.

FIGURE 11.1
Potential abatements by country and sector for the reference scenario.
Due to rounding, numbers presented may not add up precisely to the totals indicated and percentages may not precisely reflect the absolute figures for the same reason.

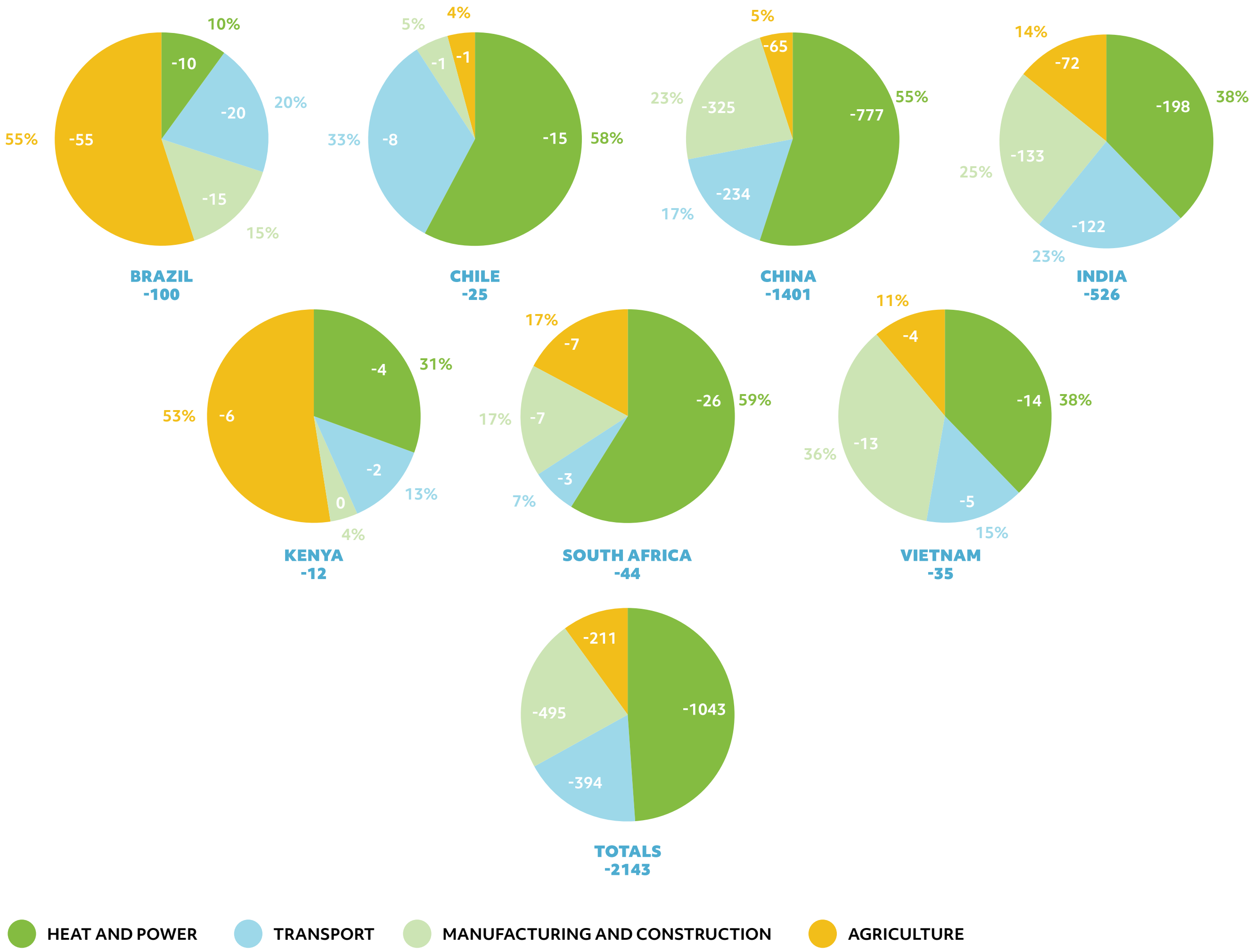
	HEAT AND POWER		TRANSPORT		MANUFACTURING AND CONSTRUCTION		AGRICULTURE		TOTAL
BRAZIL	-10	10%	-20	20%	-15	15%	-55	55%	-100
CHILE	-15	58%	-8	33%	-1	5%	-1	4%	-25
CHINA	-777	55%	-234	17%	-325	23%	-65	5%	-1401
INDIA	-198	38%	-122	23%	-133	25%	-72	14%	-526
KENYA	-4	31%	-2	13%	0	4%	-6	53%	-12
SOUTH AFRICA	-26	59%	-3	7%	-7	17%	-7	17%	-44
VIETNAM	-14	38%	-5	15%	-13	36%	-4	11%	-35
TOTAL	-1043		-394		-495		-211		-2143

ALL ABATEMENT FIGURES ARE IN MT CO_2E PER ANNUM.
THE (%) FIGURES REPRESENT THE SECTOR PERCENTAGE SHARE
OF THAT COUNTRY'S TOTAL POTENTIAL ABATEMENT.

FIGURE 11.2
Potential abatements by country and sector for the ambitious decarbonisation.
Due to rounding, numbers presented may not add up precisely to the totals indicated and percentages may not precisely reflect the absolute figures for the same reason.

Of all four sectors, the highest abatement potential (1045 Mt CO_2e in the ambitious decarbonisation scenario) lies in the power sector, across both supply and demand intervention points. In the case of China for example, the digitally enabled accelerated decarbonisation abatement of 777 Mt CO_2e is equivalent to decommissioning over 170 average Chinese coal-fired power plants.

Significant opportunities for decarbonisation have been identified for: energy efficiency gains through many aspects of the smart grid; and for increases in distributed renewables, especially through microgrids. In fact, it is hard to envisage how a trajectory to the total decarbonisation of electricity, which is needed to achieve the Paris Goals, can occur without the integration of digital technologies. Electricity is also a sector which, at least on the supply side, is open to quite straightforward government intervention through market regulation and incentive mechanisms.



ALL ABATEMENT FIGURES ARE IN MT CO_2E PER ANNUM.
THE (%) FIGURES REPRESENT THE SECTOR PERCENTAGE SHARE OF THAT COUNTRY'S TOTAL POTENTIAL ABATEMENT.

FIGURE 11.3
Potential abatements in each country by sector

Transport has 495 Mt CO_2e abatement potential in the ambitious decarbonisation scenario from applications covering car sharing, private and commercial vehicle route optimisation, smart EV charging and facilitating public transport. For many in the world's low- and middle-income economies, there is a strong desire to replicate the levels of private car ownership and other forms of consumerism already prevalent in the industrialised nations. Avoiding the anticipated levels of growth in private car ownership is difficult. But enhancing the attractiveness of public transport may attenuate the growth, especially in large conurbations. This has the added benefit of also addressing the very poor air quality found in many of the larger cities. For the countries under investigation here, enhancing the attractiveness of public transport using digital technologies offers 56 Mt CO_2e of potential abatement in the ambitious decarbonisation scenario.

The transport area with the highest abatement potential involves road freight logistics, with 273 Mt CO_2e of potential abatement in the ambitious decarbonisation scenario. This not only reflects the expected growth in freight transport but also the significant levels of such transport already present. Careful consideration does, however, need to be given to how the e-commerce marketplace roles out with a particular focus on the final drop.

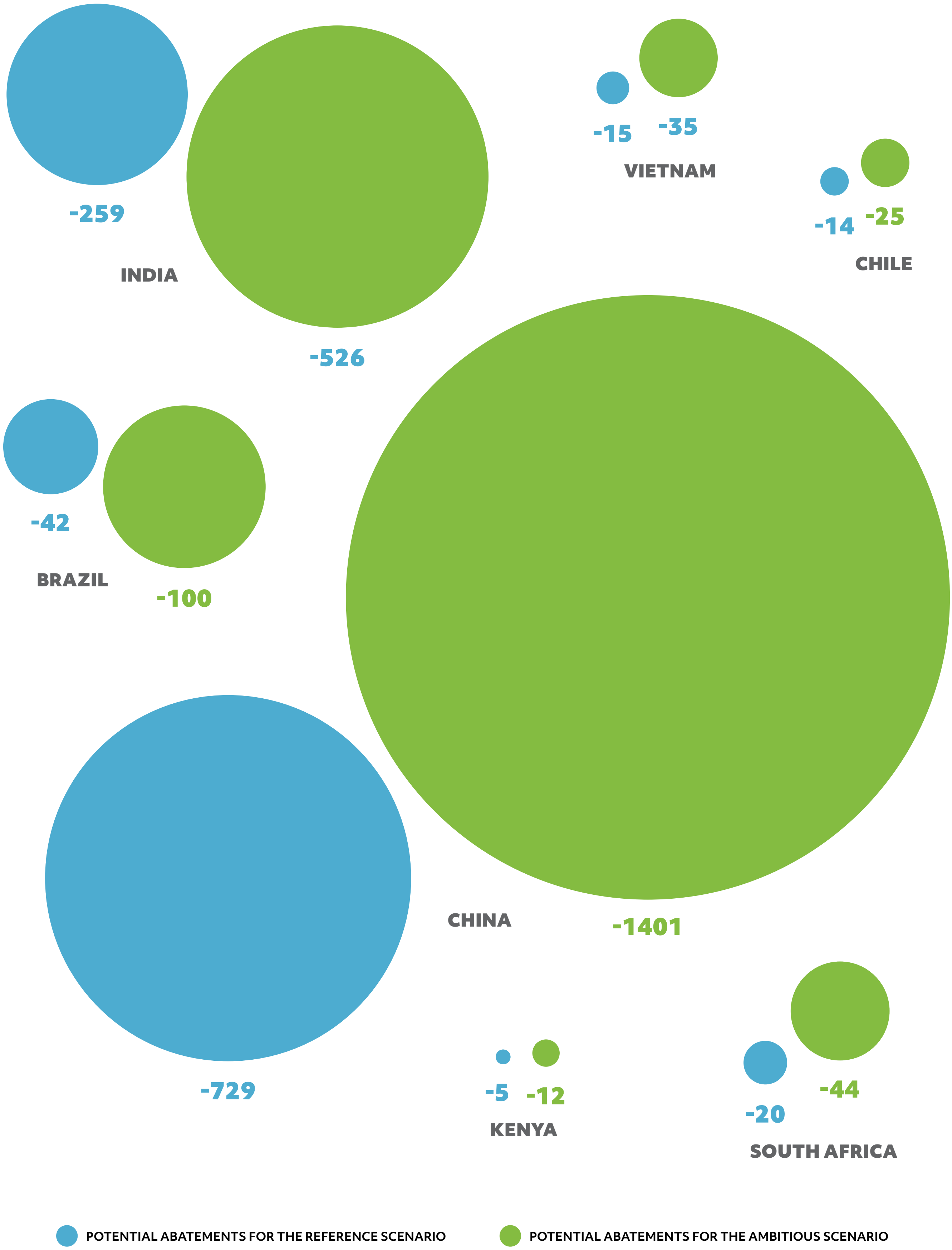


FIGURE 11.4
Side-by-side comparison of potential abatements by country under the reference scenario and ambitious scenario.
All abatement figures are in Mt CO_2e per annum

This report has focussed mainly on the power and transport sectors. For completeness, high level abatement assessments were undertaken manufacturing and agriculture that found 171 Mt CO_2e and 73 Mt CO_2e abatement potentials in the ambitious decarbonisation scenario respectively.

In previous reports, including those published by GeSI, the potential role of digital technologies in rice cultivation has not been fully assessed despite this being a major source of methane emissions in many of the countries under investigation here.

In following up on the findings of this report there are two factors that must be taken into consideration.

The first is that the calculated abatements should be taken as indicative of the role digital technologies might play in carbon emissions reductions, rather than accurate predictions. The extent to which they will materialise will depend on a large range of factors including:

- National policies on carbon reduction.
- National policies on the key sectors: power, buildings, transport, manufacturing, construction and agricultural.
- Market and technical regulations.
- Political ambition.
- Available investment.

And secondly, it should be noted that the abatements given above are before consideration of any rebound effects. These effects may be sizeable - up to 50% in some cases. Again, the extent of any rebound will be dependent on a number of factors which are likely to vary substantially across the countries and sectors.

For example, any digital intervention that simply improves the energy efficiency of a carbon intensive process will most probably result in high levels of rebound. This is because the reduced energy consumption will lower the cost of production which, in turn, will increase consumption levels. Energy efficiency improvements in manufacturing are likely to fit into this category.

On the other hand, digital technologies that lower cost or technical barriers to low and zero carbon approaches thus making them competitive with existing approaches, have a lower risk of rebound. The replacement of fossil fuel generated energy by renewable sources is likely to fit in this category.

In addition to the specific recommendations made above, there are a number of areas where high level framing policies should be encouraged as summarised in the following.

I INTRODUCE MARKET REGULATION TO INCREASE DIFFUSION WHILE ENCOURAGING DECARBONIZATION IN THE SECTOR

- Investigate regulation designs that focus on efficient investment incentives for electricity grid expansion and smart solutions, allowing new market actors to enter
- Include an obligation in the terms of reference of energy market regulators to achieve levels of decarbonisation in the sector, reflecting the opportunities afforded by digital technologies

II SUPPORT DIVESTMENT AND COAL EXIT EFFORTS THROUGH DIGITAL TECHNOLOGIES

- Develop an open-access database and monitoring tool on companies across the national coal value chain to inform divestment and coal exit strategies

III ESTABLISH A FAIR, BALANCED AND CONSISTENT REGULATORY APPROACH TO ICT SOLUTIONS

- Set general and sector specific standards on ethical and technical levels to ensure trustworthiness and data security

IV INTEGRATE DIGITAL TECHNOLOGIES IN PUBLIC PROCUREMENT CONTRACTS

- Integrate the funding and development of digitally enhanced abatements with carbon reduction and climate change adaptation ambitions

V CREATE INCENTIVES TO INVEST IN BROADBAND INFRASTRUCTURE DEPLOYMENT

- Connect schools and libraries to broadband, increasing digital literacy to drive adoption and raise ICT access and awareness

VI COLLECT AND PROVIDE OPEN ACCESS DATA TO FACILITATE THE DEVELOPMENT AND EXPLOITATION OF DIGITAL APPLICATIONS

- Develop a digital infrastructure that collects real-time data including demand and supply information on power grids; public transport arrival and departure times; traffic congestion etc. Build the data into relevant projects along with the development of open data portals with suitable APIs (Application Programming Interfaces).

VII PROMOTE THE BENEFITS OF SMART HOME AND SMART BUILDING SOLUTIONS

- Establish an engagement plan for end-users by market segment (innovators, early adopters, early majority, late majority, laggards), marketing enrolment through whole-house upgrades
- Partner with industry stakeholders to develop standards and guidelines for: design, functionality, data and privacy, and assessment

VIII CONSIDER ICT WITHIN THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) PROCESS AS A KEY INSTRUMENT TO SUPPORT COUNTRIES IN ACHIEVING THEIR CLIMATE TARGETS

- Develop guidelines on how donor countries and organisations can embed the use of ICTs within climate change mitigation and adaptation programmes

IX UNDERTAKE IN-DEPTH ASSESSMENTS WHICH INVESTIGATE THE ROLE OF DIGITAL TECHNOLOGIES IN AGRICULTURE, INCLUDING RICE CULTIVATION

- As many low- and middle-income countries are rural with vast agricultural diversity, considerations must be made to different regions and the differing potential for impact and trends
- Broader studies can be conducted by strengthening private-public partnerships (PPPs) and engaging civil society across different levels

X UNDERTAKE IN-DEPTH EXAMINATION OF THE IMPACTS OF E-COMMERCE IN LOW- AND MIDDLE-INCOME COUNTRIES

- Focus the case study selection on specific cities and produce recommendations to better understand the impacts through an integrated transport and digital infrastructure

FOR THE ICT INDUSTRY

I SET EMISSIONS TARGETS AT INDUSTRY OR BUSINESS LEVELS

- Deciding to set and communicate its own target and performance will bring greater commitment and transparency

II INVEST IN LOW- AND MIDDLE-INCOME COUNTRIES TO INCREASE ENERGY EFFICIENCY AND DEVELOP LOW-CARBON PARTNERS TO SPEED UP DEPLOYMENTS

- Promote low-carbon economic growth through innovative funding mechanisms through PPPs, safeguarding community-based solutions and ownership

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ANNEX A

ABATEMENT CALCULATION METHODOLOGIES

HEAT AND POWER			
ABATEMENT	2030 BASELINE	ABATEMENT CALCULATION	ABATEMENT CALCULATION SOURCES
Decrease in Power Production due to Smart Grids and Buildings	Depending on availability: predicted 2030 power sector emissions based on IEA ETP, official country data	= [2030 baseline] x [maximum possible impact] x [projected adoption rate in country]	SMARTer 2030 & Gartner
Increase in Distributed Renewable Electricity	Increase in distributed renewables since 2014 based on IEA renewables forecasts, comparative best estimates, country policies and NDCs	= [2030 baseline] x [projected grid carbon intensity in 2030] x [extent distributed renewable generation is dependent on digital]	IEA ETP or comparative best estimates, GeSI team country specific estimates

TRANSPORT			
ABATEMENT	2030 BASELINE	ABATEMENT CALCULATION	ABATEMENT CALCULATION SOURCES
Car sharing	= [number of cars in 2030] x [average distance covered by each car] x [car fuel efficiency]	= [2030 baseline] x [increase in adoption rate since 2014] x [[% distance reduction due to sharing] – [marginal % distance increase of shared cars]]	Official country statistics SMARTer 2030 GeSI team country specific estimates
Efficient routes	= [number of cars in 2030] x [average distance covered by each car] x [car fuel efficiency]	= [2030 baseline] x [increase in adoption rate since 2014] x [[% distance reduction due to route optimisation] + [% increase in fuel efficiency due to route optimisation]]	Official country statistics SMARTer 2030 GeSI team country specific estimates
Electric vehicles: smart vehicle charging	= [number of EVs in 2030]	= [2030 baseline] x [increase in adoption rate since 2014] x [[decrease in fossil fuel emissions due to displacement of internal combustion engine vehicles] – [increase in power sector emissions]]	IEA ETP or comparative best estimates Official country statistics SMARTer 2030 GeSI team country specific estimates
Public Transport attractiveness	= [number of cars in 2030] x [average distance covered by each car] x [car fuel efficiency]	= [2030 baseline] x [increase in public transport adoption rate due to digital technology since 2014] x [avoided use of private transport]	Official country statistics SMARTer 2030 GeSI team country specific estimates
Fall in transport used: road freight	= [total 2030 road freight in ton km] x [CO2 intensity]	= [2030 baseline] x [% reduction in road freight distance due to digital technology] x [increase in adoption rate since 2014]	Official country statistics SMARTer 2030 GeSI team country specific estimates
Fall in transport used: rail freight	= [total 2030 rail freight in ton km] x [CO2 intensity]	= [2030 baseline] x [% reduction in rail freight distance due to digital technology] x [increase in adoption rate since 2014]	Official country statistics SMARTer 2030 GeSI team country specific estimates

MANUFACTURING AND CONSTRUCTION			
ABATEMENT	2030 BASELINE	ABATEMENT CALCULATION	ABATEMENT CALCULATION SOURCES
Industry 4.0 Efficiency gains	Depending on availability: predicted 2030 manufacturing and construction sector emissions based on IEA ETP, best estimates, based on CAIT data	= [2030 baseline] x [impact from digital technology intervention] x [increase in country adoption rate since 2015]	IEA ETP or country specific estimate, Digital with Purpose

AGRICULTURE			
ABATEMENT	2030 BASELINE	ABATEMENT CALCULATION	ABATEMENT CALCULATION SOURCES
Nitrogen fertilisers	CAIT 2014 baseline extrapolated to 2030 based on historic pathways	= [2030 baseline] x [impact from digital technology intervention] x [increase in country adoption rate since 2014]	CAIT Digital with Purpose
Enteric	CAIT 2014 baseline extrapolated to 2030 based on historic pathways	= [2030 baseline] x [impact from digital technology intervention] x [increase in country adoption rate since 2014]	CAIT Digital with Purpose

ANNEX B

DIGITAL SOLUTIONS USE CASES

DIGITAL WIND FARM

The Digital Wind Farm is a 2015 EU technology project using IoT, Cloud and Cognitive technology.

BACKGROUND

Traditionally, for a wind farm, digitalisation was seen as a 'nice-to-have' and not as a 'must-have'. However, digital solution can enable wind turbines to achieve an optimal level of performance, thus extending the life cycle of the turbines, reducing operation costs, and enhance energy generation.

FUNCTIONALITY

By creating digital ‘twins’ for the prognosis of failure in key components of a wind farm, GE’s digital wind farm solutions help operators to decide at what point to carry out maintenance, overhaul and replacement of components in order to reduce operation costs and improve efficiency. In addition, a built-in predictive analytics can forecast wind speeds over a period of time, resulting not only in impacting the wind energy generated, but also the transmission capacity that power lines can host.

TECHNOLOGY

A wind farm solution consists of IoT based sensors on turbines, operation software of turbines, real-time weather data exchange, performance analytics, and predictive model operated on the cloud.

Digital Wind Farm solution can boost a project's annual energy production (AEP) by up to 20%.

CONCLUSION

The solutions can particularly benefit large fleets. The same solutions can also be applied to renewable energy plants such as hydro and solar[1].

MOVING SERVICE TO CLOUD

Moving Service to Cloud is a 2018 Mexican buildings technology using cloud.

BACKGROUND

Choosing cloud can help an organisation run more smoothly and save on costs through efficient resource usage. Colegio de Bachilleres, a high school in Mexico, has 5 computer centres and over 100,000 enrolled. The school was looking for ways to lower its electricity consumption and reduce the use of papers.

FUNCTIONALITY

The Oracle's cloud-based 'Paperless project' implemented the Oracle Cloud Infrastructure Objective Storage Classic and Oracle Cloud Platform to provide students, academic, administrative, managerial staff, with online access to information, enrollment, grade and coursework. It replaced physical computers with virtual machine centre on Oracle Cloud. It also eliminated trips to school to enrol, coursework submissions, and access information, thus reducing emissions from road transport.

TECHNOLOGY

The technology used is Oracle Cloud Platform and Mobile to access the Cloud Platform and its impacts can:

- Save up 50% of electricity consumption
- Reduce paper waste significantly
- Reduce the number of trips for information and administration

CONCLUSION

Moving services to the cloud is a simple and easily implementeable solution. It can save IT related and energy consumption significantly for all types of public and private organisations such as SMEs[2].

REMOTE IRRIGATION CONTROL

Remote irrigation technology is a 2004 Indian technology using IoT and digital access.

BACKGROUND

Groundwater pumping is the biggest emission source, accounting for 60.97 % of total irrigation emissions. The GHG emission intensity of irrigation depends largely on water use efficiency, and improving it can be an effective way to reduce emissions.

FUNCTIONALITY

Nano Ganesh water pump uses mobile phones to remotely monitor and switch on irrigation pumps for watering crops. Since 2004 it has been widely used in India, saving water and time for around 400,000 farmers. Even low-literate users can practice environmentally-friendly and sustainable farming using the service, which is largely audio-based and requires basic mobile phone skills and numeracy.

TECHNOLOGY

Digital access and IoT based remote control are the main technology used; every 5 horsepower water pump installed can save 1,000 litres of water, 3- 5 units of electricity, 2 hours of labour and 1 litre of fuel.

CONCLUSION

Remote irrigation control can be a very simple and effective solution, particularly for the least developing rural area. It is very cost-effective, investment of $100 in a unit, yield total save of $600 per year. A unit can save 10g CO_2 per day. The remote control system can be more sophisticated by having additional sensors and analytics models for large farms[3].

ALPHABET NEST SMART HOME

The Alphabet Nest Smart Home is a 2011 American buildings technology using IoT and Cognitive technology.

BACKGROUND

Energy consumption for residential buildings is a main contributor, particularly in cities. ACEEE estimates that 17% of energy saving can be achieved if smart homes are implemented in all households in the US. Smart meters and smart homes can help in optimising demand management of the grid.

FUNCTIONALITY

Alphabet Nest is a smart thermostat for homes that reduces energy consumption by adapting to user behaviour. Post its installation in a house, it observes and learns its occupants' habits and then adjusts the temperature. It brings up option menus for switching from heating to cooling, access to device settings, energy history, and scheduling.

TECHNOLOGY

Nest is a self-learning WIFI enabled thermostat. Nest can learn people's schedule, which temperature they are used to and when. Using built-in sensors can shift into energy-saving mode when it realises that nobody is at home.

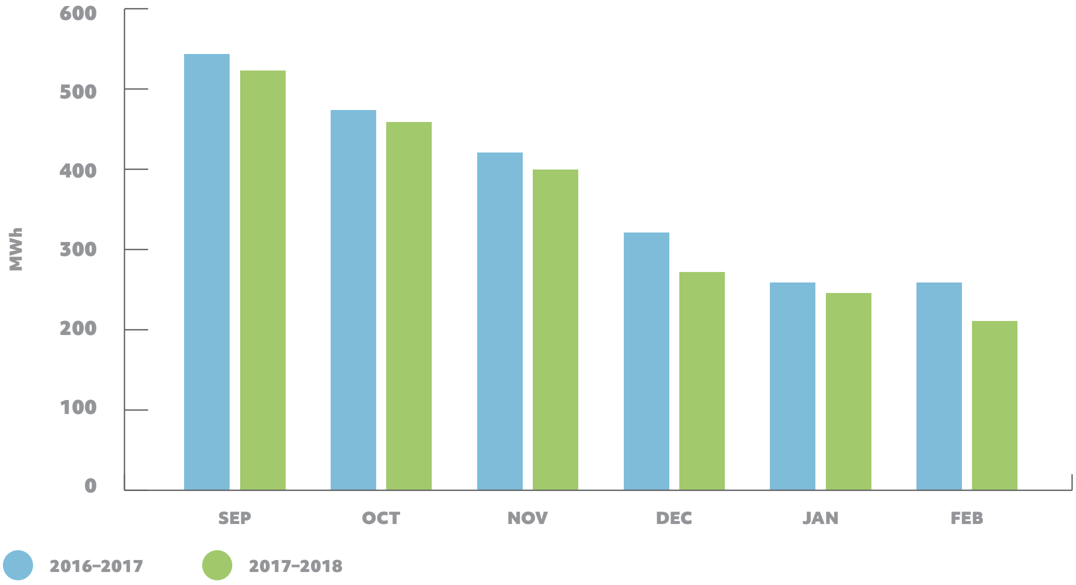
It can lead to a monthly energy saving of 10-12% per household and, according to ACEEE, an overall energy saving of 17% in case all homes adopt smart solutions.

CONCLUSION

Smart home solutions can play an important role in areas where residential buildings are big energy consumers such as zones with extremely cold and warm climates. Together with smart meters and variable tariffs, smart home solutions can play an crucial role in the stability of the grid, having a big impact on the overall efficiency of the energy sector[4].

DUBAI HIGH RISE ENERGY EFFICIENCY

The Dubai High Rise Energy Efficiency is a 2018 UAE buildings technology using IoT and cognitive technology.



BACKGROUND

Buildings account for 40% of total direct and indirect CO_2 emissions globally. Having recognised the challenge, a growing number of countries adopt policies to improve building energy performance. Smart Building solutions using IoT and AI have demonstrated their contributions to achieve emissions reduction goals.

FUNCTIONALITY

The Emirates NBD Asset Management real estate company has installed a comprehensive Smart Building solution for a 28-floor building. The solution comprises IoT sensors collecting energy usage data in real-time, a big data and AI-based analytics model to identify best strategies from over 30 energy-saving opportunities.

TECHNOLOGY

The technologies involved in this are IoT based sensors and AI and Big Data analytics model; the analytics model can operate in the cloud and it can save 7% of GHG emissions from buildings.

CONCLUSION

Smart building solutions can enable returns on investment from energy savings; normally 3 years as break-even point[5].

SMART STREET LIGHTING

Smart street lighting is a 2015 Benin buildings technology and policy using IoT and cognitive technology.

BACKGROUND

The street lighting is a major contributor to total energy consumption. For example, in Quezon City, Philippines, street lighting counts for 65% of the city's electricity costs, 5% of the municipal overall budget. Smart Street Lighting can reduce energy consumption, save maintenance costs and improve road safety and security.

FUNCTIONALITY

The Benin government has built solar street lights, smart street lighting and solar micro-grid in major cities and 105 villages in the country. The smart street lights are connected through wireless communications for automatic control. The lights can be adjusted according to ambient brightness, season and traffic flow to achieve optimised energy efficiency, safety and security.

TECHNOLOGY

The smart street lighting system uses sensors on light poles, which enables them to detect Wireless movement network to connect sensors, collect data and control remotely; It can generate more than 70% secondary energy saving.

CONCLUSION

Smart street lighting projects are government initiative and need political and financing support. Procurement of smart street lighting is challenging to avoid vendor lock if there are only limited suppliers[6].

SMART WASTE BIN

Smart waste bin is a 2016 German waste technology and policy using IoT.

BACKGROUND

As urbanisation and waste production increase on a global scale, cities face the challenge of how to manage their waste effectively and to minimise their negative impacts on public and environmental health. Smart waste management has demonstrated that it can provide a cleaner city while reducing costs.

FUNCTIONALITY

The Deutsche Telekom Smart Bin Solution provides detailed information on the fill status of the container through IoT sensors and wireless communication. It enables dynamic routing to reduce transport cost and to improve visibility of waste collection issues in a city. It provides detailed information on waste collection from individuals and the overall city, enabling fair charging policy.

TECHNOLOGY

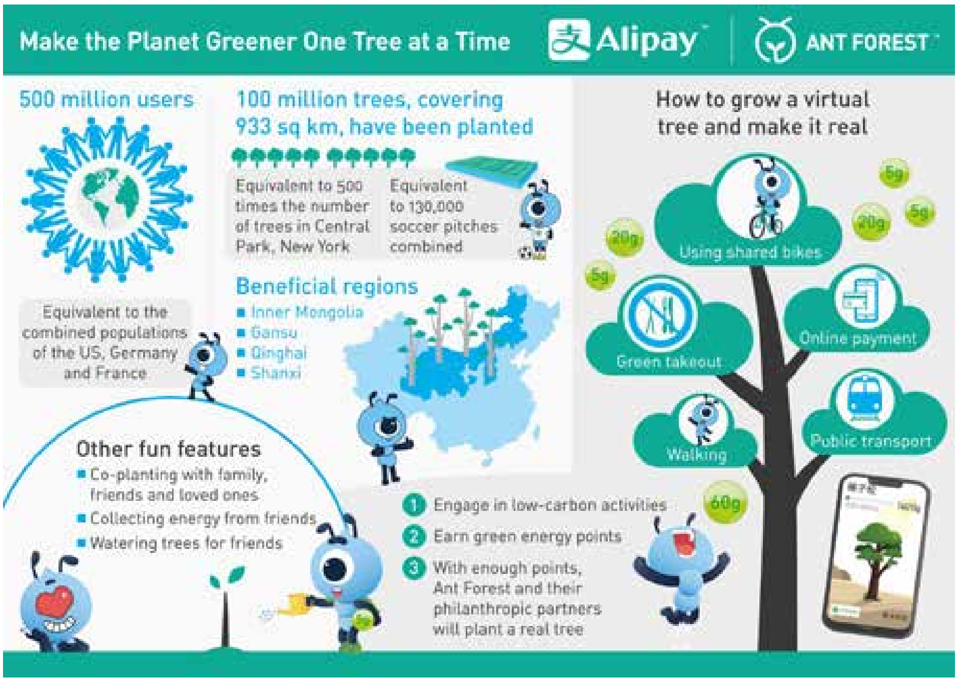
The solution gathers information from the fill-level sensors in the containers and the bin identification system on the trucks to enable route optimisation. It also tracks the exact position and temperature of containers and provides information on its weight at pick-up. This can contribute to savings up to 40% of fuel and overall waste collection cost and to an improvement of the overall waste management services.

CONCLUSION

The solution enables the optimisation of waste management in a city. It is flexible and scalable to all size of cities and waste collectors[7].

ANT FOREST

Ant Forest is a 2016 Chinese AFOLU financing using Digital Access.



BACKGROUND

China considers reforestation as a key measure to absorb GHG emissions since the country has paid a price with incorrect deforestation, including desertification, soil erosion and sandstorms, especially in the north and northwest of China.

China's consistent efforts in reforestation to deal with soil erosion, air pollution and climate change have also contributed to global environmental protection.

FUNCTIONALITY

Alipay, one of the most popular online payment platforms in China, launched the scheme 'Ant Forest' in 2016. Combining finance and low-carbon lifestyle, it offers a personal carbon account and a public benefit activity. Each user can collect carbon credits by choosing low carbon options such as public transports. The carbon credit is that a user can grow 'a virtual tree' on the platform. The company turns virtual trees to real ones.

TECHNOLOGY

Digital access and payments can evaluate user's purchase choices, thus encouraging low carbon lifestyle. This can lead to 10.25 million trees planted, equal to absorbing 1.22 million ton GHG.

CONCLUSION

It is a simple and easy solution to encourage users' low carbon lifestyle. It is not only an innovative financing scheme for reforestation, but also an excellent education and campaign tool for a low carbon society[8].

CLIMATE CHANGE ANALYSIS TOOL

The Climate Change Analysis Tool is a 2019 American AFOLU cognitive technology.

BACKGROUND

Rising sea levels and extreme weather events can have direct impacts on infrastructure. AT&T recognised the impacts on its physical infrastructure deployed nationwide and it prepared and adapted to the impacts of climate change.

FUNCTIONALITY

The Climate Change Analysis Tool visualises climate change risks on company's infrastructure and business operations 30 years into the future. It aims to help the company to make smarter, climate-informed decisions for the future. It can help plan for maintenance, disaster recovery, future construction of cables and cell sites.

TECHNOLOGY

The Climate Change Analysis Tool combines regional climate modelling data with sophisticated mapping capacities from Argonne National Laboratory to project sea-level rise, likelihood of flooding and hurricanes, and to identify climate change risks to the company.

This technology can prepare and adapt to climate change and encourage non-state actors' effort in climate adaptation activities.

CONCLUSION

Better anticipating, preparing and adapting to the impacts of climate change is vital for a resilient future. Such tool may be applied to business, communities, a nation and even a region[9].

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ANNEX C

ADDITIONAL SOLUTIONS IDENTIFIED DURING THE COURSE OF THE RESEARCH

ENERGY SUPPLY				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
E1	Brooklyn Microgrid	USA	Community level small scale small grid application, using blockchain technology	Shift to renewable energy.
E2	Smart Grid LTE	Brazil	Smart Grid using LTE in Atibaia to improve efficiency of grid, using fast internet, IoT	Improving energy efficiency from the energy supply sector.
E3	Digital Wind Farm	EU	Built-in wind forecast model, can prevent/ detect malfunction, based on IoT, Cognitive	Shift to renewable energy
E4	PAYG Home Solar Panel	East Africa	Consumers rent a solar home kit + mobile banking and PAYG, using digital access	Shift to renewable energy; providing clear and safe energy to home
E5	Mobile Payment for Solar	Sub-Saharan Africa	Compact/ light weight solar photo-voltaic panels + mobile banking, digital access	Shift to renewable energy; providing clear and safe energy to home
E6	WeShareSolar Crowd Funding	The Netherlands	Connects site owners who have a suitable roof with consumers, using digital access	Shift to renewable energy

SMART BUILDINGS				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
B1	Dubai High-Rise Energy Efficiency	UAE	Project has used AI and IoT to optimise energy consumption of high rise buildings	Improving energy efficiency from the building sector
B2	Moves Services to the Cloud	Mexico	Moving all administrative school services to cloud service to save energy and paper	Reducing energy consumption Reducing waste Reducing emissions from road transport by saving journeys
B3	Beijing Municipal Building	China	Computerised maintenance management system for asset and performance data	Improving energy efficiency from the building sector
B4	Melia Smart Energy Building	Latin America and the Caribbean	Measuring energy consumption in real time and remotely controlling lighting and AC	Improving energy efficiency from the building sector
B5	Alphabet Nest Smart Home	USA	Reduces energy consumption by optimising energy use and adapting to user behaviour	Improving energy efficiency from residential buildings
B6	Intelliekon Project	Germany	Intelligent metering, communication, and tariff systems for household energy	Improving energy efficiency from residential buildings; Shift to renewable energy
B7	Smart Street Lighting	Benin	Street lights can be adjusted according to brightness, time, season and traffic flow	Reducing energy consumption from communities and shift to renewable energy
B8	Smart Lamp Posts	EU	Smart lamp posts as cloud-based solution to manage city resources more sustainably	Reducing energy consumption from cities and shift to renewable energy

INTELLIGENT TRANSPORT SYSTEMS (ITS)				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
T1	Park&Joy App	Germany	Helps to find parking spots along the way to final destination through smart algorithms	Reducing emissions from the road transport sector
T2	Surtrac by Rapid Flow	USA	Optimises traffic networks through signal planning based on sensor data, AI and IoT	Reducing emissions from the road transport sector
T3	Mobility-as-a-Service	EU	Comprehensive range of mobility services provided to customers by mobility operators	Reducing emissions from the road transport sector; facilitating sustainable urban mobility
T4	Air Pollution Monitoring	Brazil	Population volume and movement with other data sources to map pollution levels	Encouraging use of public transport and sustainable transport modes, e.g. walking and cycling
T5	ITS4Mobility in Goiânia	Brazil	1300 buses & 6000 bus stops with IoT for real time fleet tracking for user information	Encouraging use of public transport
T6	Eco-Driving Systems	Global	Eco-driving can help drivers to reduce fuel consumption and corresponding emissions	Reducing emissions from the road transport sector

WASTE MANAGEMENT				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
W1	Smart Waste Bin	Belgium	Garbage containers With solar battery can squeeze waste + info when the bin is full	Reducing emissions from waste management
W2	Smart Waste Management	EU	Detailed information container fill status for dynamic routing to reduce transport costs	Reducing emissions from waste management
W3	WeBio Web Platform	EU	Connect bio-waste owners and energy producers to reduce bio-waste in landfill	Reducing waste and emission from waste management
W4	Grind2Energy	USA	Turns food waste from grocery stores and restaurants into electricity, heat + fertilizer	Reducing waste and emission from waste management; Shift to renewable energy
W5	China-waste.com	China	The online platform to connect waste owners and buyers to trade recycled machinery, vehicles, e-waste, chemical materials, white goods etc.	Reducing waste and emission from waste management; protecting natural resources and land

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
I1	Cloud Processing & Storage	Global	Using cloud service for processing servers and data storage to reduce the energy use	Reducing emissions from IPPU
I2	DeepMind Google Data Centre	USA	AI-powered system to improve the energy efficiency of Google's own data centres	Reducing emissions from IPPU
I3	Connected & Reusable Pallets	USA	AT&T LTE-M low-power wide-area network, enabling locating pallets to avoid pallet loss	Reducing waste and emission from waste management
I4	Remote-monitored Cooling	Turkey	Smart meter system with daily recording of electricity consumption trends and IT loads	Reducing emissions from IPPU
I5	Climate-KIC BE CIRCLE Project	EU	Generate local industrial fabric, sustainable supply flows, identify partners and solutions	Improving energy efficiency in IPPU and reducing emissions from the transport sector
I6	Frozen Food Storage	Global	Keep food safe, save energy and reduce emissions with sensors and smart meters	Improving energy efficiency in food supply

AGRICULTURE, FORESTRY, AND OTHER LAND USE (AFOLU)				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
A1	AliPay Ant Forest Project	China	Users to take up low-carbon actions, collect credit for virtual trees, turns into real ones	Influencing behaviour change; contributing to reforest
A2	RiceKing Project	USA	Sensors in rice fields to minimise water use through IoT connection to water pumps	Reducing emissions from the agriculture sector; enhance capacity of adaptation to climate change
A3	Remote Irrigation Control	India	Cellular based wireless remote control and alarm system for water pump operation	Reducing emissions from the agriculture sector; enhance capacity of adaptation to climate change
A4	Precision Agriculture	EU	Machine Guidance System for vehicles to match actual need for fertilizer and seeds	Reducing emissions from the agriculture sector; enhance capacity of adaptation to climate change
A5	Rainforest Connection App	Latin America and the Caribbean	Collect sounds using phones mounted on trees + solar, to alert illegal logging activity	Prevention of deforest
A6	FORMIS Forestry Platform	Vietnam	Information integration, remote-sensing, mobile technology for managing forestry	Prevention of deforest; sustainable land use

ADAPTATION AND RESILIENCE				
#	DIGITAL SOLUTION NAME	COUNTRY/ REGION	SHORT DESCRIPTION OF SYSTEM AND TECH	CONTRIBUTIONS TO NDCs
R1	Smart Drain Solution	Australia	Use of a network of sensors and cloud technology to monitor drains in real time	Enhance city's capacity of adaptation to climate change
R2	Mobile Phone Tracking for Resilient Communities	Bangladesh	People's movement during climate related natural disasters to identify vulnerability	Sustainable land use; enhance capacity of adaptation to climate change
R3	Climate Change Analysis Tool	USA	Forecast impacts of climate change and map these for climate-informed decisions	Sustainable land use; enhance capacity of adaptation to climate change
R4	Weather Monitoring	Argentina	Interconnected sensors that automatically measure environmental parameters	Enhance capacity of adaptation to climate change