RESEARCH & INNOVATION

FUTURE OF SPACESHIP EARTH

Will the Sustainable Development Goals be reached?

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SAFER, SMARTER, GREENER

Bjørn K. Haugland
Executive Vice President,
Chief Sustainability Officer
DNV GL

Jorgen Randers
Professor Emeritus
Climate Strategy
BI Norwegian Business School

FOREWORD

GUIDING SPACESHIP EARTH TOWARDS A SAFE AND SUSTAINABLE FUTURE

In September 2015, global society – through its only system of global governance, the United Nations – established a set of global goals to be reached by 2030. The ambition with these is to create a safe and sustainable future for everyone, and especially for the less privileged passengers on board "Spaceship Earth", as it hurtles through space and time.

Huge efforts for reaching the 17 new Sustainable Development Goals (SDGs) are already in place – benefiting from the considerable momentum that has built up over the last fifteen years as the world's nations have worked hard to meet the Millennium Development Goals (MDGs) for 2015, set in the year 2000. The global challenge now is to continue and strengthen this ongoing effort, and to focus more urgently on those goals that are least likely to be achieved.

Thus, the primary objective of this first phase of The Future of Spaceship Earth project is to clarify, at the outset of the SDGs, what resources are most in need to reach the goals.

How did we do this?

We chose the following approach: We drew on a great variety of information to create a clear and consistent picture of what we think will be the trajectory of Spaceship Earth over the next several decades – in the absence of extraordinary action by humankind. Using this forecast as a basis, we focused on likely developments in the shorter term – over the next 15 years – and more specifically within five different world regions. We then assessed the likelihood of each SDG being achieved, in each of these five world regions. In many cases the answer was an obvious "yes", and in other cases it is apparent that extraordinary actions will be necessary to reach the goal.

Using clear language, this report seeks to describe which of the SDGs will not be met unless global society allocates more effort to tackle that specific challenge. Our answers often differ among the five regions of the world. In short, we are signaling to the crew aboard Spaceship Earth where the danger zones lie and thus how to navigate and operate the vessel on a safer and more sustainable path.

Obviously, our forecast can, and will, be improved in the years ahead, and so will our assessment of the likelihood of the different goals being reached.

We are open to and invite all inputs into a process of continuous improvement of our forecast. In order to keep the SDGs in focus and to create motivation for further effort, it is our intention to repeat the SDG assessment every 2-3 years.

The project is based on two intellectual inputs, for which we are immensely grateful. First, we acknowledge University of Oslo Professor Nina Witozsek's suggestion (in the prologue to the 150 year celebration of DNV GL) that DNV GL would ultimately grow from its past of certifying vessels to a future of certifying "Spaceship Earth". And second, *2052 – A Global Forecast for the Next Forty Years* demonstrated that it is indeed possible to make a credible forecast of what will actually happen in the world during the decades ahead.

In the old days, DNV GL would have directed its conclusions from this kind of study to the shipping, offshore and wider infrastructure industries. DNV GL would have advised asset owners to change their construction practices and operating procedures in order to promote safety and lower risks in general, along with associated insurance premiums.

We still perform that role, but on an ever-widening scale. And the urgency increases as the world after COP21 in Paris has agreed to embark on a new stretch goal of limiting global warming to 1.5 °C above pre-industrial levels.

So, we are proud to present, in this report, our advice for the benefit of the crew and all 7 billion passengers aboard Spaceship Earth.

Høvik, April 2016

Bjørn Kjærand Haugland | J Randers

ACKNOWLEDGEMENTS

DNV GL wishes to thank all contributors, including the steering committee, project team and workshop participants. Your valuable insights and reflections have been important to the success of this project. A complete list of contributors is included in Appendix B.

In particular we want to thank our "expert friends" who have kindly commented upon our work:

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- Karen Sund, Sund Energy

Our colleagues Bobbie Ray-Sannerud and Asun St.Clair from DNV GL have also been particularly helpful reviewers.

None of these experts has reviewed all our work, but they have individually looked into and commented parts of our work where they have deep competence. We are immensely grateful for their input and encouragement. Jorgen Randers' enthusiasm for the project and his important role as part of the project's steering committee following the work closely and assisting in its completion has been instrumental for the success of the project. Finally, we want to thank the recently-retired previous President and Group CEO of DNV GL, Henrik O. Madsen, who made this project happen and who will eagerly follow its further progress in his new capacities as Chairman of the Norwegian Research Council and Board Member of the UN Global Compact.

Images - We wish to thank the Global Goals organization (globalgoals.org) for graphics relating to the Sustainable Development Goals and for permission to reproduce images from their media gallery.

WHAT ARE YOUR THOUGHTS?

We encourage our readers – both inside and outside DNV GL – to interact with our forecast model and to give us your view on Spaceship Earth.

- **DNV GL colleagues** will find the model and additional material by searching "Spaceship Earth" on our intranet. They are also invited to join conversations on the Spaceship Earth Yammer Group.
- We invite **other readers** to explore and interact with the material made available on **www.dnvgl.com/spaceshipearth**

WHERE TO CONTACT US

research@dnvgl.com
blogs.dnvgl.com/sustainability
@DNVGL #spaceshipearth
facebook.com/dnvgl

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1. EXECUTIVE SUMMARY

In the *Future of Spaceship Earth* project, DNV GL presents a "most likely future" forecast of what will happen on our planet through to the middle of this century. 2050 is quite some way off into the future, and very few, if any, organisations and governments have set specific targets that extend for more than three decades into the future. However, in September 2015, the UN adopted its 17 Sustainable Development Goals (SDGs) for the year 2030. We found that we could use our consistent, long term forecast to assess the likelihood of global society achieving each of the 17 SDGs (in the absence of extraordinary action[1]). We have now completed this assessment and used it as basis for making recommendations about which extraordinary efforts should be implemented over the next 15 years in order to create a better future, one that fulfils all SDGs.

Some might question the value of forecasting what will happen through to 2050. They might argue that a 35-year time horizon is too long for a business organization like DNV GL. Our response is that our customers typically invest in assets – vessels, wind farms, pipelines, distribution grids etc. – with an operating life between 20 to 50 years. As a world-leading provider of rules, standards and technical assurance services, we see it as our duty to have a consistent and well-considered view of what will happen if there is no extraordinary action. Such a long-term outlook will serve as a useful guide when our customers and our own organisation prepare for the future. Will a given proposed solution work? Will there be demand?

By having a well thought-through view on the most likely future and by building up increased and multifaceted competence on what are likely to be

1). Extraordinary beyond the ordinary actions, where ordinary actions are everything we have taken into account in our forecast

the most critical areas, like climate, energy, water, ocean, food, and health – our mission is to turn DNV GL's vision *Global Impact for a Safe and Sustainable Future* into action.

WHAT WILL THE WORLD LOOK LIKE IN 2050?

If this question is viewed from the perspective of human well-being, then we can confidently say that there will be progress. The world will be a better place in sum, but plagued by huge differences among regions and within nations. The averages will look better, but the number of underprivileged people will also be significant, at least as numerous as today. There will be much broader access to education, energy, food, clean water and sanitation. But there will still be distinct differences between the developed world – which in 2050 will include China – and the still-developing world. Some emerging economies will have followed in the tracks of Japan, Korea and China and will have achieved fast and sustained economic development. Many of the poor nations will remained mired in relative poverty. The currently rich world will stay ahead, with slower growth in the output per person and increasing inequity.

Population

Our most likely forecast says that the world population will increase to 8.5 billion – a figure lower than the predictions of most other forecasters. Our view is based on our prediction that fertility rates in the developing world will continue their decline, with more and better female education, health, contraception and increased urbanisation as the major drivers.

Global Gross Domestic Product (GDP)

The total value of the world's annual output of goods and services, the GDP, will be around twice as big in 2050 as it is now. This is in spite of the fact that GDP

Figure 1.1 Likelihood of meeting the 17 Sustainable Development Goals in the five regions of the world.

growth will slow down and almost stop in the developed world – as these economies continue to evolve from being manufacturing-based to being increasingly dominated by services, culture and care provision.

Energy use

Global energy use will increase significantly over the next 15 years, but thereafter almost plateau as reduced energy intensity counteracts energy demand linked to GDP growth. Renewable energy will provide half the energy used by the world in 2050, but the world will still be burning a lot of coal, oil and gas. As a result, accumulated CO_2 emissions will by then have overshot the acceptable carbon budget – the limit that would ensure that global warming stays below 2 °C above preindustrial levels. That will certainly produce noticeable affects by 2050, with global average temperatures up by 1.8 °C above preindustrial levels. But it is in the decades that follow when problems start to compound and deepen. Inertia in the global energy system will eventually drive the global average temperature to around 2.5 °C above the preindustrial temperature. The world then enters dangerous territory with unknown consequences.

Ecological footprint

2050 viewed from an environmental perspective is, sadly, a picture of deterioration. The rate of environmental degradation will slow, but resources will continue to be used beyond the carrying capacity of the planet. And emissions will stay high enough to increase the global average surface temperature. Needless to say, our picture of the future both can and will be improved over the years ahead. One reason to present our current forecast, as openly and honestly as we can, is to invite everyone who cares to help us improve our forecast – in order for us all to better know what is most likely to happen if there is no extraordinary action. To the extent that it highlights the need for extraordinary action, it pleases us to see that the outcome of the COP-21 in Paris in December 2015 is consistent with our forecast.

ASSESSING THE LIKELIHOOD OF MEETING THE SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) describe what humanity wants the future to bring. Collectively, they constitute the world's common view of what a safe and sustainable future will look like, defined by 17 goals and 169 targets. Comparing our forecast with the SDGs gives an indication of the size of the gap between desire and reality in 2030.

Many organizations already track global performance on the SDGs, and some are doing the same as us: assessing the likelihood that humanity will reach the SDGs. But no other organization is basing its assessment on a quantitative, consistent and dynamic forecasting model, which provides the quantitative backbone for the future development of five world regions. On the other hand, many do what we also do, which is to enrich the quantitative analysis with qualitative assessments based on multidisciplinary experience with the real world.

We have used our quantitative model in a transparent way to arrive to our assessment – the framework and inputs are available for any interested party to see. Not all of the assessments follow directly from the quantitative model. In the following we make it clear where the quantitative model does not significantly inform the assessment.

As can be seen from Figure 1.1, none of the 17 SDGs will be achieved in all regions of the world, according to our assessment. Human development goals like food, health and water/sanitation generally achieve high scores (i.e. are likely to be achieved), while the ambitions of stable climate, equality and sustainable consumption achieve low scores.

Our assessment demonstrates large regional differences in goal achievement. For the rich world (OECD including USA) most goals will be reached, but nevertheless there will be large challenges with over-consumption and climate change. China will increasingly resemble OECD, reaching more than half of the per capita income of the rich world in 2030, and achieving many of the SDGs. The bigger emerging economies like Brazil, India, South Africa ('BRISE'), and to a greater extent the Rest of the World ('ROW'), will fail to achieve most goals, but will nevertheless make significant progress in many areas.

WHAT SHOULD BE DONE?

Importantly, our analysis shows that many more SDGs can be reached if humanity chooses to put in the necessary extraordinary action. The 17 goals are closely interlinked, and achieving one goal will often require – and contribute towards – success within other goals.

Looking at the results, the two most serious challenges are inequality and climate change, represented by SDG 10 and SDG 13, both with red scores for all five regions.

Our analysis shows that increasing the renewables share of the energy mix is the most important factor for reducing CO_2 emissions, and the only realistic measure that can limit global warming to below 2 °C above preindustrial levels. Luckily there is already significant development in the area of renewables, but extraordinary effort is needed if the relevant SDGs are to be reached.

Redistribution, being simply to "take from the rich and give to the poor", is the obvious solution on the inequality challenge. As simple as it is in theory, the redistribution proves extremely difficult in action.

Our recommendation is further that global society should pay extraordinary attention to the following general issues in order to increase the likelihood of achieving all the SDGs:

- **Action:** Ensure early actions, as it is urgent to start the progress now to achieve the Sustainable Development Goals
- **Governance:** Strong governance embracing effective taxation, positive incentives and smart regulations will be crucial in making quick progress towards the SDGs
- **Business:** Business leadership to support the primary role of business sector as an "effective problem solver" in the society. Transforming tomorrow's leadership into "Corporate Statesmanship" with companies actively contributing to solve societal challenges
- **Emissions:** Enable early emission reductions and climate resilience, ensure financing and enable smart regulations to stimulate technology uptake and scale
- **Solutions:** Learn from pilots, share best practice and scale up new sustainable solutions on regional, country and city level

As mentioned, we conclude that none of the SDGs will be achieved in all regions, unless extraordinary efforts are made. Based on this, it is fair to say that all SDGs need attention. Specific recommendations for extraordinary action are therefore needed for all SDGs. To coin a phrase from another famous starship, humankind needs, "To boldly go where no man has been before." In this report we are making a first, humble, attempt in this direction by offering a set of detailed recommendations for extraordinary effort in the areas where DNV GL has its strongest competence – Energy consumption and production, Climate Change and the Ocean space.

In the years ahead we will seek to sharpen our forecast, our conclusions and recommendations, together with our partners and customers.

As a 151-year-old organization our purpose of Safeguarding Life, Property and the Environment remains. Inspired by our vision, *Global Impact for a Safe and Sustainable Future*, we will continue to guide our customers and prepare our organization for the future.

The Future of Spaceship Earth project builds a knowledge platform that gives us foresight to guide priorities and resource use and thereby increase the wellbeing of Earthlings.

We welcome all your comments, reflections and any help in this effort!

www.dnvgl.com/spaceshipearth

Afroreggae raised a flag to represent Goal 10, Reduced Inequalities, in Morro de Alem o in Rio de Janeiro, Brazil, to support the UN Global Goals for Sustainable Development. Credit: Cristina Granato, courtesy globalgoals.org

2. INTRODUCTION

In the *Future of Spaceship Earth* project, DNV GL presents a "most likely future" forecast of what will happen on our planet towards 2050. Chapter 3 in the report explains the methodology for our forecast continues with the model forecast itself, with model structure, key assumptions, results, and sensitivities. Further results and assumptions are included in Appendix A.

Using forecasted values for 2030 as a backdrop, we assess the extent to which global society will reach the UN's 17 Sustainable Development Goals (SDGs). The assessment, including methodology and conclusion, is described in Chapter 4, where we have also used the forecast and the assessment as a basis for recommendations on extraordinary actions that would give the world a better chance of fulfilling all SDGs. Chapter 4 also contains an assessment of each SDG in 17 double-page spreads.

This project is a joint effort by the DNV GL Sustainability Office and Strategic Research & Innovation, with the work for this project mainly undertaken in the latter unit, as part of our long term research focus.

The idea behind the project came from Jorgen Randers and has been further developed in the DNV GL organization. The previous work of Jorgen Randers, both his *2052* (Randers, 2012a) and the models behind *2052* (Randers, 2012b), has been the starting point for the model developed by DNV GL in this project and has given us important guidance along the way. The work and conclusions presented here are, however, DNV GL's own.

As described in Chapter 5, this project is only the start of a long journey, where the *Future of Spaceship Earth* will be built upon and used widely both internally and externally.

OBJECTIVE

Some might question the value of establishing, as we have done, a forecast for what will happen to 2050. They might argue that a 35-year time horizon is too long for a business organization like DNV GL. Our response is that our customers typically invest in assets – vessels, wind farms, pipelines, distribution grids etc. – with operating lives extending decades into the future. As a world-leading provider of technical assurance services, we see it as our duty to have a consistent and well-considered view of what will happen. Such a long-term outlook will serve as a useful guide when our customers and our own organisation prepare for the future.

By having a view on the most likely future and by building up increased and multifaceted competence on what are likely to be the most critical areas, like climate, energy, water, ocean, food, and health – our aim is to turn DNV GL's vision of Global Impact for a Safe and Sustainable Future into action.

FURTHER REFERENCE

This report comprises the main documentation of the work on this project. The complete models and all the results and graphs, as well as the complete statements from our expert friends, can be found at www.dnvgl.com/spaceshipearth.

THE SPACESHIP EARTH TERMINOLOGY

The term "Spaceship Earth" is almost as old as DNV GL and a well-used expression. The term was probably first coined by Henry George in *Progress and – Poverty* in 1879, and popularized by Buckminster Fuller in the 1960s. The phrase has been used relatively frequently since then, e.g., by the former UN Secretary-General U Thant, normally as a term describing our planet.

In DNV GL, the term was used by Professor Nina Witoszek for our 150-year anniversary, and suggested as a project by Jorgen Randers.

3. MODEL FORECAST

3.1 GENERAL

In this project we deliver a detailed forecast of the most likely future for Spaceship Earth in 2050.

How did arrive at this detailed forecast?

We first surveyed over a dozen forecasting models (described in Section 3.2 below), paying special attention to the relevance of each model to the 17 Sustainable Development Goals.

We then used the project network, notably our steering group, to arrive at a set of core assumptions that would drive our forecasting model. Aligning the assumptions and making sure they were consistent was far from trivial. Here, we were helped by the list of five different "Story Lines" developed by the Intergovernmental Panel on Climate Change - IPCC (van Vuuren et al, 2011), called "Shared Socioeconomic Pathways" - SSPs. Of the five SSPs developed by the IPCC, we found greatest congruence between the SSP1.

We explored historical trends in the key drivers for our assumptions and attempted to establish stable relationships between various flows and stocks in the global system. These stable relationships reflecting the SSP1, our trend analysis and our judgment we called "key model assumptions". We used them to run our models, and iterated their formulations so that the differences in model output resulted from model's structural differences, and not from differing assumptions.

For some assumptions, we judged there to exist significant uncertainty. We ran sensitivity analyses to investigate the impact of these on our forecasted future. Additional sensitivity tests resulted from the differing structures of our models. Once these sensitivity iterations finished, the results were called our "forecast of the most likely future".

3.1.1 Regions

We have divided the world into 5 regions, each region sharing broad features in common in terms of economic, social, and development indicators. Two regions, USA and China, are also nations. Members of the Organization for Economic Cooperation and Development (OECD), comprise the third region, containing mostly developed nations. We have omitted USA, Turkey, and Mexico from OECD, and included the two latter in the group of emerging economies, BRISE (Brazil, Russia, India, South Africa and ten big emerging economies) as shown in the table below. The final category is Rest of the World (ROW) – an eclectic blend of 186 countries with a total population of 2.25 billion in 2015.

Region	Countries included
USA	USA
China	China
OECD	OECD (standard definition except USA, Turkey, and Mexico), then being: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom
BRISE	Brazil, Russia, India, South Africa and ten big emerging economies (Indonesia, Mexico, Vietnam, Turkey, Iran, Thailand, Ukraine, Argentina, Venezuela, and Saudi Arabia)
ROW	Rest Of the World: all countries in the world not mentioned in the four regions above

Table 3.1 The five regions

3.1.2 Underlying story: Safe and Sustainable Future – SSP1

Although we have produced a forecast of the most likely future, this is clearly not the only possible future. Many institutions are developing overviews of possible futures – not least the IPCC with its five Shared Socioeconomic Pathways (SSPs), illustrated in Figure 3.1 overleaf. In undertaking our forecast, we could see that our most likely future in many ways resembles Shared Socioeconomic Pathway 1 - (van Vuuren et al, 2011). SSP1 is the most hopeful of all five SSPs. Figure 3.1 depicts and contrasts this future

17 young people delivered and raised the first non-governmental flag at Number 10 Downing Street in London, United Kingdom, to represent Goal 17, Partnerships for the Goals, to support the UN Global Goals for Sustainable Development.
Credit: Chris Jackson / Getty Images

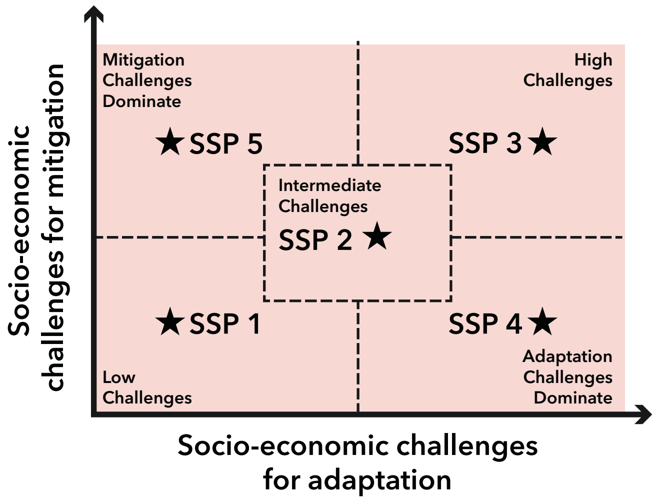


Figure 3.1: Ensemble of SSPs and how they map

SSP1 - the 'Sustainability' Scenario	
GENERAL	AGRICULTURE
• Rapid development of Low Income countries (LIC) • Reduction of inequality among and within economies • Low population growth • Reducing resource intensity • Reducing fossil fuel dependency • Increased planned urbanization in LIC and MIC • Opened globalized economy • Countries cooperate to achieve development and environmental goals • Rapid technological change and technology transfer • Standards of living converge	• High land productivity • Rapid tech change – yield increasing technologies • Rel. low level of animal consumption • (IPCC, WGIII, 2014)

Table 3.2: Highlights of SSP1on the mitigation and adaptation dimensions

with other futures envisaged by the IPCC, and Table 3.2 highlights the characteristics of SSP1. It is worth mentioning that the DNV GL vision of "Global impact for a safe and sustainable future" resonates well with SSP1, which informs some of our key assumptions on fundamental parameters, such as population, and related issues like education dynamics. However, we are well aware of the difference between a vision and a forecast of greatest likelihood.

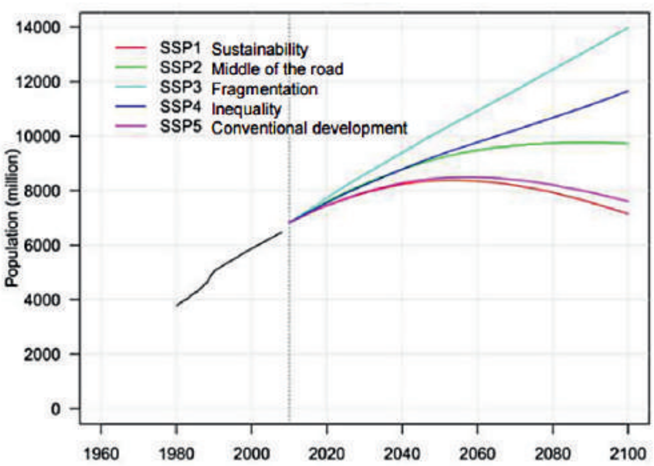
Our approach is both empirical and science-driven. As the word forecast implies, we cast into the future from inertias established in the past. Rather than limiting ourselves to simple and often inconsistent linear extrapolations, we use a systems dynamics approach, wherein complex interacting factors are often self-reinforcing and non-linear, producing counterintuitive results.

3.1.3 Implications of SSP1 for key assumptions

Our approach and assumptions, although reflecting the general view of SSP1, have been empirically based wherever possible. So, for instance, in our forecast of the future energy mix, we have devised an approach in which we identify investment trends and forecast these. But as these trends obviously cannot continue indefinitely, and also create incon-

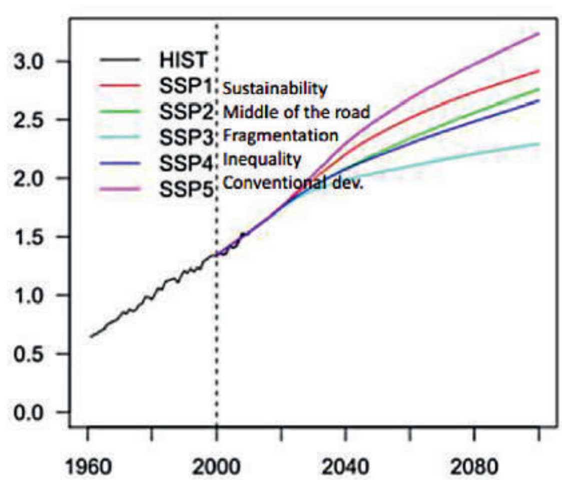
A POTTED VIEW OF SHARED SOCIOECONOMIC PATHWAY 1 ('SSP1)
Sustainability - taking the green road (from O'Neil et al, 2015)

"The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Increasing evidence of, and accounting for, the social, cultural, and economic costs of environmental degradation and inequality drive this shift. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and international organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading to a relatively low population. Beginning with current high-income countries, the emphasis on economic growth shifts toward a broader emphasis on human well-being, even at the expense of somewhat slower economic growth over the longer term. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Investment in environmental technology and changes in tax structures lead to improved resource efficiency, reducing overall energy and resource use and improving environmental conditions over the longer term. Increased investment, financial incentives, and changing perceptions make renewable energy more attractive. Consumption is oriented toward low material growth and lower resource and energy intensity. The combination of directed development of environmentally friendly technologies, a favourable outlook for renewable energy, institutions that can facilitate international cooperation, and relatively **low energy** demand results in relatively **low challenges to mitigation**. At the same time, improvements in human well-being, along with strong and flexible global, regional, and national institutions imply **low challenges to adaptation**."



(IPCC, WGIII, 2014)

Figure 3.2: World population as a function of the SSPs



Crop yield developments projected as a function of GDP per capita. (Havik et al., in prep.)

Figure 3.3: Global crop yield development

sistencies (e.g. extrapolating investment trends can imply too much energy in several regions), we have made adjustments to assure consistency between energy demand and supply. In doing so, we drew on assumptions in SSP1. In other instances, the general assumptions of SSP1 may be at odds with our data analysis. In such circumstances, the data win and the SSP is disregarded. For instance, when our forecast produces increased inequalities within nations, we conclude that this is the more likely future despite it not being in line with the SSP1 definition of "reduced inequalities within nations".

3.1.4 Uncertainties

Our forecasted most likely future (MLF) is not the only future: Other futures might materialize. We deem it important to highlight factors that might possibly alter our forecast, and further investigate them. For such issues, sensitivity tests have been performed to map out the uncertainty space. Sensitivity tests follow two paths, which we investigate separately: First - forecast implications of uncertainties in data assumptions. Second, forecast uncertainties resulting from how to represent the global system's interconnectedness, i.e., uncertainties arising from what the "correct" model structure is.

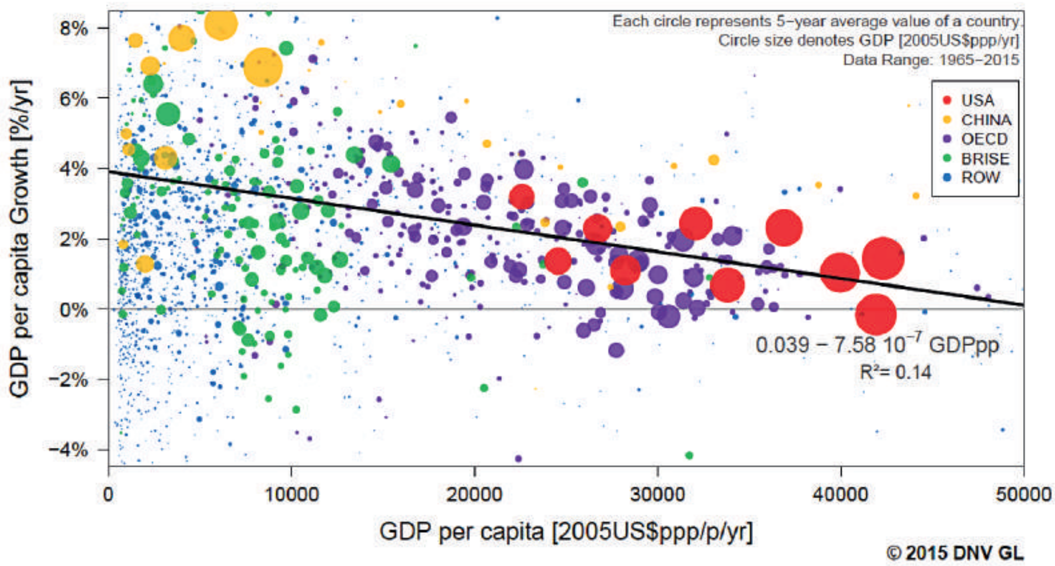


Figure 3.4: GDP growth declines as per capita GDP increases

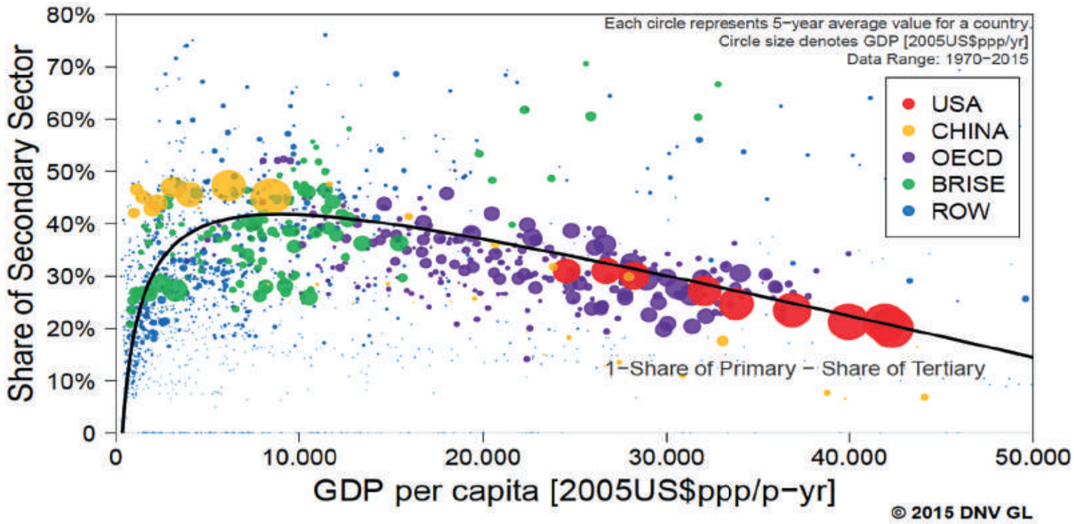


Figure 3.5: The bell-shaped curve of GDP share in the secondary sector declines with increasing standard of living.

3.1.5 Challenges

We are a small team, and this is both an asset and a liability. Ideally, we would have liked to build our own forecast model, to reflect global and regional causality from our perspective. However, this option was closed by resource limitations. Nevertheless, resource limitations have also provided the impetus for familiarizing ourselves with various modelling approaches and model contents. Perhaps the most revealing insights about model complexity is from one of the really experienced model teams, for which accumulated model development efforts reflect hundreds of man-years which meant that the inertia of the model and its successive inclusions of various issues has led to a model monster, internally called 'the beast', where individual users and issues mattered less than the model itself which in reality decided upon most issues all by itself.

The forecasting team has had to familiarize itself quickly with global dynamics, in addition to differing model schools and modelling approaches. Again, the lack of detailed understanding is a mixed blessing – allowing us to maintain an overview and use common sense, but also with the implicit risk of insufficient understanding of important physical and societal processes that are imbedded in our MLF.

3.1.6 Synthesis of the forecast analysis

The world population will grow, notably in those regions of the world associated with high human fertility. But both there and in the OECD countries, growth will reduce considerably, approaching global stability a little after 2050. Within ten years, the OECD population will already have stabilized, and China's population will start to decline after 2030. As noted by Lutz (2014), wider access to education for girls and increased urbanization (where the option of having many children will be much less attractive than in a rural agricultural setting) will lead to women choosing contraception, later marriage and longer birth spacing.

There are important uncertainties in this development. Extremely low fertility, such as occurs in southern Europe and China might spread, as has been assumed by Randers (2012a). Should that happen, the world population might peak in 2040, rather somewhere around 2060 as predicted by our MLF. If so, world energy emissions and other ecological footprint variables will benefit. On the other hand, the UN Population Office forecasts that the world population will reach 9.7 billion in 2050 (UNDP 2015a), with Africa's population quadrupling from 1 to 4 billion before 2100. In our opinion, such a forecast is implausible. With the current population of Africa at 1 billion, we already see a massive exodus from Africa. However, the SSP2 scenario, with a global population growing to 9.4 billion in 2050, and peaking just before 2100, might well materialize. Our sensitivity analysis indicates that in that case consumption per person will suffer in the poorer parts of the world. Nevertheless, since these additional people will essentially also create value, consumption loss will be minimal compared with our MLF. OECD and China will experience the opposite result, with the additional population more than paying for themselves.

Productivity growth[2] will slow down considerably towards 2050 as shown in the graph below. However, as noted in our sensitivity analysis of the Regional Integrated Climate-Economy (RICE) model, slower productivity growth as economies mature and move into the service sector is typically not well reflected in economic models that dominate the forecasting scene. Consequently, our forecast of GDP slightly more than doubling from now to 2050 is far lower than mainstream forecasts (Chateau et al, 2011) that typically predict a tripling of world GDP over the same period.

The main reason behind this declining GDP growth is that economies tend to follow the bell-shaped curve in figure 3.5, showing secondary sector employment. To the left, poor countries are mainly agricultural. To the right, employment is mainly in the service sector, where productivity improvements are less easy to find and exploit.

The R^2 of the graph in Figure 3.5 is low, reflecting that the shape of falling productivity growth is far from certain. The upside is substantial. Our sensitivity analysis, using global GDP forecast/person for 2050, affords the world about 50 % higher consumption per capita than our MLF, with both US and ROW nations reaching 66 % higher consumption levels than in the MLF (although with accompanying devastating footprint effects). The downside is also substantial, reaching almost 50 % in developing nations. However, our sensitivity analysis shows only upside potential for China. This contrasts with the sensitivity analysis comparing RICE with '2052', in which China's GDP in 2050 will be 25 % **lower** than the MLF. Nevertheless, even with our sensitivity analysis of the assumptions, significant model uncertainties remain.

The backdrop of this report is being able to address sustainability questions, such as those arising from the SDGs. With respect to the ecological footprint measured in the common denominator of global hectares, energy emissions weigh more heavily than any other source, owing to the afforestation required to neutralize effects of carbon emissions. The world's sustainability future is critically dependent on the successful transition to a low carbon future. Our MLF is founded on trend forecasting of gross capacity additions from 2003-2013. This appears to be a solid foundation and, emission-wise, coincides with CO_2 forecasts 2015-2030 of two NGOs, "Carbon Action Tracker" (2015) and "Climate Interactive" (2015) taking fulfilled Intended Nationally Determined Contributions (INDC) pledges into account, with the average world temperature stabilizing at around 3 °C above the pre-industrial average. However, MLF further takes into account the 2015 Conference of Parties 21 (COP21) agreement of meeting again every five years ahead, and that such talks succeed in bucking the trend, with fossil investments disappearing totally in 2050. This will result in carbon budget depletion before 2040, but also that remaining carbon emissions peter out over the next generation, with climate temperatures probably stabilizing at about 2.5 °C above the levels established in the mid-1800s.[3]

Sensitivity around the future energy mix is substantial. Most importantly, a high-carbon energy mix, even when allowing for COP21 pledges being met, will allow world temperatures to rise by 3.5 °C (Climate Interactive, 2015), with devastating knock-on effects on climate and world population. Conversely,

2). Though normally measured as output pr hour worked, we use a much wider definition of productivity if not otherwise described: Productivity (def) = Societal Productivity = Output/living person

3). Detailed analysis for the energy use and mix in the post-2050 period has not been carried out.

Model name	Main author	SDGs																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Poverty	Hunger	Health	Education	Gender equality	Water access	Energy access	Economic growth	Infrastructure. innovation, industry	Inequality	Cities	Consumption / production	Climate change	Sustainable oceans	Ecosystems	Peace, justice	Meeting SDGs
DICE	Nordhaus	Y	N	N	N	N	N	N	Y	N	Y	N	Y	Y	Y	N	N	N
REMIND	Potsdam Inst.	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	Y	N	N
WITCH	Fondazione Eni Enrico Mattei	Y	N	N	N	N	N	Y	Y	N	N	N	Y	Y	Y	N	N	N
MERGE	Stanford U.	N	N	N	N	N	N	Y	Y	N	N	N	N	Y	N	N	N	N
GLOBE	Global Trade Analysis Project (Perdue University)	Y	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N
IGSM	MIT Joint Program on the science and policy of global change	Y	Y	Y	N	N	N	Y	N	N	Y	Y	N	Y	Y	Y	N	N
IMPACT	IFPRI	Y	Y	N	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N
IMAGE	PBL Netherlands Environmental Assessment Agency	N	Y	Y	N	N	Y	Y	N	N	Y	N	N	Y	N	Y	N	N
ENV	OECD	N	Y	N	N	N	Y	N	Y	N	N	N	N	Y	N	N	N	N
GCAM	PNNL (Pacific Northwest National Laboratory)	Y	Y	N	N	N	N	Y	Y	N	N	N	N	Y	Y	Y	N	N
2052	Randers	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
WORLD 1 -4	Forrester LTG Team-Randers	Y	Y	N	N	N	N	N	Y	Y	N	Y	Y	N	N	Y	N	N
Threshold 21	Millennium Institute	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	N
En-ROADS	Climate Interactive	N	N	N	N	N	N	N	N	Y	N	N	Y	N	Y	Y	N	N

Table 3.3: Initial assessment of relevance of various models for forecasting. Red colour indicates little or no relevance; green indicates substantial relevance.

success in increasing energy costs through, e.g., carbon pricing will move consumption to renewables. Moreover, the International Energy Agency (IEA), in their 450 scenario, which we have used as our low carbon sensitivity variant, foresees reaching energy intensity levels 25 % lower than our MLF, similar to the results obtained with the Threshold 21 (T21) model when requiring a renewable fraction of 50 %. By definition, the IEA 450 scenario forecasts a global temperature increase that stabilizes before reaching 2 °C.

3.2 MODEL FORECAST

In order to forecast the future of Spaceship Earth, we first investigated the usefulness of 14 potential models, as depicted in Table 3.3 below. We pursued several models, including Integrated Global System Model (IGSM), Dynamic Integrated Climate-Economy model (DICE), and Threshold 21 (T21) to determine administrative, software, and other availability issues. In doing so, we also identified several new model candidates, including a regional version of DICE, Regional Integrated Climate-Economy model (RICE), as well as the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE model) of the International Institute for Applied Systems Analysis (IIASA). Separate meetings were held with individuals from Massachusetts Institute of Technology (MIT), The Millennium Institute, and IIASA to assess potential cooperation.

We opted to use '2052' as our main model, mostly owing to accessibility, supported by DICE in its regional version (RICE) and T21. While '2052' was originally formulated in the system dynamics tradition and is divided into 5 regions, it contains none of the feedback loops that are the trademarks of system dynamics models. T21, (Pedercini and van der Voorn, 2014) by contrast, is a feedback rich, but non-regionalized, fully-fledged system dynamics model. There is a family of T21 models and we used the global version, originally tailor-made to investigate questions on agricultural production and related yield, crops, and hunger issues (Pedercini and van der Voorn, 2014). '2052' (Randers, 2012a) and T21 thus complement each other, and one can be used for quality assurance of the other. RICE was designed by Nordhaus (Nordhaus, 2013) in the economics tradition, and is a CGE (Computable, General Equilibrium) model, that for each time-step calculates an optimum solution between competing demands on resources, notably integrating typically non-market values, such as natural capital.

In our view, the three models selected are not only complementary to each other, but also enable a common set of assumptions to be reflected, and consequently to investigate model sensitivity issues. We had direct access to '2052' and RICE, but T21 was not run by us, but handled through a contract with the Millennium Institute. This allowed us to specify parameters, and change these interactively in order to reflect our assumptions.

3.3 MODEL STRUCTURES

3.3.1 '2052'

The model is loosely informed by the MIT System Dynamics Group chronology of World models (1-3). It was designed by Jorgen Randers (co-author of the seminal "Limits to Growth" study in 1972) and his team in conjunction with the 40-year anniversary of the original book (Meadows et al, 1972).

'2052' is inspired by system dynamics models. These are typically feedback models, focusing on self-reinforcing and self-correcting processes (Sterman, 2000). Yet '2052' is feedback-poor and hardly qualifies as a system dynamics model; many of the model results are driven entirely from the outside, independently of what else is happening to the model. The exception is the Kaya identity, for which population and productivity dynamics drive GDP. This further drives emissions, taking into consideration the dynamics of the energy mix and the energy intensity of the economy.

Apart from these links that connect about half the model variables (albeit only in a feed-forward mode), other variables are independent. The '2052' model's main advantages are ease of use and its transparency. While the IGSM model suite at MIT, for example, is described as "the beast" by its core users (admitting that a user must have more than a year's experience to be fully cognizant of its strengths and weaknesses), '2052' is usable after less than half an hour of self-directed introduction. Another way to avoid its lack of interconnectedness is to ensure that the user provides the missing software links. One key aspect of ensuring consistency is to provide 40-year historical data series for the most predicted variables, thus making it apparent to the analyst – and reader – of trend shifts. Trend shifts, when occurring, must be well argued, as they are generally less likely than trend continuations.

'2052' is implemented in an Excel spreadsheet. The model structure is shown in figure 4.5. This figure is defined identically and in parallel for all five regions, noting that these are autonomous - there is no flux of anything between regions. Thus, all food produced in one region is consumed there. Similarly, all energy consumed within a region is also produced there. Moreover, there can be no migration between regions.

Key drivers, i.e., assumptions, are on the far left side, and key outputs, i.e., results, on the far right. Intermediate results are between assumptions and outputs. Key assumptions are population, productivity, energy (intensity and mix – contributions of various sources), and food production. In the model structure, these are determined independently of each other and of other model variables. However, they drive other model issues, and we argue that these assumptions are critical. Sensitivity analyses are also run on these assumptions.

Intermediate results are Labour Force, Production and consumption, Energy Use, and Ecological Footprint. These issues are of less interest to humanity, but give significant mileage in understanding the dynamics of the final results – that **are** of interest to humanity.

The final results are those that matter to the daily lives of people. These issues are classified as Consumption/person, Standard of Living, CO_2 emissions, and (the Physical) State of Affairs.

It should be noted that although broad, the model shows its engineering heritage in that the items modelled are physical quantities that can (and are) extensively quantified. This allows for extensive data analysis and model verification. Thus, the State of Affairs does not contain information about how happy people are, but whether biodiversity is improving or deteriorating, whether global temperatures are rising or falling, and so on.

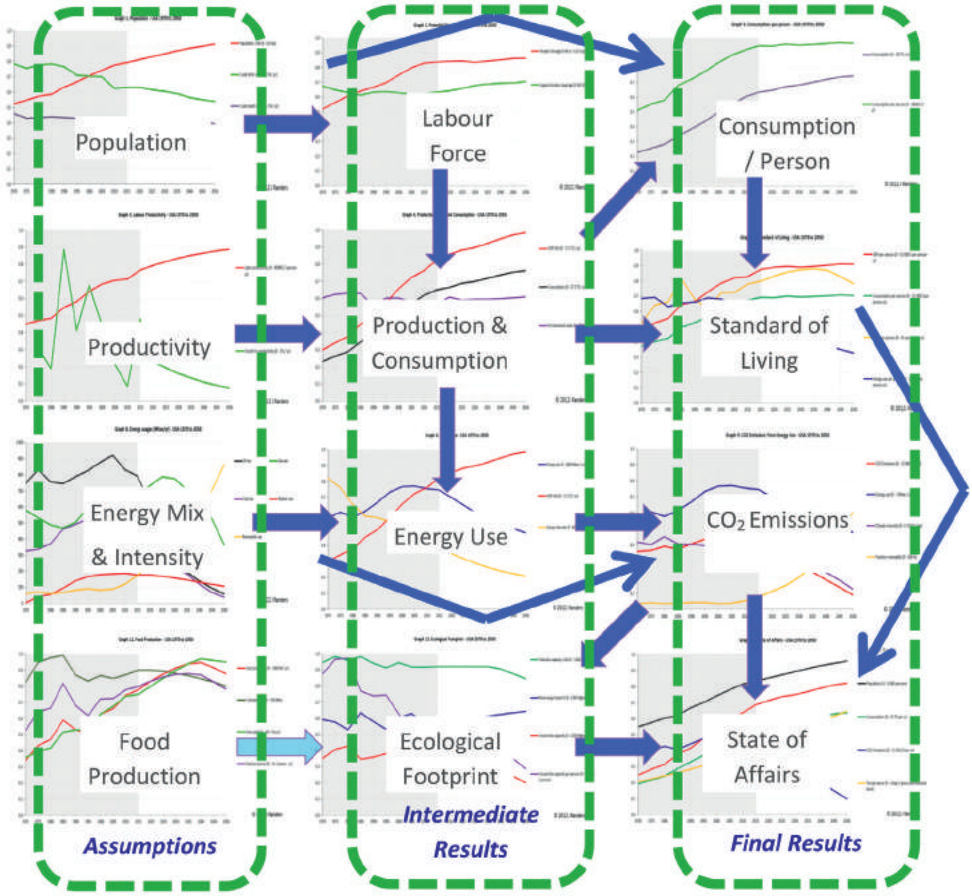


Figure 3.6: Model structure, with key drivers, i.e., assumptions, on the far left side, and key outputs, i.e., results, on the far right. Intermediate results are in the middle.

In the model, we determine exogenously and independently, mainly through trend analysis, each region's main flow variables. The model uses forecasts of these flows to compute future stock variables

1. Population growth
2. Productivity growth
3. Change in energy intensity
4. Changes in various energy source stocks

Below, we describe two key model interrelationships

Energy, carbon, and human ecological footprint

The Kaya identity (Kaya, 1990) forms the key structure of each region's carbon footprint.

CO_2 Emissions
= Population x Productivity x Energy intensity of the GDP x Carbon intensity of the energy mix
= Population x (GDP/Population) x (Energy/GDP) x (CO_2/Energy)

In the above; GDP = Population (of working age) x Productivity

Although the energy footprint is regarded as the most taxing for Spaceship Earth's future sustainability (see also footprintnetwork.org), we also forecast the ecological footprint. In the model, this footprint forecast is dependent on emissions, but is otherwise taken from footprintnetwork.org (http://www.footprintnetwork.org/en/index.php/GFN/). In our analysis, the future footprint's dependence of population, GDP, and food production is not hardwired into the model. In reality, these issues are linked, but such dependencies have been insured by our best judgment in the inputs and not through hardwired model links (this is indicated through the transparent arrow on the bottom left of Figure 3.6). Similarly, food production is also forecast independently of GDP and population where again best judgment served as quality assurance.

Investment and Consumption

Contrary to common economic models, capital is not an explicit factor of production, but part of the productivity equation. Thus, capital accumulation, commonly called investments, serves a different

purpose in the model - it reduces consumption using the following formula:
Consumption = GDP – Investment
Investment = Normal investments – climate change adaptation investments (CCAI)
CCAI = Voluntary CCAI + Forced CCAI
Voluntary CCAI = Preventive investments in infrastructure to enable climate resilience
Forced CCAI = Remedial investments in infrastructure after climate events

3.3.2 Threshold 21 (T21)

T21 is a family of bespoke models, originally designed to promote more effective national and regional policies of how to achieve the UN's Millennium Goals through better understanding linkages between society, economy, and the environment. There are a host of country-specific and region-specific T21 versions. We have used T21 Global. This unitary global model's approach and feedback structure is depicted below in Figures 3.7 and 3.8.

T21 is a true system dynamics model in that feedback loops abound. In Figure 3.8, positive-link polarity is shown by blue arrows, whereas negative links are red. To take one example to illustrate the logic: towards the top of the figure (farm) employment detracts from land (red arrow), while agriculture land itself enables employment (through food – not shown). Similarly, agriculture land detracts from other land (i.e., land area is a zero sum relationship between agriculture and other land), but should other land increase for any reason, this will also lead to additional agriculture land.

3.3.3 Regional Integrated Climate-Economy model (RICE)

RICE was designed to help optimize policies (how much to invest in climate mitigation now, knowing how much it will help reduce climate damage costs tomorrow). RICE is an integrated assessment model (IAM), combining scientific aspects of climate change (such as the relationship between greenhouse gas (GHG) emissions, temperature, and impacts) with economics. It is based on neoclassical economic growth theory (see particularly Solow 1970; Nobel Prize 1987), where emissions are seen as negative natural capital. It is implemented as a General Computable Equations model. We have used the version that is downloadable and executable in an Excel spreadsheet. It may be run on standard Excel, but requires an additional optimization module to take full advantage of all its features. We have used the latter.

Solving the model's equations amounts to maximizing a welfare function, including a utility function,

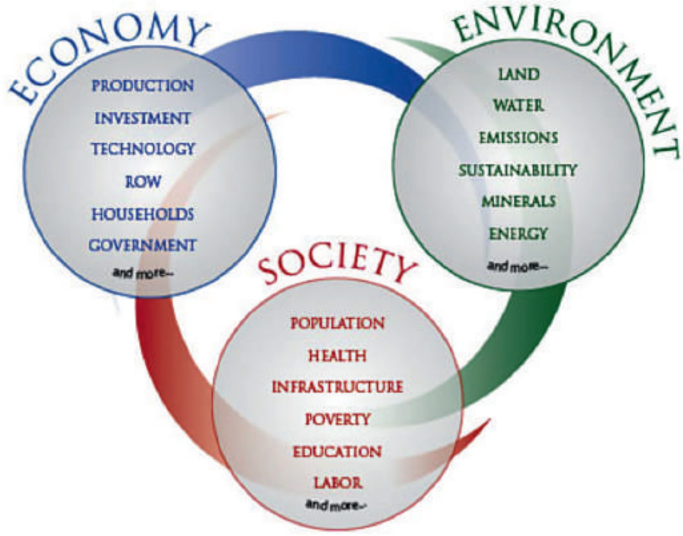


Figure 3.7: The T21 approach is to link, through feedback relationships, issues of society, economy, and environment.

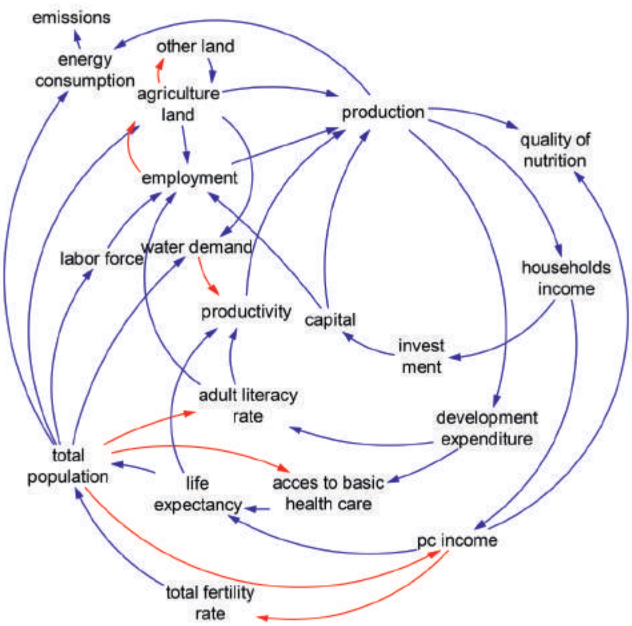


Figure 3.8: T21 feedback structure.

consumption elasticity of marginal utility, and pure rate of time preference.

The importance of a generation's per capita consumption depends on the size of the population. The relative importance of different generations is affected by two central parameters, the rate of social time preference ("generational discounting") and the elasticity of the marginal utility of consumption. These two parameters interact to determine the discount rate on goods, which is critical for inter-temporal economic choices

The general welfare function is a Bergson-Samuelson social welfare function over regions of the form W= W(U1,…,Un) where Ui is the preference function of the Ith region. The model is specified using the Negishi approach in which regions are aggregated using time- and region-specific weights subject to budget constraints, yielding:

$$W = \sum_{t=1}^{T\,max} \sum_{I=1}^{N} \psi_{I,t} u^{I} [c^{I}(t), L^{I}(t)] R^{I}(t)$$

Building blocks

Production (or output) Yt is a Cobb-Douglas production function of capital Kt and labour Lt, multiplied by a technological progress factor, At, costs incurred for reducing emissions Λt (mitigation efforts) and a damage factor Dt (adaptation effort):

$$Y_t = \frac{1 - \Lambda_t}{D_t} A_t K_t^{\gamma} L_t^{1-\gamma}$$

Capital stock Kt production uses capital that is accumulated over time. Capital is the sum of the invested capital of previous period and capital stock less depreciation. Investment being everything produced but not consumed It:

$$K_{t+1} = (1 - \delta_k) K_t + I_t$$

Emission flow, Et, is the ratio of uncontrolled industrial emissions to output σ_t carbon-intensity of output multiplied by an emission-control rate μt:

$$E_t = \sigma_t (1 - \mu_t) A_t K_t^{\gamma} L_t^{1-\gamma}$$

GHG concentrations are the stock accumulated by the emissions from previous year minus the fraction of emissions naturally depleted, accentuated by changes in land use and forestry. Temperature rises result from radiative forcing.

3.4 KEY DATA ASSUMPTIONS

Largely in line with SSP1, our assumptions are provided below, with further details documented in the appendix. Table 3.4 below shows a summary of assumptions and values in 2050, where not otherwise indicated.

Key assumptions		
Population	• (Bn people)	8.4
Societal Productivity	• Intensity (2050/2015) • Mix (Fraction Non-Fossils)	0.54 0.52
Investments & Consumption (Fraction of GDP)	• Climate Change Investments - Forced - Voluntary • Capital Formation • Consumption	 0.014 0.014 0.72 0.25
Food Production	• Acreage (2050/2015) • Gross Yield (t/ha)	1.07 6.17
Regeneration	• Unused Bio Capacity (gha/person)	0.13

Table 3.4: Key assumptions with values for 2050 (where not otherwise indicated)

In line with Figure 3.6, we make assumptions notably on population and productivity growth, and changes in both energy intensity and energy source stocks.

3.4.1 Population

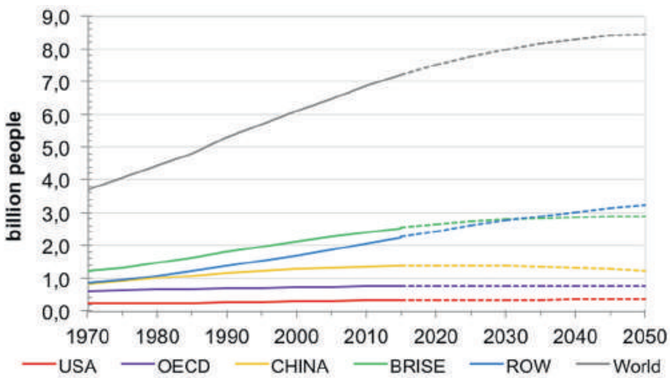


Figure 3.9: Global population dynamics, based on Wittgenstein (2015).

As noted in the appendix, and as described by Lutz (2014), we assume US fertility rates to stay constant, while death rates will stabilize after the next decade. By contrast, China will experience continued fall in their fertility rates, while death rates will increase, thus its population will start to decline in about ten years. The near doubling of the Chinese crude death rates over the next 35 years must be explained by its extremely low fertility rates, only half as low in 2050 as any other regions. Thus China's population will be the oldest of all regions and death rates will have to reflect the fact that a population with average age of 60 will experience much higher death rates than a population with average age of 40. Beyond the horizon of our analysis, the SSP1 scenario we have copied from Lutz et al, leads to a Chinese population in 2100 that has nearly fallen to half of what it is today. The forecast assumption is that OECD will mirror USA's increasing fertility rates, but that OECD will not see the same disparity between death and birth rates as will USA, and the OECD population will start to fall in 2045. A fate it will share with BRISE. Though ROW will experience sharp falls in fertility and is already seeing its crude death rates flattening out (the combined effect of increasing average age and better health), its population growth will only decline to about 1 per cent per year in 2050, from about the double today. In total, this implies that the world population will still be climbing in 2050, when it passes 8,5 billion. But it will peak a few years after at about 8.6 billion. Note that while the population reference (Lutz, 2014) allows for migration, our '2052' approach does not.

3.4.2 Productivity

Figure 3.4 and the Appendix shows data sources and the approach that we have used to establish history and forecast productivity assumptions. We have found that productivity slows as regional GDP/person increases, which is why ROW and BRISE sustain far higher productivity[4] growth rates, while OECD in general, and USA in particular, see growth rates grind to a halt. The resulting productivity growth and labour productivity are shown in Figures 3.10 and 3.11.

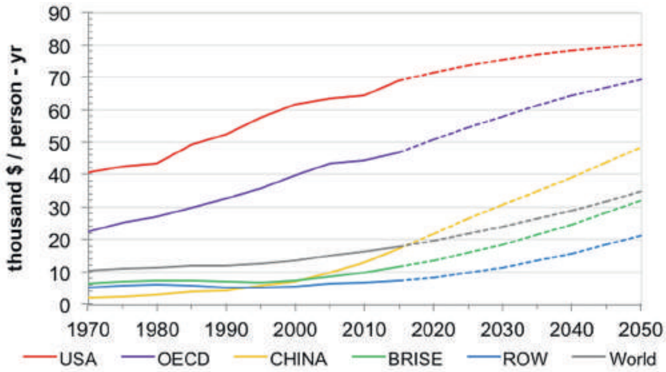


Figure 3.11: Labour productivity

3.4.3 Energy intensity

Energy intensity approach and data are also shown in the Appendix. The developed world has shown declining use of energy per unit output since 1970. Developing nations to experience this downward trend somewhat later, but over the last 25 years they too share this fate as shown in Figure 3.12 below. We investigated several hypotheses as to what may explain declining rates in energy intensity. A natural one is that nations going through a "manufacturing phase" in their economy, as China has done, experience slower decline rates than service based economies – influenced by the dynamics in secondary share of GDP as shown above. But we find no such relationship – time best explains the intensity dynamics, technology probably being the behind-the-scenes explanation (though this was never formally tested in our analysis). In the future, we thus forecast this trend to continue for all regions, and that they will mimic the energy intensity improvement leader, OECD, though with a time lag.

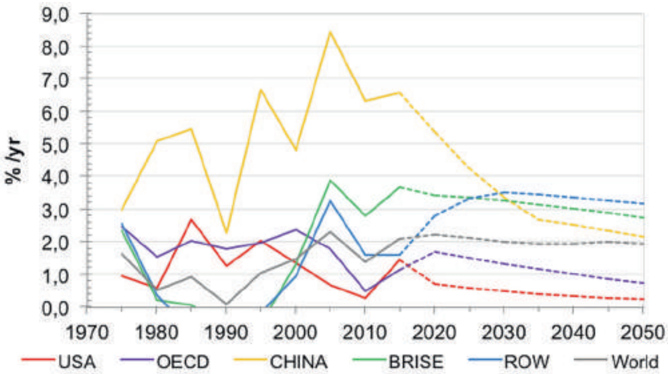


Figure 3.10: Labour productivity growth

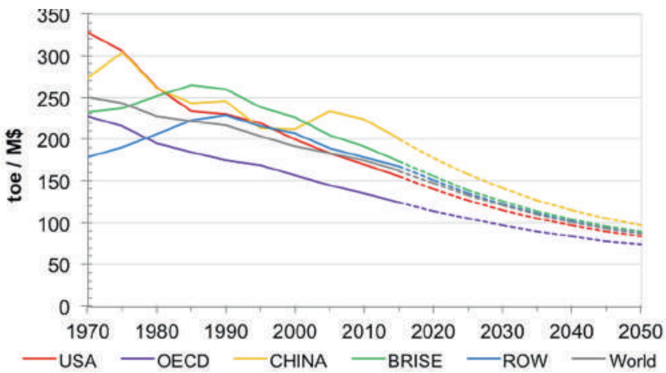


Figure 3.12: Dynamics of regional economies' declining historical and forecasted future energy intensities.

4). Labour productivity we define as output per person in the 15-64 year age group.

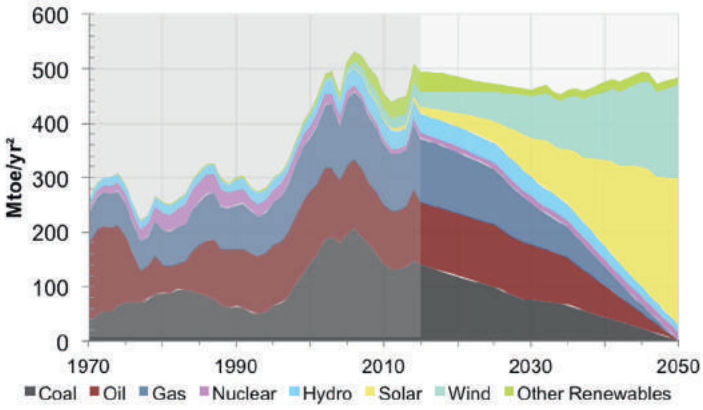


Figure 3.13: Dynamics global capacity additions

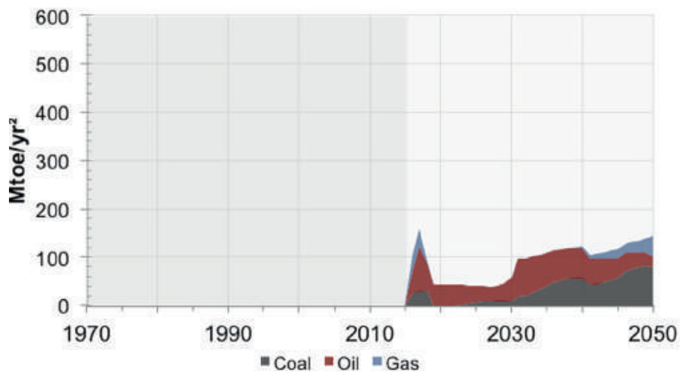


Figure 3.14. Dynamics of asset stranding in world

3.4.4 Energy mix

The assumptions of the energy mix largely determine key aspects of CO_2 and related emissions. We have thus explained in some detail how this was determined:

We established separate gross capacity additions trends for 8 different energy sources. Trends build on data from the last ten years. Linear trends mostly explain the history, with the exception of solar energies, where the trend shows exponential growth. We then assumed a trend shift, starting in 2030 towards zero fossil energy investments after 2050, but assumed a 10-year (2025-2035) "historical-to-new trend" adjustment period.

We thereafter used the trend-shifted capacity additions forecast to establish the regions' future energy production capabilities, classified into the various energy sources. The Kaya identity, which starts from regions' populations and productivity and energy intensity projections, was then used to establish energy consumption requirements. Once these requirements are more than fully met, assets must be stranded to establish demand/supply balance. Our approach to asset stranding has been informed by the dual forces of sustainability and costs that work in the same direction: first we strand coal, then oil, and lastly gas.

Capacity additions are shown in Figure 3.13 below, and corresponding assets stranding in Figure 3.14.

3.4.5 Food production

Regional food production is not a true assumption, as it results from the product of assumed future cultivated land, and the assumed agricultural yield of that land. The yield and cultivated land assumptions are in themselves projections from Randers (2012b) interpretations of the forecasts from the UN's Food and Agriculture Organization (FAO) own forecasts. These are shown in Figures 3.15-3.18 below.

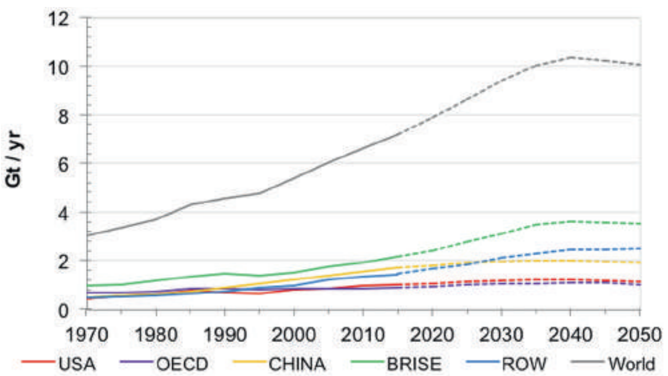


Figure 3.15: Food production

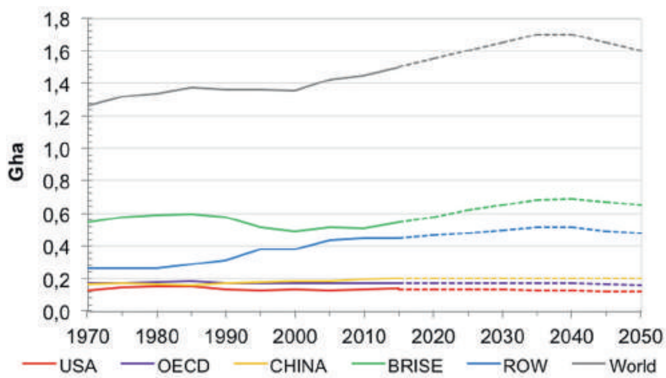


Figure 3.16: Cultivated land

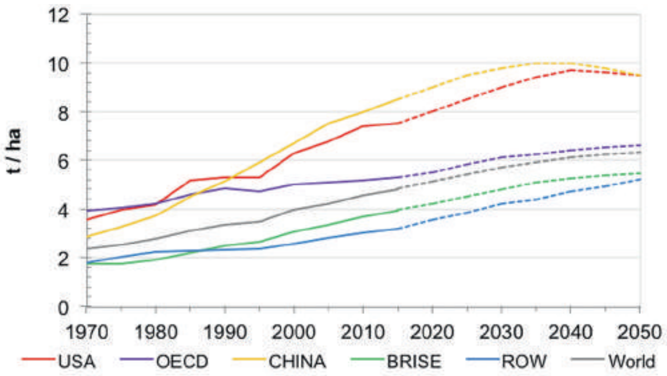


Figure 3.17: Gross yield

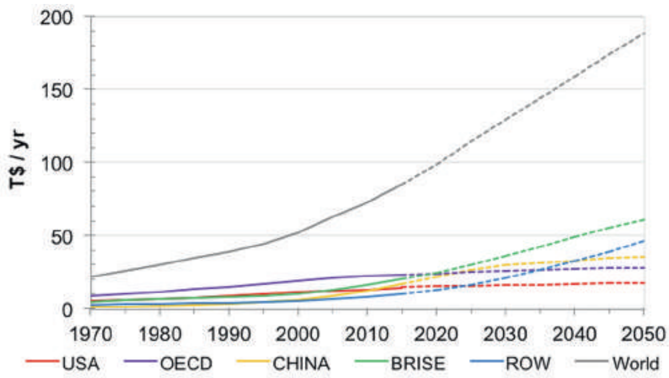


Figure 3.20: GDP

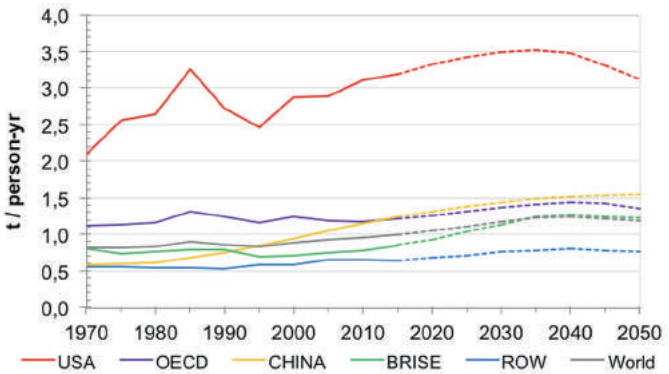


Figure 3.18: Food per person

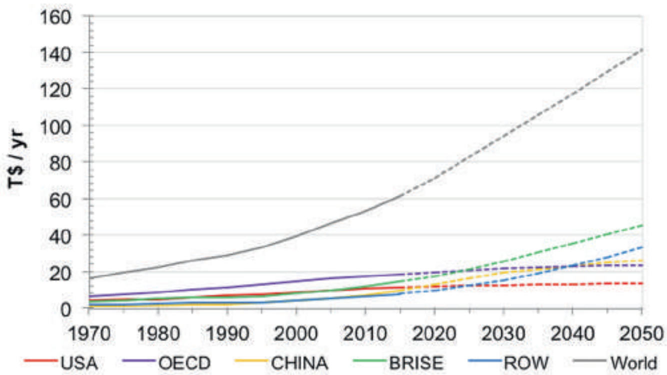


Figure 3.21: Consumption

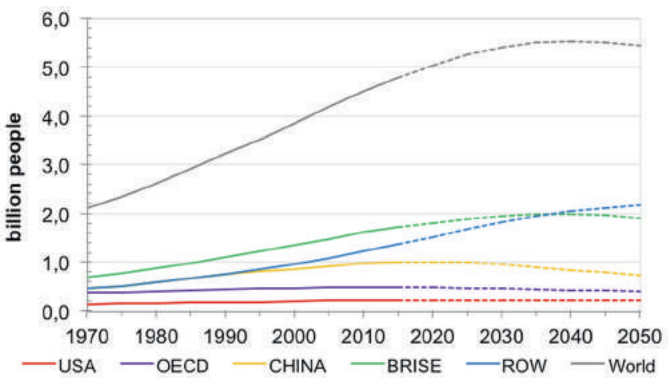


Figure 3.19: People aged 15-64 years

3.5 FORECASTING THE FUTURE STATE OF SPACESHIP EARTH FOR THE NEXT 35 YEARS

In the sections above, key assumptions have been explained. In this section we first show the intermediate results, and then the final results (ref Figure 3.6).

3.5.1 Intermediate results

Labour Force

The labour force is defined as the entire population aged 15-64. It reflects two major trends: first, population, second, age distribution. While population peaks about 2055, the labour force peaks 15 years earlier. China experiences the strongest decline in its labour force; it will peak within the next few years.

Production and consumption

World GDP will more than double to 2050, reflecting a quintupling of ROW's and near quadrupling of BRISE' GDP, while OECD's and USA's will stay nearly flat and China's is forecast to develops somewhere in between these two extremes of the developing and developed world (Figure 3.20). Rich countries poor GDP growth is mainly the dual effect of stagnating populations and stagnating GDP growth, while poorer nations will score higher on both those dynamics and thus see their GDP skyrocket. Consumption is here defined as GDP minus investments. Climate adaptation efforts takes increasing shares of investments away from real capital formation, but still only accounts for 2.8% in 2050. Investments in general mimics GDP, hence consumption also does (Figure 3.21).

Energy Use

Energy consumptions corresponding to the energy needs are as shown in Figure 3.22 below.

USA and OECD see their energy consumption starting to fall very soon, impacted by slow GDP growth and substantial reduction in Energy intensity. China follows their lead, but must wait until 2030 before energy usage declines. The richer parts of the developing world will see initial strong growth in energy usage peter out towards 2050, while ROW sees few such signs before 2050.

Ecological Footprint

The energy footprint amounts to CO_2 emissions and is shown elsewhere. Non-energy footprint stabilizes over the coming 30 years (Figure 3.23), due to better farming techniques and stewardship initiatives in oceans and on land. The exception here is ROW, where such efforts have a harder time being implemented, also because the double challenge of a fast rising and increasingly "rich-world-pattern" consuming populations (Figure 3.24).

3.5.2 Final results

Consumption/Person

USA remains the region with the highest consumption/person, but OECD and China in particular is closing the gap, mainly because their populations decline while their GDP is still increasing somewhat (Figure 3.25). China's consumption per person will surpass the world average in about five years and reach about half the US level by 2050.

US lead on Food per person shows few signs of declining (Figure 3.26). Yet over the last 10 years of the forecasting period, US' agriculture production will become more stressed and its population will have

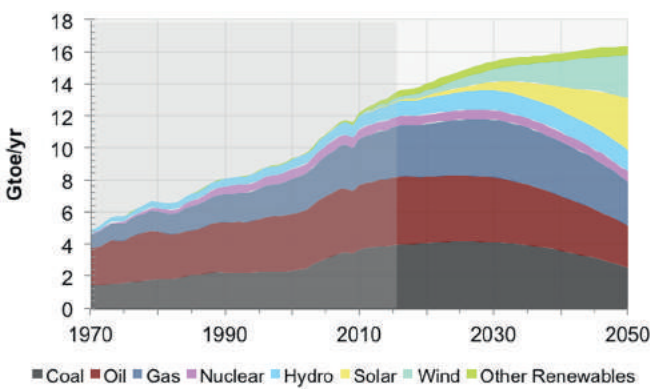


Figure 3.22: world energy use

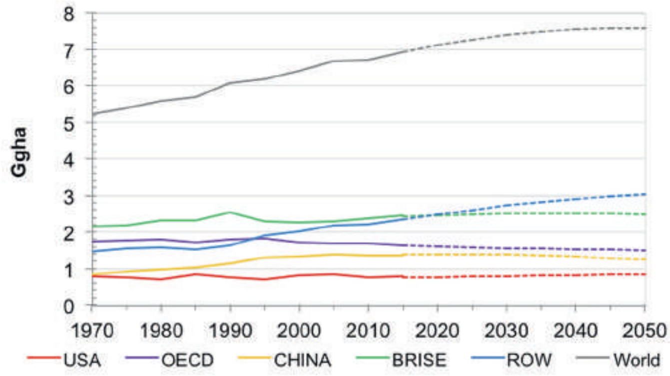


Figure 3.23: Non-energy footprint

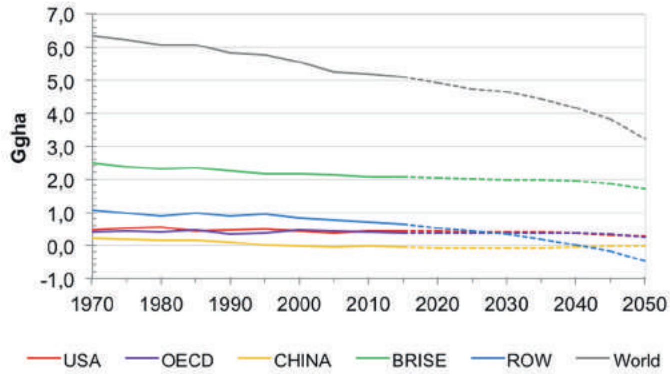


Figure 3.24: Unused bio capacity per person

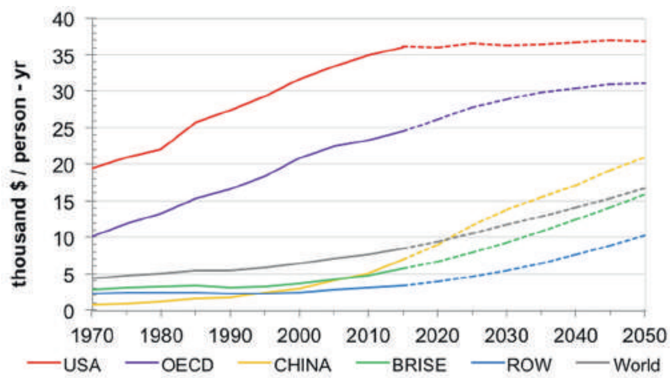


Figure 3.25: Consumption per person

to contend with less food. BRISE will see their food consumption per person double, while ROW experience much slower increases and hunger will still be an issue in substantial parts of these countries. Our assessment of the SDGs corroborates the picture of an improving, but complex, nutrition picture.

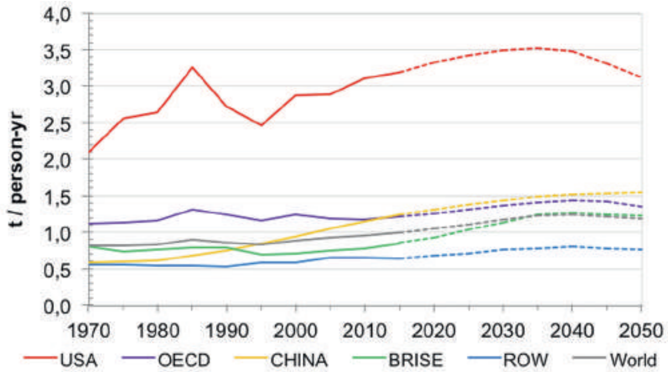


Figure 3.26: Food per person

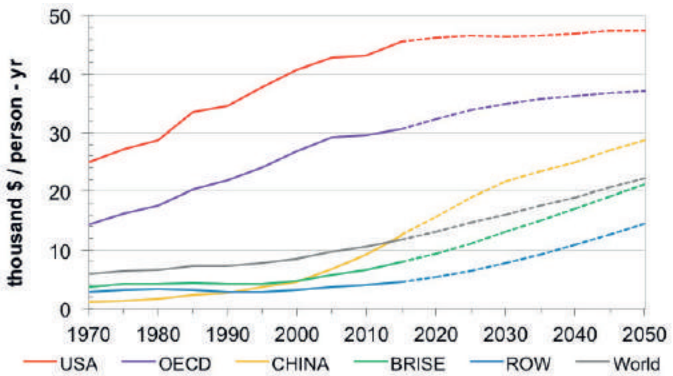


Figure 3.27: Energy use per person

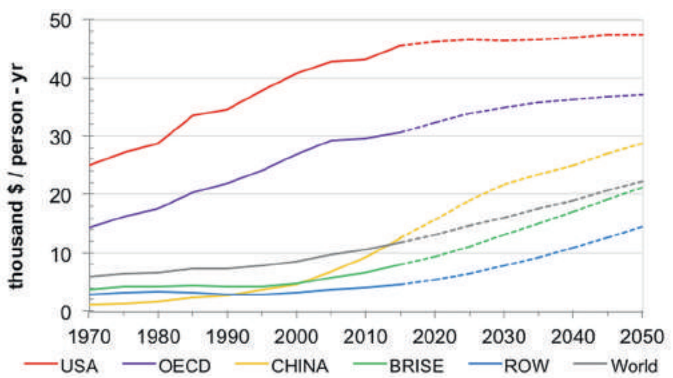


Figure 3.28: GDP per person

Standard of Living

For the non-OECD part of the world, increasing use of energy is partly a precondition for sustainability and prosperity, partly an indication of prosperity. For the developed world, sustainability is largely impacted negatively by high energy consumption. Thus the forecast of decreasing per capita energy consumption in the rich world and decreasing energy consumption elsewhere are encouraging (Figure 3.27). Likewise the GDP per capita picture, where the richer nation's plateau, while developing nations still increase, is beneficial in a wider sustainability picture (Figure 3.28). Nevertheless, the two figures above need to be combined with an energy mix that empties the carbon budget by 2037 and still 13 years thereafter still has less than ½ of the world's energy being provided by renewable sources.

CO_2 Emissions

While rich world CO_2 emissions have long been in decline, China's will peak before the next few years (Figure 3.29). Yet the growth and fossil mix of energy in poorer nations where emissions will still grow over the next 25 years prolong the world's peak emission till after 2025. This dire forecast happens, even though the global climate intensity is cut in half before 2050 (Figure 3.30) due to fossil fuel shares falls by half, especially coal.

State of affairs

As will be clear from the assessment, the world develops largely positively on the human dimension, but at a rising cost to the environment. Most of the indicators above have been discussed already, but not the climate. The carbon budget is emptied by 2037, i.e. if all carbon emissions were to grind to a sudden and complete halt in that year, when the figure above indicates that the instantaneous tem-

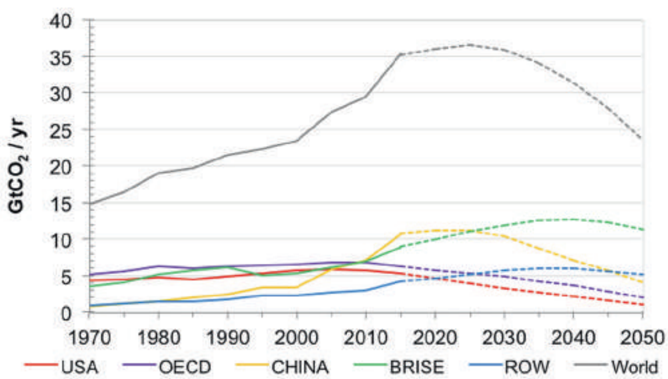


Figure 3.29: CO_2 emissions

perature is about 1.7 degrees C higher than it was during preindustrial times, climate inertias will push it to 2 degrees before it stabilizes (Figure 3.31). But in our forecast the carbon emissions are still substantive and the anthropogenic climate effects still on the rise. What will happen beyond 2050 is not analysed in our forecast, but indications are that world temperature averages will not stabilize before they reach about 2 ½ degrees above preindustrial times.

3.6 SENSITIVITY TESTS

3.6.1 Sensitivities to differences in the forecasting models' structures

RICE

RICE and 2052 are both parameterized with the same population dynamics as shown below in Figure 3.32. Although their structures for calculating GDP differ significantly, they both produce almost the same GDP dynamics, as shown in Figure 3.33. Nevertheless, as shown in Figure 3.34, the regional GDPs that they produce are very different. Whereas in '2052' GDP grows more slowly as an economy becomes richer, RICE assumes similar growth patterns quite independently of the status of economy. As shown above in Figure 3.4, USA's GDP/person growth in '2052' grinds to a halt in 2050 and in OECD also grows slowly, but in China GDP/person growth in '2052' still grows fast until 2030, before its growth pattern resembles that of RICE.

Note that '2052' emissions are energy-related carbon emissions, which are referred to by RICE as "Industrial emissions" (Figures 3.35 and 3.36). RICE adds carbon emission increases from changes in land use, which happens only in BRISE and ROW, to obtain "total emissions". The difference in car-

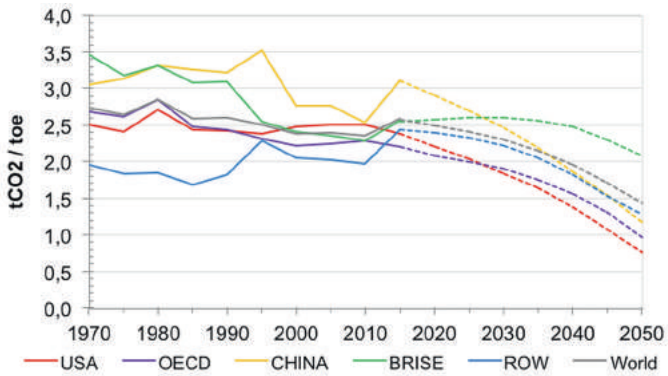


Figure 3.30: Climate Intensity

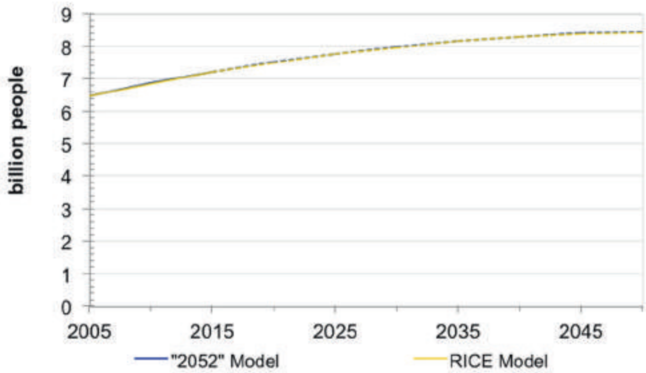


Figure 3.32: Global population in '2052' and RICE are identical

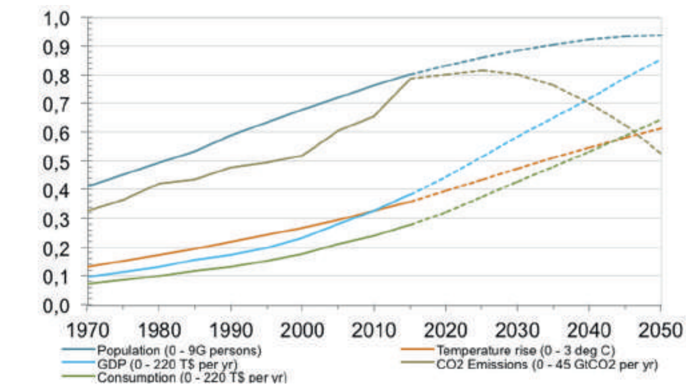


Figure 3.31: State of affairs

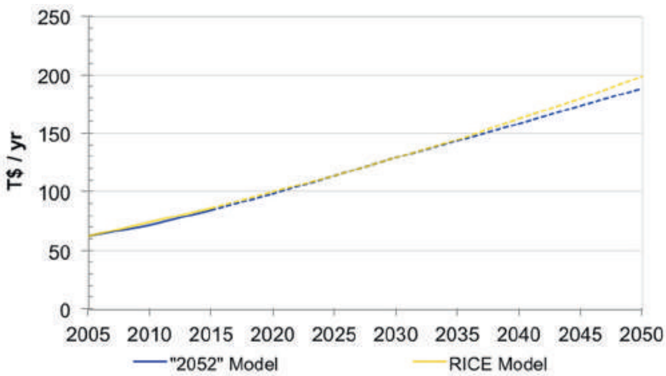
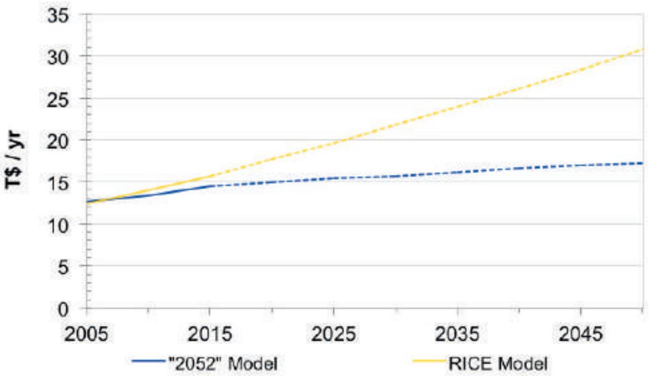
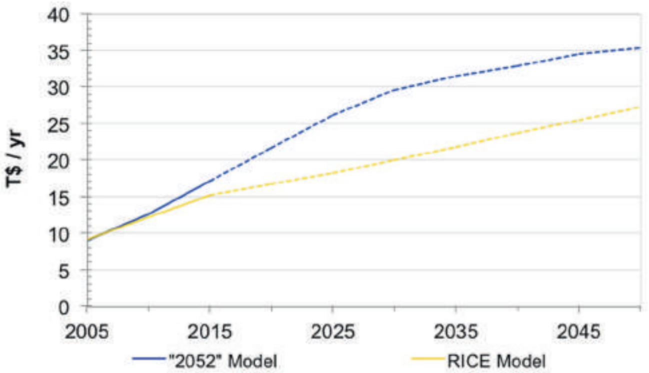


Figure 3.33: In spite of vastly differing approaches, the global GDPs achieved by RICE and '2052' are very similar

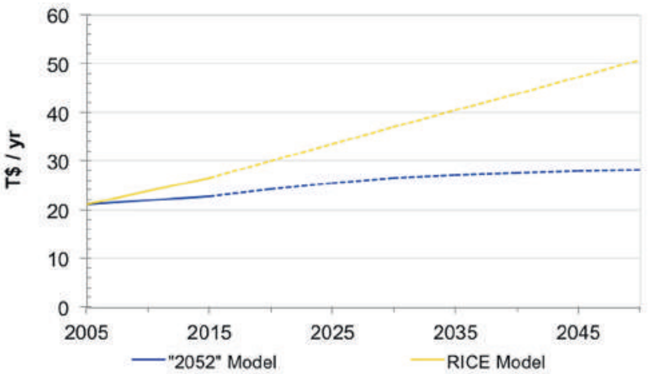
bon intensity in China explains most of the overall differences in global carbon intensity (Figure 3.37). In combination with '2052' indicating vastly higher GDP than RICE for China, this explains China's, and thus global, emissions being significantly higher in '2052' until year 2050 (Figure 3.38). It appears clear that for 2015, the RICE emissions output is about 50 % lower than the observed values, while '2052' values are within the uncertainty band of observed emissions (http://www.bbc.com/news/science-environment-33972247).



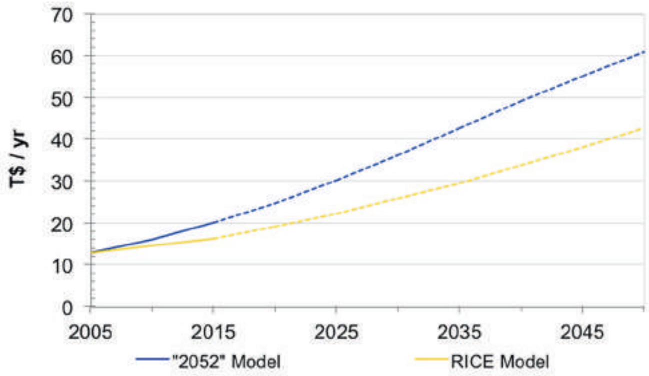
a) USA



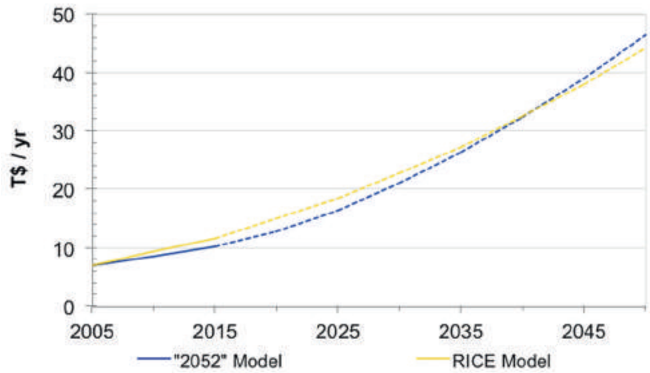
b) China



c) OECD



d) BRISE



e) ROW

Figure 3.34: '2052' forecasts very moderate GDP growth in OECD, but substantial growth in China (see Figure 3.4 for explanation). RICE uses similar growth rates regardless of GDP/person level

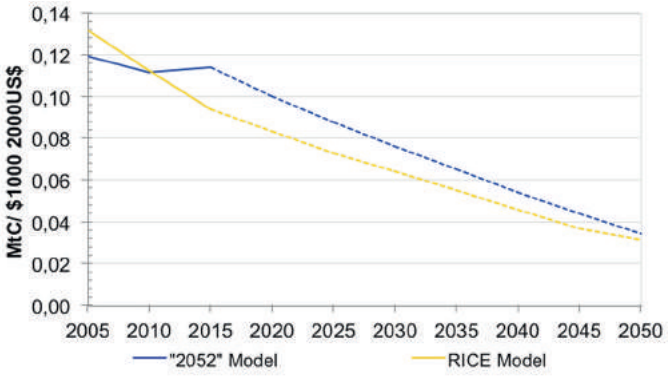


Figure 3.35: '2052' forecasts higher carbon intensity

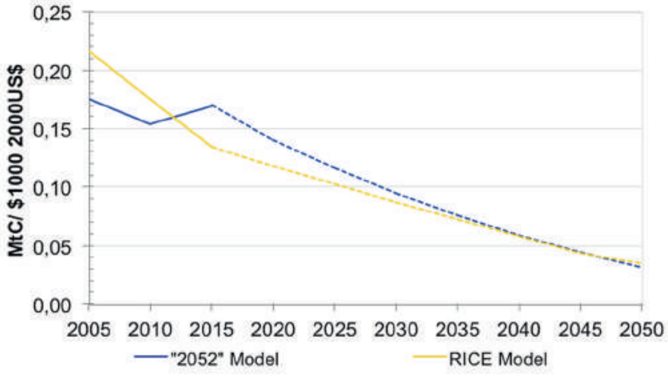


Figure 3.37: '2052' forecasts higher Chinese carbon intensity

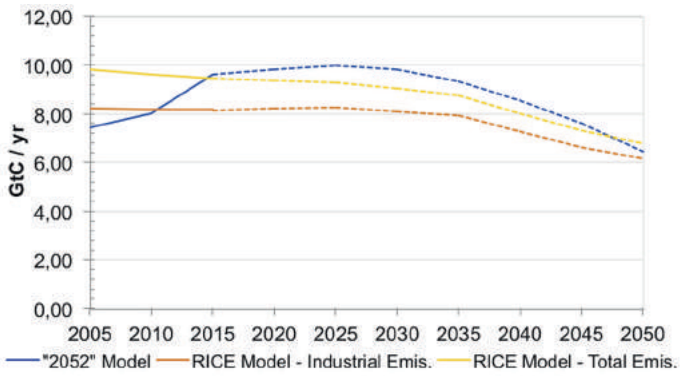


Figure 3.36: '2052' forecasts intensity higher global emissions

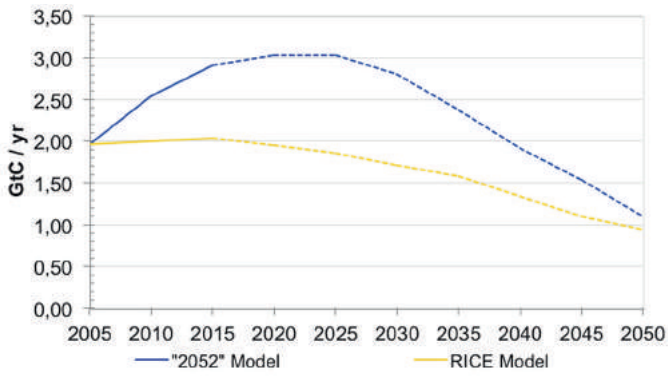


Figure 3.38: '2052' forecasts higher Chinese emissions

Threshold 21

T21 is a feedback-rich model and therefore population, for example, is endogenous, depending on education, GDP, etc. Similarly, energy intensity depends on GDP as well as energy costs. We have attempted to calibrate, with the few free parameters available in T21, to recreate key results in '2052'. We have arrived at similar population dynamics, GDP, and renewable energy fraction as shown in Figures 3.39, 3.40 and 3.42. Agriculture yields and food production are also similar, but not shown. However, in order to achieve this, energy costs had to be increased significantly. Thus, T21 endogenously creates much lower energy intensity in 2050 (almost down to 3/4, compared with '2052' values) as seen in Figure 3.41.

Our analysis is that in order for the renewable fraction to reach 50 % within the next 35 years, fossil energy prices in particular will need to increase. If the underlying T21 structure is correct, this will not have a negative impact on GDP, but will have the co-benefit of decreasing energy consumption, as shown in T21, which after 2030 obtains almost 25% lower energy intensity than derived using '2052'.

Note that historical values of the renewables share are 50% higher in T21 than in '2052'. This is because '2052' defines only traded renewables, in line with BP (2015) In contrast, T21 also includes non-traded renewables, in line with IEA (2015)). The difference is mainly wood that is collected for heating and cooking, and is not accounted for in '2052'. This difference disappears in the future, as most renewable energy is traded.

We speculate that the apparent inconsistency between the identical renewables share in 2050 across models, lower T21 energy consumption (Figure 3.43), yet higher T21 CO_2 emissions (Figure 3.44), might be due to the different relative emission factors for various fossil fuels between the two models.

3.6.2 Sensitivities to assumptions.

As indicated above, key assumptions relate to the following five headings: Population, Productivity, Energy Mix, Energy intensity, Food production

Population

Although the UN medium population forecast is for

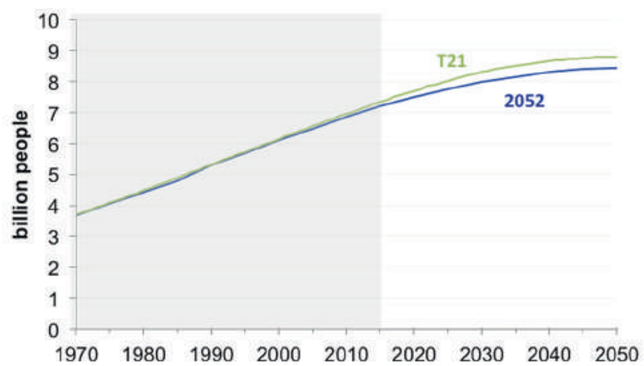


Figure 3.39: '2052' forecasts similar population

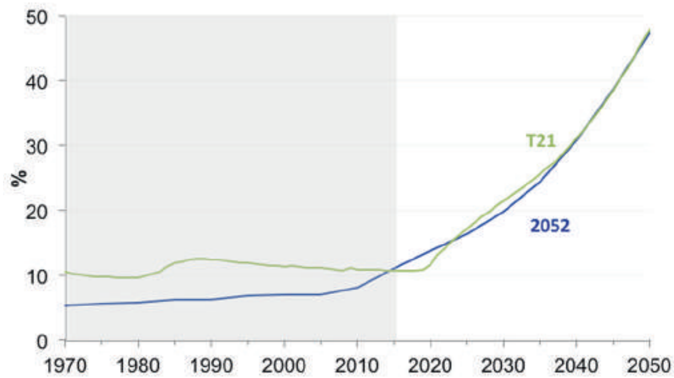


Figure 3.42: '2052' forecasts similar Renewables share dynamics

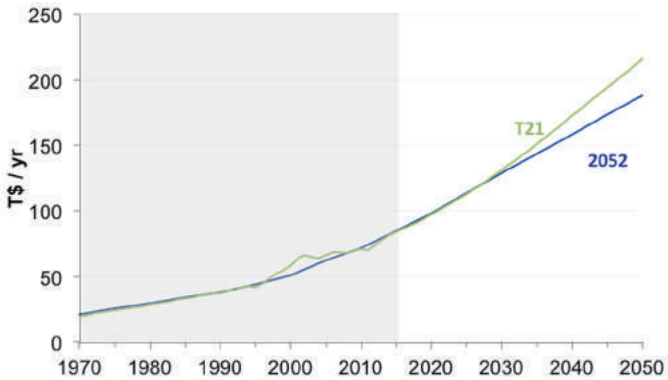


Figure 3.40: '2052' forecasts similar GDP dynamics

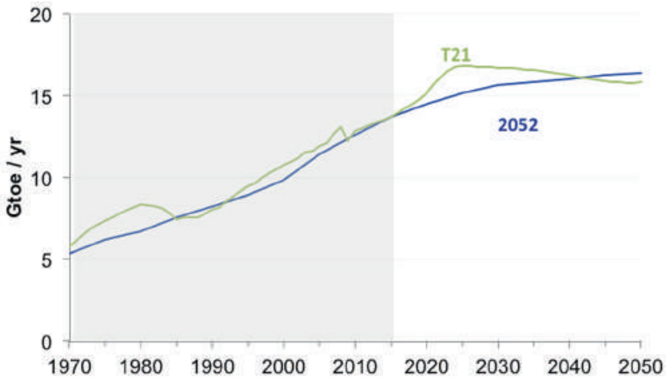


Figure 3.43: T21 forecasts slightly lower final energy consumption

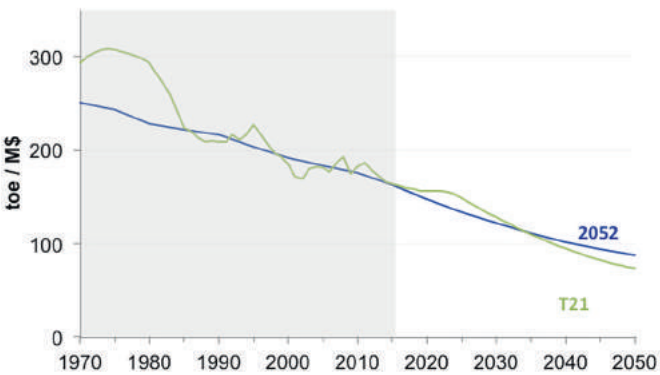


Figure 3.41: '2052' forecasts slightly different energy intensity

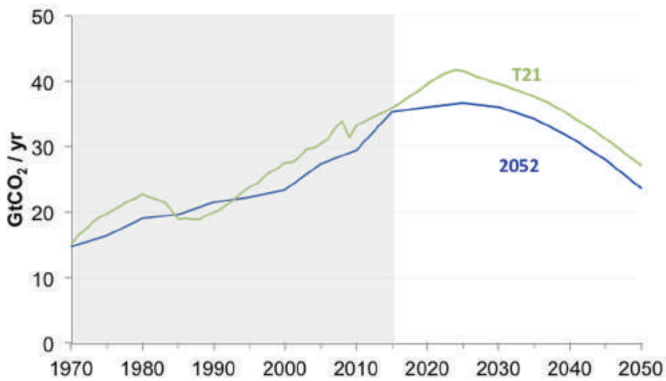
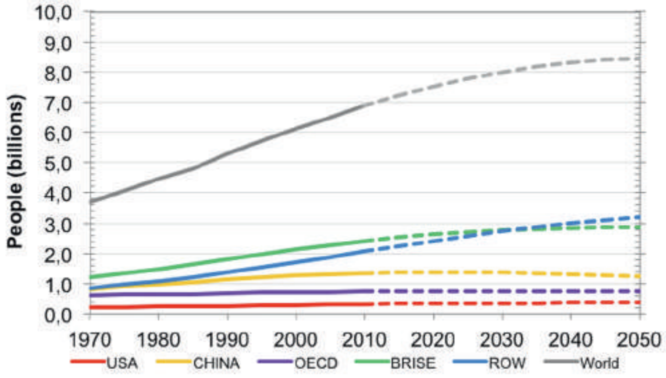


Figure 3.44: T21 forecasts slightly higher emissions

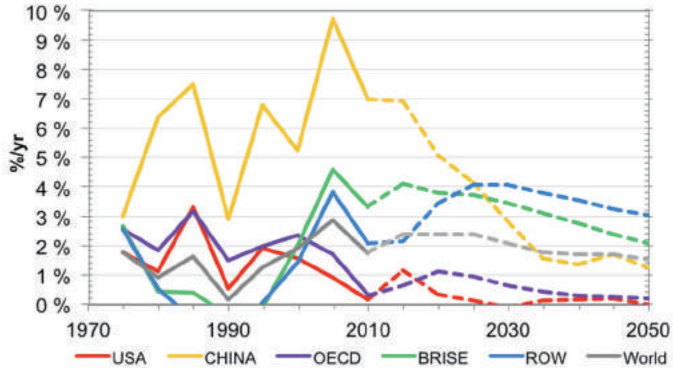
9.8 Bn in 2050, in our opinion this forecast is implausible. Already in 2015, African youth is migrating, partly due to population issues. Doubling the African population appears impossible – and it is Africa that will bear the weight of the population increase. It seems entirely plausible, however, that the world might follow a SSP2 path that has been deemed most likely by the Wittgenstein institute (2015), and thus have chosen their SSP2 – CER (Constant Enrolment Rate [i.e., in education]) as our High sensitivity variant. Our low variant is the Randers forecast (Randers, 2012b) as shown in Figure 3.45 below.

Productivity

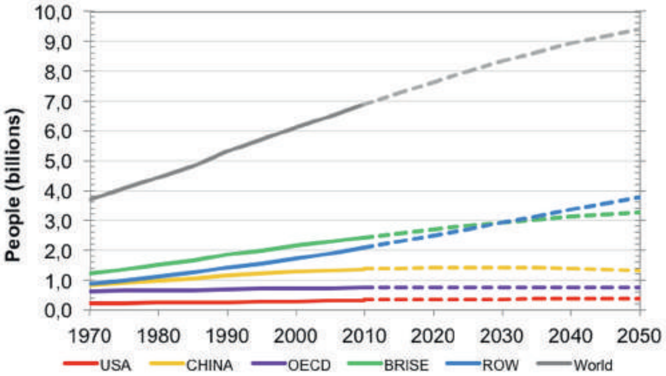
Figure 3.46 shows the low and high variants of productivity. We have again chosen Randers (2012b) as



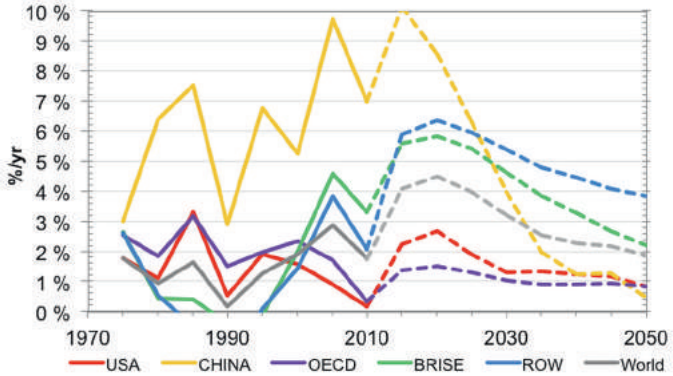
(a) Base



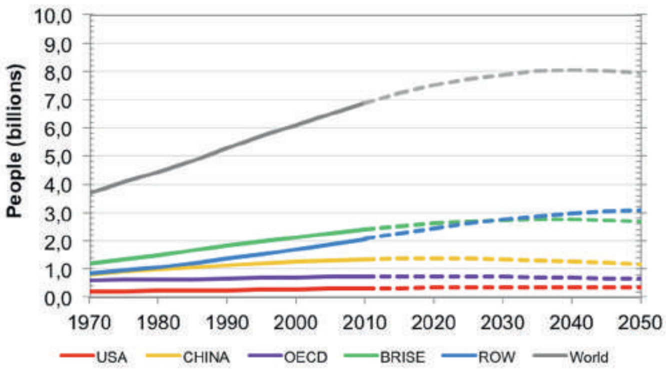
(a) Base



(b) High

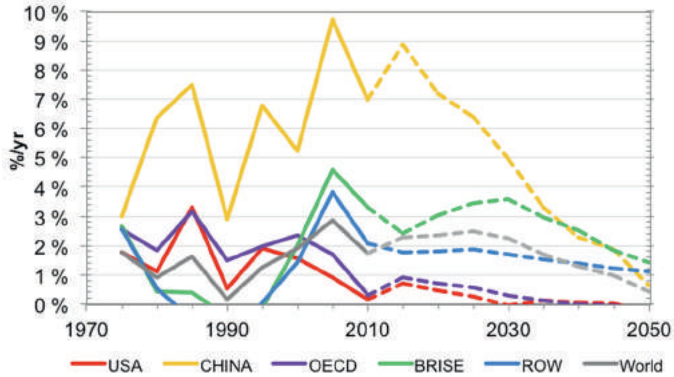


(b) High



(c) Low

Figure 3.45: Base, high and low levels of population.



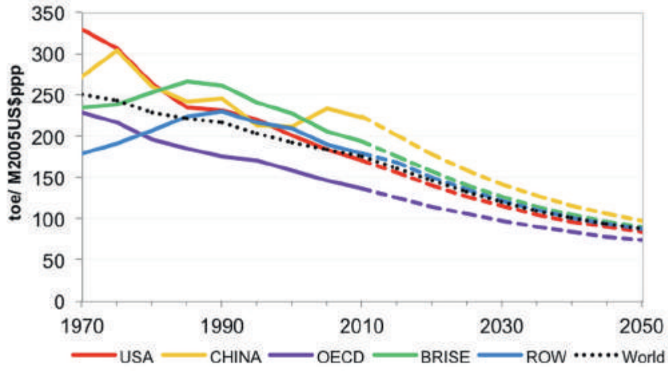
(c) Low

Figure 3.46: Base, High and Low productivity growth patterns.

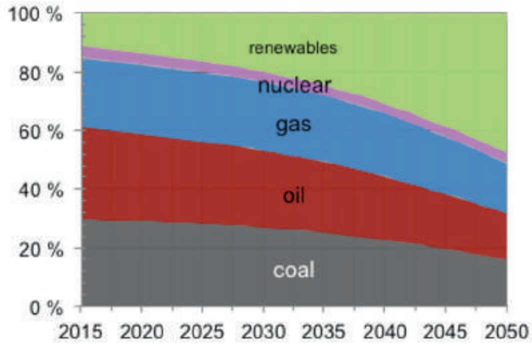
our low variant. He foresees US productivity growth rates turning negative after 2045, and OECD and elsewhere becoming negative 10 years thereafter. The high variant again comes from Wittgenstein SSP2. The Figure 3.4 showed our productivity growth formulation in detail, and we find little reason that it should be much higher than we forecast.

(Decline in) Energy intensity

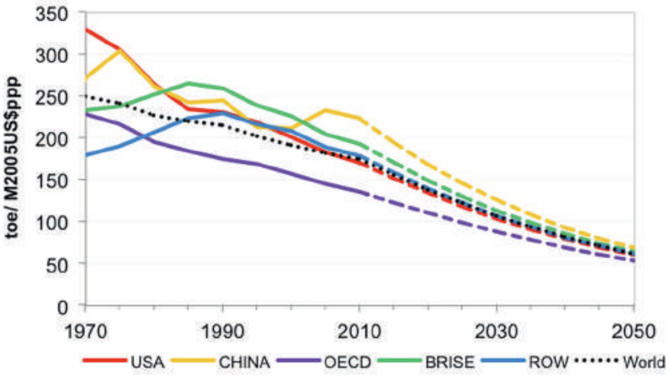
Again, we have chosen Randers (2012b) as our low variant. The high variant is now derived from IEA (Figure 3.47). Their sustainability, 2°C scenario (named '450' in line with the fact that global GHG emissions stabilize at 450 ppm), which we have ourselves extended beyond 2040 to 2050, reduces the global



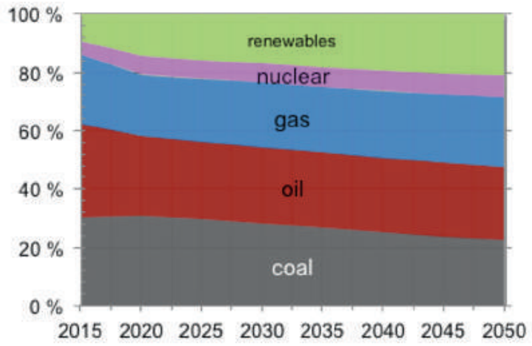
(a) Base



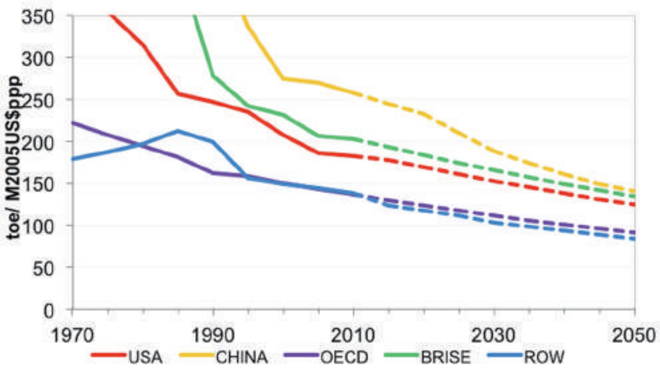
(a) BASE World



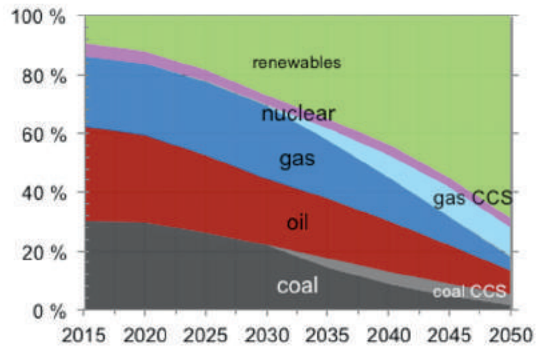
(b) High



(b) LOW World



(c) Low



(c) HIGH World

Figure 3.47: Base, High, and Low energy intensity patterns

Figure 3.48: High and Low renewables share of the energy mix

energy intensity of the economy to 40% of current levels in 2050. We have implemented this in a similar way to our own base, as shown in the Appendix.

Energy mix

Here, the high variant of renewables share of the energy mix gain is taken from our extension from 2040 to 2050 by the IEA 450 scenario (IEA, 2015) where we have estimated that a significant amount of CO_2 will be sequestered using CCS techniques towards 2050 as the high renewables variant. Conversely, the IEA MLS – the "New Policy Scenario" is taken as the low renewables variant, as shown below in Figure 3.48.

Sensitivity of assumptions on final results:
We have subjected these to sensitivity tests to investigate their impact on final results, as presented in Figures 3.49 – 3.54.

Consumption/person
In line with the Kaya identity, consumption/person is insensitive to energy intensity or energy mix.

Standard of living

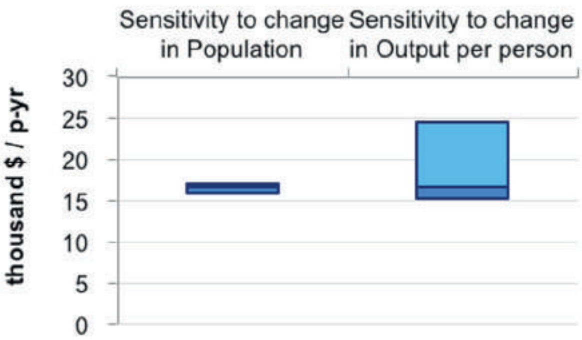


Figure 3.49: Impact of population and productivity assumptions on consumption per person.

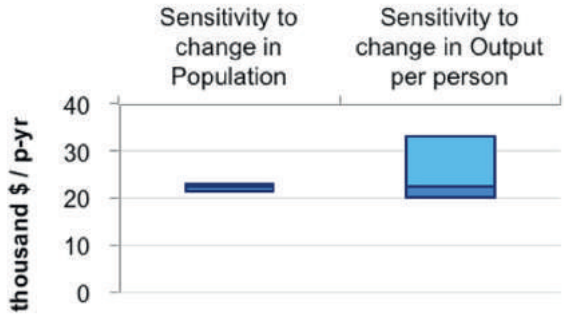


Figure 3.50: Impact of all sensitivity assumptions on GDP per person.

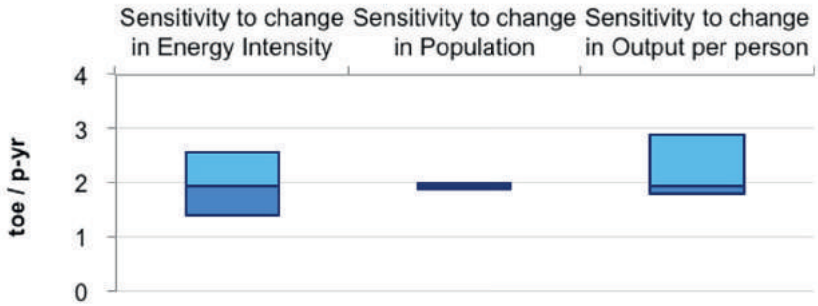
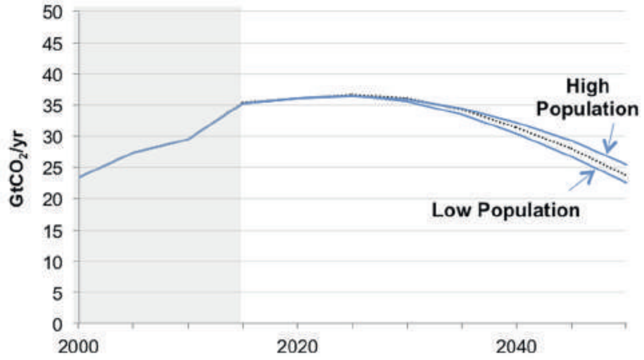


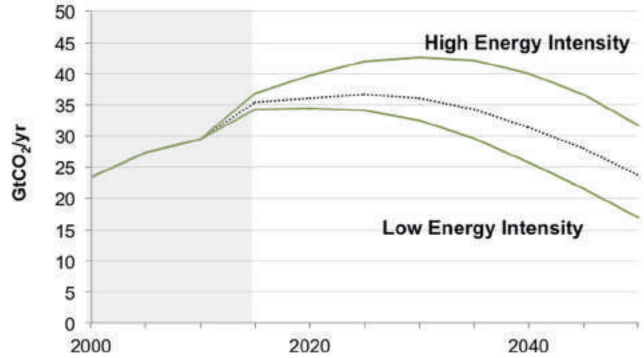
Figure 3.51: Impact of all sensitivity assumptions on energy use per person.

Explorer Inge Solheim, raised a flag, representing Goal 13, Climate Action, in the community closest to the North Pole, to support the UN Global Goals for Sustainable Development, courtesy globalgoals.org

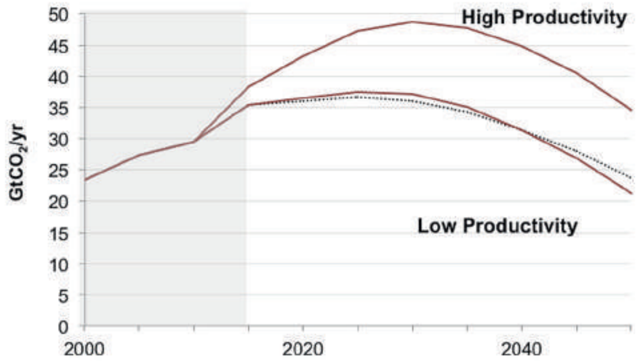
CO_2 emissions



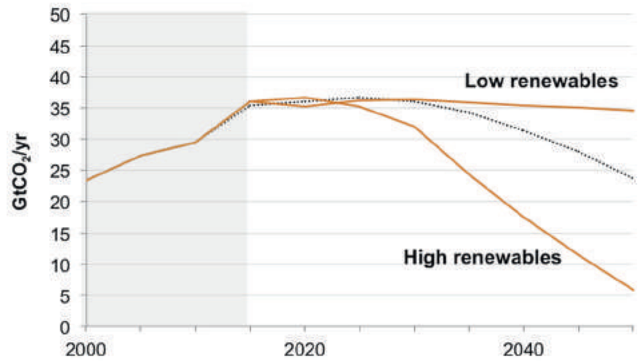
(a) Population



(c) Energy Intensity



(b) Productivity



(d) Share of renewables

Figure 3.52: Impact of all sensitivity assumptions on global energy-related emissions

State of affairs

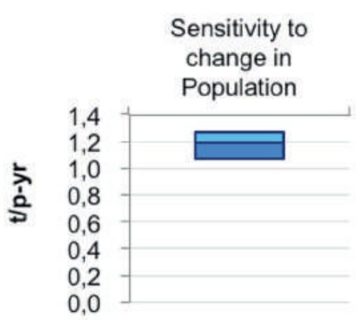


Figure 3.53: Impact of all sensitivity assumptions on food per person: only population dynamics has an impact.

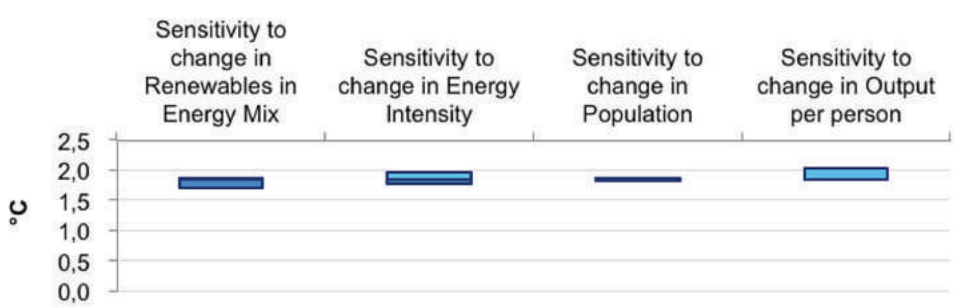


Figure 3.54: Impact of all sensitivity assumptions on global temperature increase

Children in traditional dress raised a flag to represent Goal 9, Industry, Innovation and Infrastructure, in Uhuru Park in Nairobi, Kenya, to support the UN Global Goals for Sustainable Development. Credit: James Ochweri, courtesy globalgoals.org

4. LIKELIHOOD OF REACHING THE SDGs

2015 was the final year for the Millennium Development Goals and the year that the 17 new Sustainable Development Goals (SDGs) were launched, outlining what the world wants to achieve by 2030 (UN, 2015). The SDGs are wide-reaching, extending from biodiversity and energy use to gender equality and hunger. The individual SDGs are also wide, each of them covering a broad aspect of their theme, which is detailed in a number of targets.

4.1 WHY COMPARE WITH THE SDGs?

A forecast is neutral. But in order to understand the forecast it needs to be comparative. We need to compare it to, for example, something we want to achieve, or want to happen. A forecast of the future can therefore compared with the future that we want. By doing this, we are able to say whether the forecast is positive or negative.

Each of us has different views of the future we want, so such an comparison would be subjective and very challenging. The announcement of the 17 new SDGs was very timely, being negotiated over the last year and adopted in September 2015. These 17 goals state what the 191 member states of UN want to achieve by 2030. In spite of their limitations, the SDGs provide the best representation of the future that humanity wants. Using this approach enables us to say whether our forecast is the future humanity wants, or whether our most likely future falls short of meeting the 17 goals. In order to make the comparison, we need to look at our forecast for 2030. As our forecast was developed through 2050, we have intermediate 2030 values to use for comparison.

4.2 THE METHODOLOGY FOR OUR COMPARISON

In this project we are assessing likelihood that the goals and targets will be met. In order to illustrate our assessment, we have used a colour-coding scheme, with green, yellow, and red ratings.

Many of the targets are absolute, with terms such as “end hunger” and “all girls and boys” being used. The absolute intention is clear, and is emphasised

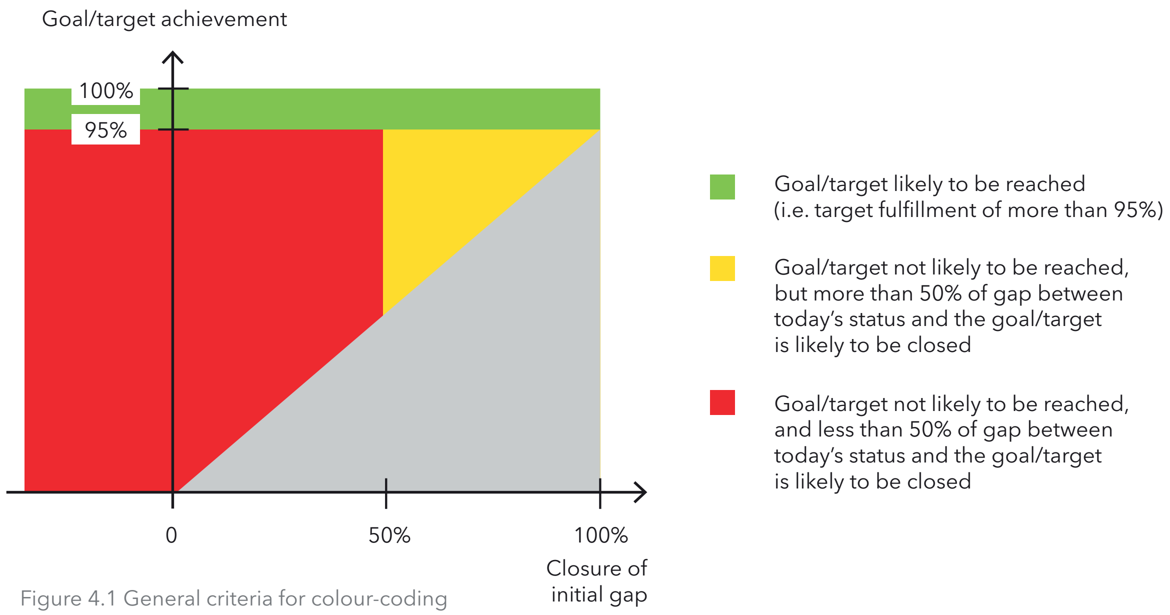


Figure 4.1 General criteria for colour-coding

by the pledge that "no one will be left behind" (UN, 2015). A very strict interpretation of the goals and targets will therefore give only red ratings, as a single hungry person on the planet would mean failure to achieve that particular goal or target. It is therefore expedient to include an interpretation that enables us to present a less absolute, all or nothing, overview of success or failure. The criteria explained in Figure 4.1 of the colour-coding scheme are DNV GL's own, and are not derived from official UN principles.

According to the criteria we have used, the target or goal is considered to have been achieved if the likely degree of fulfilment is 95 % or more, and a green rating is given. If less than 95 % of the target is fulfilled, then the target has not been achieved. Nevertheless, it is still useful to determine whether we are moving in the right direction. Therefore, a yellow rating is given if we are likely to close more than 50 % of the gap between the starting point in 2015 and the target value. If we are not even likely to close half the gap, then the target or goal is given a red rating.

There are 17 goals, 169 targets, and hundreds of potential indicators that cover the targets. We present a rating for 16 of the 17 goals. To achieve the rating of the goals, we investigated a number of targets, but far from all. Addressing all the targets would be a very comprehensive exercise, and, furthermore, many targets are not quantified or we have no available or reliable data.

The goals are comprehensive, and each of them covers a number of dimensions. In order to conduct the rating, we have used quantifiable indicators that, in our opinion, represent the various dimensions of the individual goals. These indicators have been used to rate the relevant targets. The official list of indicators for the SDGs has not yet been developed by UN. In selecting indicators, we used SDSN (2015) as guide, and also been inspired by ODI (2015) and Bertelsmann (2015). The choice of indicators used is our own, and for some goals and targets, we developed our own indicators. For most goals we investigated several indicators and assessed several targets. For rating the overall goal, we weighted the targets and indicators we have included equally, and used the average rating.

The assessment we present is regionalized, using the same five regions as in our forecast. We build up each global rating from five regional ones. The SDGs are also relevant for developed countries, to a much larger extent than the MDGs which focused mainly on developing nation issues. Nevertheless, for most goals there are large differences between the regions and their likely degree of success, and our assessment is reflects this. The regions used in our assessment are the same as those used in our forecast. Ideally, the assessment would have used another regionalization, in particular splitting the ROW region into South East Asia, North Africa / Middle East, Sub-Saharan Africa, and Latin America. Although this has not been possible for this phase of the project, it may be possible in future iterations of the project.

Unlike other predictions on the likely success or failure of meeting the SDGs, we have based our assessment on our own forecast. Our forecast addresses a number of areas and dimensions contained in the SDGs, and the assessment is consistent with our forecast. Some of the indicators are direct output from the models, others are directly or indirectly informed by the forecast, while some goals, targets and indicators are not included or informed by our forecast. The models are used transparently in our assessment, and we also make clear where they do not inform the assessment.

For each goal we present a two-page spread with an overall comment for the goal, an explanation on how our forecast has been used as a basis for our rating, a comment on any regional aspects of the goal, and a conclusion on the overall rating. More detailed documentation of our assessment of the relevant targets and key figures we have used to arrive at our assessment are also provided.

The 17 SDGs are closely interlinked, and achieving one goal will often require success within other goals, while failing one goal could reduce the likelihood, or render impossible, of achieving other goals. Although DNV GL investigated the links in dependencies between goals and between targets, the results were too comprehensive, complicated, and subjective to be included directly in our assessment. We have therefore ranked each of the 17 SDGs individually, while realizing that there are strong dependencies between them. The forecast we use as input, and the assumptions we base our conclusions on, are consistent for all SDGs.

4.3 CONCLUSION AND RATING OF THE 17 SDGs

Comparing our most likely forecast with the 17 SDGs reveals that none of the goals will be met without additional effort. Achievement is most likely for the human development goals like hunger, health, and water/sanitation, and least likely on con-

sumption, climate, environmental indicators, and inequality.

There are large regional differences in the likelihood of achieving the SDGs. The rich world (OECD and USA) will reach most, but face large challenges in meeting consumption and climate goals. China will resemble OECD and achieve many of the SDGs. ROW, and to a lesser extent BRISE, will fail to achieve most goals, but nevertheless make significant progress in many areas.

It is worth noting that the 17 SDG are ambitious, and progress is relevant even when the goals are not achieved. Our rating includes indicators of progress, with the yellow rating used when it is predicted that more than 50 % of the initial gap will be closed. Furthermore, in many of the instances where we have assigned a red rating to regions on certain goals, we also expect some progress to be made - but not enough to close half the initial gap.

The scores of the regional assessment for the 17 SDGs are summarized in Figure 4.2.

The detailed two-page spreads with explanation of the results and the details of all the targets and indicators that we have rated are included in Section 4.4. Table 4.1 summarises the main conclusions for the assessment of each SDG.

SDG	Conclusion on the likelihood of reaching each goal
1. NO POVERTY	• We assessed extreme and relative poverty. • High extreme and relative poverty in ROW gave a red score. • OECD and USA have low extreme poverty, but do not succeed in reducing relative poverty, and so score yellow. • BRISE and China improve on both relative and extreme poverty, but not enough to have a green overall score.
2. ZERO HUNGER	• We assessed ending hunger measured as proportion of population living above minimum dietary requirements. • ROW and BRISE reduce hunger, but not fast enough to close half the gap, and therefore get a red score. China continues its strong downward trend and achieves the goal. • In USA and OECD hunger is, and remains rare, and they achieve the goal.
3. GOOD HEALTH AND WELL-BEING	• We assessed maternal and under-5 mortality, population living with HIV, and probability of dying from non-communicable diseases. • USA and OECD are rated green on all targets. • China is green in all but one. • BRISE is forecast to obtain green, yellow and red target achievements, and ROW yellow and red; both regions get an overall yellow rating, with ROW close to red.
4. QUALITY EDUCATION	• We assessed completion rates for primary and secondary education, gender parity for tertiary enrolment, and literacy rates. • China, OECD and USA score green on all three indicators. • BRISE scores red, yellow, and green on the three indicators and gets a yellow score in total. • ROW has two red and one yellow score and gets a red score in total.
5. GENDER EQUALITY	• We assessed gender differences in primary and secondary school completion, women aged 18-24 years that were married or in a union, ratio of women to men in labour force participation, and gender gap in wages. • Gender equality continues to be a challenge all over the world, also in 2030. • USA and OECD do not achieve the goal despite it being on the agenda for a long time, as many challenges remain in gender parity within working life. • ROW, BRISE, and China get a red rating as they will continue to fail to meet most indicators.
6. CLEAN WATER AND SANITATION	• We assessed access to safely managed water and sanitation, and proportion of total water resources used. • ROW gets a red rating with significant challenges in both water and sanitation. BRISE and China both get a yellow rating, but with China close to achieving a green rating. • USA and OECD score green.
7. AFFORDABLE AND CLEAN ENERGY	• We assessed energy used and access to electricity, renewable energy share, and decrease in energy intensity. • China scores high on all indicators and gets a green rating. • All other regions score low on some indicators and high on others, and get an overall yellow rating.
8. DECENT WORK AND ECONOMIC GROWTH	• We assessed growth rate in GDP/person, ecological footprint intensity, and Palma ratio. • ROW, BRISE, and China succeed with high growth and improved sustainability of this growth, but fail on distribution and so get a yellow rating. • USA and OECD fail on both growth and distribution of growth, but partly succeed on sustainability of growth. They get a red rating.
9. INDUSTRY, INNOVATION AND INFRASTRUCTURE	• We assessed Internet access, share of GDP coming from the industrial sector, and personnel in Research and Development (R&D). • China, USA and OECD score well on all indicators and are rated green in total. BRISE scores red, yellow, and green on the three indicators, receiving yellow in the overall rating. • ROW gets yellow, based on the two indicators we were able to rate.
10. REDUCED INEQUALITY	• We assessed the Palma ratio as the sole indicator for SDG 10. • With growing inequalities across the world generally, no regions reach this goal, and all get a red rating. As regional differences are likely to reduce, a better rating could have been given.
11. SUSTAINABLE CITIES AND COMMUNITIES	• We assessed slum populations and urban air pollution. • ROW is unlikely to ensure safe wellbeing of the urban population over the coming 15 years and gets a red rating. • China faces huge challenges, both with slums and pollution, and thus also gets red, but this is uncertain, and yellow could be given. • BRISE is more diverse and gets a yellow rating, with somewhat better figures on both indicators. • OECD and the USA are rated green.
12. RESPONSIBLE CONSUMPTION AND PRODUCTION	• We assessed ecological footprint per person. • All regions except ROW have a 2030 footprint that is higher than the global threshold giving them a red rating. • ROW is on the threshold, giving it a green rating.

13. CLIMATE ACTION	• We assessed total energy related emissions. • On climate emissions the planet succeeds or fails together; therefore no regional breakdown is provided. • Our most likely forecast is that carbon emissions will remain at a level that empties the remaining carbon budget in 2042. We are therefore unable to meet the goal, and give a red rating.
14. LIFE BELOW WATER	• We assessed eutrophication, acidity through CO_2 emissions, and likelihood of achieving universally agreed fisheries management plans • ROW and BRISE and China continue to face huge challenges on the local scale as well as global challenges with acidification, and so receive a red rating. • USA and OECD will solve many of the local challenges, but remain vulnerable to acidification and global fishery challenges, and thus get a yellow rating.
15. LIFE ON LAND	• We assessed forest area, agricultural land, restoration of degraded land, and Red List Index. • BRISE and ROW score low on all indicators and are rated red. • China, OECD and USA are likely to achieve some targets and not others, and are given a yellow rating.
16. PEACE, JUSTICE AND STRONG INSTITUTIONS	• We assessed violent deaths and perception of public sector corruption. • ROW and BRISE score high on both violence and corruption and get a red rating. USA and OECD get a rating of yellow on both targets. • China is on the borderline and gets a yellow rating.
17. PARTNERSHIPS FOR THE GOALS	• We assessed tax revenue and Official Development Assistance (ODA). • For this goal we did not give an overall rating for the regions. We have found two indicators that describe part of the goal, but the goal is very complex and has so many dimensions, that in our opinion these indicators do not provide sufficient information to represent the overall goal.

Table 4.1 Likelihood of reaching each of the 17 SDGs

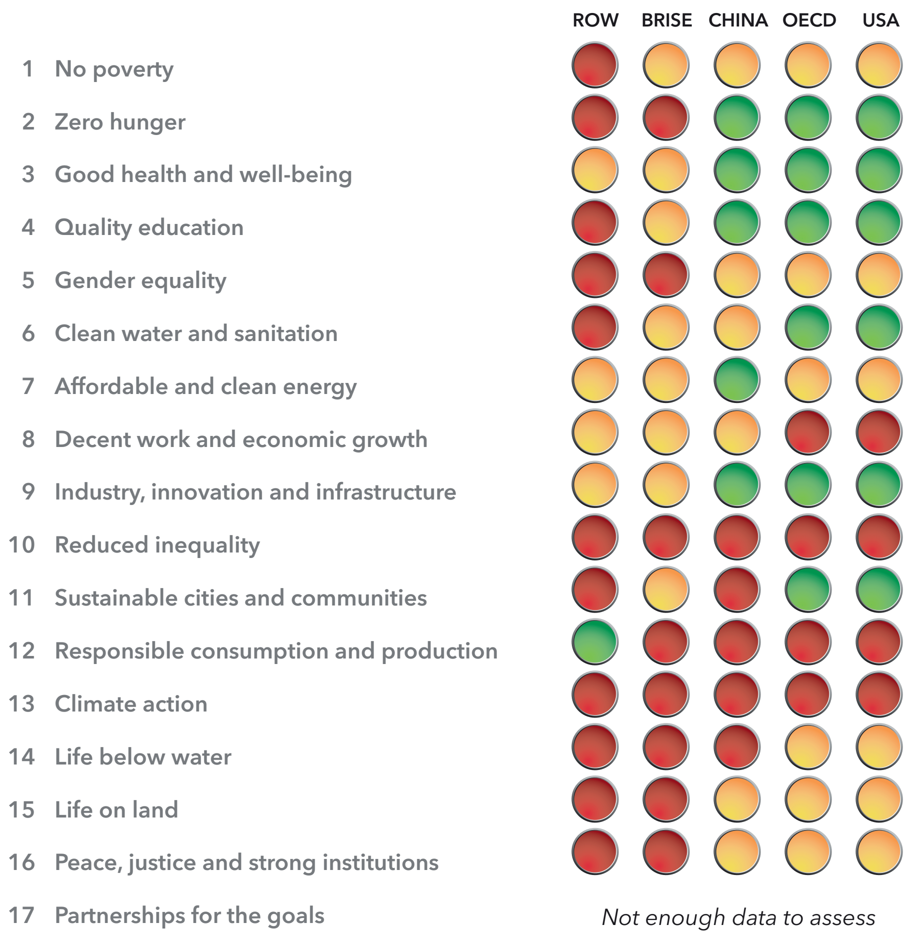


Figure 4.2 Likelihood of reaching the SDGs, with regional rating

4.4 DETAILED ASSESSMENT OF EACH OF THE 17 SDGS

In the following pages we devote a double page spread to each of the 17 SDGs, where we give our assessment of the likelihood of the goal being reached, both globally and regionally.

1. Qiciao and Qixi, a pair of giant panda twins, inspect a flag to represent Goal 7, Affordable and Clean Energy, raised at the Chengdu Research Base of Giant Panda Breeding in China, to support the UN Global Goals for Sustainable Development. Credit: Mr. Yuan Tao and Ms. Yan Lu

2. WFP officer Nimdoma Sherpa, raised a flag to represent Goal 2, Zero Hunger, in a remote mountain village in North-West Nepal, to support the UN Global Goals for Sustainable Development. Credit: WFP/Samir Jung Thapa

3. The Dumagat tribe raised a flag to represent Goal 15, Life on Land, in the Marikina Watershed near Manila in the Philippines, to support the UN Global Goals for Sustainable Development. Credit: Jasper Lucena

4. A flag to represent Goal 11, Sustainable Cities and Communities, is raised in Sydney, Australia, to support the UN Global Goals for Sustainable Development. Credit: Shane Thaw

5. Crown Princess Mary of Denmark raised a flag to represent Goal 5, Gender Equality, outside of the Ministry of Foreign Affairs of Denmark in Copenhagen, to support the UN Global Goals for Sustainable Development. Credit: Ulrik Jantzen

All images, courtesy of www.globalgoals.org

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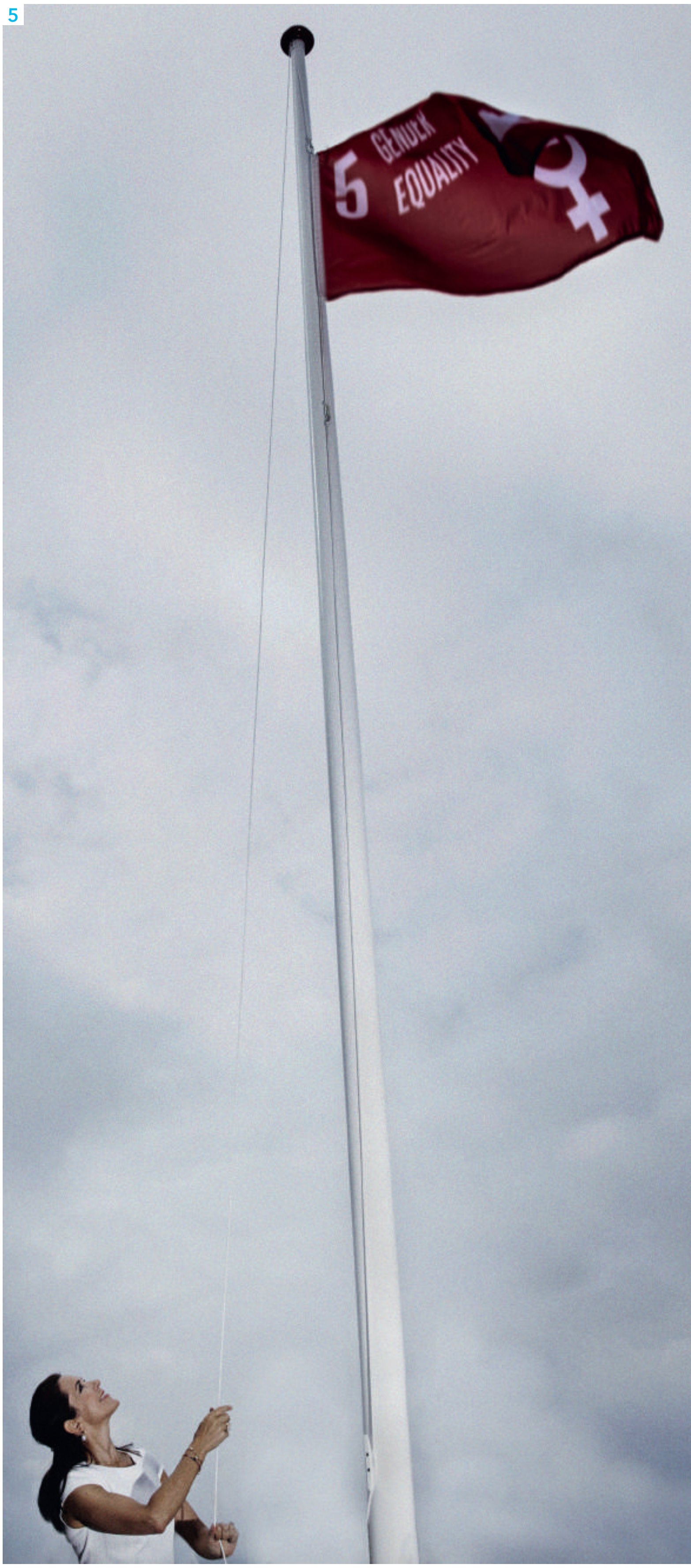
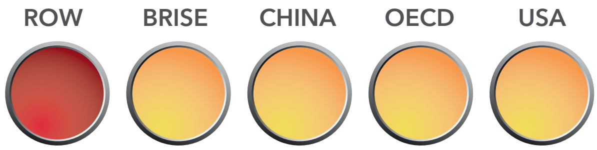


1 NO POVERTY



End poverty in all its forms everywhere

SDG1 on ending poverty sits at the heart of the SDGs. This is the main yardstick by which the successes and failures of the SDGs are likely to be measured, and the principle of leaving no one behind is clearly rooted in this goal. Poverty in all its forms includes extreme poverty and relative poverty that differs between the nations, and also has the multi-dimensional poverty aspect.

MODEL INPUT

Our main model does not give poverty numbers. Economic poverty is correlated with GDP, and the GDP growth/person is forecast to continue, with relatively high figures in the three developing regions. However, growth for China is considerably slower than the last 15 years (see SDG8 for exact figures). The T21 model, show in Figure 4.1.1, forecasts a 25 % reduction in absolute numbers and 33 % in share of population living in extreme poverty. These are nowhere near the target of eradicating extreme poverty.

REGIONAL CONSIDERATIONS

Extreme poverty is mainly an issue for developing countries. The regions in our assessment do not give a sufficient breakdown for a good illustration of the challenge, as both BRISE and ROW, in particular, have huge individual and geographical differences – in their past and in their likely future success of meeting the target on eradication of extreme poverty.

CONCLUSION

High extreme and relative poverty in ROW ensure a red score. OECD and USA have low extreme poverty, but do not succeed in reducing relative poverty, and so score yellow. BRISE and China improve on both relative and extreme poverty, but not enough to have a green overall score. The score is based on assessing economic poverty, as we have little input for scoring multi-dimensional poverty.

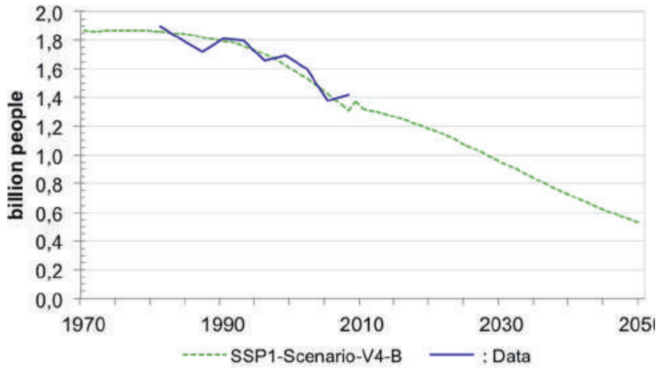


Figure 4.1.1 Number of people in extreme poverty

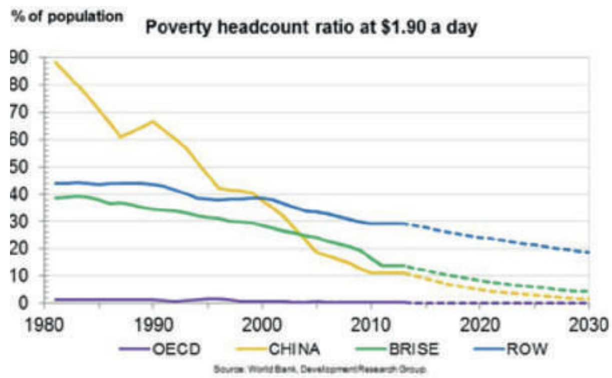


Figure 4.1.2 Poverty headcount at $1.90 a day

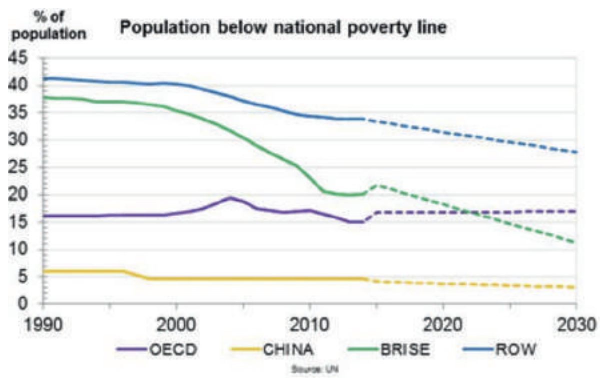


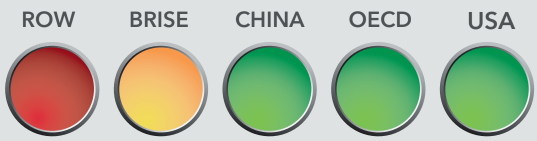
Figure 4.1.3 Population below national poverty line

DOCUMENTATION OF OUR ASSESSMENT

We have chosen to rate the two targets that are quantifiable, with target 1.1 representing extreme or absolute poverty, and target 1.2 representing national or relative poverty.

Target 1.1

By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day.



Indicator chosen

Percentage of population living on less than $1.25 (PPP) per day.

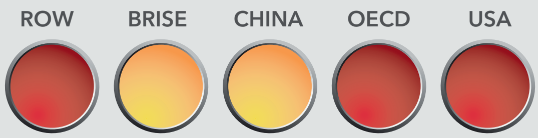
Eradicate poverty has been the most visible of the MDGs, with the goal being to half the number of people living on $1.25 PPP/person-day between 1990 and 2015. The goal was met five years ahead of the 2015 deadline, mainly driven by welfare increases in China, resulting from its strong economic growth.

The goal for the next 15 years is to end extreme poverty for the remaining 800 million people, and is likely to be much harder. Several international studies, including those from the World Bank, have projections of between 3 and 8 % of the people remaining in extreme poverty in 2030, with the vast majority in Sub-Saharan Africa. The threshold for extreme poverty was changed in 2015 from $1.25, 2005 PPP to $1.90, 2011 PPP. The number of poor people remained unchanged using the new definitions (World Bank, 2015), so this does not influence our assessment.

Many developing countries, including large countries like Nigeria, still have over 50 % extreme poverty, and, in some sub-Saharan countries like Madagascar and Zambia, the trend is heading in the wrong direction. As shown in Figure 4.1.2, in ROW the goal is not likely to be met, mainly due to the challenges in Sub-Saharan Africa. The progress in most BRISE countries has been considerable and the region is likely to close more than half of the gap from the current 14 %. India is key to meeting the target in BRISE. In China, the rapid progress is expected to continue, and it is likely to meet the target with less than 5 % share in 2030. However, it should be remembered that the last share is hardest. Absolute poverty is rare in OECD and the USA.

Target 1.2

By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions.



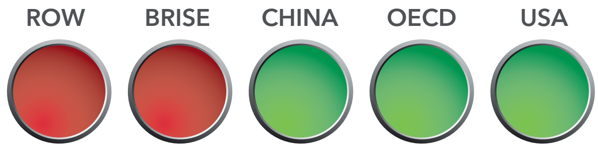
Indicator chosen

Percentage of population living below national poverty line.

Poverty in all its dimensions goes beyond economic poverty, however, for this target, we consider the indicator of percentage of population living below the national poverty lines.

Unlike extreme poverty, relative poverty is an important issue for the developed countries also. In OECD countries national poverty rates of around 10 % are common, and statistics for OECD show little improvements over the last 10 years, as illustrated in Figure 4.1.3. USA figures are not included in the World Bank data, but data from the US Census Bureau (2015) show flat or increasing relative poverty in US over the last decades. With increased (USA) and stable (OECD) inequalities shown by the Palma ratio (see SDG10), neither the USA nor OECD will meet the target. China's national poverty line of 2300 yuan/person-year is just above the absolute poverty line from World Bank (Beijing Review, 2015). We forecast China to have a yearly economic average growth of 3.7 %/person to 2030; this is significantly lower than in the previous 15 years. With the last share of the population more difficult to reach, we assess China likely to reduce share of population below national poverty line, but not by 50 %, hence a yellow rating. For ROW and BRISE, reductions in relative poverty are expected to follow the reductions in absolute poverty, and the rating is as for Target 1.1.

2 ZERO HUNGER



End Hunger, achieve food security and improved nutrition and promote sustainable agriculture

SDG2 is, first and foremost, about ending hunger. Food security, nutrition, and agriculture are other key aspects of the goal. Unlike most other goals, we have chosen to rate the achievement of this goal based on only one indicator, representing whether we succeed in ending hunger.

MODEL INPUT

The forecast gives relevant input to this SDG. Key parameters like food production and cultivated land are included in our model. The model also gives forecasts for GDP/person, which is correlated with hunger. The T21 model, but not our main model, forecasts the number of people living on less than $1.25/day (illustrated under SDG1 in Figure 4.1.1), which is strongly correlated with hunger.

REGIONAL CONSIDERATIONS

If we had chosen a wider perspective on this goal than just ending hunger, the developed countries would also have challenges, because nutrition, including obesity, and sustainable agriculture are areas with significant challenges globally. With the focus only on ending hunger, this is mainly an issue for developing countries.

CONCLUSION

With one indicator only, the conclusion on the goal equals the conclusion on target 2.1. Thus, ROW and BRISE get a red rating, and China, OECD, and USA a green rating. The uncertainty is highest for BRISE, which could succeed in reducing hunger sufficiently to get a yellow or green rating.

DOCUMENTATION OF OUR ASSESSMENT

To achieve our overall assessment for this SDG, we rate only one target, that being 2.1 on ending hunger.

The most reliable parameter for ending hunger is to measure whether everyone has enough to eat, and the best indicator for this is the *Proportion of*

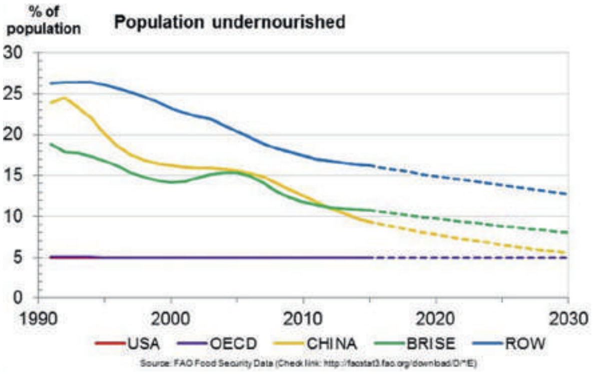


Figure 4.2.1 Proportion of population below minimum level of dietary consumption

> "From a sustainability perspective, I find it difficult not to take environmental and social welfare into account. I realize that environmental and social welfare are much more difficult to assess than hunger and therefore, hunger is the only dimension that can be evaluated at this point in time. However, hunger is the outcome of dynamic feedback relationships with food system activities and food system drivers."

Birgit Kopainsky, UiBergen

population below minimum level of dietary energy consumption. This is also a continuation of an MDG indicator, for which historical data are easily available. Target 2.1 covers more than minimum level of dietary energy consumption, but in our opinion this indicator gives a good proxy for measuring the success of SDG2.

Target 2.1

By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.

Indicator chosen

Proportion of population below minimum level of dietary energy consumption.

Our model forecasts an 18 % increase in food/person over the coming 15 years. Even more relevant is the prediction of a 32 % increase in BRISE and a 20 % increase in ROW, which are where the majority of hungry people live. Table 4.2.1 illustrates historical figures and our forecast.

The food produced does not say anything of distribution and import/export. and thus only provides input to the indicator. However, both India (in BRISE) and the most populous ROW countries that have most people below the minimum level of dietary consumption are net food importers. Hence, increased food production is likely to result in fewer people hungry.

The model also gives figures for GDP, and, over the next 15 years, we expect an annual GDP growth/person of 3.6 % in ROW and 3.4 % in BRISE. For ROW this is significantly higher than the 2.5 % experienced in the last 15 years. We can expect that the increased output – given a relatively flat expectation on income distribution (addressed in SDG10) for the poorest people - will ensure more food. Based on the above, we assume a downward trend that is 1.5 times faster (in percentage change per year) than in the previous 15-year period, mainly based on the increasing food production forecasts.

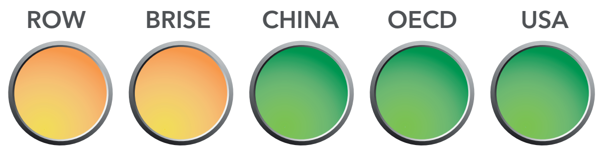
Figure 4.2.1 shows the historical figures for proportion of population below minimum level of dietary consumption for the last 25 years, and the forecast for the next 15. For this indicator, UN data are presented as "5" when the value is 5 or less, hence the graph looks somewhat strange with a lower cap on 5. Our estimate is that towards 2030, China will continue its strong downward trend, and achieve the goal of having less than 5 % of its population living below the minimum level of dietary consumption in 2030. BRISE will continue its downward trend, and we forecast a decrease from 11 to 8 %, and ROW will also continue its trend, with a forecast reduction from 16 % to 13 %.

With this, neither BRISE nor ROW will achieve the goal, nor will they close 50 % of the initial gap; hence they get a red rating despite their forecast progress.

Region	1990	1995	2000	2005	2010	e2015	f2020	f2025	f2030
USA	2,7	2,5	2,9	2,9	3,1	3,2	3,3	3,4	3,5
OECD	1,3	1,2	1,2	1,2	1,2	1,2	1,3	1,3	1,4
China	0,8	0,8	0,9	1,0	1,1	1,2	1,3	1,4	1,4
BRISE	0,8	0,7	0,7	0,8	0,8	0,9	0,9	1,0	1,1
ROW	0,5	0,6	0,6	0,7	0,7	0,6	0,7	0,7	0,8

Table B2.1 – Food produced [tons/person-year]

3 GOOD HEALTH AND WELL-BEING



Ensure healthy lives and promote well-being for all at all ages

After the creation of the MDGs, there has been tremendous progress in reducing child mortality, improving maternal health, and tackling HIV/AIDS, tuberculosis, malaria, and other diseases. This ambition continues with SDG3, which aspires to promote the best possible health and wellbeing for all. Four targets were selected for assessment of the third SDG, as these have the most comprehensive datasets. These targets addressed a reduction in the global maternity mortality ratio; an end to preventable deaths of newborns and children under 5-years of age, and an end to the AIDS epidemics; and a one third reduction of premature mortality from non-communicable diseases.

MODEL INPUT

The forecast gives relevant input to this SDG. Key parameters include under 5-years of age mortality rate per 1,000 live births. The T21 model forecasts the number of under-5 mortality to decrease substantially; however, the world as a whole will not reach the target of under-5 mortality of 25 or lower per 1,000 live births by 2030, as illustrated in Figure 4.3.1. Figure 4.3.1 Forecasted under-5 mortality.

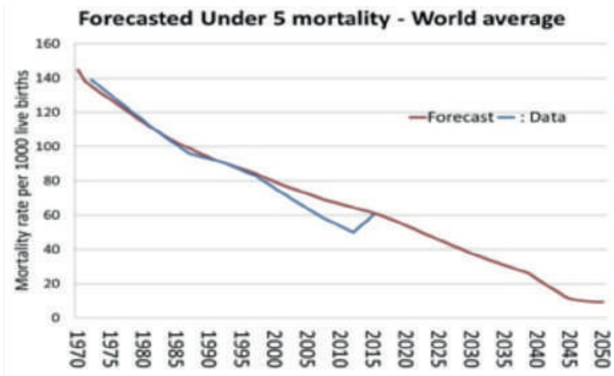


Figure 4.3.1 Forecasted under-5 mortality

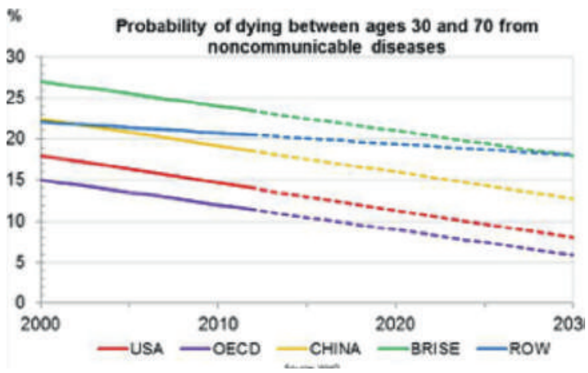


Figure 4.3.2. Probability of dying between 30 and 70 years from non-communicable diseases

REGIONAL CONSIDERATIONS

Despite great achievements in the field, AIDS is still the leading cause of death among adolescents in Sub-Saharan Africa and 22 million people living with HIV do not have access to life-saving antiretroviral therapy (UNDP, 2015a). On a global scale, non-communicable diseases (NCDs), mainly cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes represent 63 % of all deaths. In all developing regions, the maternal mortality ratio has been nearly halved in the past 25 years. However, only 51 % of countries supply data on causes of maternal death. (UNDP, 2015a).

CONCLUSIONS

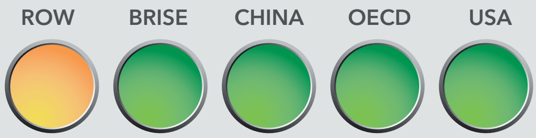
The forecasts for USA and OECD are rated green for all targets. With the exception of premature mortality from NCD, China is also rated green for overall goal achievement. The forecast for BRISE is green, yellow, and red for the four targets, and ROW has been rated yellow and red. Both regions get a yellow rating in total, with ROW close to a red rating. There are significant uncertainties in our assessments.

DOCUMENTATION OF OUR ASSESSMENT

We assess maternal and under-5 mortality, the population living with HIV, and the probability of dying from NCD for SDG3.

Target 3.1

By 2030, reduce the global maternal mortality ratio to less than 70 per 100,000 live births.



Indicator chosen

Maternal mortality ratio per 100,000 per live births.

Maternal mortality rates indirectly reflect the status of healthcare for all. Despite longstanding international commitments to reducing maternal mortality, it remains substantial in BRISE and ROW. New technological developments, such as mobile health, that enables access to healthcare in remote and poor areas, contribute to our assessment that BRISE will succeed in reaching the target, while ROW will close more than 50 % of the initial gap. OECD, USA, and China are already at the target today.

Target 3.2

By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1,000 live births.

Indicator chosen

Infant mortality ratio per 100,000 per live births.

Child mortality is closely linked to target 3.1 on improving maternal health. Most countries have come a long way in reducing child mortality and our forecast shows that all, except ROW, will achieve the target of under-5 mortality to below 25 per 1,000 live births. ROW is likely to close 50 % of the gap, and is therefore rated as yellow.

After the MDGs, there was a great push towards curtailing AIDS in developing countries. The latest available data show that the overall trend of HIV infection is generally decreasing, but also that there are many newly infected, as well as many undetected, cases. This means that many still die from AIDS-related causes. This is particularly true in sub-Saharan Africa

Target 3.3

By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.

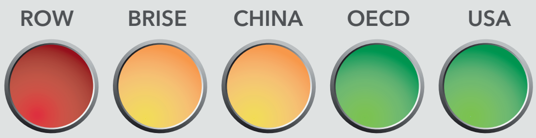
Indicator chosen

People living with HIV, aged 15-49 years, percentage.

and in various populations at high risk of HIV. (Lancet, 2015). "End epidemics" are difficult to quantify, but we use a threshold of 0.5 % of the population as a quantifiable threshold here. Although the numbers are decreasing, ROW and BRISE are unlikely to close 50 % of the gap to where they should be in 2030. Some literature shows an increase in HIV/AIDS infections in OECD countries due to the financial crisis. However this will not affect the overall rating, which remains green.

Target 3.4

By 2030, reduce by one third premature mortality from non-communicable diseases (NCD) through prevention and treatment and promote mental health and well-being.

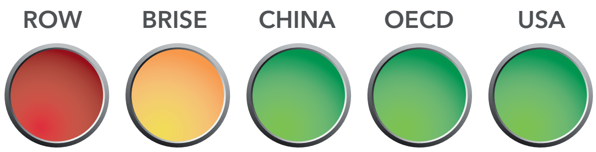


Indicator chosen

The probability of dying between ages 30 and 70 years from the 4 main NCDs - cancer, diabetes mellitus, cardiovascular disease, chronic respiratory disease.

All age groups and regions are affected by NCDs. Today, of the premature deaths, 82 % occurred in low- and middle-income countries. In our assessment, reducing the number of premature deaths by 1/6th will give a yellow rating. Thus, ROW will be red, China and BRISE are on track for a yellow rating, while OECD and USA are likely to meet the target. This is illustrated in Figure 4.3.2.

4 QUALITY EDUCATION



Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

SDG4 is key to preparing the global population for the modern world. The most crucial part of it is to ensure education, and the key principle of leaving no one behind is kept in focus through the inclusive and equitable principles. Continued lifelong learning opportunities are another part of the goal, going beyond basic education.

MODEL INPUT

Continued high focus on education is a primary assumption behind our model's fertility and thus population forecasts.

The T21 model run with our assumptions gives quantitative results on global literacy rates, forecast to increase from 88 % today to 92 % in 2030. This is illustrated in Figure 4.4.1, and the data are not regionalized.

REGIONAL CONSIDERATIONS

The quality dimension of education is very hard to measure, but inclusive and equitable education is generally in place in the developed world, and also mostly in place in China by 2030. Hence, the main challenge towards 2030 is in BRISE and ROW.

CONCLUSIONS

China, OECD, and USA score green on all three indicators. BRISE scores red, yellow, and green on the three indicators, and gets a yellow score in total. ROW has two red and one yellow score and gets a red score in total.

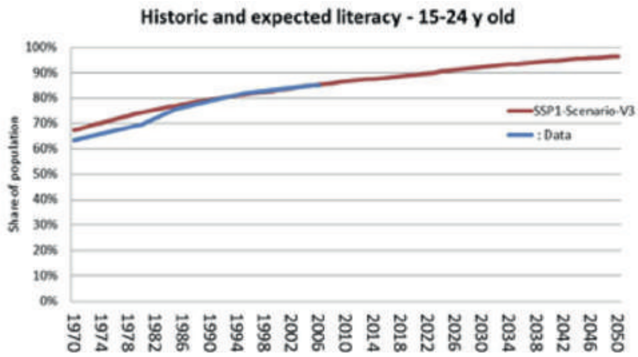


Figure 4.4.1 Global literacy rates

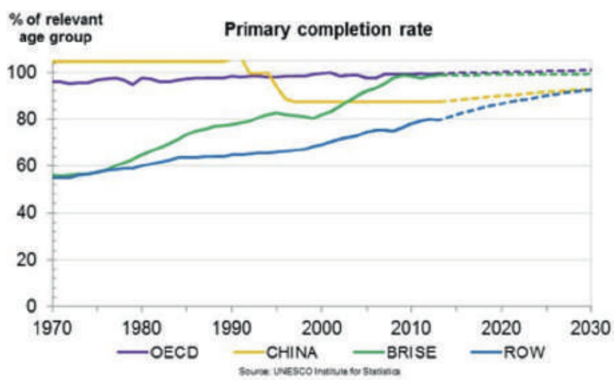


Figure 4.4.2 Primary school completion rate rate

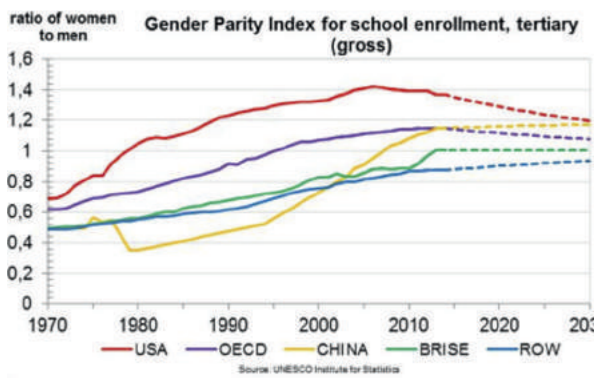


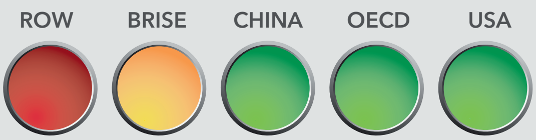
Figure 4.4.3Gender parity index for tertiary school enrolmentenrollment

DOCUMENTATION OF OUR ASSESSMENT

We included three targets in our assessment; basic education; equal access to higher education; and literacy.

Target 4.1

By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes.



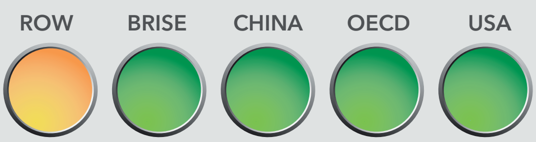
Indicators chosen

Primary completion rate.
Lower secondary completion rate.

Completing primary education will ensure basic literacy and numeracy, while secondary education will be a step towards ensuring lifelong learning opportunities. USA, OECD, and China have high completion rates, although data quality is a key challenge for this indicator, both in developing and developed countries. Data for primary completion are illustrated in Figure 4.4.2. There is universal progress on both primary and secondary completion rates, with BRISE having 91 % and 76 % respectively, to date, and ROW 73 % and 46 %. With the expected improvements, ROW cannot fill the gap, and BRISE is likely to meet the target for primary education only.

Target 4.3

By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.



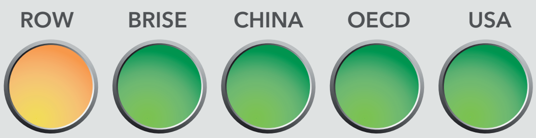
Indicator chosen

Gender Parity Index in tertiary level enrolment.

The main issue addressed by this indicator is that women do not have the same opportunities as men. Hence, more women being enrolled than men is rarely an issue of access. There are significant country variations in ROW, but the average trend is good, with the ratio of females increasing from 69 % to 81% over the last 15 years, as illustrated in Figure 4.4.3. This is expected to continue to above 90 %, but not fast enough to meet the target. For BRISE, the ratio today is at 93 % and increasing, while the other three regions are above 100 %. We give those four regions green rating.

Target 4.6

By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy.

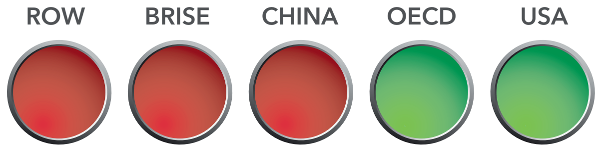


Indicator chosen

Literacy rates of 15-24 years old.

Literacy rates for youth will, over time, ensure full literacy for the entire population, and is a key indicator. Literacy rate is close to 100 % in USA, OECD, and China and will continue to be so. Literacy in BRISE has stabilized at around 90 % in recent years, with India having lower figures and pulling the average down. Literacy in ROW has improved slowly, from 74 % to 78 %, over the last 15 years, and many LDCs still have literacy rates below 50 %. Some countries, mostly in ROW, but notably also India, have poorer literacy rates in women than men.

5 GENDER EQUALITY



Achieve gender equality and empower all women and girls

This SDG covers a wide number of targets for gender equality, including education, labour participation, and ending harmful practices.

MODEL INPUT

The DNV GL model does not provide input for assessing SDG5 directly. Nevertheless, our model links gender equality, education, and reduced population growth.

REGIONAL CONSIDERATIONS

Basic education is an essential platform for gender equality and the gender equality indicator for this is high or improving around the world.

The assessment on equality measures in working life is less rosy, and improvements on these are really slow. Gender wage gaps are actually increasing, even where education goals are achieved, like in China.

Equality in working life settings is weak in all regions. ROW and BRISE have considerable challenges with early marriage.

CONCLUSIONS

Gender equality will continue to be a challenge across the world, also in 2030. USA and OECD do not achieve the goal, despite equality having been on the agenda for a long time, as the main challenges remain in gender parity within working life. ROW, BRISE, and China get red ratings as they are failing to meet most indicators.

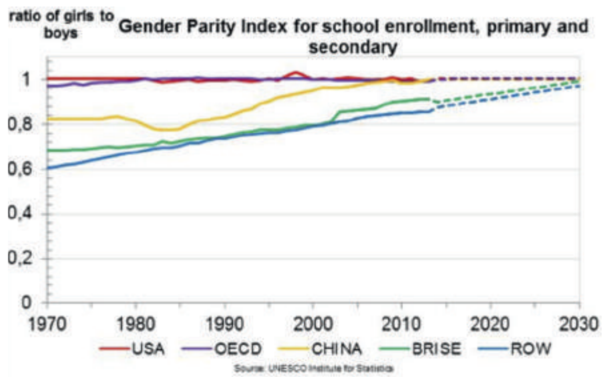


Figure 4.5.1 Gender parity index for school enrollment

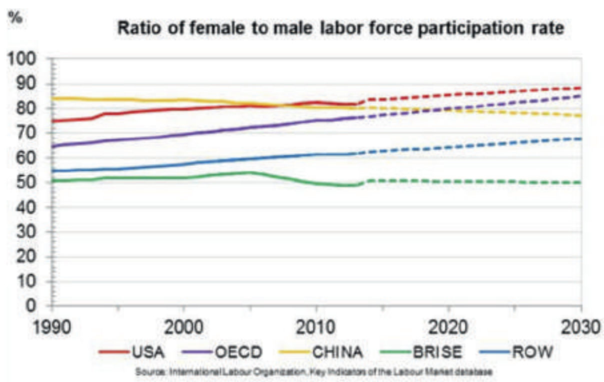


Figure 4.5.2 Ratio of male to female labor force participation rate

"I was surprised that your forecast for achievement of SDG #5 was so pessimistic, as I myself tend to assume that most indicators of women's status are improving on average worldwide."

Robert Engelmann, Worldwatch Institute

DOCUMENTATION OF OUR ASSESSMENT

For SDG5 we assess gender differences in primary and secondary school completion, women aged 18-24 years that were married or in a union, ratio of women to men in labour force participation, and the gender gap in wages.

Target 5.1

End all forms of discrimination against women and girls everywhere.

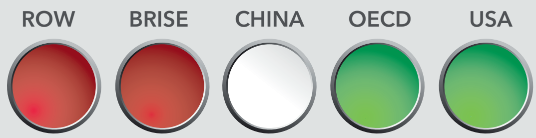
Indicator chosen

Primary school completion rates for girls and boys.
Secondary school completion rates for girls and boys.

The ratio of girls versus boys that have access to education is a good indicator for measuring gender equality. However, this says nothing about total school enrolment (see SDG4). For China, USA, and OECD the goal for this indicator is already achieved. BRISE countries are on track and should also close the gap by 2030, and the same goes for ROW.

Target 5.3

Eliminate all harmful practices, such as child-, early- and forced- marriage and female genital mutilations.



Indicator chosen

Percentage of women aged 20-24 who were married or in a union before age 18.

OECD and USA have an insignificant share of marriages before 18 years and this means a green rating. Data are not available for China. BRISE and ROW have a long way to go. The issue is considered heavily linked to cultural practices and we cannot foresee that half the gap will be covered by 2030. For ROW and BRISE there are also strong challenges with other harmful practices, e.g., female infanticide in certain countries. Many changes will be needed before all harmful practices are eliminated.

Target 5.5

Ensure woman's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic, and public life.

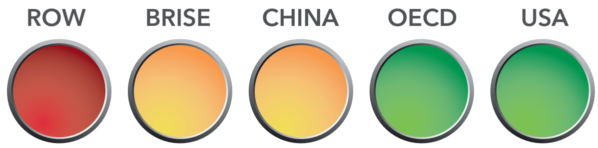
Indicators chosen

1. Ratio of female to male labor force participation rate.
2. Gender gap in wages by sector of economic activity.

Labour force participation: To have full participation, the goal is 100 %, with 95 % as the lower limit for green. China has a relatively high ratio today, but this may reduce towards 2030. Also BRISE is on a downward trend, driven by Russia and India. USA, OECD, and ROW are all moving in the right direction, but none of them are on a trend to close half the gap. Hence, they all get a red rating.

Gender gap in wages: To have equal opportunities, the goal is 0 % difference, with 5 % difference as the lower limit for green. Statistics show that USA and OECD are improving, but are not on a trend to close half of today's gap by 2030. We have data for selected ROW and BRISE countries that indicate no improvement, and we chose to use that as representative for the regions. China's gender gap in wages has increased over the last decades, and no trend indicates a drastic reduction to 2030 (Comparative Economics, 2014).

6 CLEAN WATER AND SANITATION



Ensure availability and sustainable management of water and sanitation for all

SDG6 is about access to, and quality of, water and sanitation, but also the sustainability aspects of how we use water and manage water quality. While access is mainly an issue for developing countries, the sustainability aspects are key for all.

MODEL INPUT

The model forecast informing this SDG is limited. There is a strong correlation between GDP and availability of safe water and sanitation, and we expect the strongest GDP growth for ROW, indicating further improvement. We also know that climate impact, increasing due to GHG emissions, will impact water scarcity. However, the effect is not quantified in our model.

REGIONAL CONSIDERATIONS

The main challenge for access remains in the poorer developing countries, particularly in rural areas. Within the first target that aims for universal and equitable access to safe and affordable drinking water to all, significant gaps remain. Sanitation is less developed than drinking water, and the same geographical pattern is seen as for safe water scarcity. The situation is likely to improve, but not disappear over the next 15 years.

Water sustainability is an issue in large parts of the world, correlated with precipitation patterns, but not well correlated with normal developing -developed country status.

CONCLUSION

ROW gets a red rating, with significant challenges in both water and sanitation. BRISE and China both get yellow ratings, but with China on the borderline to achieving a green rating. USA and OECD score green.

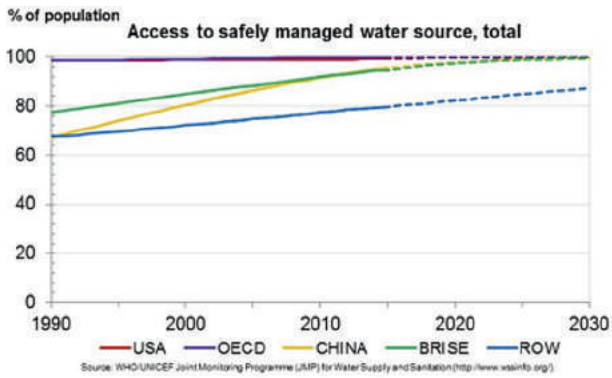


Figure 4.6.1 Percentage of population using safely managed water services

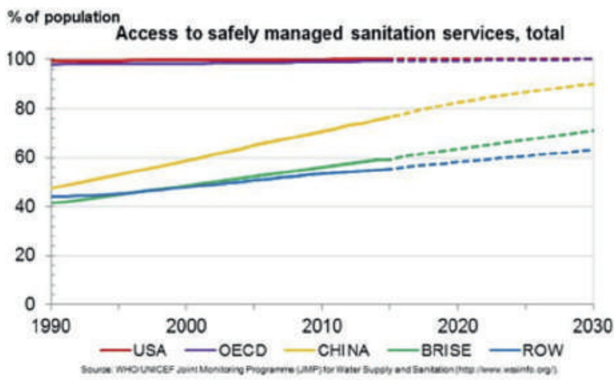


Figure 4.6.2 Percentage of population using safely managed sanitation services

> "My feeling is that we can be more optimistic. Technology (desalination, storage) hold some promises, and the investment in some poor geographical areas is increasing."
>
> Harald Siem, Norwegian Institute of Public Health

DOCUMENTATION OF OUR ASSESSMENT

To achieve our overall assessment, we quantified and rated three of the SDG targets, two of them concerned with access, the third on sanitation. Target 6.3 on pollution is highly relevant, but hard to quantify and provide trends.

Target 6.1

By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

ROW BRISE CHINA OECD USA

Indicator chosen

Percentage of population using safely managed water services, by urban/rural.

There has been significant progress on this indicator in recent decades, and also several of the least developed countries report good results on this indicator. BRISE and China has 93 % and 95 % achievement today and should reach the target, while ROW is today at 75 % (68 % in rural areas and 85 % in urban areas) and, although they are improving, it is, as illustrated on Figure 4.6.1, not likely to be fast enough to achieve the goal. The urbanization trend seen in recent decades will continue and influence this indicator, as access to safe water is generally easier in urban areas than rural areas. Progress is also expected on storage and, in some areas, desalination, but increasing amounts of flooding can worsen the situation, at least temporarily.

Target 6.2

By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

ROW BRISE CHINA OECD USA

Indicator chosen

Percentage of population using safely managed sanitation services, by urban/rural.

Access to sanitation is generally lower than access to water services all over the developing world. Although progress is seen almost globally, the progress is far too slow to meet the target in many developing countries. The urban population generally has better access than the rural population, but slum areas in cities remain a major challenge (ref. also SDG11). As can be seen in Figure 6.2, the current achievements and progress in ROW and BRISE are not sufficient to meet the goal, and, in rural areas in these two regions, less than half of the population currently meets the target. China is not likely to meet the target, but should close half the gap from today to 2030. New technologies in treatment, e.g. photocells and light, and recycling sewage for profit, give a potential upside in our forecast.

Target 6.4

By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

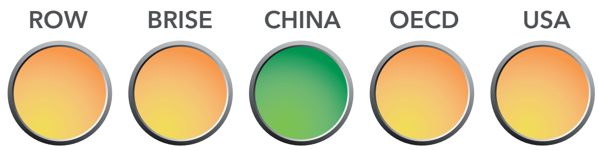
ROW BRISE CHINA OECD USA

Indicator chosen

Proportion of total water resources used.

Measuring water withdrawal is complicated, but is included to reflect that SDG6 is not only about access, but also about sustainable water use. The indicator on proportion of water resources used illustrates where there is abundant water and where water is scarce. The challenges with use of water resources are not well correlated with GDP, but are obviously closely connected to climate zones and normal rain patterns, that are, however, already influenced by climate change. Colour-coding therefore reflects that all regions face challenges in parts of the region.

7 AFFORDABLE AND CLEAN ENERGY



Ensure access to affordable, reliable, sustainable and modern energy for all

We understand this goal partly addresses world-wide access to energy (affordable, reliable), and partly to its global (sustainable) and local (modern, i.e. non-polluting) environmental footprint. Energy is a key factor for ensuring prosperous economic development, and so access to energy is critical for increased wellbeing of poorer nations. The backdrop for this goal is that parts of the world's population today suffer due to lack of access to electricity. Many LDCs use little energy, and the little that they use is mainly served by burning locally available wood in open fires. This is problematic because it contributes to deforestation, which in turn contributes to climate change and desertification. In addition, pollutant soot represents a major health hazard, causing respiratory diseases.

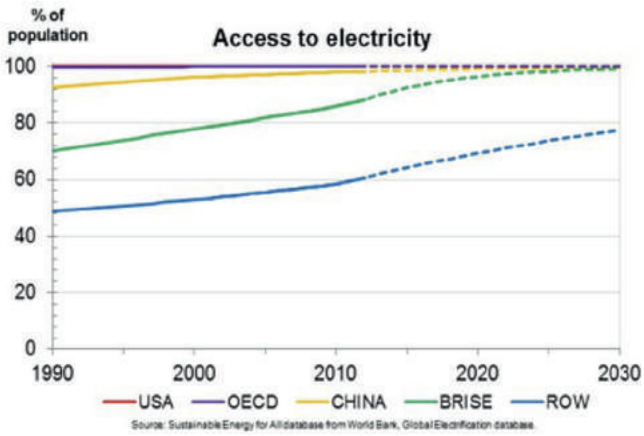


Figure 4.7.1 Access to electricity

MODEL INPUT

The model contains information to the three targets of SDG7 and is derived from populations in the various regions, the productivity growth, changes in energy intensity, and changes in the energy mix. The model builds on extensive analysis of past trends and their interactions, economic growth, energy intensity, and de-carbonization.

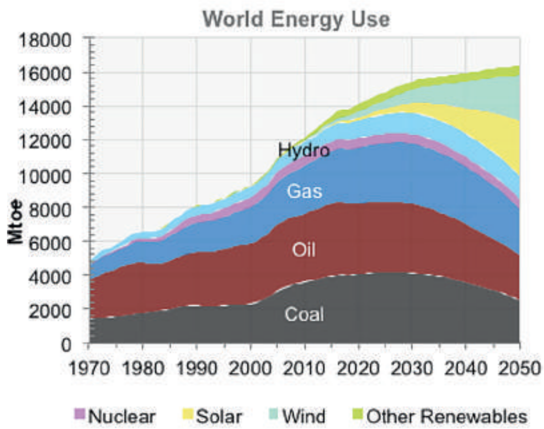


Figure 4.7.2 World Energy use

REGIONAL CONSIDERATIONS

While the environmental footprint is a major challenge for all regions, poor energy access is mainly an issue for developing nations. We consider that the continued and enormous appetite for energy in USA is a sign that it fails to fulfil the goal's demand for "modern" energy.

CONCLUSION

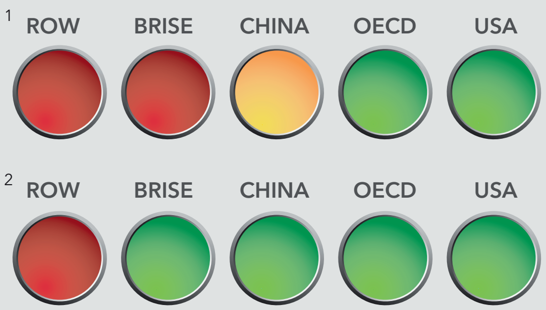
China scores high on all indicators and gets a green rating. All other regions score low on some indicators and high on others, and so achieve yellow ratings.

DOCUMENTATION OF OUR ASSESSMENT

We assess energy used and access to electricity, renewable energy share, and decrease in energy intensity for SDG7.

Target 7.1

By 2030, ensure universal access to affordable, reliable and modern energy services.



Indicators chosen

1. Energy used per person, % of OECD.
2. Access to electricity % of population.

Energy used per person: The OECD average ensures sufficient energy availability; energy shortages are not a major hindrance to economic development or wellbeing of inhabitants. By 2030, China's energy use per person grows, and is about 90 % of OECD's, while USA declines even faster than OECD's, but remains over 50 % higher. For USA, we considered a red rating as the electricity use is very high, but as the goal focuses on access rather than sustainability, we left it green. ROW is about 25 % and BRISE almost 50 % of the OECD yardstick in 2030.

Access to electricity: As indicated in Figure 4.7.1, only ROW falls far behind on this indicator, but it must be noted that within BRISE there is major uncertainty regarding India's future spread of power through its villages.

Target 7.2

By 2030, increase substantially the share of renewable energy in the global energy mix.

Indicator chosen

Achievement of doubling of Renewable energy share form 2015.

Here, we have translated this global target into separate regional targets where significant is set to at least doubling the share of renewables (from 8-17 % to 16-34 %, depending on region today). Only ROW, China and USA achieve this target in our forecast. It is interesting to note that OECD is the renewables champion throughout the period, but starting with a high share of renewable energy (17 %), the 34 % target is not met when it achieves a 29 % share in 2030. The model output on world energy use and energy mix is illustrated in Figure 4.7.2.

Target 7.3

By 2030, double the global rate of improvement in energy efficienc.

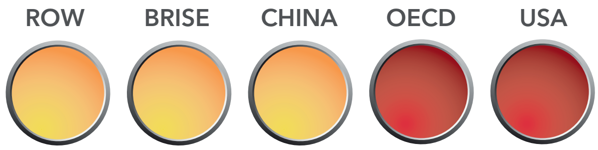
Indicator chosen

Average decrease in GDP's energy intensity 2025-2030, compared to its 2010-2015 level.

We define this target as one where regional annual reductions in energy intensity levels are doubled from today (the world average in the last five years was -0.88 %/y, and is forecast to be -1.83%/y for 2025-2030). Since this target is about improvements, China gets a much "easier" job, as it starts from a period of very modest reductions in energy intensity, while OECD and USA already are on a quite steep downward trend in energy, and will not be able to double the annual improvement.

> "I think you are too pessimistic in your forecast. All the needed technology is available, and especially energy efficiency and better transport solutions will reduce the need for some of the difficult investments. The main challenge is the will to act, which is difficult to predict. If the will is there, I am confident that all targets you discuss can be met in all regions."
>
> Karen Sund, Sund Energy

8 DECENT WORK AND ECONOMIC GROWTH



Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

SDG8 is a complicated goal that takes into account economic growth, the sustainable aspect of such growth, employment, and the principle of leaving no one behind. Our forecast includes three factors - growth, footprint of said growth, and inclusiveness.

MODEL INPUT

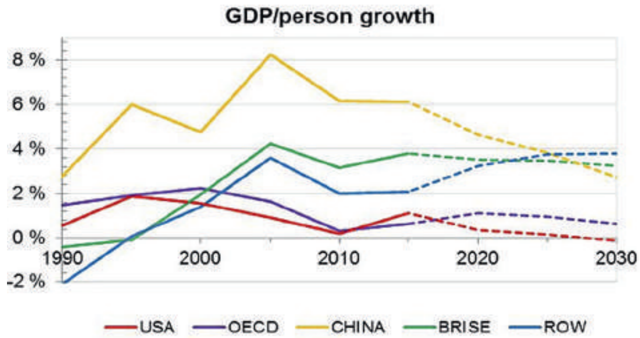
Our model gives direct input to all targets - GDP growth, GDP/person growth, and footprint intensity. The model does not give direct input regarding equality within countries, employment, or education. However, our forecast on Palma ratio is also informed from our model.

REGIONAL CONSIDERATIONS

SDG8 does not have a goal of high economic output, only on the growth rates. In our model, growth rates for the two regions that already have high output per person are expected to be very low, while China and the developing countries that have lower initial output per person, are expected to have much higher growth.

The developing countries succeed better than the developed world on decoupling economic growth from environmental degradation, where significant improvements are expected.

The employment figures are unreliable for large parts of the world and thus challenging to forecast, but the Palma ratio indicates large challenges with distribution all over the world.



Graph 4.8.1 GDP/person growth – historical and forecasted

CONCLUSION

ROW, BRISE, and China succeed with high growth and improved sustainability of this growth, but fail on distribution, and so get a yellow rating. USA and OECD fail both on growth and distribution of growth, but partly succeed on sustainability of growth. They get a red rating.

DOCUMENTATION OF OUR ASSESSMENT

Targets 8.1, 8.4, and 8.5 represent the width of the goal; growth, sustainability of the growth, and inclusiveness.

Target 8.1

Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries.

ROW BRISE CHINA OECD USA

Indicator chosen

Growth rate of GDP per person.

This target focuses solely on economic growth, and could therefore be at odds with the other targets that focus on sustainable and inclusive growth.
Our model gives an average GDP growth of 5.0 %/year and 3.6 %/person-year over the next 15 years for ROW. This is significantly higher than the last 15 years, but significantly less than the target of 7 %/year (that, admittedly, is for least developed countries). Growth targets for other countries are not given in the target. China and BRISE remain with relatively high growth on just below 4 %/year in the coming 15 years, but both with lower growth than the previous period. With no quantitative benchmark, our assessment is subjective, but we give yellow ratings to the three regions that will have sustained, quite high economic growth. OECD and USA will have very low growth rates, at less than 1 %/person-year, and thus get red ratings.

Target 8.4

Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption.

ROW BRISE CHINA OECD USA

Indicator chosen

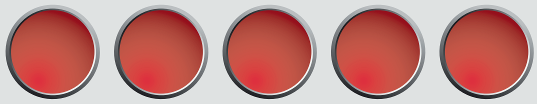
Footprint intensity [gha/USD generated].

Environmental degradation is measured here as non-energy footprint per person, and we measure the footprint in m^2/person and divide it by the global output/person, to obtain a figure for footprint intensity. The footprint per person remains relatively stable in most regions, while GDP grows most in the developing countries. The footprint intensity improves by more than 40 % over the coming 15 years in ROW, BRISE, and China, and by around 30 % in USA and OECD. No quantitative thresholds are given for the target, but we rate the three best regions as green, leaving USA and OECD with yellow.

Target 8.5

By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value.

ROW BRISE CHINA OECD USA

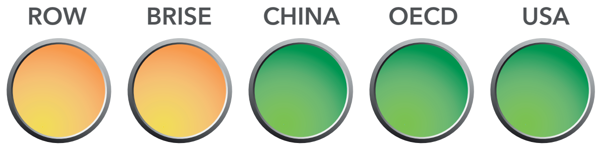


Indicator chosen

Palma Ratio (color coding equal to Goal 10)

Employment statistics can reflect only to some extent whether or not this target is met. In many countries, reliable statistics are lacking, as large shares of the population may not be registered. Also the concept of "decent" work is challenging. Employment in the developed world often follows economic cycles and is difficult to forecast. Therefore, we used the Palma ratio as an indicator for this target; as this is the best indicator for describing how wealth, and thus work, is shared among all people. The assessment of SDG 10 explains Palma ratio in more detail.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE



Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

SDG9 is primarily concerned with fostering and strengthening the engines that build modern society. Knowledge building and information access are considered key elements to facilitate this. Capacity building in R&D and Internet access are important enablers for innovation, and were therefore chosen as key parameters in assessing SDG9. In addition, we have a third parameter concerned with industrial development.

Sustainability and inclusion issues are assessed under SDG8 and not explicitly targeted under SDG9. Nevertheless, a good score on SDG9 contributes strongly to the sustainable transformation of industries.

MODEL INPUT

The model-based forecast provides related data for this SDG, notably GDP/capita and investment spending. T21 addresses hunger and poverty used to assess the downside of Target 9.1. The model does not give input on Internet use and R&D personnel.

REGIONAL CONSIDERATIONS

Many countries perform well on this SDG, but the goal is also interconnected with other goals, e.g. poverty, and ROW and BRISE face a more complex picture. It is impossible for these regions to succeed with this SDG, without solving some of the other challenges simultaneously. Increased competence building is very strong in China. OECD and USA maintain and further develop their good bases.

CONCLUSION

China, USA, and OECD score well on the indicators and are rated green in total. BRISE scores red, yellow, and green on the three indicators, receiving yellow in the overall rating. ROW gets yellow, based on the two indicators that we were able to rate.

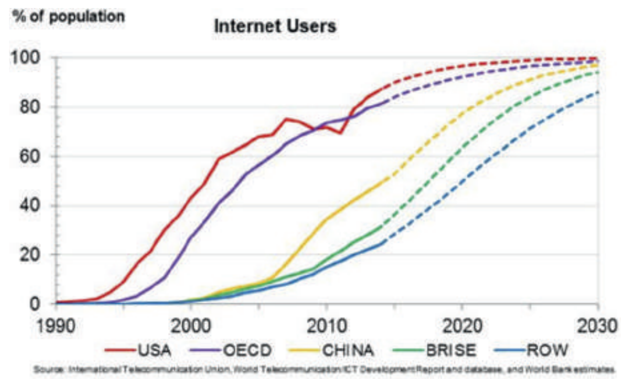


Figure 4.9.1 Rate of internet usage

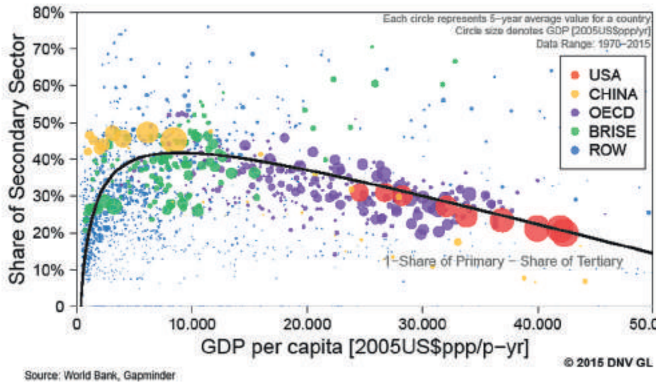


Figure 4.9.2 Share of GDP in secondary sector

DOCUMENTATION OF OUR ASSESSMENT

We included three targets in our assessment: access to infrastructure, innovation, and industrialization.

Target 9.1

Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

ROW BRISE CHINA OECD USA

Indicator chosen

Share of population that are internet users.

The spread of Internet infrastructure has been remarkable, and it is expected that general access should be easily obtained throughout the world by 2030. However, significant shares of the BRISE and ROW populations are forecast to remain in extreme poverty and suffer from hunger. That part of the population has more urgent priorities than Internet access. Hence, we expect the share of Internet users in ROW and BRISE will equal the share of population not suffering from extreme poverty or hunger. Nevertheless, these regions will close more than half the gap to 100 % as illustrated in Figure 4.9.1, meriting a yellow rating. China, USA, and OECD will meet the target and are rated green.

Target 9.2

Promote inclusive and sustainable industrialization, and by 2030, significantly raise industry's share of employment and GDP in line with national circumstances, and double its share in LDCs.

ROW BRISE CHINA OECD USA

N/A N/A N/A

Indicator chosen

Share of GDP coming from industrial sector.

This indicator is considered relevant only for BRISE and ROW, and we consider significant here to mean at least 25 %. The other regions have been through their industrialization phase already, and in our opinion it would be meaningless to target a return to an industrial era for these regions; this is illustrated in Figure 4.9.2. The BRISE region mainly consists of the emerging economies, characterized by the ability to use this trajectory to move towards higher GDP. With their forecasted GDP growth, most will meet the 25 % target. For ROW the picture is even more diverse, with South-East Asian countries achieving it to a high extent, whereas most of the African countries are not forecast to climb high enough. We rate the average as yellow, as most of the ROW population in 2030 will be African. Sub-Saharan Africa alone would have scored red on this indicator.

Target 9.5

Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

ROW BRISE CHINA OECD USA

Indicator chosen

Personnel in R&D (pr. mill habitants).

The ratio of R&D personnel in the workforce/population reflects the capability and willingness to invest today in knowledge for the future. We rate 'significant' here as 'at least 20 % increase over the next 15 years'. China has increased the ratio significantly after year 2000 and this is expected to continue over the next 15 years. OECD and USA have lower growth rates, but they are also on a good trend and are likely to manage. India comes out remarkably low, leading to a red score for BRISE. For the ROW countries, the statistics are scattered and it is difficult to provide a quantitative analysis. Therefore for ROW the score is white, but would probably have been red if a score was given.

10 REDUCED INEQUALITIES

ROW BRISE CHINA OECD USA

Reduce inequality within and among countries

SDG10 requires the adoption of sound policies to empower low-income earners and promote economic inclusion of all regardless of sex, race, or ethnicity. This involves improving regulation and monitoring of financial markets and institutions, encouraging development assistance, and directing investment to regions where the need is greatest. Facilitating the safe migration and mobility of people is also key to bridging the widening divide.

To achieve our overall assessment for this SDG, we rate only one target, Target 10.1 on achieving and sustaining income growth for the bottom 40 % of the population at a rate that is higher than the national average. Most of the other targets involve issues that we have been unable to quantify at present.

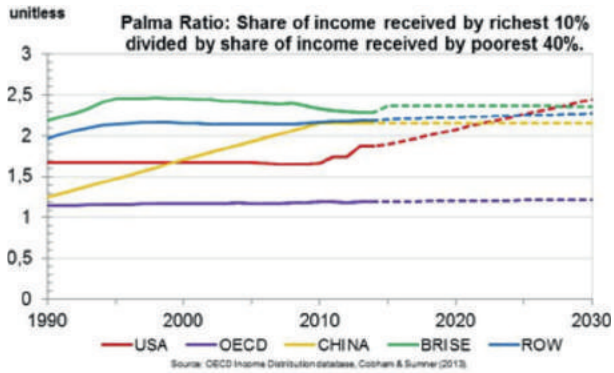


Figure 4.10.1 Palma ratio

MODEL INPUT

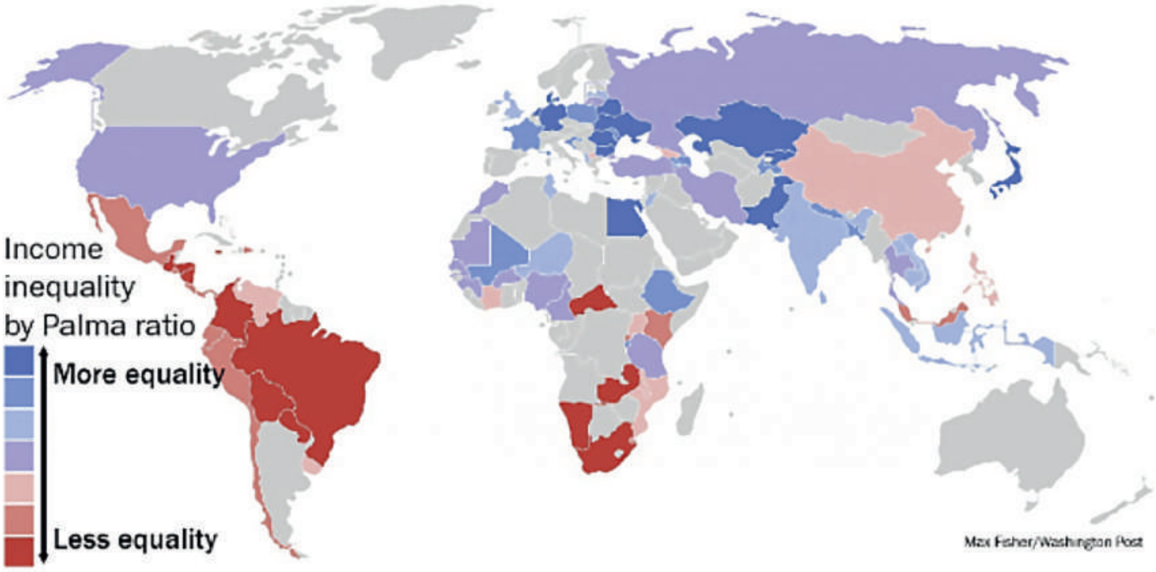
The model does not give input to inequality within countries, and these inequalities do not really correlate with GDP or other factors we forecast. The model does give input on inequality between regions.

REGIONAL CONSIDERATIONS

Figure 4.10.1 shows development in the Palma ratio, while Figure 4.10.2 shows current income inequality around the world, as measured by the Palma ratio. The results are enlightening. There is a wide range of inequality across countries—from Palma ratios of 0.8 in Slovenia and Norway to one of 8.5 in South Africa. For many countries, data are lacking, as the Palma ratio is quite a new indicator. For this reason, quality assurance is done using the Gini coefficient. This can include data from more countries, but assesses the same challenge.

CONCLUSION

With growing inequalities generally worldwide, none of the regions reach the goal, and all get a red rating. There is significant uncertainty in our assessment, and, taking into account that regional differences are likely to reduce, a better rating could have been given.



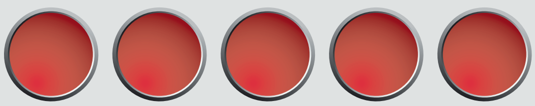
Bluer countries have better income equality. Redder countries are more unequal. Data: CGDev, DIIS. (Max Fisher/The Washington Post)

Figure 4.10.2 Palma ratio illustrated globally (Washington Post, 2013)

Target 10.1

by 2030 progressively achieve and sustain income growth of the bottom 40% of the population at a rate higher than the national average.

ROW BRISE CHINA OECD USA



Indicator chosen

Palma Ratio (HDI).

DOCUMENTATION OF OUR ASSESSMENT

Concerns about inequality focus on the top and bottom ends of the income distribution. The Palma ratio, defined as the ratio of richest 10 % of the population's share of gross national income (GNI) divided by the poorest 40 % of the population's share, seeks to overcome some of the limitations of the widely used Gini Coefficient that fails to take into account changing demographic structure.

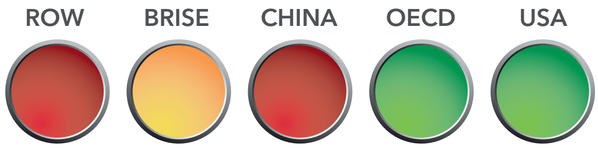
The Palma ratio is in generally highest in developing countries, but with notable exceptions, such as Pakistan, Egypt, Mali, and Ethiopia. Southern Africa and Latin America have the highest values and Europe the lowest, as illustrated on Figure 4.10.2.

Our forecast demonstrates a significant increase in the Palma ratio in USA towards 2030, and almost flat in the other regions. This is confirmed by the similar trend in the Gini coefficient. There are few signs that the trend is about to change, with USA probably demonstrating the largest negative change, and BRISE and ROW showing minor improvements.

The target addresses improvement. We interpret "achieve and sustain" improvements as being at least 25 % improvement in the Palma ratio over the next 15 years being sufficient to score green. As none of the regions is expected to achieve sustained higher growth of the bottom 40 % of the population all regions get a red rating.

The Palma ratio and Gini index measure income inequalities within countries, but they don't measure between countries. Data from our model indicate that regional differences will be reduced, as developing countries grow faster than developed countries. This is of limited help if inequalities within the countries remain.

11 SUSTAINABLE CITIES AND COMMUNITIES



Make cities and human settlements inclusive, safe, resilient and sustainable

With an increasing share of the world's population living in cities, SDG11 is increasingly important. The goal covers a wide range of areas from safety to resilience and sustainability, and also overlaps with other goals. In essence, the goal's "inclusive" wording emphasizes that no one should be left behind. Thus, eliminating slums is key to achieving the goal.

MODEL INPUT

Our models inform this SDG to only a limited extent. There is some input on losses from climate-related disasters, but they do not dominate in our assessment.

There is a correlation between GDP growth and some of the targets here, such as the slum indicator. Hence we expect that with a growing GDP, the positive trend will improve. But the model input cannot quantify the improvement.

REGIONAL CONSIDERATIONS

Many of the areas covered by the SDG are mainly challenging for developing countries, but others are of a more global nature. The developed countries have generally succeeded best within the safety perspective (represented here by air pollution). They also have a greater economic capacity to continue this trend during the next 15 years.

CONCLUSION

ROW is unlikely to ensure the safe wellbeing of the urban population over the coming 15 years and so gets red. China faces huge challenges, both with slums and pollution, and thus also gets red, though this is uncertain, and could also be yellow. BRISE is more diverse and gets a yellow rating, with somewhat better figures on both indicators. OECD and the USA are rated green.

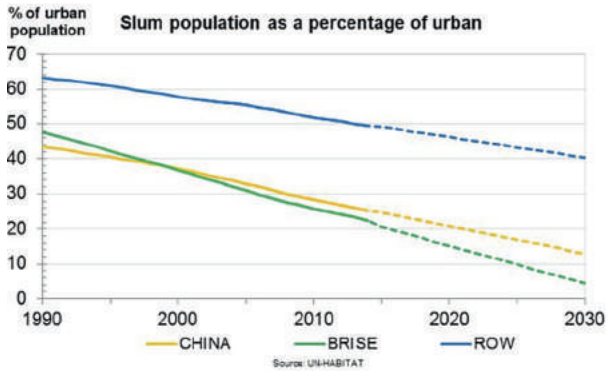


Figure 4.11.1 Slum population as percentage of urban population

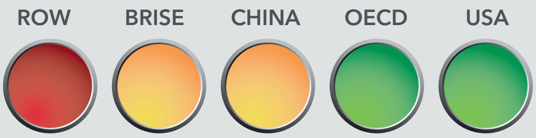
> "The exercise provides clear conclusions that can be easy to communicate, in order to push for pragmatic action in those regions with unsatisfactory performance."
>
> Carlos C Gaitan, LaCiudad Verde

DOCUMENTATION OF OUR ASSESSMENT

Although the goal has many dimensions, we chose only two relatively easily quantifiable indicators and targets in the more detailed assessment. We would have liked to include one on access to public transport, but statistics are not easily available.

Target 11.1

By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.



Indicator chosen

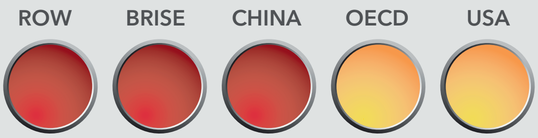
Percentage of urban population living in slums or informal settlements.

Many of the LDCs have a large proportion (50-80 %) of their urban population living in slums, and the challenges to meet the targets seem overwhelming. In many developed countries, and also in ROW, progress has been significant. Increased urbanization and no improvements in differences within the countries (ref. SDG 10) means ROW does not come close to the target, as illustrated in Figure 4.11.1, by heading towards approximately 40 % slums in urban areas in 2030. China is improving, and is on track to close half the gap by 2030. In BRISE, progress has been faster, and with continued strong GDP growth, we expect the current trend will bring BRISE to just above 5 % slums in 2030. The rating for BRISE is close to green.

The targets on water (6.1) and sanitation (6.2) are strongly connected to this goal.

Target 11.6

By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.



Indicator chosen

Mean urban air pollution of particulate matter (PM10 and PM2.5).

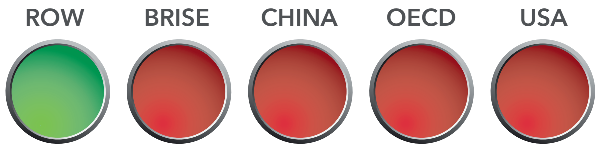
Air pollution is one of the key issues impacting the safety of people living in cities, and it is a challenge not only in the developing world, but also in certain cities in the developed world.

According to WHO standards for particulate matter (PM2.5 and PM10) concentrations, we see that cities all over the world have PM concentrations that are not only high above the air quality guideline of 10 µg/m^3 (PM2.5) / 20 µg/m^3 (PM10), but also high above the upper interim targets of 35 µg/m^3 (PM2.5) / 70 µg/m^3 (PM10) (WHO, 2014a). USA has, in general, the lowest values, with OECD, and Europe in particular, being higher. The three other regions are higher still, and well above threshold.

Measuring air pollution with proper indicators is relatively new, and few long-term trends exist. There are however strong indications that air pollution in larger cities has worsened in the last five years, with only Europe and certain Asia Pacific regions improving (WHO, 2014b). With increasing focus this might improve in the coming 15 years, but the change needed to reach acceptable levels is significant.

> "Although measuring advances in this arena proves to be often difficult, sustainable transport holds the key to significant advances in regards to urban sustainability."
>
> Carlos C Gaitan, La Ciudad Verde

12 RESPONSIBLE CONSUMPTION AND PRODUCTION



Ensure sustainable consumption and production patterns

SDG12 is about ensuring that we produce and consume goods and resources in line with a sustainable ecological footprint. This goal also requires efficient production and supply chains, food security, and a resource-efficient economy.

For this SDG, we have decided to use one indicator, the ecological footprint per person. This does not specifically address any of the targets set in the SDG, but rather enables us to give an assessment at the goal level.

Human activities consume resources and produce waste, and this must be in line with nature's regenerative capacity.

MODEL INPUT

The footprint we use as an indicator for this goal is a direct output from our model.

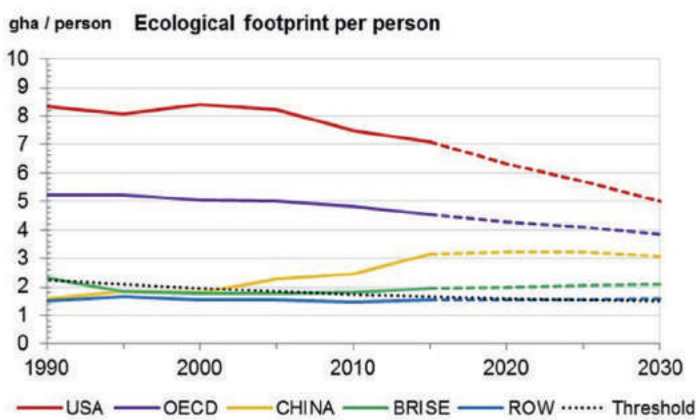


Figure 4.12.1 Ecological footprint per person-year

REGIONAL CONSIDERATIONS

There are significant differences in the various regions of the world, with the largest challenges being the high footprint of the developing world, with US on the top, as shown in Figure 4.12.1.

CONCLUSION

All regions have a 2030 footprint that is above the threshold, with the exception of ROW that is more or less on the threshold, giving it a green rating. There is high uncertainty in the assessment we should give for ROW, and some uncertainty for BRISE. The uncertainty for China, OECD and USA is low.

DOCUMENTATION OF OUR ASSESSMENT

The ecological footprint, developed by Global footprint network (Footprint Network, 2015), measures human demand on the Earth's ecosystem, in terms of the area of biologically productive land and water required to produce the goods consumed and to assimilate the wastes generated. The most commonly reported type of ecological footprint is defined as the area used to support a defined population's consumption. The consumption footprint (in gha – global hectares) includes the area needed to produce the materials consumed and the area needed to absorb the CO_2 emissions. The consumption footprint of a nation is calculated in the National Footprint Accounts as a nation's primary production footprint, plus the footprint of imports, minus the footprint of exports, and is thus, strictly speaking, a footprint of apparent consumption. The ecological footprint is a good measure for assessing whether we are in line with sustainable consumption and production patterns.

The world passed the total bio-capacity threshold in 1975. According to our forecast, illustrated on previous page, all regions except ROW are currently above the threshold and will remain above the threshold in 2030, thus the rating is red. ROW follows the threshold throughout and is thus coloured green.

We have, in addition, tried removing the CO_2 emission from the equation, and the non-energy footprint per person forecasts more positive results, with only OECD and USA being above the threshold, as shown in Table 4.12.1. In other words, energy consumption is the main reason behind the unsustainable ecological footprint. It is, however, incorrect to exclude the energy footprint, hence our rating is based on its inclusion.

Region	1990	1995	2000	2005	2010	e2015	f2020	f2025	f2030
Threshold	2,3	2,1	2,0	1,8	1,7	1,7	1,6	1,5	1,5
NEFPP, World	1,2	1,1	1,1	1,0	1,0	1,0	1,0	0,9	0,9
NEFPP, ROW	1,3	1,2	1,2	1,2	1,1	1,0	1,0	1,0	1,0
NEFPP, BRISE	1,4	1,1	1,1	1,0	1,1	1,0	0,9	0,9	0,9
NEFPP, China	1,0	1,1	1,1	1,1	1,0	1,0	1,0	1,0	1,0
NEFPP, OECD	2,7	2,6	2,5	2,4	2,2	2,2	2,2	2,1	2,1
NEFPP, USA	3,0	2,6	2,8	2,8	2,4	2,4	2,4	2,4	2,3

Table 4.12.1 Non-energy footprint per person [gha/person-year]

13 CLIMATE ACTION

ROW BRISE CHINA OECD USA

Take urgent action to combat climate change and its impacts

SDG13 is both about mitigating and adapting to climate change. Most importantly, and in line with IPCC and common approaches to mitigation, the global temperature increase must be limited to less than 2 °C above pre-industrial temperatures. In order to conclude on whether we succeed in this, a horizon longer than 2030 is needed. Our forecast looks at 2050 and the indicator we chose is accumulated CO_2 emissions from pre-industrial times.

We hold the view that the main measure of success or failure of this goal should be whether we succeed with limiting global warming. While acknowledging that adaptation to climate change impacts is also important, this is not focused upon in our assessment.

MODEL INPUT

The DNV GL model forecasts CO_2 emissions from fossils as being by far the most important factor for determining future GHG emissions and global temperature rise. We forecast that global CO_2 emissions from energy use will peak at around 2025, thereafter reducing, although relatively slowly. The model does not quantify emissions after 2050. Based on these figures, the carbon budget will be emptied in 2042, as illustrated in Figure 4.6.1.

The model assumes that CO_2 emissions from agriculture, forestry, and other land use (AFOLU), as well as those from cement, remain at current global levels of about 3 $GTCO_2$/y each.

REGIONAL CONSIDERATIONS

On the mitigation part of this target, the planet succeeds or fails together. Therefore a regional breakdown is not provided.

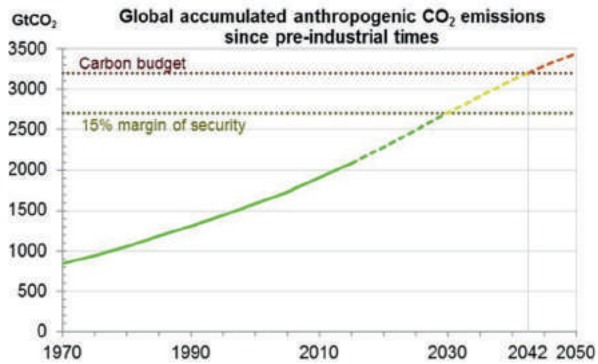


Figure 4.13.1 Global accumulated anthropogenic CO_2 emissions since pre-industrial times

CONCLUSION

Our most likely forecast is that carbon emissions will remain at a level that empties the remaining carbon budget in 2042, and continues thereafter. We are therefore unlikely to meet the goal, and give a red rating. There is little uncertainty in this assessment.

DOCUMENTATION OF OUR ASSESSMENT

For SDG13, a detailed assessment of the targets is not included. The three targets, 13.1, 13.2, and 13.3, have vague formulations, and the key indicators on CO_2 emission from energy use, CO_2 emissions from AFOLU, losses from climate-related natural disasters, and official climate financing from developed countries are the most important factors in determining whether we will meet the goal.

Global CO_2 emissions from energy use will be 102 % of 2015 emissions in 2030, and 67 % of 2015 emissions in 2050 as illustrated in Figure 4.13.2. Based on these figures we cross the carbon budget in 2037, and by 2050, we will have emitted 500 GT more CO_2 than the remaining carbon budget. The model does not quantify emissions after 2050.

In SDG #15, we forecast changes in deforestation indicating that the net decrease may slow, but is not likely to be reversed short term, hence not contributing towards SDG13.

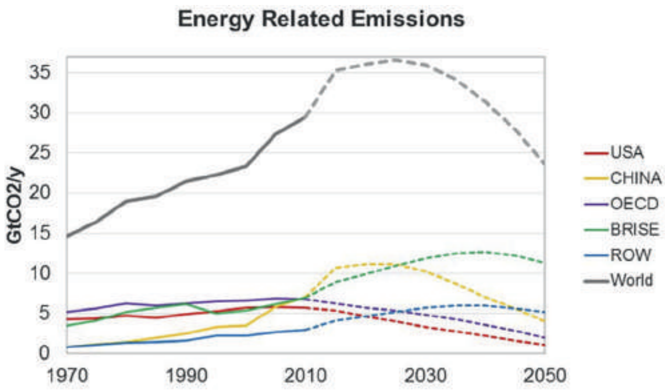


Figure 4.13.2 Energy Related emissions

"DNV-GL's detailed analysis based on rigorous modelling efforts clearly show that unless we bring about rapid and radical change, CO_2 emissions will continue to grow to a level where the 2°C limit of temperature increase by the end of the century relative to pre-industrial levels would be exceeded."

R.K.Pachauri, TERI

14 LIFE BELOW WATER

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

SDG14 is primarily concerned with taking care of the oceans. A secondary goal is to ensure a resource base for continued marine harvesting. Sustainability is squeezed from multiple directions: the degradation of the resource base, a lack of global-scale governance of the drivers of ocean acidification and warming, and a lack of rational local and regional governance of drivers/subsidies for marine resource use.

MODEL INPUT

The model provides CO_2-emissions projections and ppm-values of CO_2-concentration in the atmosphere. These define our acidification forecast. Our model suite does not cover specific marine pollution or fishing.

REGIONAL CONSIDERATIONS

Eutrophication is mainly a local issue. CO_2 emissions will have a global impact, and implications will be visible at a global scale. For coral reefs there will be regional differences, but a constantly negative impact. Coastal fisheries will be well regulated in much of the developed world, but other regions will not regulate in a way that ensures continued high levels of reproduction. Fishing is increasingly a global issue, and ocean fishing also has an impact on the sustainability of local fishing. The stressors act in concert with each other, and the resultant impacts are not easy to predict, either in scale or in geographical terms.

CONCLUSION

ROW, BRISE, and China will continue facing huge challenges on the local scale, as well as global challenges withacidification, and so receive a red rating. USA and OECD will solve many of the local challenges with continued global warming, but remain vulnerable to acidification and global fishery challenges, and hence receive a yellow rating. Uncertainty is high on various factors, except acidification that has low uncertainty.

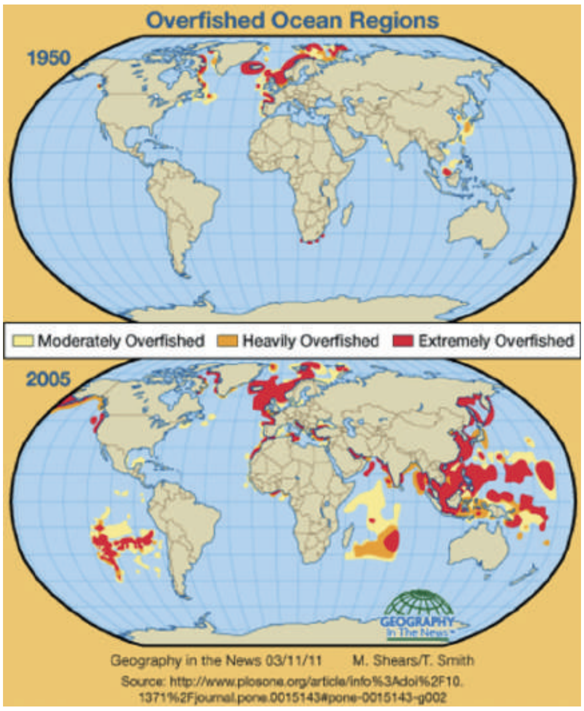


Figure 4.14.1 Overfished ocean regions (National Geographic, 2013)

> "We will need to become a lot smarter and more sophisticated to properly manage marine resources."

Kevin Noone, Swedish Secretariat for Environmental Earth System Sciences

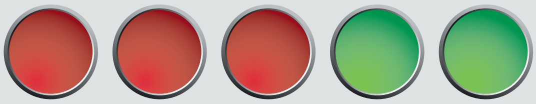
DOCUMENTATION OF OUR ASSESSMENT

We have chosen three indicators, two addressing conservation and one sustainable use.

Target 14.1

By 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution.

ROW BRISE CHINA OECD USA



Indicator chosen

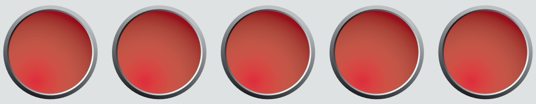
Eutrophication of major estuaries.

Eutrophication occurs due to excess of nutrients, the dominant sources being fertilizers used in agriculture and household waste (nutrients in wastewater). OECD and USA have marginal increases in fertilizer use and moreover have wastewater treatment in place. Further environmental improvements are expected, giving a green rating. Strong growth in fertilizer use, especially in South East Asia, and wastewater treatment improvements being slower than required, especially in Africa, gives ROW a red score. The same applies to BRISE, although mitigation measures are stronger here. China has similar challenges within fertilizer use and nutrients in wastewater, and although they have more structure to adjust this, they are scored red as this must be proven before it is credited.

Target 14.3

Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

ROW BRISE CHINA OECD USA



Indicator chosen

CO_2-emissions.

Ocean acidification is a consequence of increased CO_2 accumulation in the atmosphere. Our model indicates that there will be increased emissions and concentrations of CO_2. This will contribute to further acidification and lead to harsher conditions for coral reefs. Potential local mitigation will be scattered and unable to address the issue of ocean acidification effectively as a whole. Poleward migration of fish is another consequence of climate change (warming of surface ocean water) that has implications for the next indicator.

Target 14.4

By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics.

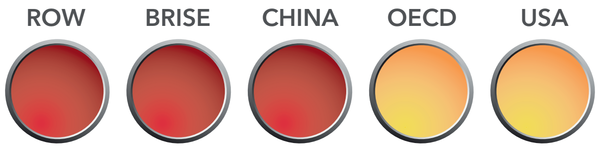
ROW BRISE CHINA OECD USA

Indicator chosen

Likelihood of achieving universally agreed fisheries management plans.

Based on lack-lustre success in global negotiations thus far, we forecast that putting a global action plan in place by 2020 is impossible, and all regions get a red rating. There are many indications that overfishing is ongoing, see also Figure 4.14.1. The world's fishing fleet continues to cover greater distances from their home base, and consequently bigger areas (see article linked to illustration). At present the subsidies in place that provide incentives for development in the wrong direction. This results in increased pressure on available resources.

15 LIFE ON LAND



Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss

SDG15 is concerned with sustainable management of our terrestrial ecosystems, in a more densely populated and resource-taxed world. Many of the targets are not quantifiable. Forest area is a primary indicator for preserving ecosystems, and includes both conserving existing forest and re-establishing forest areas – these are summed up in the indicator on total forest area. We have also included a pure conservation indicator – the biodiversity measure.

MODEL INPUT

The model gives input to the amount of cultivated land, which is not a direct indicator, but we use it to assess agricultural area and restoration of land. The model does not give input to the biodiversity dimension.

REGIONAL CONSIDERATIONS

The needed combination of efforts in development, growth and restoration is a challenge in developing countries,but developed countries also face challenges in many areas of SDG15.

The regions are classified according to expected similarities in economic development rather than geography and topography. In particular, BRISE is a very diverse region that contains both huge boreal forests in the north and rainforest around the equator, as well as urban and densely populated areas. Although there are large geographical variations within the regions, our assessment is based on average regional values.

CONCLUSION

BRISE and ROW achieve low scores on all indicators and are rated red. China, OECD, and USA are likely to achieve some targets and not others, and are given a yellow rating.

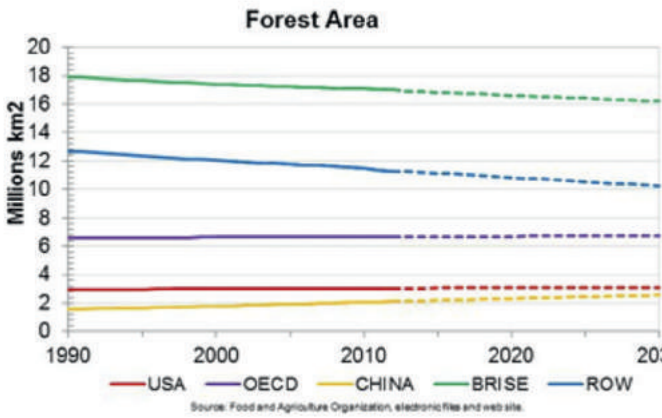


Figure 4.15.1 Forest Area

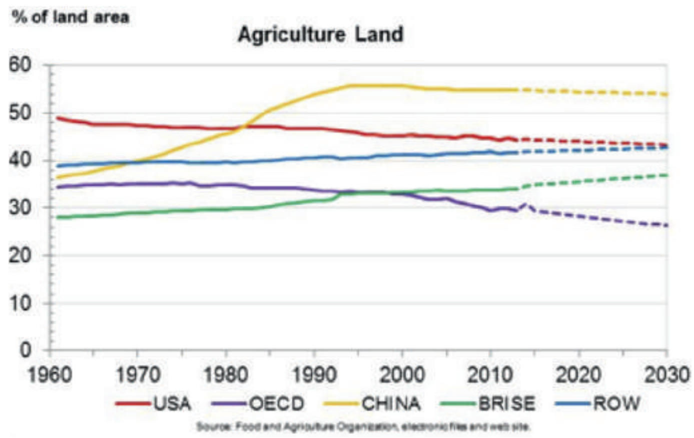


Figure 4.15.2 Agricultural land

DOCUMENTATION OF OUR ASSESSMENT

For SDG15, we assess forest area, agricultural land, restoration of degraded land, and the Red List Index.

Target 15.2

By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

ROW BRISE CHINA OECD USA

Indicator chosen

Annual change in forest area

As seen in Figure 4.15.1, we forecast a marginal increase in China's forest area. We expect USA and OECD to show flat development, and as the target is mainly about halting deforestation, these 3 regions get a green rating. Both ROW and BRISE are on a clear, continued, downward trend. Towards 2030 they may manage to turn this trend, but the target only looks at the next 5 years.

Target 15.3

By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

ROW BRISE CHINA OECD USA

Indicator chosen

Agriculture land/ restoration of degraded land.

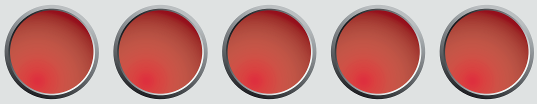
Agricultural land area is a relevant indicator, here but does not give as detailed a picture as needed. To compensate for this we have cross-checked with forestry data and the results from our model. OECD has a strong decrease in agricultural land and there is no net positive effect of any restoration measures, and thus unlikely to reach the target. Figure 4.15.2 illustrates the previous and expected trend.

Both BRISE and ROW increase their agricultural land. This is supported by our model that confirms the additional cultivated land statistics. The indicator on forest showed a reduction, indicating that the net increase does not come from restoration of degraded land, but rather from deforestation. Ongoing water stress and overgrazing could also contribute to continued degradation of land, even if the total area has increased. We assess that BRISE and ROW are unlikely to reach the target. Both China and USA are close to maintaining their total agricultural area while simultaneously increasing their forested area, and may reach the target.

Target 15.5

Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

ROW BRISE CHINA OECD USA



Indicator chosen

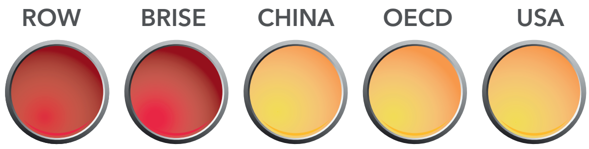
Red list index.

The Red List Index shows that all regions have difficulties maintaining biodiversity at existing levels. The number of threatened species has increased continuously over recent decades and this trend is forecast to persist even beyond 2020. The uncertainty on this rating is lower than the uncertainty on the other two indicators.ty on this rating is lower than the uncertainty on the other two indicators.

"I think the target 15.2. is rated too optimistically, as I find it unrealistic that China, OECD and US will be able to restore degraded forests and substantially increase afforestation/reforestation. I believe these scores should be yellow, and not green. The proposed plans from the relevant countries do not imply that they are on the track to reach these targets by 2020, although there are some positive signs in the right direction."

Nina Jensen, WWF Norway

16 PEACE AND JUSTICE STRONG INSTITUTIONS



Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

SDG16 addresses a divided world where some regions enjoy sustained levels of peace, security, and prosperity and others fail to move out of a cycle of conflict and violence. It is a comprehensive goal, with targets that are hard to quantify. Even when quantification is possible, different and deficient data sets preclude within- and between-region comparisons.

MODEL INPUT

The model gives no input to this goal, except the general input on reduced equalities between regions.

REGIONAL CONSIDERATIONS

The dimensions of SDG16 are relevant for all regions, but addressing them is often more challenging in developing countries. Conflict and insecurity are linked to poverty eradication and sustainable development. Marginalized countries and populations are generally more affected by violence. For many of the poorest countries in the world, violence and insecurity hinder poverty reduction and achievement of economic growth. By 2030, 75 % of people in extreme poverty will live in countries at risk from high levels of violence.

CONCLUSION

ROW and BRISE score high on both violence and corruption, and get a red rating. USA and OECD get a rating of yellow on both targets. China is borderline and also gets a yellow rating. All assessments here have high uncertainty, but the challenges seem overwhelming for the LDCs.

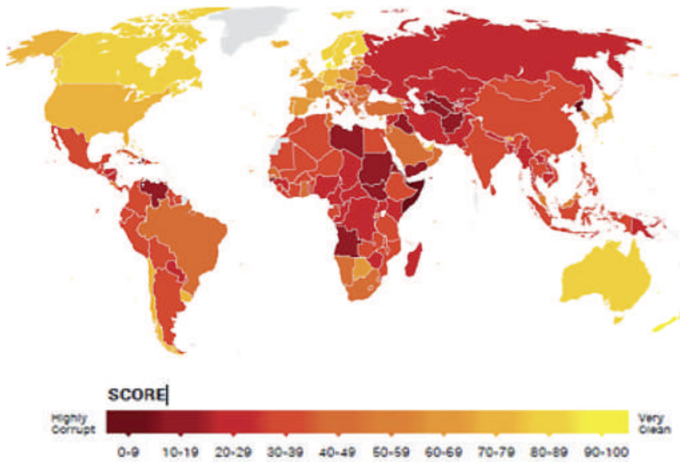


Figure 4.16.1 Corruption perception index 2014 (TI, 2014)

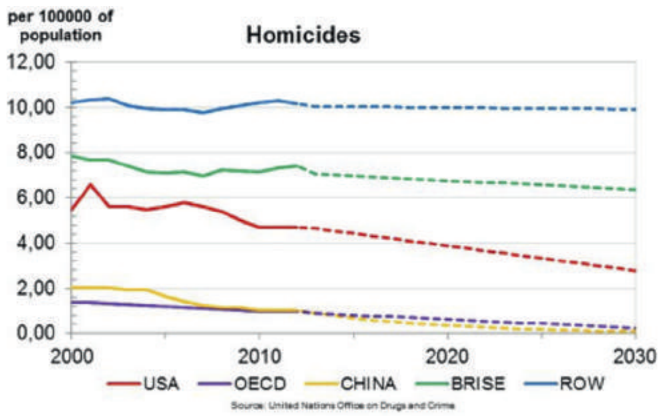


Figure 4.16.2 Homicides per 100 000 person-yeas

DOCUMENTATION OF OUR ASSESSMENT

This goal is very broad with many dimensions. For this assessment, we chose to provide forecasts for two targets where we have the best available data and that also represent two of the key issues, violence and corruption. Many of other relevant targets do not have quantifiable indicators or data availability is very limited.

Target 16.1

Significantly reduce all forms of violence and related death rates everywhere.

ROW BRISE CHINA OECD USA

Indicator chosen

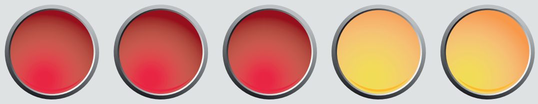
Violent injuries and deaths per 100,000 persons-years.

Looking at the rate of change and the forecasts, violent deaths are not estimated to reduce 'significantly', as demanded by the target. In fact, violent deaths are projected to remain relatively steady, with worryingly high numbers, e.g., in Brazil, the country with highest absolute number of murders in the world, 56,000 people were killed violently in 2012; in South Africa the homicide rate from 2014 was around five times higher than the 2013 global average; and in USA, the number of homicides in 2013 was 4.9 per 100,000 (more than six times higher than in the average developed country) (Saferworld, 2015). Among violent deaths, 75% are projected to occur in Latin America and the Caribbean, sub-Saharan Africa, and South Asia. We interpret green rating and significant reduction here as 50 % reduction, with yellow closing half the gap, i.e., 25 % reduction. The three regions with lowest figures are also the ones with the largest reduction, although not 50 %. USA, OECD, and China therefore get yellow rating. ROW and BRISE have the least improvement and get a red rating.

Target 16.5

Substantially reduce corruption and bribery in all its forms.

ROW BRISE CHINA OECD USA



Indicator chosen

Perception of public sector corruption.

Corruption is at the forefront of public consciousness, thus ensuring that business practices of large organizations and companies are under ever-increasing scrutiny around the world. The perception of public corruption is improving in all regions. Factors influencing corruption are weak rule of law and lack of institutional capacity. This undermines efforts to fight rooted systems of patronage, while exposure to corrupt public officials and a reliance on third party agents is also higher (Verisk, 2015). In USA and OECD, the perception of corruption in general is relatively low. It is improving in OECD, and while relatively flat in the USA in the last years, the situation is expected to improve before 2030. Thus, in 2030 both regions get a yellow rating. Though perception has improved in China, and the regime is now taking measures to reduce corruption, the level is high, and is not yet on track to close 50 % of the gap to where they should be, hence the red rating. BRISE and ROW are improving very slowly from a low level, and get a red rating.

17 PARTNERSHIPS FOR THE GOALS

ROW BRISE CHINA OECD USA

Strengthen the means of implementation and revitalize the global partnership for sustainable development

SDG17 is very comprehensive and divided into 17 targets, covering areas such as technology, trade, policy, and partnerships. One aim is to enhance North-South and South-South cooperation by supporting national plans to achieve all the targets. Sustainable development requires partnerships between governments, the private sector, and civil society. These partnerships require common principles and values, and a shared vision and goals that place people and the planet at the centre, at global, regional, national, and local levels.

MODEL INPUT

The DNV GL model does not give input to this SDG.

REGIONAL CONSIDERATIONS

The world today is better connected than ever. Throughout the globe, we witness the establishment of new partnerships for supporting developing countries to promote their international trade, but also achieving fair and just trade (UNDP, 2015b). Furthermore, international partnerships to enhance community engagement for human rights play an important role in low and middle-income countries.

CONCLUSION

For this goal we chose to not give an overall rating for the regions. We have found two indicators that describe part of the goal, but the goal is very complex and has so many dimensions, that in our opinion they do not give a good enough representation to assess the overall goal.

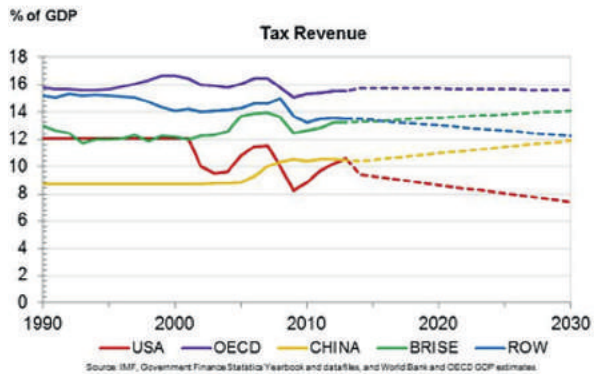


Figure 4.17.1 Tax Revenue as % of GDP

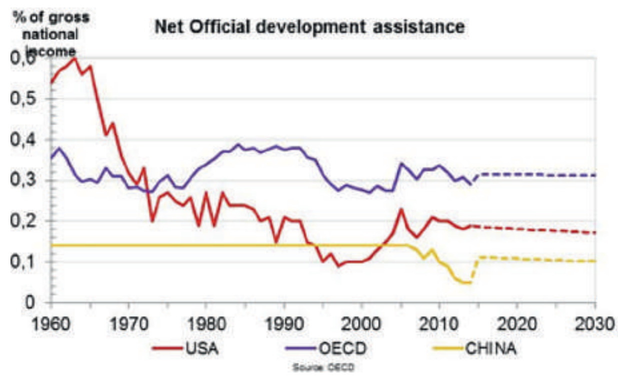


Figure 4.17.2 Net official development assistance.

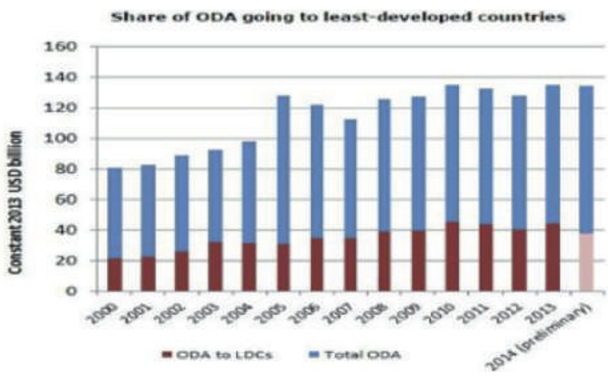


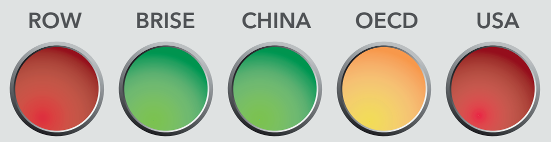
Figure 4.17.3 Share of Official Development Assistance (ODA) going to LDCs

DOCUMENTATION OF OUR ASSESSMENT

SDG17 has a number of targets, but most of them are hardly measurable. The easiest quantified target is 17.1 on tax revenue and 17.2 on Official Development Aid.

Target 17.1

Strengthen domestic resource mobilization, including through international support to developing countries, to improve domestic capacity for tax and other revenue collection.



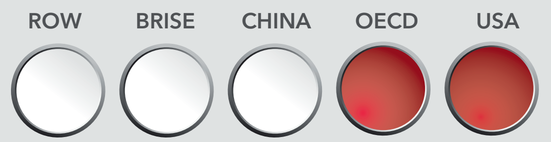
Indicator chosen

Tax revenue as share of GDP.

Strengthening governmental financial tax revenues will strengthen domestic resource mobilization capacity. Other governmental revenues are also relevant, but the quality of the data is poor. The target is not quantified, and we interpret a positive development as green, flat as yellow, and negative as red. We lack solid input to argue that the regions will deviate from their current trends (illustrated in Figure 4.17.1). These show a positive development in China and BRISE, flat development in OECD, and negative development in ROW and USA. It should be noted that for China, it is hard to measure tax revenue, as a lot of governance income come from state owned enterprises.

Target 17.2

Developed countries to implement fully their official development assistance commitments, including the commitment by many developed countries to achieve the target of 0.7 per cent of ODA/GNI to developing countries and 0.15 to 0.20 per cent of ODA/GNI to least developed countries; ODA providers are encouraged to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries.



Indicator chosen

Official development assistance and net private grants as percent of GNI.

This target requests that developed countries commit to spending 0.7% of GNI in official development assistance (ODA) to developing countries, of which 0.15-0.20 % goes to least-developed countries. ODA makes up more than two thirds of external finance for least-developed countries.

The expenditure on aid as a proportion of GNI can fluctuate substantially as it depends on political will. This is subject to national politics and policies that should be in alignment with international strategies for international aid. In this context, a global partnership is a pre-requisite, showing coherent policy development. In the years 2000-2014, the ODA from developed countries increased by 66 % in real terms, and imports from least developed countries, increasingly receive preferential treatment from developed countries (UNDP, 2015c). However, as shown in Figure 4.17.2, as most developed countries do not devote 0.7 % of their GNI to developing countries, we do not expect they will reach this target by 2030. In fact, Figure 4.17.3 (OECD, 2015) shows that the share of revenue going to LDCs is decreasing.

Only 5 of the OECD countries (Sweden, Luxemburg, Norway, Denmark, and UK) exceed the 0.7 % target today. Thus, we rate this target red for USA and OECD. We do not rate China, as it is not categorized as a developed country. We have figures for a few other countries in ROW and BRISE that also are providers of development assistance, but they are scattered and cannot be considered representative, so they are not included in the figure. They are not rated as they are mostly developing countries.

> "I like the proxy "tax revenue" for domestic resource mobilization. But I am not convinced at all that ODA is a good one. A way out would be the construction of a new proxy that captures "good will" and willingness for cooperation."
>
> George Kell, UN Global Compact

4.5 GENERAL RECOMMENDATIONS

Our assessment reflects many positive trends and reasons to be optimistic, but also indicates a bleak future for some, as none of the goals will be met in all regions. Most SDGs are within reach if humanity chooses to make adjustments. For some goals, trend shifts are needed to reach the goals. While trends shifts are not likely, they are not impossible – history does not need to repeat itself. This section outlines the more general recommendations for how we, collectively, can succeed in meeting the SDGs.

The 17 goals are closely interlinked. Many of the recommendations are common for all or most of the targets, and therefore we do not list recommendations individually for each goal. However, for certain recommendations, we pinpoint individual goals. Owing to the associations between goals, remedial actions are likely to affect multiple goals.

What should we do?

There is no single solution to the many challenges implicit in the SDGs. Instead, the world should focus on the following general actions, detailed below: Reduce emissions, Reduce inequality, Take action, Strengthen governance, Commit business, and Bottom up:

Reduce emissions

Adverse effects from global temperature rise with subsequent consequences for agriculture, fisheries, water access, habitability, extreme weather and climate events, biodiversity and a range of other consequences make minimising temperature increase and climate change not only a goal in itself, but also a goal that will have strong effect on a range of other SDGs. The by far most important factor to reduce climate change is to reduce emissions from fossil fuel. Our analysis demonstrates that increasing the renewables share of the energy mix is the most important factor for reducing CO_2 emissions, and the only realistic measure that can limit global warming to below 2 °C above preindustrial levels.

Reduce inequality

Many human development goals and targets reflect problematic and increasing inequalities. The distribution of wealth and consumption is vastly skewed within and between countries and regions. SDG10 addresses inequalities specifically and SDG5 addresses gender equality, but many other SDGs also are concerned with inequalities or the results of inequalities. Hence, one important general recommendation is to work constantly, and in all areas, to reduce inequalities. Improvement in this area will have a positive influence on a number of other areas. Redistribution, being simply to "take from the rich and give to the poor", is the obvious solution on the inequality challenge. As simple as it is in theory, the redistribution proves extremely difficult in action.

Take action

The urgency of dealing with the GHG emissions is shared by other areas, because:

- the situation is vulnerable to self-reinforcing negative trends (e.g. deforestation),
- some actions cannot be postponed (e.g. biodiversity),
- late action is more expensive than early action (e.g. poverty),
- a period of inaction can cause significant suffering (e.g. hunger).

The many delays in dealing with GHG emissions to date reveal that understanding the urgency is not enough: early action is needed. This should be emphasized as a general principle across the SDGs.

Strengthen governance

Strong governance embraces effective taxation, positive incentives and smart regulations and will be crucial in order to fund and transform societies fast towards SDG progress.

With a few exceptions, such as CO_2 emissions and resulting ocean acidification, the challenges are local or regional, and can be addressed locally or regionally. The individual nations have a considerable responsibility and possibility of achieving the goals. Establishment of country level status and ambitions and governance to follow this up are needed to obtain an overview of the situation and the scale of the challenge.

The developing countries, and in particular least developed countries (LDCs), are in a double bind: they share the biggest challenges – climate-related ones largely inflicted upon them by the past sins of big GHG emitters – but have the least resources to combat them. SDG 17 addresses development aid directly, while poverty and climate change are other areas where financing is needed. With a clearer understanding of the challenge and the gap, investments must not only be targeted towards solving problems, but also be cognizant of the fact that infusing money into regions with poor institutions might exacerbate, rather than build-up, human and institutional capability gaps. The world society needs to find mechanisms that deal with this challenge. While the environmental goals on climate, oceans, and land use share some similarity with the human development goals, one distinct difference is that the people suffering from environmental degradation are often not the people of today, but the people of the future. Failing to achieve environmental goals creates irreparable damage, whereas human development may be postponed without the same irreversibility. Thus, immediate, stronger, and faster international cooperation and governance must be ensured for environmental sustainability, with areas such as technology transfer for renewable energy, global fisheries, threatened species, and deforestation as key focal areas.

Commit business

Business leaders need increased awareness on the primary role of business sector as an “effective problem solver” in the society, moving tomorrow’s leadership into “Corporate Statesmanship” aiming companies to actively contribute to solve societal challenge. The private sector needs to learn and engage. Specific recommendations in this regard are provided in DNV GL’s publication, *Impact. Transforming Business, Changing the World, The United Nations Global Compact* (DNV GL, 2015). Closer, better engagement with and by the private sector will lead to better results for the SDGs and increased opportunities for the private companies that engage.

The UN has, historically, been an organization of nation states, working for the wellbeing of the world. Recently, however, there has been a growing understanding in the UN that the private sector also has a key role to play to ensure a well-functioning world and a sustainable future. The private sector is also important for achieving the SDGs, but it is challenging for the sector to find its place. Health, energy, and innovation are a few examples of areas where the private sector has a key role to play. The UN needs to involve the private sector in the work, extensively and creatively, in order to achieve the SDGs.

Bottom up

Achieving the 17 SDGs requires combined effort, not only from the UN, but from a united world. In order to manage this, it is important to be inspired. We should be inspired by, and learn from, countries that succeed. We should be inspired by individuals from all walks of life – politics, academia, business, and government – who take intelligent decisions and act on them. They prove that the challenges can be solved, and inspire us all to further action. We should share best practice and scale up new solutions on regional country and city level.

In order to develop reliable indicators and measure status and progress, significant improvements in the availability and quality of data are needed for almost all goals. This is particularly the case in the LDCs. The ongoing efforts to develop an official set of indicators will provide impetus for this development, but more can be done at the national level and by international and branch organizations.

What does it take?

Due to the complexity of the goals, we do not aim to calculate the effect of our recommendations, stating that certain recommendations will give a green rating (achieving at least 95 % of the SDG). The assessment we have done is, however, transparent. It is easy to see what it takes to “get to green”.

As stated, extraordinary efforts are needed. How large is extraordinary? We have not quantified the effort needed in monetary or other terms, but we contend that extraordinary effort in the short-term is less expensive and strenuous than doing nothing Longer term, both experience and analyses show that the net present value (NPV) is often positive, the co-benefits considerable, and the alternative –no action – is much more expensive - as noted in, e.g., New Climate Economy (2014). It is likely that the combined efforts to achieve all the goals are well within reach for existing budgets, given a willingness to prioritize smartly.

4.6 SPECIFIC RECOMMENDATIONS

In DNV GL we work to solve many of the challenges addressed in the SDG's particularly in areas such as sustainable transport, renewable energy, or air pollution. As an organization we strive to improve the technology, standards, and mechanisms that contribute to achieving the goals. In these areas we also work with a large set of very specific solutions and recommendations to achieve the goals. Over time, we are likely to expand our reach into further areas, and this project is well-positioned to help us with this.

Figure 4.3 illustrates the areas where this report is providing specific recommendations. (Next page).

Our forecast-based assessment concludes that none of the SDGs will be achieved in all regions, unless extraordinary efforts are made. Based on this, it is fair to say that all SDGs are urgent focus areas. Specific recommendations on how to achieve these goals are therefore needed for all SDGs.

DNV GL currently has a certain expertise. In this project we have performed a wide forecast and done assessments on all SDGs, stretching and extending our competence. We could have offered a complete set of detailed recommendations from DNV GL, but rather than doing that, in this report we offer a set of detailed recommendations to achieve the SDGs for which DNV GL has the strongest competence. These are being SDGs #7, #12, #13, and #14, included in Table 4.2. In the continuation of this report, we will involve our partners in developing recommendations for all the other SDGs as well.

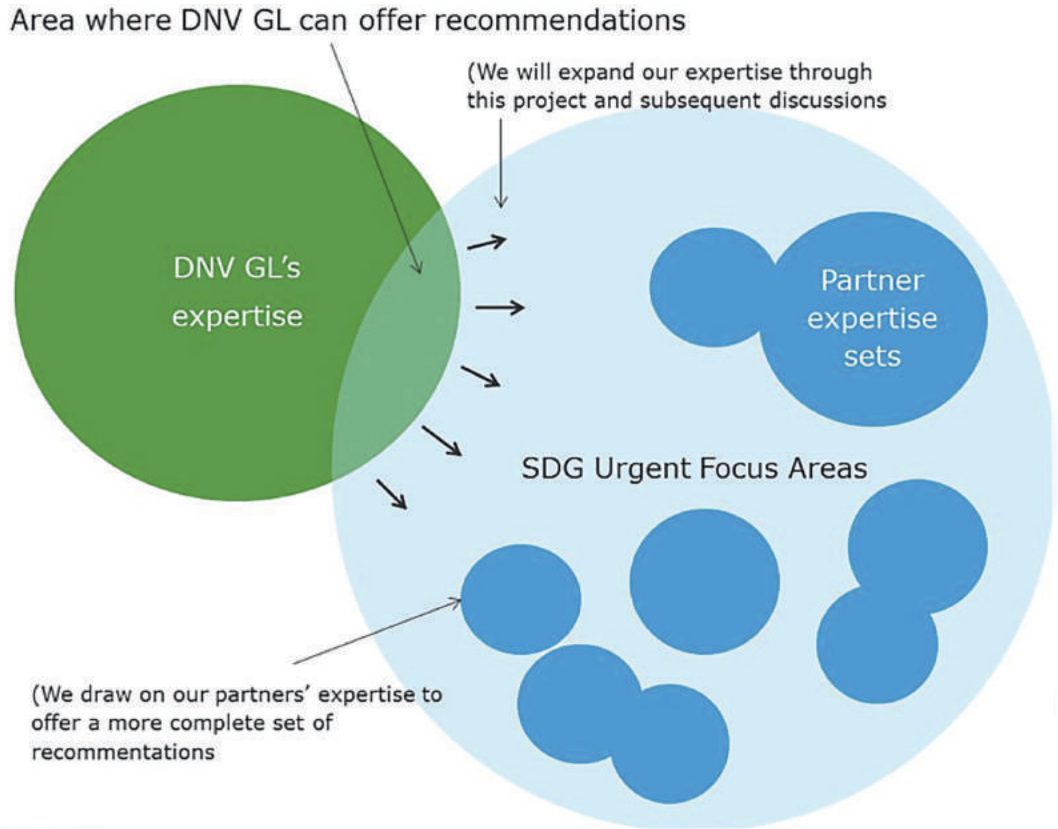


Figure 4.3 Diagram of areas where we offer recommendations

Free diving world champion Umberto Pelizzari, raised a flag to represent Goal 14, Life Below Water, off the coast of Formentera, to support the UN Global Goals for Sustainable Development. Credit: Enric Sala

7. AFFORDABLE AND CLEAN ENERGY	In addition to those recommendations advocated by The International Energy Agency (IEA) in their 450 scenario description (e.g., phase out fossil energy subsidies; urgently introduce a global carbon tax; intensify carbon capture and storage (CCS) research), we recommend: • No new fossil capacity additions allowed anywhere after 2030. • A global tax on fossil investments, reaching 100 % in 2025 with proceeds going to a new global clean energy investment fund. • This fund being targeted to BRISE and ROW nations to focus primarily on off-grid renewables solutions to jump-start developing nations' electrification efforts. • Halving the implementation times in current fuel standard improvement and making them worldwide for vehicle manufacturers, applicable to all vehicle types, and loopholes being closed. • Tighten and apply the new Scandinavian energy-efficiency building standards to all OECD and Chinese buildings, with BRISE and ROW to lag behind by no more than 5 years. • Build resilience in the grid infrastructure by speeding up research and investments in integration of new renewables in the grid.
12. RESPONSIBLE CONSUMPTION AND PRODUCTION	• Sustainable production: Companies should demonstrate their commitment to globally recognized principles of sustainability, corporate social responsibility, ethical business practices & behaviour, and involvement of stakeholders. • Responsible supply chain processes should be used for any kind of product line. Companies need to ensure that they are providing transparent information that demonstrates performance (e.g., effectiveness, efficiency, quality, risk) of processes, organizations, products, supply chains and assets, including stakeholder requirements, and compliance to policies, guidelines, regulations, standards, statutory obligations, and alike. Credibility of assurance hinges on the recognition, professionalism, and competence of the assurance provider; thus assurance is preferably provided by trusted, independent, branded, assurance bodies. • Governments can lead the way by supplying environmentally comprehensive public services and infrastructure to foster the transition to sustainable consumption. It is essential that they provide trustworthy information and prepare incentives to nudge consumers in a greener direction (e.g., schools to provide local, organic, and/or fairly traded food; ensuring good public transport to encourage people to drive less; proximity to recycling bins to reduce waste generation; increasing recyclable waste separation).
13. CLIMATE ACTION	The #7 recommendations involve climate change mitigation, hence the recommendations here focus on climate adaptation. • Through tougher building standards, and by zoning, forbid any construction activity that will have a significant exposure to 100-year floods, rains, or waves. • Within five years, create 100% surtax on all buildings and construction-related insurance premiums to be added to a climate mitigation fund. Fund to serve climate adaptation construction. • Standardize reporting on hazards and mitigation events, in line with current earthquake reporting.
14. LIFE BELOW WATER	The #7 recommendations involved mitigation of ocean acidification, hence these are recommendations beyond these: • Further develop UN and regional frameworks to enhance international cooperation in regulating and supervising the fishing industry, including better sustainability measures and data. • Ensure that fishing international waters is also regulated and monitored. • Establish an International Court, similar to the International Criminal Court in the Hague for International Human Rights violations, to enforce regulation in international waters. • Subsidize activities that increase the resilience of fisheries, and remove subsidies on activities that degrade resilience.

Table 4.2 Detailed recommendations

5. FURTHER WORK / WAY FORWARD

Spaceship Earth is a research project that has significant potential to be used in DNV GL in a number of different ways.

Our plan is to develop this DNV GL report into a Flagship Report before the end of 2016. In doing this, we will not only improve form, but also content. DNV GL is already looking into areas where our forecast and assessment can be improved. We expect too that external feedback on assumptions, results, and conclusions will help us to improve our work further.

This report is the first DNV GL forecast for Spaceship Earth. The exercise may well be repeated at regular intervals, both as a forecasting exercise, and also as an updated assessment of the SDGs.

By repeating the exercise and presenting updated forecasts and assessments, DNV GL may come to be

Shachi Somani, the only Indian female cyclist participating in the HERO MTB Challenge 2015 and cyclist Gurman Reen raised a flag to represent Goal 4, Quality Education, in India, to support the UN Global Goals for Sustainable Development. Credit: Ashish Sood, courtesy globalgoals.org recognized as a well-known source for sustainability forecasting, and as a skilful analyst of very large data sets.

In the *Future of Spaceship Earth*, we have built an "engine", and the model platform behind our forecast can be used in a number of ways. In this project, the model has been used as basis for answering the question: Will the SDGs be reached?

This forecast platform can have many uses in the future, e.g. answering questions such as:

- How to reach a 1.5 °C future?
- What are the consequences of the COP-21 agreement?
- What results can we expect from meeting the INDCs (Intended National Determined Contributions)?
- What are the consequences of speeding up – or slowing down – the low-carbon energy transition?
- What will happen to the ecological footprint of humanity when the global productivity doubles?

Modelling and understanding the low carbon energy transition are key themes in the Climate Change Unit in DNV GL Strategic Research & Innovation (SR&I). The model will be included in the model suite of the Climate Change Unit, and the connections between population, GDP, energy intensity, climate intensity, and the other parameters in our forecasts will be subjects for further research.

The topics of this project are the topics of the future - and relevant for all people and companies. We foresee many interesting discussions with our customers, based on the forecast and assessment. Commercially, a forecast like this should engender considerable interest in, e.g., assurance, reinsurance, and the banking industry. Dialogues and potential services around this will be investigated.

Certainly, the engagement levels of individual (non-SR&I) employees in this exercise – after only very gentle prompting via the intranet – have been extraordinary. It has generated a rich conversation string in Yammer, and individuals volunteered their time and attention to the assessment of individual SDGs. In short: employees are likely to find this ongoing effort stimulating, meaningful, and competence-enhancing.

This work has also placed the project team in contact with leading institutions and authoritative individuals. Not only does this enhance DNV GL's relationship capital, but, from feedback received, it is clear that our exercise is among the most systematic and comprehensive worldwide, and will deepen further contact and relationships with leading institutions and individuals.

Finally, the forecast, and, in particular, the assessment of the SDGs, provide DNV GL with increased insights into a number of areas that not only represent existing business, but also emerging and future business. Health, water, food, oceans, agriculture, and fisheries are a few examples.

DNV GL Strategic Research & Innovation and DNV GL Sustainability office will continue to explore these areas, preparing DNV GL for a future where we will enter new and exciting areas.

WHAT ARE YOUR THOUGHTS?

We encourage our readers – both inside and outside DNV GL – to interact with our forecast model and to give us your view on Spaceship Earth.

- **DNV GL colleagues** will find the model and additional material by searching "Spaceship Earth" on our intranet. They are also invited to join conversations on the Spaceship Earth Yammer Group.
- We invite **other readers** to explore and interact with the material made available on **www.dnvgl.com/spaceshipearth**

WHERE TO CONTACT US

research@dnvgl.com
blogs.dnvgl.com/sustainability
@DNVGL #spaceshipearth
facebook.com/dnvgl

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A child from the Zaatari Refugee Camp raised a flag to represent Goal 6, Clean Water and Sanitation, in Jordan, to support the UN Global Goals for Sustainable Development. Credit:unicefjordan/badran, courtesy globalgoals.org

APPENDIX A – FORECAST

MODELS DOCUMENTATION

GENERAL: STOCKS AND FLOWS

Figure 4.66 delineated assumptions, and intermediate and final results. Our analysis has gone to the core of the drivers, which is equivalent to the rates of change that modify the stocks that impact on the world. Thus, when we have determined our assumptions, we have looked into, and documented, population through birth and death rates; productivity through its drivers – change in output/person as a function of the level of a regions GDP/person. The change in energy intensity was found to be a function of time, regardless of GDP/person, fraction of GDP in various sectors, or other plausible causal explanations. Finally, the investment trends in eight different fuel types sensibly predict future energy stocks. Food production was addressed by simply reusing FAO medium forecasts without further investigating their soundness.

FLOWS

Population

We used the IIASA/Wittgenstein approach to population analysis, and, in accordance with the SSP1 logic, and corroborated by the stability of their past fertility history, we used their SSP1 analysis as our own (http://www.oeaw.ac.at/vid/dataexplorer/). Conceptually, this analysis builds on the logic depicted below in Figure a1.

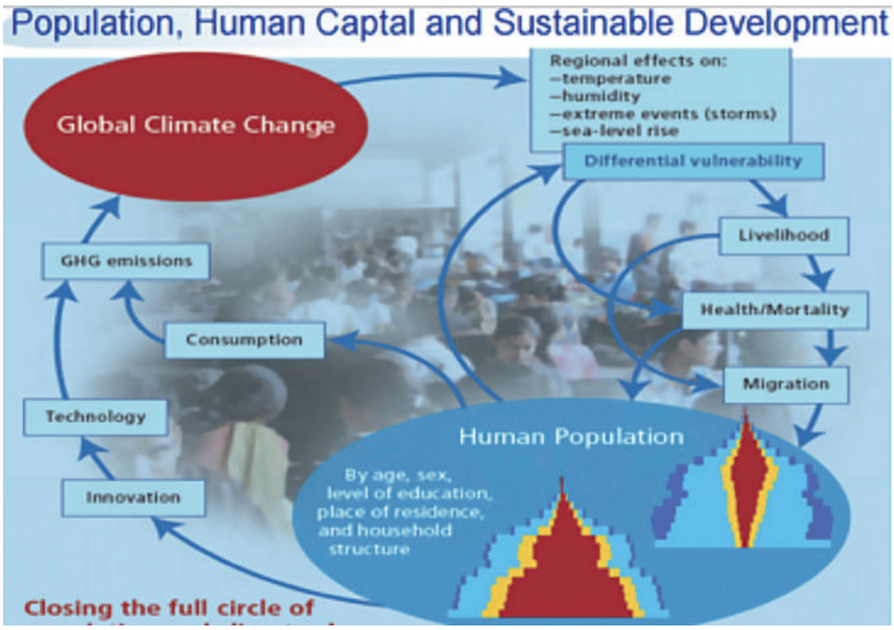
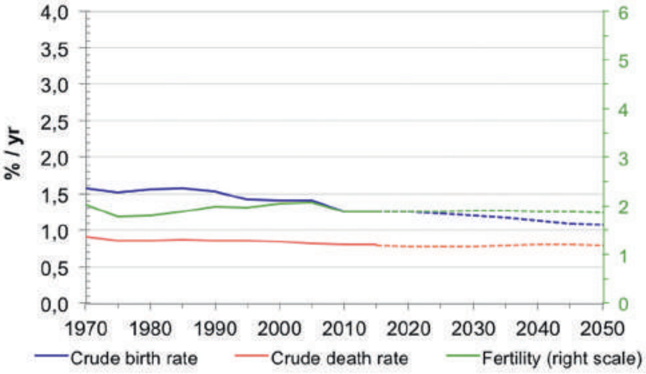
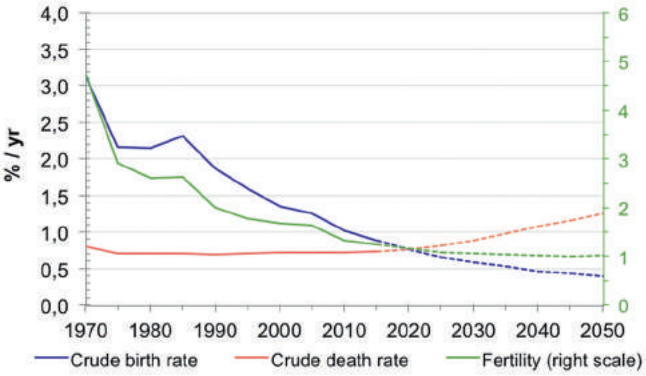


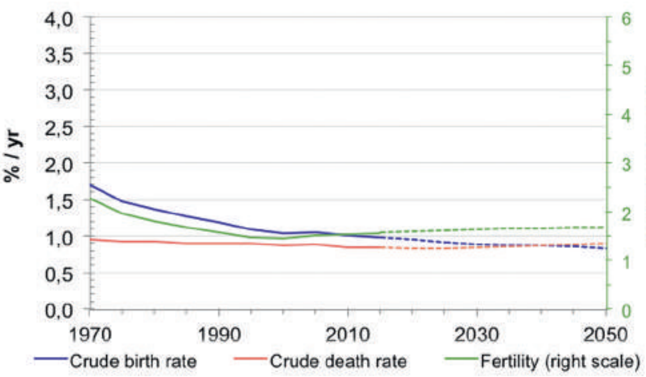
Figure a1: Underlying logic of SSP1 population dynamics. The conceptual feedback loops (i.e., they are reflected in the demographers' heads, not in their model equations) reflected in the spirit of Wittgenstein (2015) SSP1 analysis, thus mirrored in '2052' MLF.



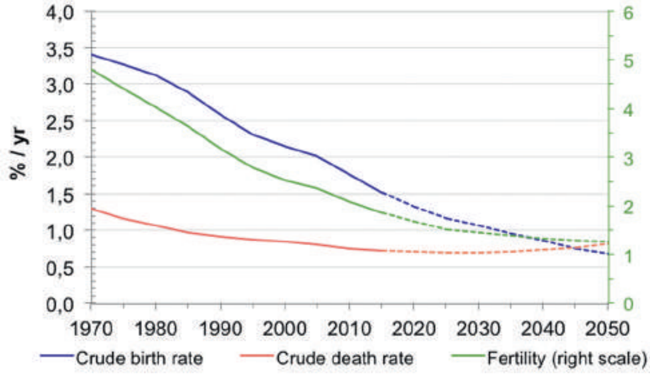
(a) USA



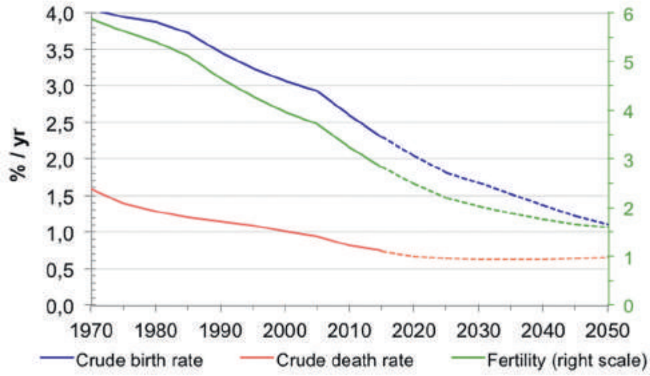
(b) CHINA



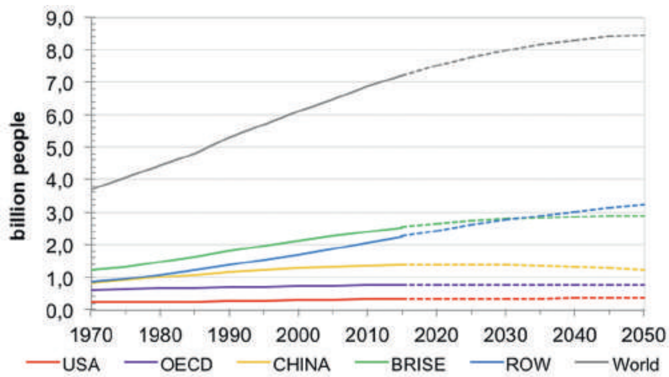
(c) OECD



(d) BRISE



(e) ROW



(f) World population

Figure a2: Birth and Death Rates on left, with Fertility rates shown on right axis for regions. And consequent population dynamics peaking just after 2050.

Productivity

Labour productivity growth forecasts are based on a single global linear regression model that uses GDP per capita as the predictor variable. For each country, the 5-year average growth rate of GDP per capita is plotted against GDP per capita level: as a country's GDP per capita rises, its GDP per capita growth rate declines, as depicted in Figure a.3 below. The reason why nations experience this dynamic is seen in figure a.4 further below – manufacturing, with substantial potential for productivity improvement, sees its share of an economy dwindling as the nation's population becomes wealthier.

Our productivity forecast for the regions followed this logic: By using country GDPs as weights, we calculated the regression equation linking GDP per capita growth rate to GDP per capita. Finally, using current regional GDP levels, we iteratively updated GDP per capita and established future growth rates of GDP per capita for five regions. The regression equation explains a long-term correlation, but the transition from current growth rates to the rate suggested by the equation does not necessarily hold for the first regional forecast period. Notably, for China and ROW the initial differences were so large that we assumed a 15-year transition period between the established regression equation and their initial, empirical, GDP/capita growth status. We furthermore analysed and found labour productivity growth rate to follow GDP per capita regional growth rate patterns extremely closely. Therefore, we used future GDP growths rates as future labour force growth rates, the latter driving GDP in the '2052' model as indicated in Figure 4.21.

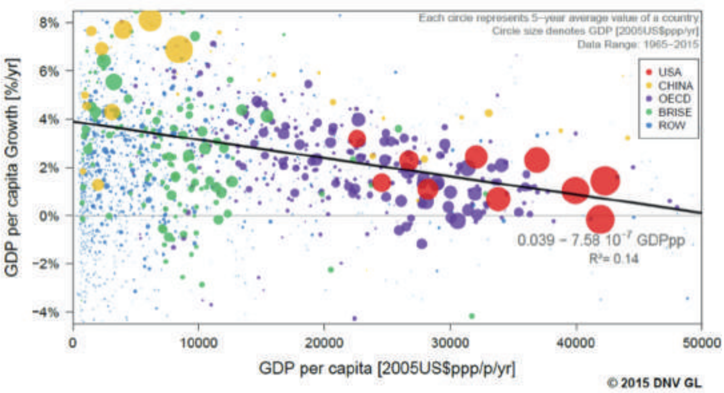


Figure a.3. GDP growth declines as per capita GDP increases

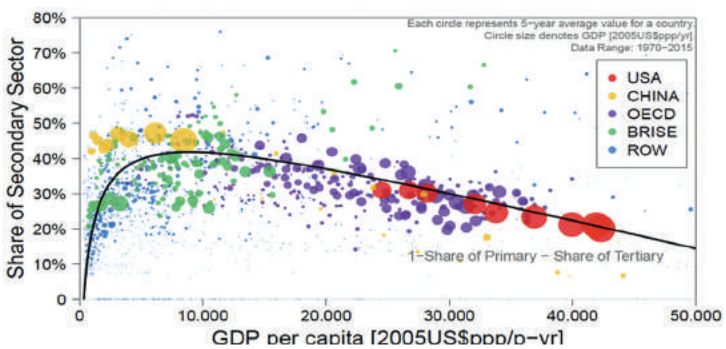


Figure a.4. Share of secondary sector as a function of GDP per capita

Energy intensity

Analysing the past, it appears that of the potential causal factors that could explain changes in energy intensity, such as level of GDP, or state of the manufacturing sector, only time (possibly mediated by technological developments) explains these changes. We leaned on the studies of IEA (2015 –), where their 450 scenario allows for a 60% decline from current energy intensity levels when trend forecasted by us from theirs 2040 figures to 2050, while their New Policy Scenario extended to 2050 affords a 40 % decline from current levels. In 2013 The World Energy Council (WEC 2013) issued two widely diverging scenarios, where energy intensity was notably robust with respect to differing assumptions, both yielding a 50-53 % intensity decline. The question thus arose of whether it is likely that regions will converge towards a common energy intensity, given that the "worst-in-class" China uses 60 % more energy per GDP $, than "best-in-class" OECD today (200 vs 125 toe/M$). If so, what would be the speed of convergence, and could a reasonable speed of convergence be consistent with this be consistent with a global 50% improvement from current levels. Iterating using OECD as a guiding star (Figure a.5), we found that the change in future OECD energy intensity, combined with all other nations lagging OECD's energy intensity (stock, not rate), as a first order smoothing - with a time constant of 11 years - in fact yields a global reduction in 2050 by 50% (Figure a.6).

Energy mix

The sensitivity analysis shows that the world ecological footprint, and thus the predicament of mankind,

A UNDP representative raised a flag to represent Goal 1, No Poverty, is raised in Pyongyang, North Korea, to support the UN Global Goals for Sustainable Development, courtesy globalgoals.org

hinges upon changes in the future energy mix, notably limiting the use of fossil fuels.

Our approach established that investment trends indicate significant inertia. Our analysis established separate capacity additions trends for 8 different energy sources in the 5 global regions. We used British Petroleum's (BP, 2015) database of energy consumption showing most nations' use. We assumed that average capacity utilization has not changed over time, so that fuel use is an indicator of capacity. Subtracting yearly capacity retirements, using IEA life-expectancy figures, we then calculated gross capacity additions for every energy source for each region. Because capacity utilization figures clearly matter and make this approach of synthetic establishment of capacity additions extremely noisy, we averaged each year's capacity additions by defining it as the average of additions of the current year, plus the four preceding and the four future years. Trends build on the last ten years' averaged data. Coming closer to the last year (i.e. 2013), we could not look four years into the future, and so successively averaged shorter time spans, starting with 7 years (not 9) in 2010, 5 years in 2011, 3 years in 2012, and only the one year in 2013. Forty (5 x 8) trends where thus developed. We used our best judgments, generally preferring linear extrapolations, but with solar additions, we favoured exponential trends. We also considered, and in a few places used, polynomial trends. For a couple of places, these simple trend extrapolations did not provide satisfactory results, and for these cases we devised specific, non-linear trends.

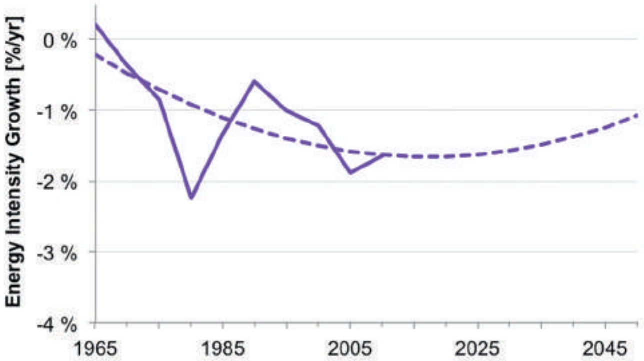


Figure a.5: "best-in-class" OECD will not retain its rate of decline in energy intensity, implying (see Figure A3) that all other regions will have.to show stronger decline rates

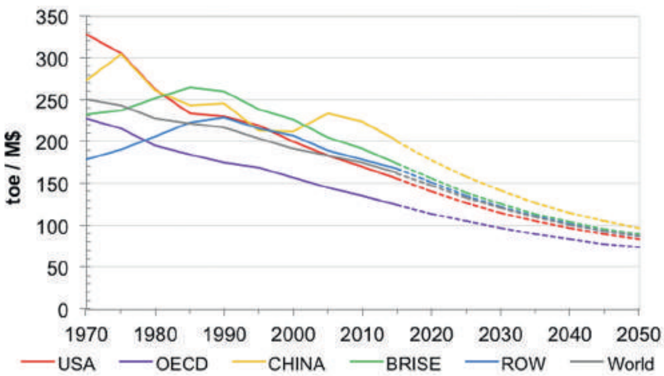


Figure a.6: regional energy intensity dynamics

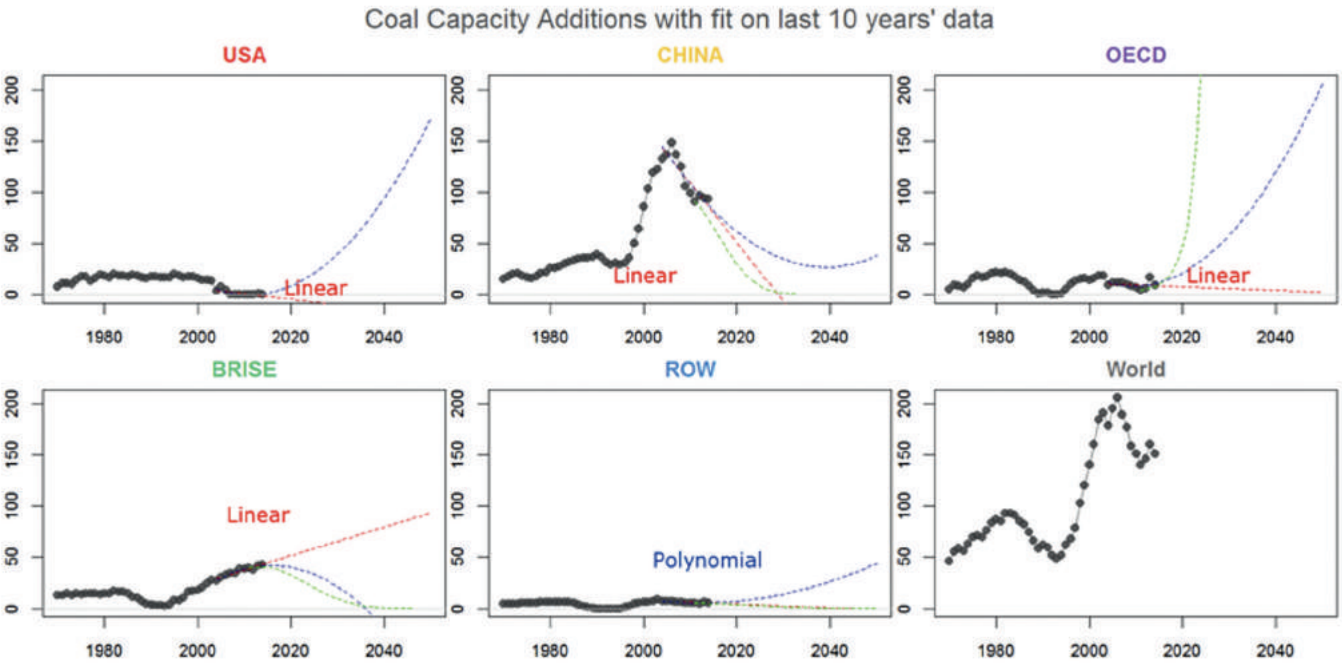


Figure a.7: Coal gross capacity additions

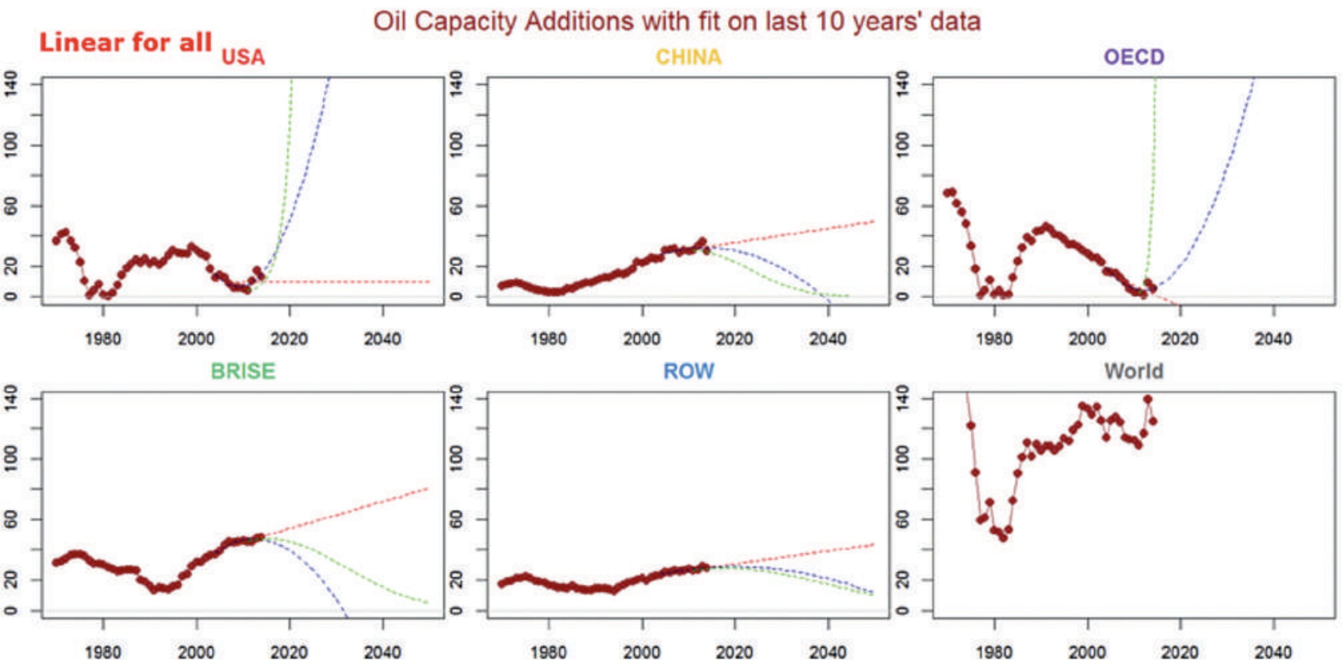


Figure a.8: Oil gross capacity additions

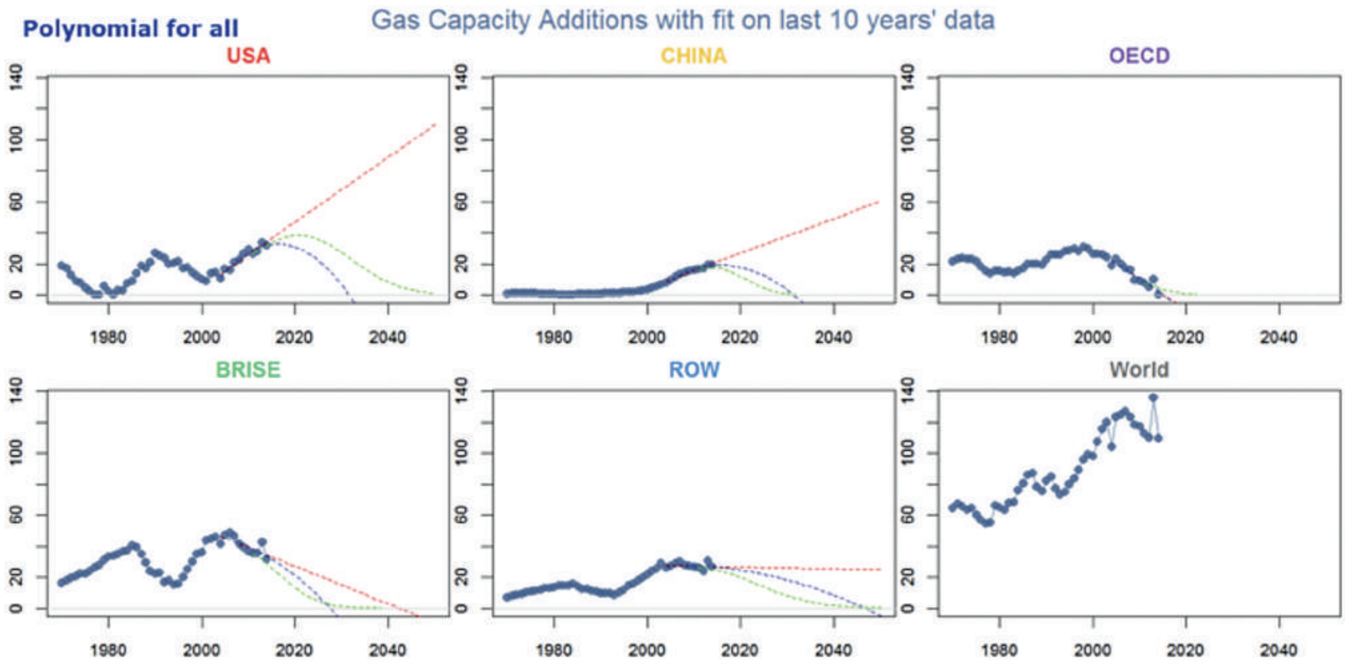


Figure a.9: Gas gross capacity additions

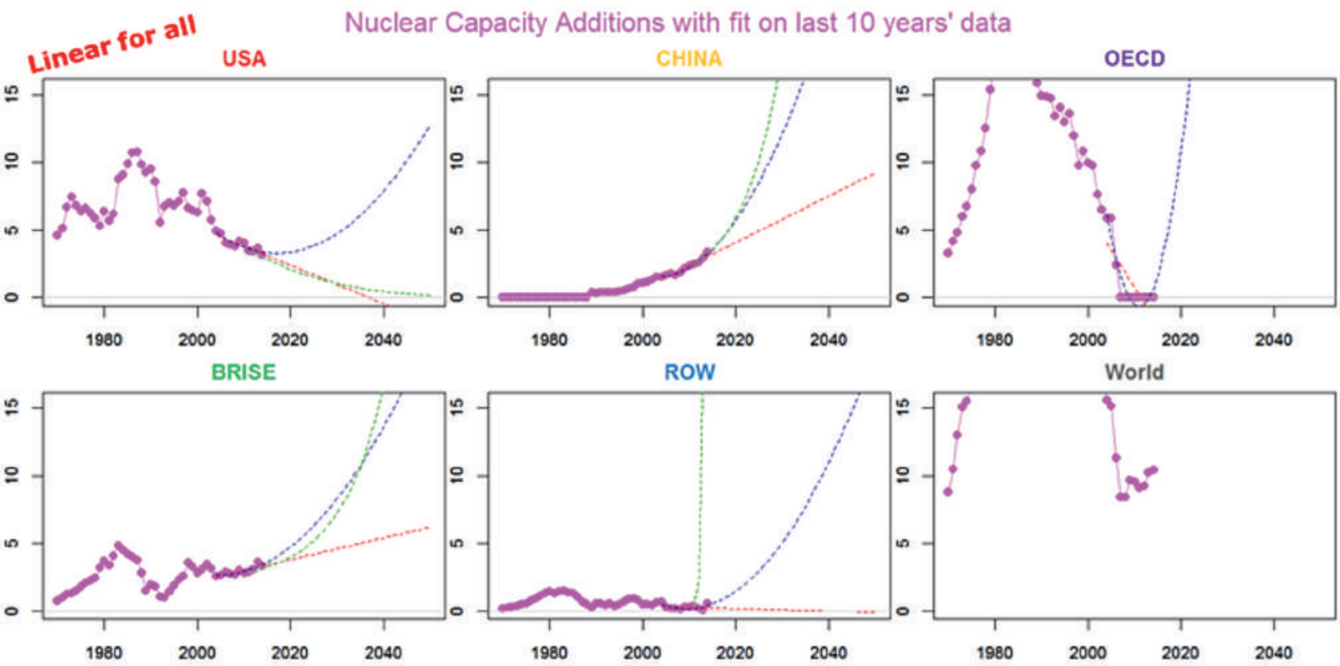


Figure a.10: Nuclear gross capacity additions

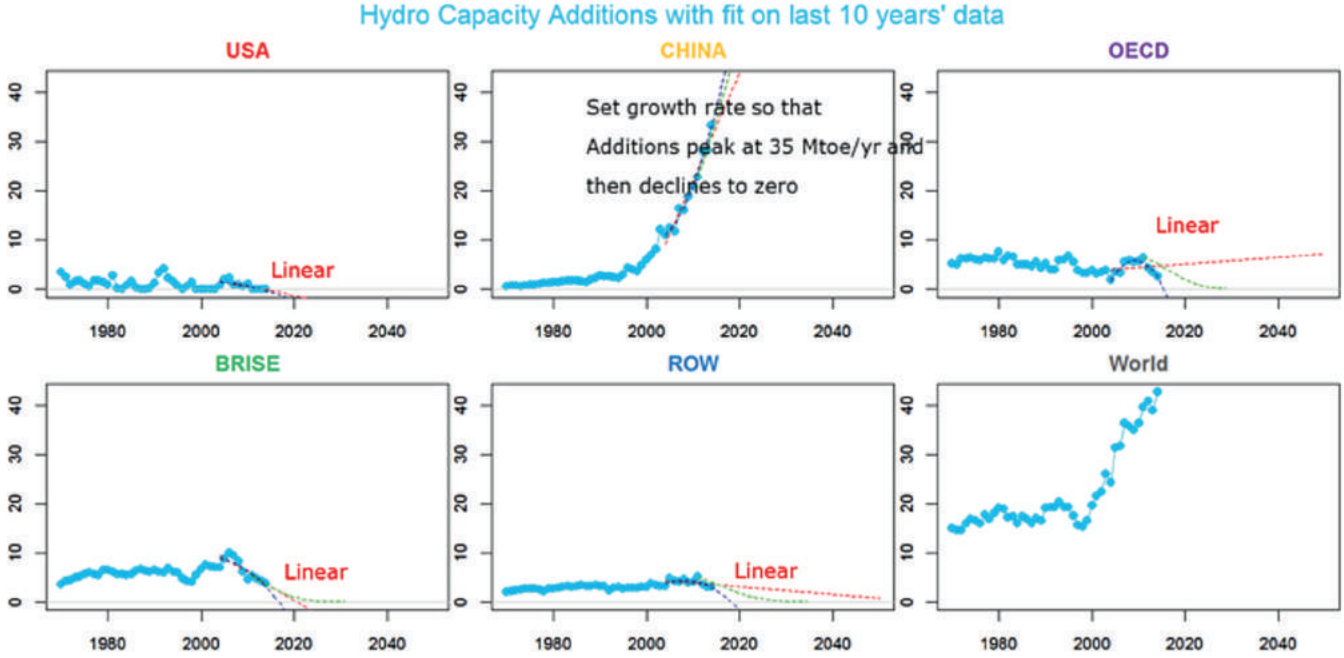


Figure a.11: Hydro power gross capacity additions

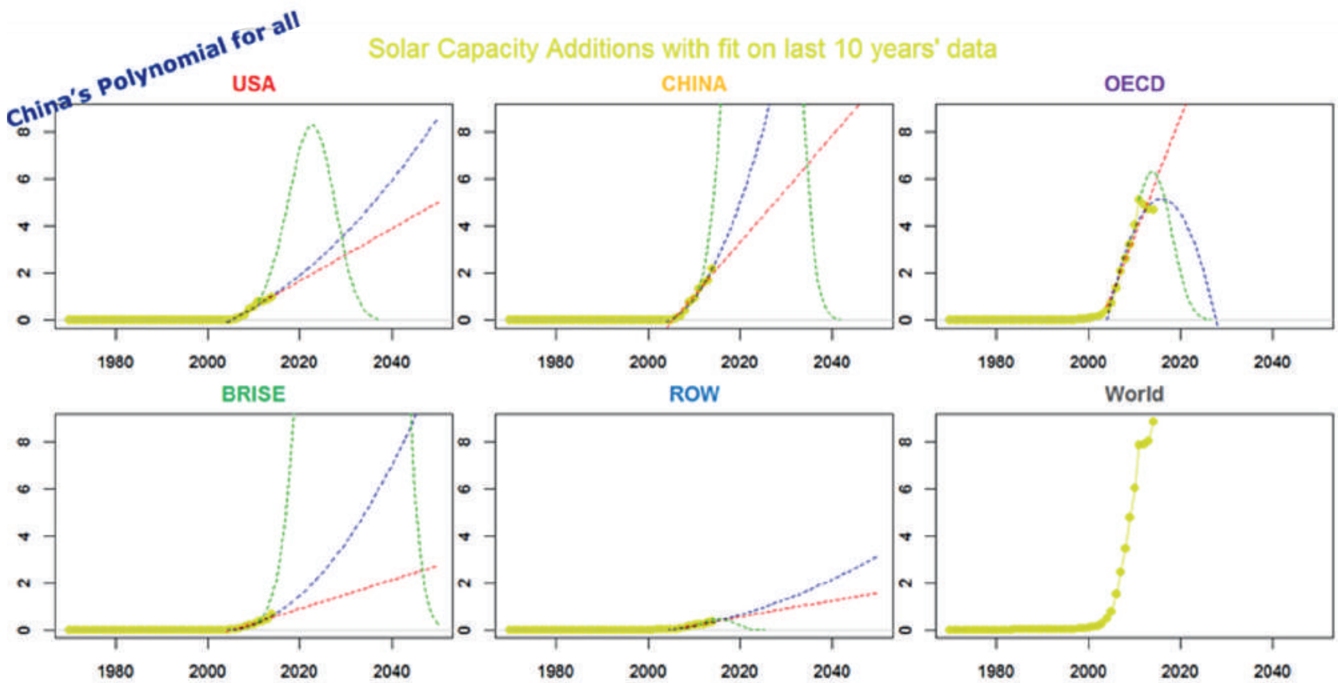


Figure a.12: Solar gross capacity additions

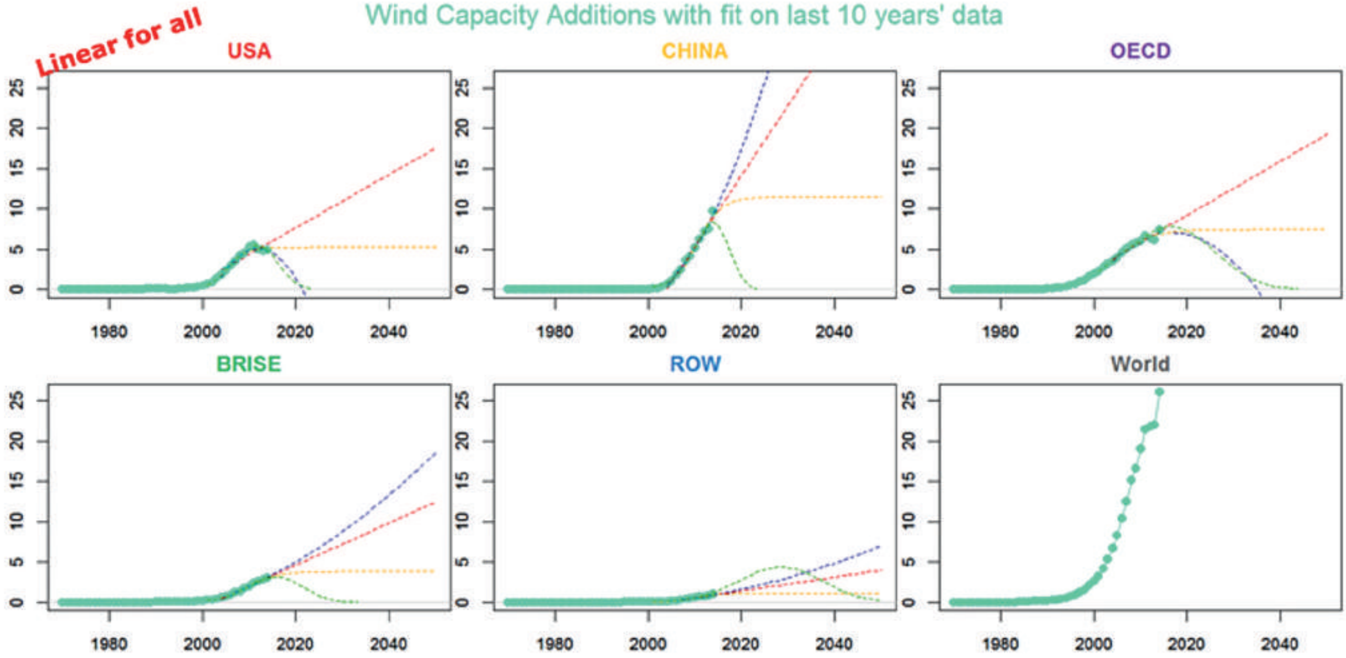


Figure a.13: Wind gross capacity additions

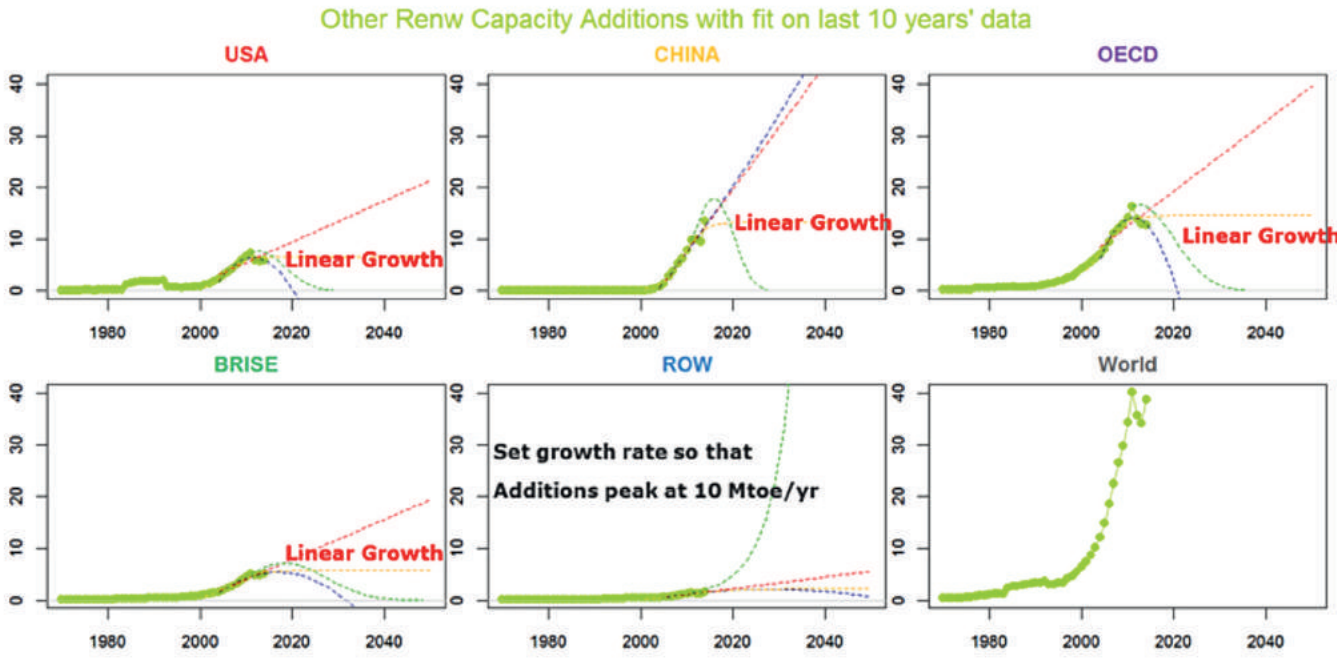


Figure a.14: Other renewable gross capacity additionsww

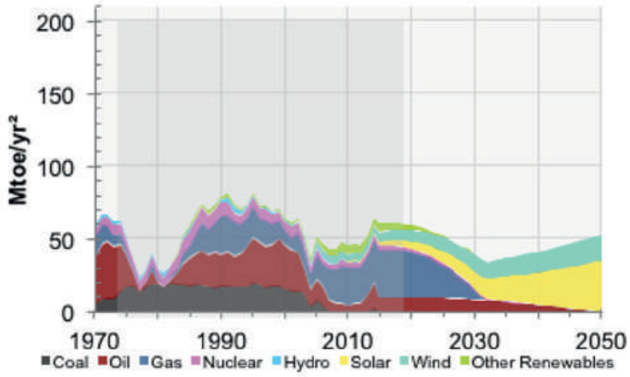
We used the Kaya identity, which starts from regions' populations and productivity, and energy intensity projections, to establish energy consumption requirements. These requirements are more than fully met, and assets must be stranded to establish demand/supply balance. Our approach to asset stranding has been informed by the dual forces of sustainability and costs that work in the same direction: first we strand coal, then oil, and finally gas.
Given this approach, a pure historically-based trend extrapolations implies no trend shift, and estimates the renewables fraction of the global energy mix to be about 38 % in 2050, and, with the addition of nuclear energy, gives the following regional non-fossil shares in 2030 and 2050.

We then used our best judgment, especially in light of the COP21 Paris discussions and agreements to reconvene frequently. We conclude from our analysis of these discussions that all regions will decide to stop any fossil-based capacity additions in 2050. This trend will start in 2030, but there will be a ten-year trend shift period. In this case also, all regions capacity needs were mostly met. Where they were not met, the gap could be filled by allowing pro rata renewable additions, starting from the pure trend-based approach. Any surplus energy would be stranded using the above approach of first coal, then oil, last gas. These capacity additions result in the total energy usage shown in Figures a.15-a.17, and enters the '2052' as 5-year shares of the various energy sources, summarized as non-fossil shares Table a.2.

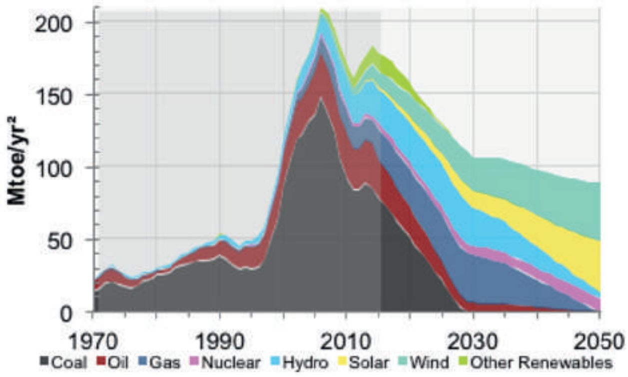
	US	China	OECD	BRISE	ROW	World
2030	28	30	38	15	18	22
2050	58	60	62	19	32	42

Table a.1: Non-fossil percentage shares of the energy mix, given simple trend extrapolation of capacity additions.

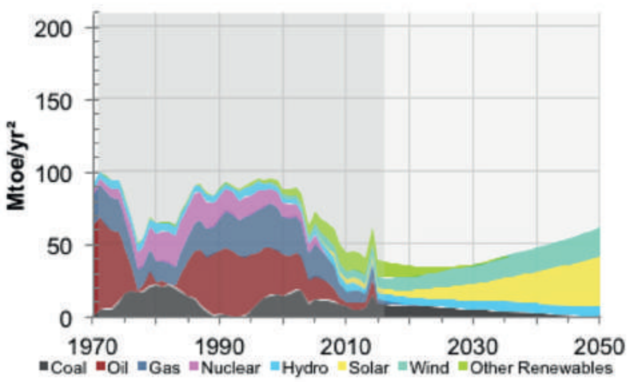
Nobel Peace Prize nominee Victor Ochen, raised a flag to represent Goal 16, Peace and Justice Strong Institutions, at the Barlonyo Massacre Burial Site in Northern Uganda, to support the UN Global Goals for Sustainable Development. Credit: Semine Lykke Brorson & AYINET, courtesy globalgoals.org



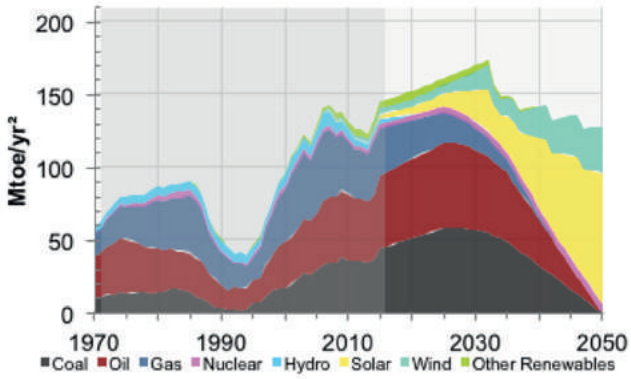
(a) USA



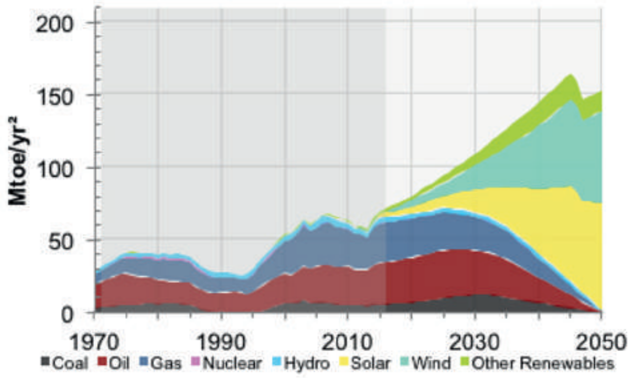
(b) CHINA



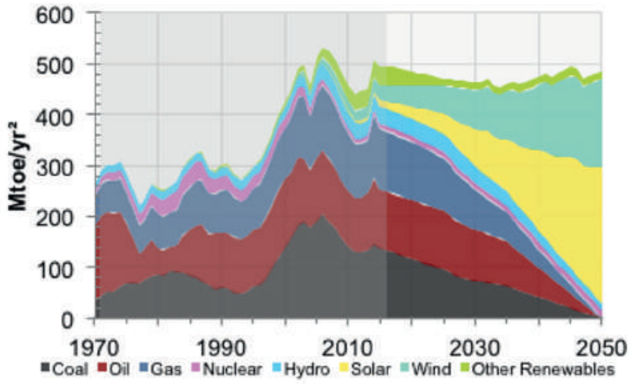
(c) OECD



(d) BRISE

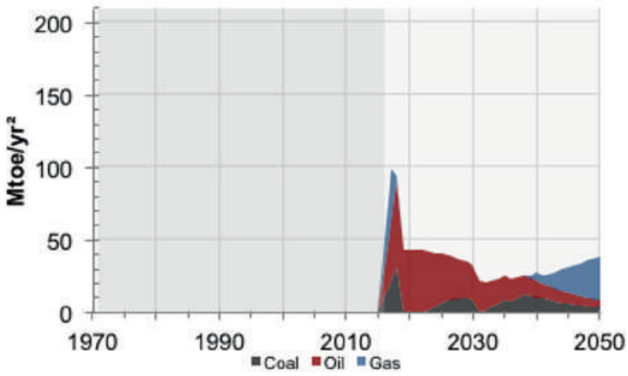


(e) ROW

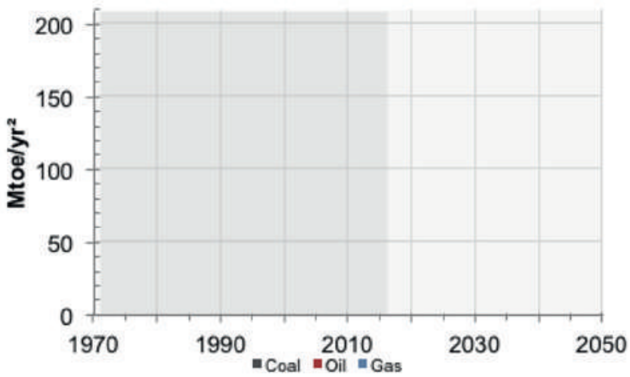


(f) World

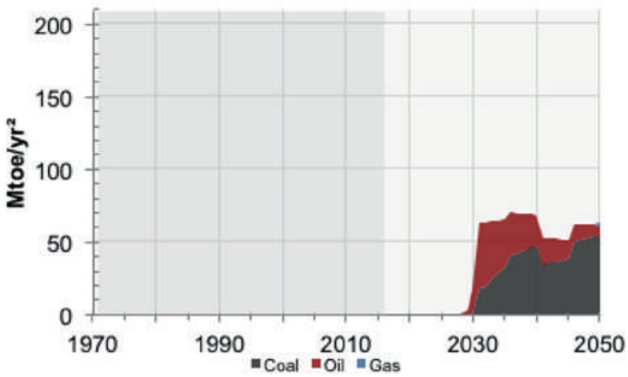
Figure a.15: Dynamics global capacity additions



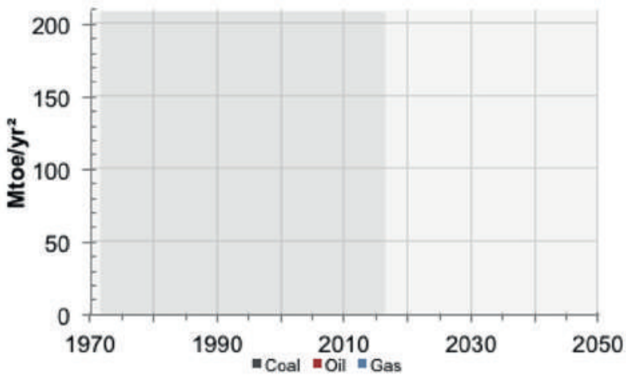
(a) USA



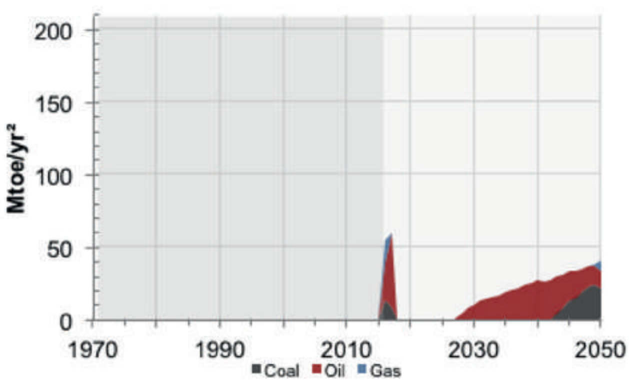
(d) BRISE



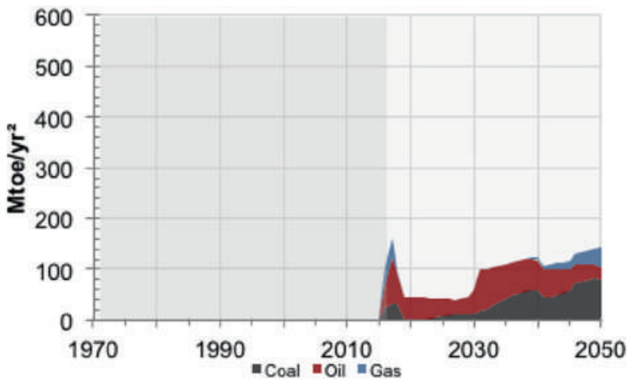
(b) CHINA



(e) ROW

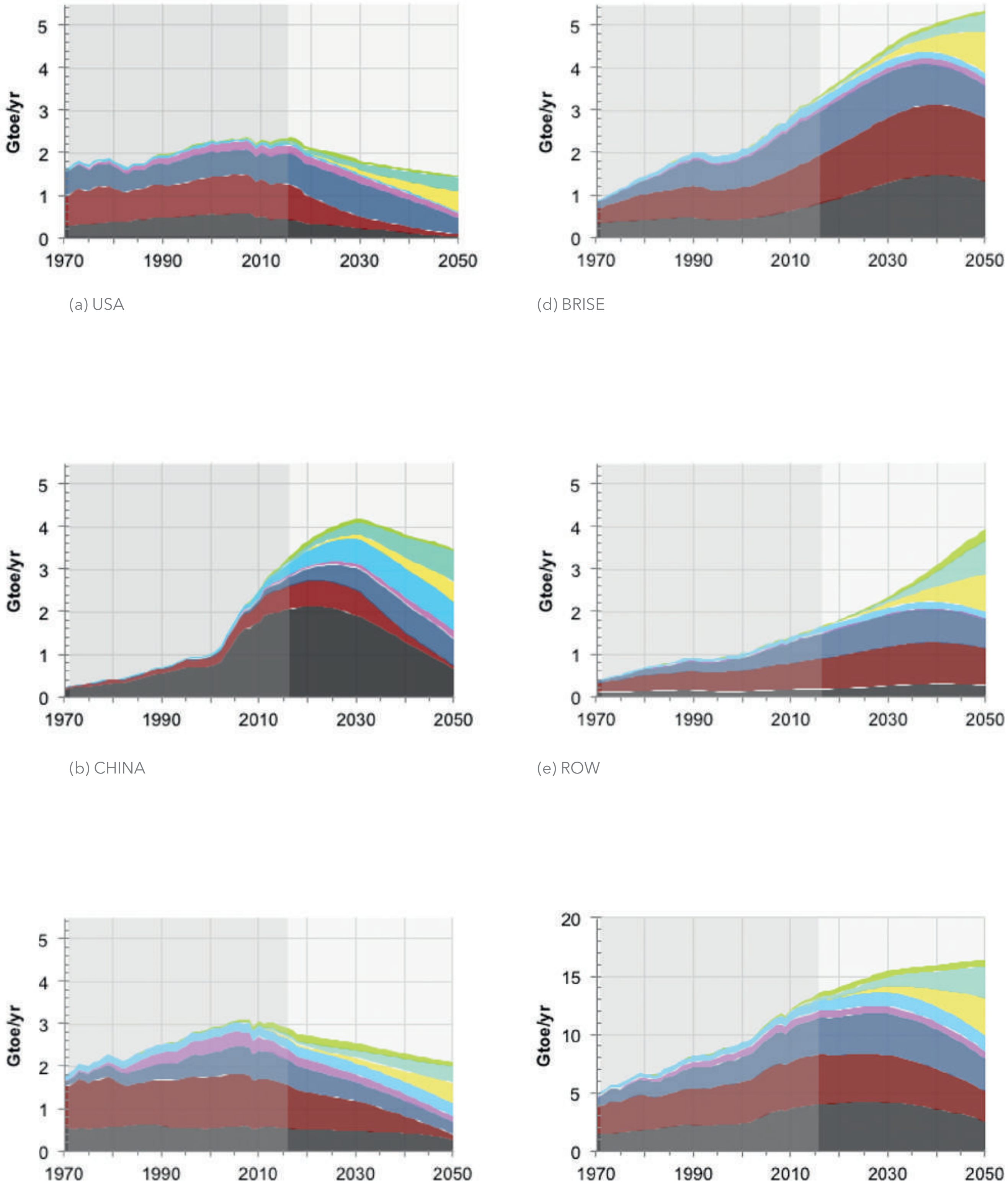


(c) OECD



(f) World

Figure a.16: Dynamics of asset stranding in world; note the absence in BRISE and ROW



(a) USA

(d) BRISE

(b) CHINA

(e) ROW

(c) OECD

(f) World

Figure a.17. Dynamics of energy use

	US	China	OECD	BRISE	ROW	World
2030	29	27	36	14	18	23
2050	68	61	68	33	54	51

Table a.2: MLF: Non-fossil percentage shares of the energy mix, given simple trend extrapolation of capacity additions to 2025. A trend shift for fossil capacity additions occurring over the following ten years, with new fossil capacity additions trend established in 2035 towards zero in 2050.

We asked two questions relating to the soundness of our approach to energy. First, will the world be able to afford the massive investments required in renewable energy. Figure a.18 below shows two findings. First, that the combined effect of higher shares of renewables and steadily lower prices of these renewables will lead to lower world energy investments in the future. This will continue to increase as shown in Figure 3.13 above, despite energy capacity additions in BRISE and ROW. Second, the implied energy trend shift after 2025 is entirely possible and affordable. The fact that the total and renewables curves are not identical in 2050 is due to nuclear investments for that year; no fossil investments occur.

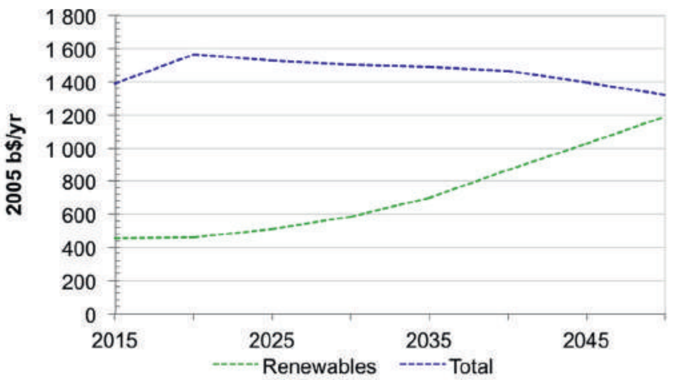


Figure a.18. Global investments in energy sources 2015 – 2050: MLF trend shift towards no fossil energy investments after 2050 is entirely affordable.

Figure a.18. Global investments in energy sources 2015 – 2050: MLF trend shift towards no fossil energy investments after 2050 is entirely affordable.

A second quality assurance comes from whether our energy forecast is shared by others. The WEC scenarios, Jazz and Symphony, cannot be used for such triangulation. The IEA does not provide an energy forecast, yet their "New Policies Scenario (NPS)" attempts to account for all probably new policies being implemented. NPS purports to take INDC pledges into account provided that IEA considers them likely to be implemented. We have chosen to look at its future values for three issues. Global energy use, renewables fraction, and total energy-related carbon emissions. We have also looked at two carbon emission analyses; Carbon Action Tracker – CAT (2015), and Climate Interactive – CI(2015) of the INDC emissions reduction pledges made before December 2015 COP21 in Paris about goals for 2030, and 2050 if any.

Forecast	Issue	Unit	2015	2020	2030	2040	2050	2030/2015	2050/2015	Note
MLF	Energy used	BTOe/y	14	15	16	16	16	1.14	1.20	
	Fossil share	%	85	82	77	66	49	0.91	0.58	Only traded REN
	CO_2e emissions	$MTCO_2$e/y	35	36	36	31	23	1.03	0.67	Energy + LUCF + Cement
IEA NPS	Energy used	BTOe/y	14	15	16	18	19	1.17	1.39	
	Fossil share	%	81	79	77	75	73	0.95	0.90	Also non-traded REN
	CO_2e emissions	$MTCO_2$e/y	32	33	35	37	39	1.09	1.22	Energy only
CI INDC	CO_2e emissions		60	62	65	67	70	1.08	1.17	Includes all GHG
CAT INDC	CO_2e emissions		48	50	52	51	50	1.08	1.04	

Table a.3. Energy related forecast. MLF, IEA NPS, CI and CAT. Note that the dynamics for table values in all four forecasts are similar for the 2015 to 2030 period.

SENSITIVITY ANALYSES

As indicated in chapter 3, we ran sensitivity analysis by varying assumptions relating to population, productivity,

Energy Intensity and Energy Mix. In this appendix, we first delineate the regional breakdown of these assumptions, then we show the regional consequences of varying those assumptions. The detailed assumptions and their detailed impacts are depicted in the graphs below.

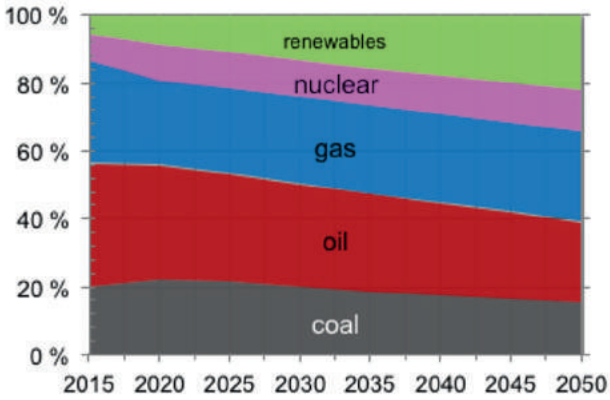
DETAILED IMPACTS

Population in 2050 (million people)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	8 445		365		1 231		758		2 876		3 215	
	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
Sensitivity Runs	7 930	9 375	337	358	1 166	1 287	664	739	2 695	3 245	3 069	3 745
	-6.1%	+11.0%	-7.7%	-1.8%	-5.3%	+4.5%	-12.4%	-2.4%	-6.3%	+12.8%	-4.6%	+16.5%

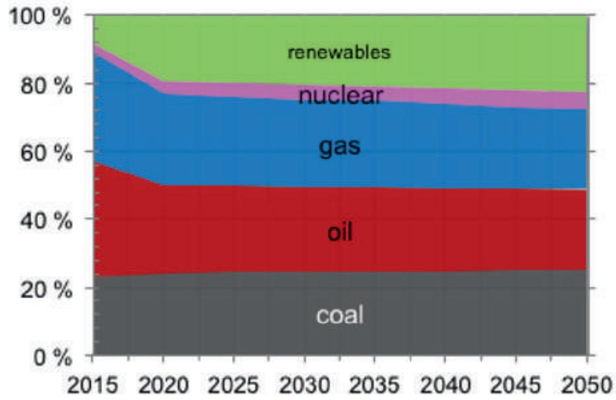
Table a.4: Population sensitivity values for the world and regions.

Output per person in 2050 (thousand $/ person/yr)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	22.3		47.3		28.7		37.1		21.2		22.3	
	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
Sensitivity Runs	20.3	33.0	45.9	79.4	43.9	39.9	33.3	45.4	17.8	29.7	7.4	25.0
	-9.0%	+47.9%	-3.0%	+67.7%	+53.2%	+39.3%	-10.1%	+22.3%	-16.0%	+40.3%	-66.8%	+12.1%

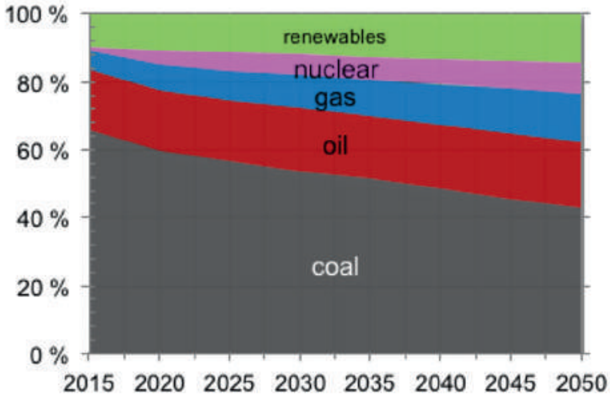
Table a.5: Productivity sensitivity values for the world and regions.



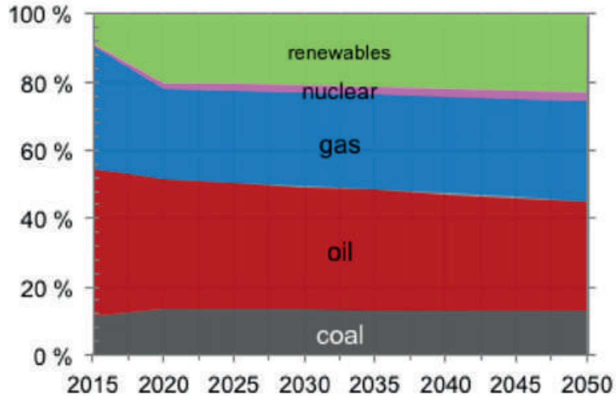
(a) LOW USA



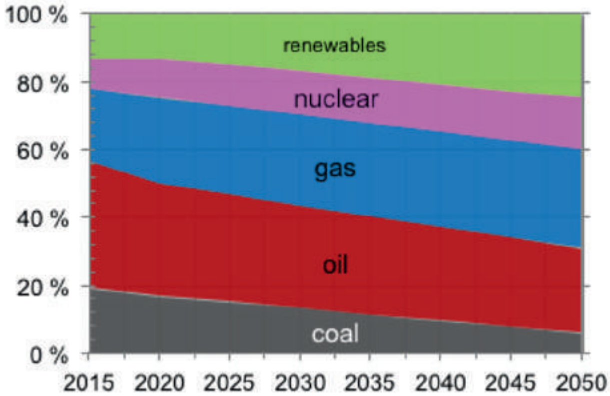
(d) LOW BRISE



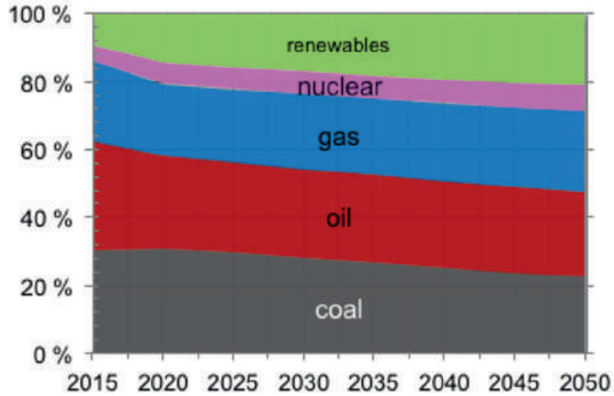
(b) LOW CHINA



(e) LOW ROW

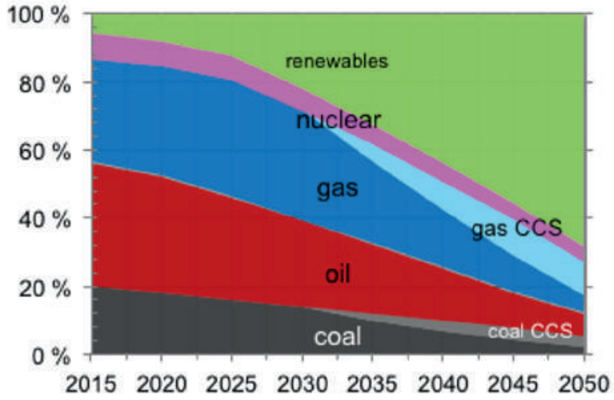


(c) LOW OECD

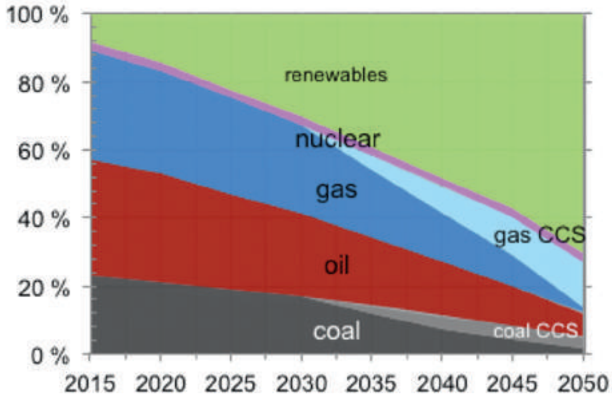


(f) LOW World

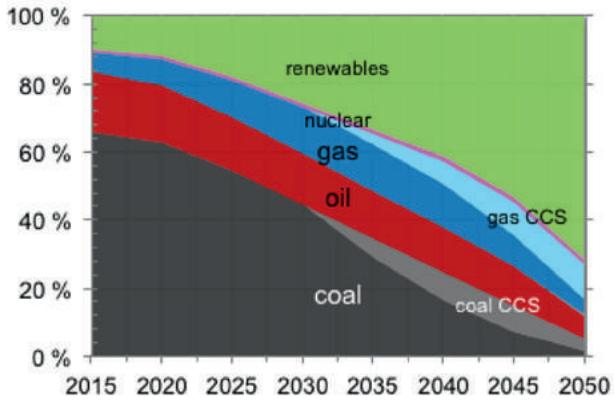
Figure a.19: High and Low renewables share of the energy mix



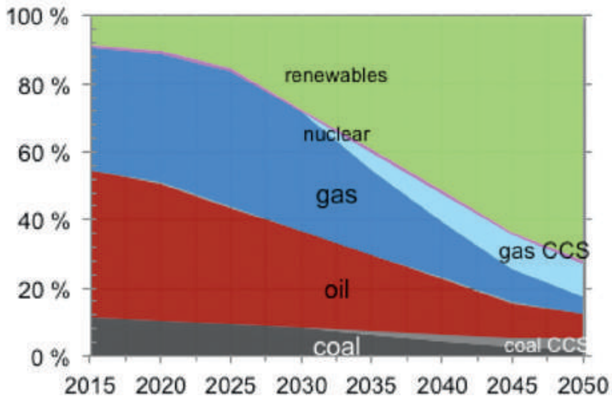
(g) HIGH USA



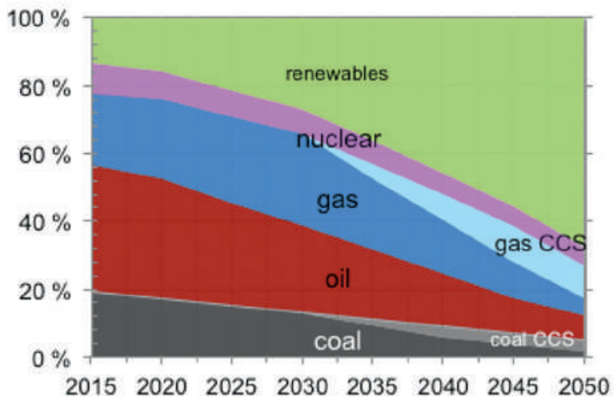
(j) HIGH BRISE



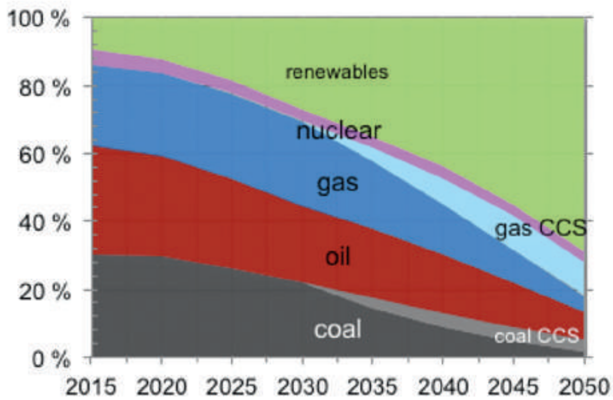
(h) HIGH CHINA



(k) HIGH ROW



(i) HIGH OECD



(l) HIGH World

Figure a.19: High and Low renewables share of the energy mix

DETAILED IMPACTS

Consumption per person in 2050 (thousand $/person/yr)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	**17**		**37**		**21**		**31**		**16**		**10**	
	LO	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**
Sensitivity to change in Population	17 +2.6%	16 -3.8%	41 +11%	37 +1.9%	21 +1.3%	21 +1.9%	33 +6.6%	32 +3.3%	15 -2.5%	15 -2.3%	11 +8.3%	10 -6.3%
Sensitivity to change in Output per person	15 -8.8%	25 +47%	35 -3.0%	61 +68%	32 +53%	29 +39%	28 -10%	38 +22%	13 -16%	22 +40%	5 -49%	18 +73%

Table 4.4: Impact of population and productivity assumptions on consumption per person.

GDP per person in 2050 (thousand $/yr-p)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	**22**		**47**		**29**		**37**		**21**		**14**	
	LO	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**	**LO**	**HI**
Sensitivity to change in Renewables in Energy Mix	22 -	22 -	47 -	47 -	29 -	29 -	37 -	37 -	21 -	21 -	14 -	14 -
Sensitivity to change in Energy Intensity	22 -	22 -	47 -	47 -	29 -	29 -	37 -	37 -	21 -	21 -	14 -	14 -
Sensitivity to change in Population	23 +2.7%	21 -3.7%	52 +11%	48 +1.9%	29 +1.3%	29 +1.9%	40 +6.6%	38 +3.3%	21 -2.5%	21 -2.3%	16 +8.3%	14 -6.3%
Sensitivity to change in Output per person	20 -9.0%	33 +48%	46 -3.0%	79 +68%	44 +53%	40 +39%	33 -10%	45 +22%	18 -16%	30 +40%	7 -49%	25 +73%

Table 4.5: Impact of all sensitivity assumptions on GDP per person.

Enery use per person in 2050 (toe/p-yr)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	1.9		3.9		2.8		2.7		1.9		1.3	
	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
Sensitivity to change in Renewables in Energy Mix	1.9 -	1.9 -	3.9 -	3.9 -	2.8 -	2.8 -	2.7 -	2.7 -	1.9 -	1.9 -	1.3 -	1.3 -
Sensitivity to change in Energy Intensity	1.4 -28%	2.6 +32%	2.8 -28%	5.5 +39%	2.0 -29%	3.5 +25%	2.0 -27%	3.3 +22%	1.4 -28%	2.7 +43%	0.89 -29%	1.6 +26%
Sensitivity to change in Population	2.0 +2.7%	1.9 -3.5%	4.4 +11%	4.0 +1.9%	2.8 +1.3%	2.8 +1.9%	2.9 +6.6%	2.8 +3.3%	1.8 -2.5%	1.8 -2.3%	1.4 +8.3%	1.2 -6.3%
Sensitivity to change in Output per person	1.8 -7.7%	2.9 +48%	3.8 -3.0%	6.6 +68%	4.3 +53%	3.9 +39%	2.5 -10%	3.3 +22%	1.6 -16%	2.6 +40%	0.64 -49%	2.2 +73%

Table 4.6: Impact of all sensitivity assumptions on energy use per person.

Emissions in 2050 (GtCO$_2$/yr)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	24		1.1		4.0		2.0		11		5.2	
	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
Sensitivity to change in Renewables in Energy Mix	35 +47%	5.7 -76%	2.7 +143%	0.5 -51%	8.7 +115%	1.3 -68%	3.3 +62%	0.8 -61%	12 +4%	1.6 -85%	8.3 +60%	1.5 -71%
Sensitivity to change in Energy Intensity	17 -28%	32 +34%	0.8 -28%	1.5 +39%	2.9 -29%	5.0 +25%	1.5 -27%	2.4 +22%	8.1 -28%	16.2 +43%	3.7 -29%	6.5 +26%
Sensitivity to change in Population	22 -4.6%	25 +8.1%	1.1 +2.2%	1.1 +0.1%	3.9 -4.1%	4.3 +6.6%	1.9 -6.6%	2.0 +0.7%	10 -8.6%	12 +10%	5.3 +3.4%	5.6 +9.1%
Sensitivity to change in Output per person	21 -10%	35 +47%	1.1 -3%	1.8 +68%	6.2 +53%	5.6 +39%	1.8 -10%	2.5 +22%	9.5 -16%	15.8 +40%	2.6 -49%	8.9 +73%

Table 4.7: Impact of all sensitivity assumptions on global and regional energy-related emissions

Food per person in 2050 (t/p-yr)	WORLD		USA		CHINA		OECD		BRISE		ROW	
Base Run	1.2		3.1		1.5		1.4		1.2		0.77	
	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI	LO	HI
Sensitivity to change in Renewables in Energy Mix	1.2 -	1.2 -	3.1 -	3.1 -	1.5 -	1.5 -	1.4 -	1.4 -	1.2 -	1.2 -	0.77 -	0.77 -
Sensitivity to change in Energy Intensity	1.2 -	1.2 -	3.1 -	3.1 -	1.5 -	1.5 -	1.4 -	1.4 -	1.2 -	1.2 -	0.77 -	0.77 -
Sensitivity to change in Population	1.3 +6.5%	1.1 -9.9%	3.4 +8.3%	3.2 +1.8%	1.6 +5.6%	1.5 -4.4%	1.5 +14%	1.4 +2.5%	1.3 +6.7%	1.1 -11%	0.81 +4.8%	0.66 -14%
Sensitivity to change in Output per person	1.2 -	1.2 -	3.1 -	3.1 -	1.5 -	1.5 -	1.4 -	1.4 -	1.2 -	1.2 -	0.77 -	0.77 -

Table 4.8: Impact of all sensitivity assumptions on food per person: only population dynamics has an impact.

School children from Escuela Central San Sebastián in San Jose raised a flag to represent Goal 12, Responsible Consumption and Production, at the University for PEACE Campus in Costa Rica, to support the UN Global Goals for Sustainable Development, courtesy globalgoals.org

APPENDIX B – CONTRIBUTORS

LIST OF ALL CONTRIBUTORS

STEERING COMMITTEE:
Bjørn Haugland
Bente Pretlove
Jorgen Randers, BI Norwegian Business School
Rune Torhaug

Project team:
Sverre Alvik
Bent Erik Bakken
Caroline Brun Ellefsen
Ole Flagstad
Mark Irvine
Bradd Libby
Stephen Leyshon
Cecilie Mauritzen
Stefan Midteide
Deepika Mital
Asun Lear St.Clair
Eva Turk
Onur Özgün

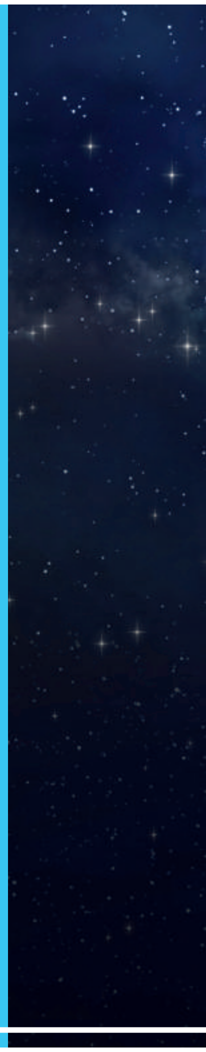
Workshop participants:
Richard Bordesoulles
Alex Castellanos
Liliana Castro
Martijn Douwes
Anne Kirsti Egtvedt
Jamie Elliot
Guido Friedreich
David Fullbrook
Torleiv Grimsrud
Lin Jacobsen Hammer
Ida Helsing
Tor Jensen
Jan Land
John Kristian Lindøe
Frederike Reher
Bettina Reinboth
Christina de Santa Maria Saenz
Daniel Struwig
Chris Urwin
Li Zhang
Øivind Aarnes

External Experts:
Robert Engelmann, Worldwatch Institute, SDG#5
Carlos C Gaitan, La Ciudad Verde, SDG#11
John Fullerton, Capital Institute, SDG#12
Øiyvind Hetland, Norwegian Red Cross, SDG#16
Nina Jensen, WWF Norway, SDG#15
George Kell, UNGC, SDG#17
Birgit Kopansky, UiBergen, SDG#2
Nebosja Nakicenovic, IIASA, SDG#8
Kevin Noone, Swedish Secretariat for Environmental Earth System Sciences, SDG#14
RK Pachauri, Teri, SDG#13
Bobbie Ray-Sannerud, DNV GL, SDG#3
Harald Siem, Norwegian Institute of Public Health, SDG#6
Asun St.Clair, DNV GL, SDG#1
Karen Sund, Sund Energy, SDG#7


8
DECENT WORK AND
ECONOMIC GROWT

Mafikizolo raised a flag to represent Goal 8, Decent Work and Economic Growth, at Constitution Hill in Johannesburg, South Africa, to support the UN Global Goals for Sustainable Development. Credit: Nicki Priem, courtesy globalgoals.org

SAFER, SMARTER, GREENER



DNV GL AS
NO-1322 Høvik, Norway
Tel: +47 67 57 99 00
www.dnvgl.com

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