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How to achieve the Sustainable Development Goals within planetary boundaries by 2050

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Rising to the grand challenge

What will it take to bring about human prosperity and equity within a safe biosphere? If the world is serious about the Sustainable Development Goals (SDGs), and thus the need for a truly integrated prosperous and peaceful people-planet trajectory for development, what will it take to succeed? Is it at all possible to transition the world to global sustainable development as it is now defined: attaining the SDGs within Earth's planetary boundaries (PBs) – through conventional means of economic development? What potential trade-offs and synergies do societies face when taking a truly systemic approach to the SDGs? And, most importantly, what are the transformational requirements to succeed in attaining human prosperity within a safe operating space on Earth?

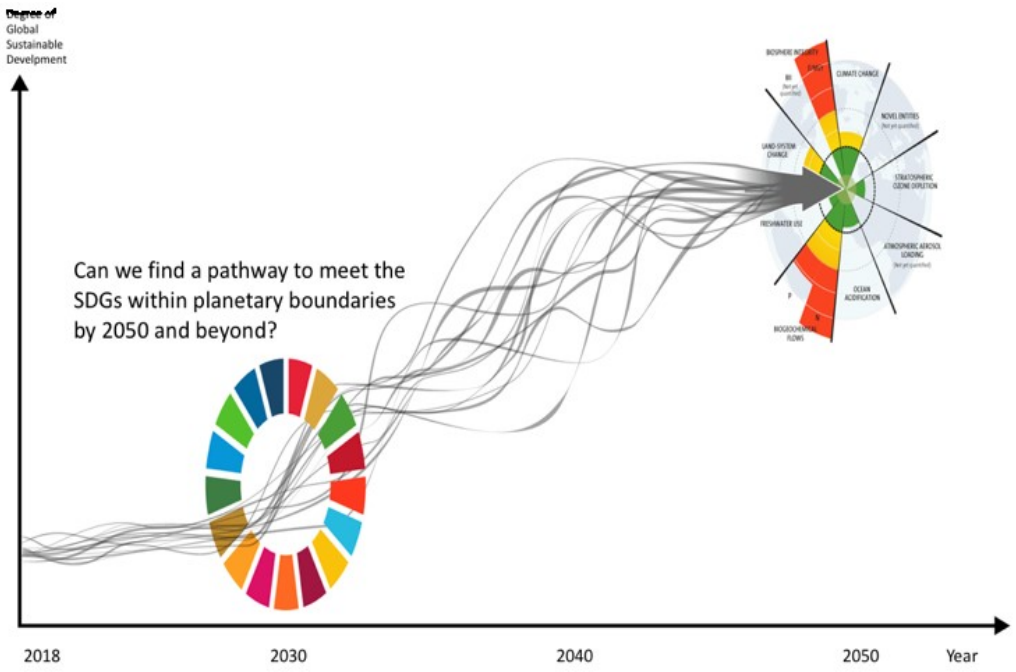
This paper will provide an adapted excerpt from a research project[147] aiming to answer the above questions. The project, named SDGinPB for short, developed a transparent, integrated and easily understandable modelling framework, which we call Earth3 (See Box 1) to give science-based answers.

Pathway analysis for achieving SDGs within PBs

The Earth3 model calculates the effects on the 17 SDGs of major socio-economic developments for seven regions of the world, and assesses the status of global environmental pressures on the nine PBs. In essence, it is a tool to answer the question: will given policies help the world move in an inclusive direction while staying within Earth's safe operating space?

[147] The full report is available here: Randers, J., Rockström, J., Stoknes, P. E., Goluke, U., Collste, D., & Cornell, S. (2018a). *Transformation is Feasible - How to Achieve the 17 SDGs within planetary boundaries*. BI, Stockholm Resilience Center. Retrieved from https://www.stockholmresilience.org/publications/artiklar/2018-10-17-transformation-is-feasible---how-to-achieve-the-sustainable--development-goals-within-planetary-boundaries.html So far, two research articles have been released in pre-print version, while in peer-review for publication Randers, J., Rockström, J., Stoknes, P. E., Goluke, U., Collste, D., & Cornell, S. (2018b). *Achieving the 17 sustainable development goals within 9 planetary boundaries,* https://doi.org/10.31223/osf.io/xwevb and Collste, D., Randers, J., Goluke, U., Stoknes, P. E., Cornell, S., & Rockström, J. (2018) *The Empirical Bases for the Earth3 Model: Technical Notes on the Sustainable Development Goals and Planetary Boundaries* https://doi.org/10.31223/osf.io/ephsf. Earth3 includes a simple system dynamics model, ESCIMO (Earth System Climate Interpretable Model) which is able to reproduce the main output from more complex climate models. ESCIMO represents the main causal mechanisms at work in the Earth system and is able to reproduce the broad outline of climate history from 1850 to 2015. See Randers, J., Golüke, U., Wenstøp, F., & Wenstøp, S. (2016) "A user-friendly earth system model of low complexity: the ESCIMO system dynamics model of global warming towards 2100" *Earth System Dynamics*, 7(4), 831–850. https://doi.org/10.5194/esd-7-831-2016 .

Figure 1 What pathways can lead to achieving the SDGs within planetary boundaries in 2050?



Box 1: About the Earth3 model

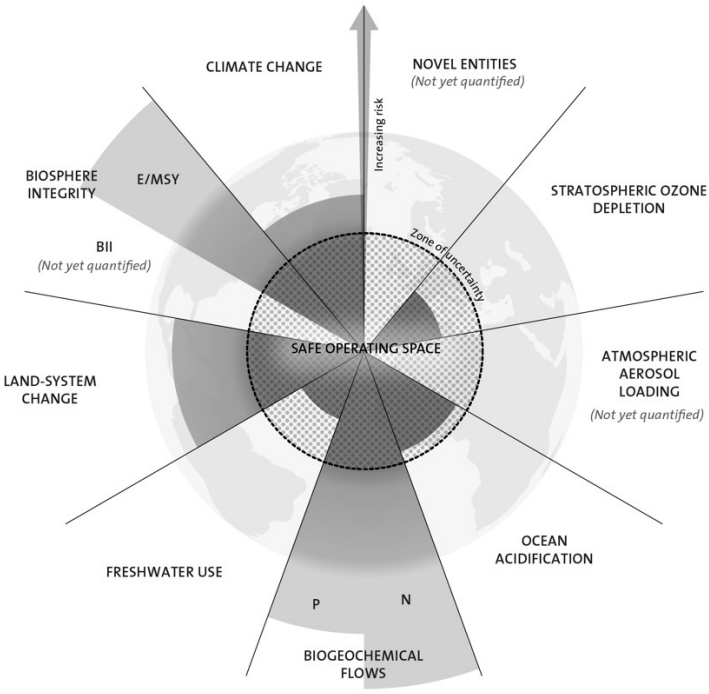
Earth3 is a Global Systems Model linking socio-economic and biophysical processes. It builds on more than 100,000 historic and new data points, from existing databases all over the world.

Earth3 first calculates the main socio-economic developments (GDP, population, distribution, energy use, etc.). Then it calculates estimates of how many of the 17 SDGs can be achieved by adopting certain policies in seven regions of the world. It also gives estimates of the status of global pressures on nine planetary boundaries for different world-development trajectories to 2030 and 2050.

Our modelling approach is described in Randers et al. (2018b). Data sources are further described in appendix 2 of the "Transformation is Feasible" report and in Collste (2018): "The empirical basis for Earth3 model system". How we model the Earth's biophysical systems, including 15 identified tipping points, are described in Randers (2016) "A user-friendly earth system model of low complexity: the ESCIMO system dynamics model of global warming towards 2100."

The SDGinPB project has focused on calculating the effects of policy actions needed for meeting the globally agreed development goals within the safe operating space of a stable planet. Earth's safe operating space is defined through the nine planetary boundaries boundaries – global quantifications of human-caused environmental changes, where continued pressure risks destabilizing the long-term dynamics of the Earth system (see figure 2).

Figure 2 Nine planetary boundaries (PB) from Rockström et al. (2009) and Steffen et al. (2015). The dotted area represents the safe operating space. The greater the human-caused perturbation, the greater the risk of large-scale abrupt, and irreversible Earth system changes.



The grand ambition quantified: the SDG success score and PB safety margin

Our guiding question is: **how can the world succeed in achieving the Sustainable Development Goals within planetary boundaries?**

New studies show that currently no country meets the basic needs for its citizens at a globally sustainable level of resource use.[148]

To study the whole world's progress on the SDGs into the future, we calculate the number of SDG achieved every year, the "SDG success score". The SDG success score thus goes from 0 to 17.[149] This is done for each of seven regions in the world as well as aggregated for the whole world weighted by population. We also calculate how this progress impacts the Earth's safety margin. To see if any SDG achievement is inside the planetary boundaries, we calculate how this progress impacts the Earth's safety margin over time. Earth's safety margin goes from 0 to 9, in steps of 0.5. If all PBs are in the safe zone (green), the safety margin is nine. If all PBs are violated (high risk = red), the safety margin is zero. Which would give a high probability of irreversible decline in Earth's life supporting systems and possibly societal collapse.

[148] O'Neill, D. W., Fanning, A. L., Lamb, W. F., & Steinberger, J. K. (2018). A good life for all within planetary boundaries. *Nature Sustainability*, *1*(2), 88–95. https://doi.org/10.1038/s41893-018-0021-4

[149] We grade the SDG achievement in a simple way: An achieved goal (green) means 1 point. A goal that has passed the half-way target is 0,5 point (yellow). A red, i.e. not achieved goal is 0 points. See table 5.5 in appendix 1 of the *Transformation is Feasible* report for details on goals, chosen indicators and thresholds. Targets and thresholds are as far as possible based on Sachs et al. (2016). *SDG index & dashboards: A global report.* Bertelsmann Stiftung.

We assume that most of humanity would agree that a SDG success score of 17 with a PB safety margin of 9 is where we all want to be, whatever the population size is. The vision of 9 billion people living well on one planet,[150] can now be expressed more concretely as 9 billion people achieving 17 SDGs with Earth's 9 life-supporting systems in a safe state.

Figure 3 The UN 17 Sustainable Development Goals (SDGs), implemented by all the world's countries in 2016.

The SDGinPB project approach

In short, the project answers the research question by analysing the developments in all 17 SDGs, the 9 planetary boundaries across 7 regions of the world to 2050. To our knowledge, this is the world's first study to see if all SDGs can be reached within the PBs based on an integrated Global System Model.

The main types of input to our modelling approach are socio-economic data from 1980 to 2015 for all the world's countries. These include economic growth rates, population, education, health data, resource use and more aggregated into the regions. We use the most suitable publicly available databases to establish the historical trends.[151]

The Earth3 model includes parameters that can reflect policy levers in many areas. The parameters can be seen as a "policy dashboard" for running the world model to 2050. There are levers per region to influence the expected a) Growth rates, b) Jobs, poverty and inequality levels, c) Energy use and composition, d) Food- and agriculture productivity, and finally e) Education, health and gender variables.

Based on this input, the Earth3 model can then calculate the SDG Success Score for each region and the Earth's common safety margin based on the state of the planetary boundaries.

[150] World Business Council for Sustainable Development. (2011). *WBCSD - Vision 2050*. Retrieved Aug 27, 2018, from https://www.wbcsd.org/Overview/About-us/Vision2050/Resources/Vision2050-Road-Map
[151] One such central database is Feenstra, Robert C., Robert Inklaar and Marcel P. Timmer (2015), "The Next Generation of the Penn World Table" American Economic Review, 105(10), 3150-3182, available for download at www.ggdc.net/pwt For more on the databases, see Collste (2018), ibid.

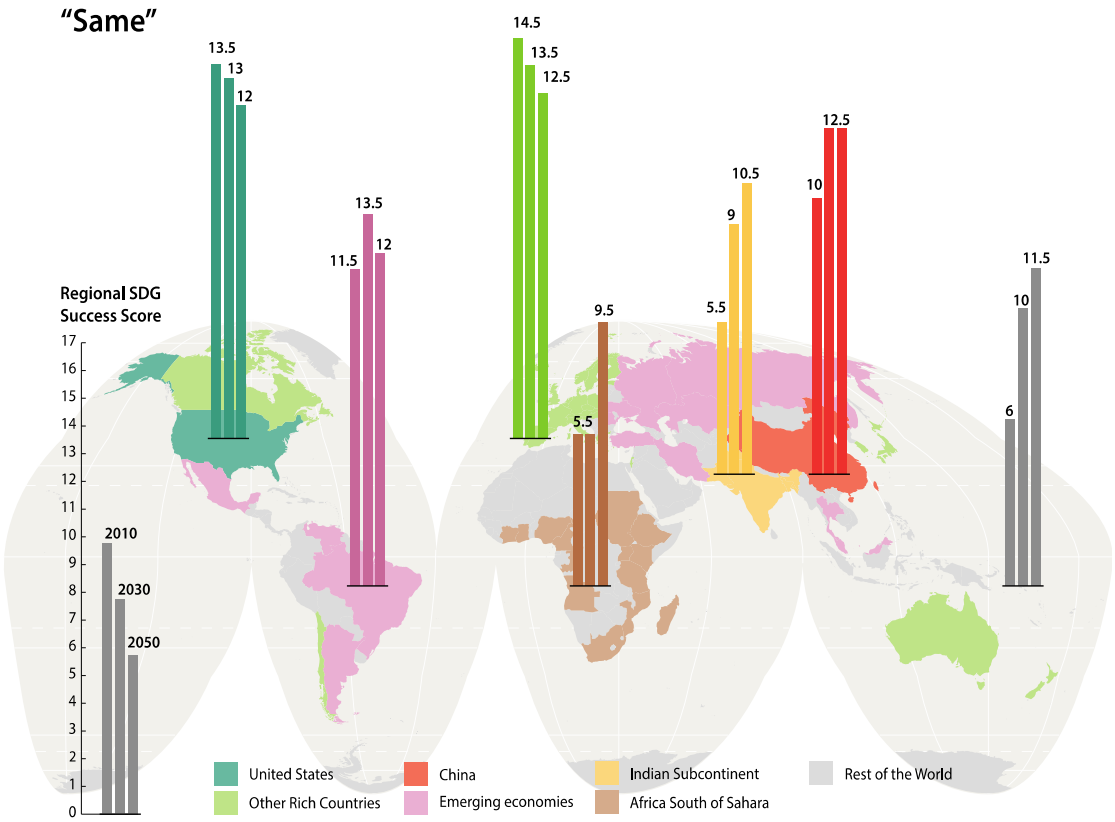
The project explored four possible and plausible pathways to 2050. The exploration consisted of four scenario simulations of how the world can respond to the grand challenge, with each scenario giving both a regional and a world SDG as well as a global PB score. The four scenarios are all based on the same historic facts but are shaped by different policy and investment choices made in the coming decade(s).

We do not assign probability to the scenarios, which means they are not predictions. Some people may consider the first, business-as-usual scenario most likely and the fourth transformational scenario very unlikely. Others the opposite. We hope such foresight analysis will stimulate debate and create understanding about the long-term view on the SDGs, the synergies between them, and how they are systemically related. But based on historic and current trends, using the best socio-economic and biophysical data available, the modelling clearly shows that only the most transformational scenario points to a sustained higher and inclusive human wellbeing. This fourth, "Smarter" scenario achieves most of the SDGs while staying within most of the PBs. Thus, the results from our analysis show that only one out of the four pathways actually rises to the grand challenge.

Summary of four scenarios to 2050:
Through the scenarios we tested four different answers to the same research question: *"How can the world achieve the Sustainable Development Goals within planetary boundaries?"* The first answer comes from modelling how far the world will get by following business as usual to 2050. The second from simulating how far the world could get with faster economic growth. The third by pushing known policies harder toward sustainability. The fourth by calculating the scale of key transformational actions actually needed to get there. Below I give a short summary of the three first scenarios, and then a more detailed description of the fourth.

Scenario 1) *"Same":* how far will business as usual take the world to 2050?
This baseline scenario explores a future where the ***Same*** policies and actions are applied at the same pace into the future. Governments and industry will respond to technology, inequality and climate change in the conventional ways that the world has done over the last three decades. Despite rapid technological changes, digitalisation in particular, the data from the last decades shows that most rates of socio-economic change are slow. In a more-of the-***Same*** world, there is even more *talk* about sustainability and SDGs, but in practice nations still continue to change at the very same pace. But this pace of progress proves insufficient to deliver on the SDG targets by 2030 nor 2050. The good news is that poverty and hunger is finally eradicated by 2050! However, the economy's large resource use and waste flows leads to more planetary boundaries in the red zone. This leaves many of Earth's life-supporting systems in a high-risk of irreversible decline, and people's prospects for wellbeing, particularly the poor, bleaker by 2050. In total, the world's SDG score only improves from 9 in 2015 to 11 in 2050. The main two reasons are that inequality continues to grow both within and between countries, and the second that total human footprints are too high. Planetary boundaries in high risk zones along with failing achievement on SDGs 13-15, pull scores downward to 2050. By responding to our new problems in the ***Same***, conventional ways, most people on Earth end up in a more precarious situation in 2050 than we are in 2018.

Figure 4 SDG success score per region in the **Same** scenario. Regional SDG scores for 2010, 2030 and 2050 are shown.



Scenario 2) *Faster*: will accelerating economic growth help?

This scenario explores what happens if governments and industry succeed with faster economic growth. Higher incomes can give extra funds to pay for more education, clean water, food, more jobs and the other SDGs for all people. The ***Faster*** growth scenario explores the effects of accelerated economic growth all the way to 2050. To achieve this, governments ramp up conventional policy tools, such as increasing trade, innovations and investments, keeping corporate taxes and interest rates low. We model growth rates that are +1% higher in GDP per person than the historic trend, which makes the global economy significantly larger by 2050. In this way, higher incomes are available to solve the world's problems. But this approach only delivers a little bit better on the weighted SDG success score, from 8.8 in 2015 to 11.7 in 2050. Indeed, the planetary boundaries are more severely violated than in the ***Same*** scenario. Many people get very wealthy, but societies suffer even more destabilising inequality, and humanity as a whole undermines Earth's safe operating space by overexploiting nature's life-supporting systems. Earth's safety margin is down from 8 in 1980 to 3 in 2050 (see figure 10 below).

Scenario 3) *Harder*: what if both governments and industry try even harder to deliver on SDGs?

In this scenario, we explore where working harder for sustainability on all fronts will lead. The world's decision-makers focus real attention and energy on achievement of the SDGs. They allocate more funds to pay for more education, clean water, food, more jobs and the other

SDGs for all people. In this way, governments strengthen their conventional policy tools, starting in 2018 and soon do on average 30% more rapid progress on SDG-achievement than they did in the 1990–2015 period. More workforces and funds are redirected to projects that help achieve SDGs and/or reduce the pressure on PBs. But by delivering on the SDGs one by one in a piecemeal way, department by department and ministry by ministry, there are many trade-offs. And by 2040 the planetary boundaries are still under strong pressure, which leads to flat SDGs scores from 2030 to 2050. Many regions still struggle with destabilising inequality that undermines the sustainability policies. The ***Harder*** pathway leads humanity to still undermine Earth's life-supporting systems, even if less so than in ***Same*** or ***Faster***.

Scenario 4) *Smarter*: what if governments and industry actually choose transformational actions?

This scenario explores five bold transformations in our societies and economies to see whether these can bring the human world to a desired future on Earth. This is a challenge-and-response scenario which describes the extent of what is needed to "hit target". Rather than repeating the ***Same*** conventional solutions, growing ***Faster*** or trying ***Harder***, this scenario explores what would happen if five bold, extraordinary actions were rapidly executed by decision- and policymakers in all regions. The ***Smarter*** scenario assumes that the world's countries and their leaders together, pushed by their citizens, become aware of the massive scale of the challenge ahead, and that the changes in mind-sets spread worldwide. Then, they rise to the challenge by implementing five turnarounds:

1. Rapid renewable energy growth – sufficient to halve carbon emissions every decade from 2020.
2. Accelerated productivity in food chains – improving resource productivity by +1%/year.
3. New development models in the poorer countries – which follow relevant models such as China, Scandinavia, Ethiopia or Costa Rica.
4. Active inequality reduction – ensuring that the richest 10% take no more than 40% of income.
5. Investment in education for all, gender equality, health, family planning – stabilising the world's population.

Despite initial criticisms for being too radical during the 2020s, in the ***Smarter*** scenario these five transformative efforts are then widely adopted, accelerated, and scaled over the coming decades. The scenario model runs indicate that these actions together create synergies that are capable of attaining (nearly) all SDGs while staying within (nearly all) planetary boundaries.

What are the transformational requirements to succeed?

As the focus has been to explore a scenario which leads to transformation, I will in the following deepen the description of this "Smarter" pathway to 2050. The 5 requirements to succeed mentioned above are all systemic interventions that hold the promise to achieve multiple of the SDGs simultaneously.

Smarter progress by focusing on human wellbeing

In this scenario, during the 2020s, the most governments increasingly accept that maximizing GDP as a first priority is not the best way to achieve sustainable human wellbeing. The EU's

work on "Beyond GDP"[152], OECD's work on wellbeing[153] and China's work on *héxié shèhuì*[154] (a harmonious society) and the China dream, all reflect a deeper value shift in many societies. In the ***Smarter*** world, the broader objectives of society are seen as better defined by the first generally agreed sustainability framework signed up to by the majority of the world's nations back in 2016: achieving all SDGs without endangering planetary ecosystem. This proved – in seen retrospect from 2050 – a paradigm shift for global development, when the move away from a sectorial approach to dealing separately with social, economic and environmental issues to a model of mutual leverage.

Recognizing the deep transformation required, more governments explicitly shift their long term purpose to *maximizing wellbeing and human capabilities*. They acknowledge that a conventional market-based growth approach has weak incentives to achieve SDGs; and none at all for protecting the commons, social welfare or any other non-economic values. In national decision-making, the wellbeing measure is accordingly widened from the previous function of just consumption, to also include the SDGs.

The "Smarter" pathway to 2050: How five transformational policies are rolled out

Rather than pushing for faster growth or working incrementally harder at each SDG separately, the ***Smarter*** approach happens through a systems transformation where five main policy initiatives start to create synergies and deliver on multiple SDGs at the same time.

1) Smarter Energy: accelerated renewables growth

A worldwide *rapid electrification* in power, transport, as well as heating and cooling, is rolled out. This happens by scaling up mainly solar and wind power, energy efficiency, distributed energy storage, electric vehicles, heat pumps and necessary distribution infrastructure, all digitized and integrated in smart grids to replace fossil fuels. Nearly all investments in fossil fuels (a historical average of 1.5%-2% of GDP per year[155]) are shifted to renewables and power infrastructure during the 2020s. The higher investments are driven both by a combination of demand-side pull as renewables start delivering higher profitability than fossils, with a government push through tougher regulations. This results in a doubling of the annual growth rates in wind, solar and other renewables during the 2020s.

Most countries also put in place bans on new fossil-fuel investments, including announcements during the 2020s of coming bans on sales of new fossil-fuel cars. Most regions adopt some form of the "Carbon Law"[156]: That means halving carbon emissions every decade, starting in 2020. This rapidly reduces global carbon emissions and at the same time eliminates human suffering by spreading affordable electricity to cities, slums and remote areas. In this field China takes the global lead, with strong policies for transforming coal-reliance to low-cost distributed renewables and electric mobility that make it profitable for

[152] EU Commission, (2013), *Progress on 'GDP and beyond' actions*, Commission Staff Working Document http://ec.europa.eu/environment/enveco/pdf/SWD_2013_303.pdf
[153] OECD Statistics, (2018), *Measuring Well-being and Progress: Well-being Research* http://www.oecd.org/statistics/measuring-well-being-and-progress.htm
[154] Joshua J. (2017) *China's Economic Growth: Towards Sustainable Economic Development and Social Justice.* Palgrave Macmillan, London
[155] IEA / OECD (2018) World Energy Investment 2018, , accessed 1 Aug. 2018 from https://www.iea.org/wei2018/
[156] Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. *Science*, *355*(6331), pp. 1269–1271. https://doi.org/10.1126/science.aah3443

other countries to follow. The direct use of fossil fuels and in buildings are replaced with electrification and smart system redesign. In this ***Smarter*** scenario, global carbon emissions fall from over 30 $GtCO_2$ in 2015 to 20 in 2030, 10 in 2040, and just 6 in 2050.

The effect of this energy system transformation is that it starts to wean the world off fossil fuels and hits the nail on the clean energy goal (SDG7). Giving most people access to safe and clean energy creates a functioning energy democracy, which improves the development of many other SDGs (1, 2, 6, 8, 9, 11-13). There is, finally, "power to the people". It provides better access to light, education, clean water and communications. In addition to reducing climate change (13) it also helps fight poverty (1) and make more jobs (8). It makes innovations and infrastructure (9) more available, reduces food-waste and hunger by access to refrigeration and logistics. It helps making city air cleaner (11) by replacing combustion. In sum, universal access to cheap and clean electricity changes everything!

2) Smarter Food: accelerated shift to sustainable food chains

In the ***Smarter*** scenario, the world also accelerates the transformation to sustainable agriculture, linking production to better logistics that drives down food waste, as well as fertilizer and pesticide overuse. People shift their diets to more plant-rich foods which lowers the share of meat per person (particularly in richer countries).[157] The food system gets more direct links between food producers and consumers, i.e. direct delivery of easily available, affordable and nutritious foods that people actually need and want. This brings down food waste along the entire food chain, from soil to table.

New technology builds on the rapid development of digitalization of agriculture, cheap sensors, satellite monitoring and the Internet of Things to make real-time big data available to monitor the state of each field, river, crop and shop. Through better water management, total water use is brought within planetary boundaries. Intelligence embedded in water pipelines helps stop water loss from leakages and secures good water management in all river basins. It makes fresh-water pricing more accurate and feasible, giving incentives for better water efficiency. Biogas and composting replace landfills and surface run-off to the oceans, creating the capacity to recapture nitrogen and phosphorus and circulate these nutrients within bioregions.

These kinds of both low-tech and high-tech solutions enable increasingly regenerative agriculture to produce more food without any further land expansion. The release of bioactive nitrogen starts to decline. Climate-smart agriculture becomes a net carbon sink and draws down over one billion tons of carbon into the soil per year from 2040.

A less waste-full and more productive food system will also increase people's health as they get more nourishing and affordable food. With recycling of nutrients, it also improves clean water (SDG6), responsible consumption (SDG12), and reduces the pressure on climate change, life on land and life below water (SDG 13-15). In sum, all these improvements lower the footprint of the entire food chain by an extra 1% per year, relative to the ***Same scenario***.

3) Smarter Growth in poor countries: rolling out new development models

A higher growth rate is achieved in the world's poorest countries by increasing investment, strengthening institutions and allowing favorable trade arrangements in the early stages of

[157] See p. 39 ff. in Hawken, P. (Ed.). (2017). *Drawdown: the most comprehensive plan ever proposed to reverse global warming*. New York, New York: Penguin Books.

industry development. The liberal market ideal is supplemented with various planned developments where certain industries that are of national interest are cultivated – inspired by role models of countries such as China, South Korea, Ethiopia, Scandinavia and Costa Rica. First Japan, then South Korea, Singapore and China managed to quadruple the GDP per person over thirty years. As other poor countries repeat these feats, they start providing each citizen with a reasonable standard of living. China has achieved an unprecedented duration of sustained economic growth and lifted hundreds of millions of people out of poverty in the process. (See box 2, on "the Chinese model".)

The Chinese model is preferred by many such countries over the Washington Consensus, which prescribes policies such as macroeconomic stabilisation, rapid economic opening with respect to both trade, finance and investment, and the expansion of market forces within the domestic economy. During the 2020s many of the world's poorer countries thus roll out forward-looking protectionist policies too, to raise standards of living by allowing their economies to catch up, and protect infant industries, without full immediate exposure to competition with advanced global industries in their home market in the beginning stages.[158] The effects in these countries are more rapid inclusive economic growth that lifts many millions more out of poverty quicker, and also delivers on hunger, jobs growth, clean water, better health, education, infrastructure (SDGs 2, 3, 4, 8, 9).

Box 2: What do we mean with "the Chinese model"?

"The Chinese model" is often equated with authoritarian capitalism – single-party rule combined with extensive state ownership and control over the economy. Others call it a political meritocracy[159] in contrast to democracy.

Rather than just authoritarianism dominating over markets and people, it seems there were many factors stimulating China's dynamism in the latest decades. Key factors were the introduction of some democratic qualities through bureaucratic reforms according to *long-term plans*, and Beijing's willingness to allow and direct local improvisation. In her research, Yuen Yuen Ang found that under Deng's rule: "Instead of trying to command their way to rapid industrialisation and growth, reformers focused on creating the right conditions for lower-level officials to kick-start development in their own communities using local resources."[160] Instead of only top-down commands, the country often leveraged local knowledge and resources, promoted diversity, and motivated and incentivized people to step up efforts and share ideas.

In short, with "the Chinese model", we refer in this report to the characteristics and conditions under which certain newer historic experiences in China – and in several other countries such as Ethiopia and Costa Rica – may have high relevance and serve as inspiration for the development of other countries. No such model is a perfect ideal to copy-paste; and each should be seen in the light of the other transformational strategies (further rapid transition from coal to renewables, reduction of inequality, etc). The rapid, intentional and positive change these models have delivered substantiate our claim that this kind of transformation is possible and shows how it can be done.

[158] Reinert, E. S. (2008). *How rich countries got rich... and why poor countries stay poor*. London: Constable.
[159] Bell, D. (2015). *The China model: political meritocracy and the limits of democracy*. Princeton, New Jersey: Princeton University Press.
[160] Yuen Yuen Ang,(2018), "The Real China Model", *Foreign Affairs*, accessed 1 Aug 2018 https://www.foreignaffairs.com/articles/asia/2018-06-29/real-china-model

4) Smarter inequality reduction

Increasingly both rich and poor countries face the need to reduce growing unemployment and inequity. During the early years of the 2020s there is a series of political crises which are fed by broad protests and discontent among the public about the extreme unfairness of wealth inequality. A push for fairer wages and more progressive taxation succeeds at redistributing total output. Many developing countries intensify the domestic resource mobilization by improving their tax systems. As a result, there are funds for better service delivery and development for the majority.[161] There is, also in richer countries, growing accept of the recommendations from IMF[162] and OECD[163] to reduce inequality to enhance growth and wellbeing. By shortening the work-year for everyone, it becomes possible to create and share more jobs, even in regions and sectors where there is low or no per capita GDP growth.

By 2025, there is broad and growing recognition among voters that it is of interest to national stability to ensure that the 10% richest take no more than 40% of income. Downward redistribution of wealth, work, and incomes through policies such as higher unemployment benefits and a shorter working year is the best way for businesses and banks to guarantee a stable economic future in the developed world, because it will put more money into the pockets of the poor. It allows the less well-off to spend more, which also improves conditions for business, investors, and the banking sector.

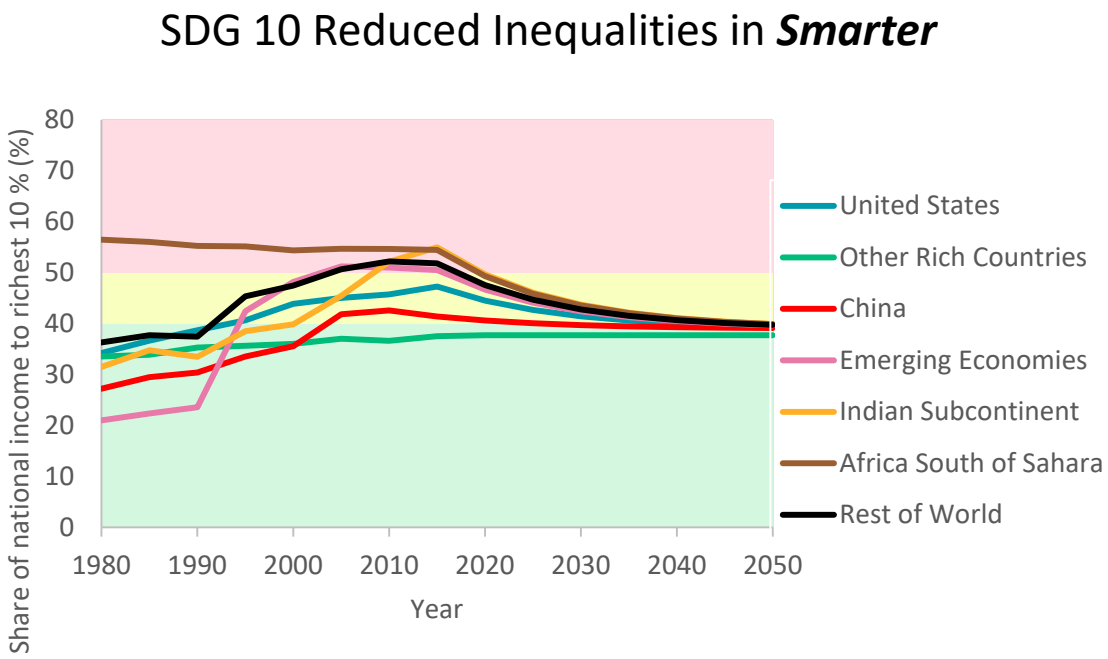
The funds raised by progressive taxation of income and wealth are also used to stimulate well-being by delivering on SDG achievement (particularly on health, education, infrastructure, sustainable cities and responsible consumption, i.e.SDGs 3, 4, 9, 11 and 12). Extensive downward redistribution efforts through more progressive taxation and unemployment benefits are stepped up in most countries during the 2020s. The historic trend of a falling median incomes since the 1980s is reversed starting in the 2020s. This proves conducive to regain more trust in government and stability in politics, which strengthens institutions (16) and partnerships for the goals across national borders (17).

5) Smarter investment: education for all, gender equality, health, family planning

Global funds that focus on education, especially for all women, are strengthened. This gives women broader opportunities for autonomy and work. In addition, better family planning and urbanization give women more freedom to choose the kind of life they want. The more female leaders the world gets, the more women become empowered to take positions of leadership, a self-reinforcing loop.

[161] Lundstøl, O. (2018) 'Tax in Development: Towards a Strategic Aid Approach' *ICTD Working Paper 77*.
[162] IMF, 2017, The IMF's Work on Inequality, https://blogs.imf.org/2017/02/22/the-imfs-work-on-inequality-bridging-research-and-reality /
[163] OECD, 2012, Reducing income inequality while boosting economic growth: Can it be done? https://www.oecd.org/eco/growth/49421421.pdf

Figure 5 In Smarter, in an overall richer world by 2050, the regions gradually succeed in reducing income inequality to the before-1990 levels, at which the top 10% richest take <40% of total incomes.



While women worldwide were closing the gender gap before 2018 in critical sectors such as health and education, significant gender inequality persists in the workforce and in politics. The rate of progress for women starts slow, too. Between 2006 and 2016, the proportion of female leaders increased by only 2%.[164] But when women are better represented in leadership roles, more women are hired across the board. This picks up speed from 2025 and onwards, when the world recognizes that to encourage more female leadership is one of the levers for increasing gender equality in the entire workforce. Results speak for themselves, and by the 2030s it is becoming increasingly clear that a good gender balance is much smarter and more profitable[165] (SDGs 5, 8, 16) than the conventional male-dominated networks.

This also results in women choosing freely to have lower average birth rates. In many countries, these five factors (education, urbanization, job opportunities, family-planning and reproductive health) combine to give better wellbeing for both women and children.

Smarter, but there's still widespread resistance to transformation…

Regardless of good progress and smarter policies, environmental stresses – air pollution, water, heatwaves, wildfires – have been building up and worsening for many decades. These cause more urban crises and waves of migration, in the decades up to 2040 relative to 2015, and contribute to conflicts, and sometimes civil wars. These put severe pressure on many fragile institutional structures. Political crises, corruption and distrust of interventionist

[164] World Economic Forum, 2.nov. 2017 https://www.weforum.org/agenda/2017/11/women-leaders-key-to-workplace-equality
[165] Noland & Moran, 2016, Study: Firms with More Women in the C-Suite Are More Profitable**,** HBR, https://hbr.org/2016/02/study-firms-with-more-women-in-the-c-suite-are-more-profitable

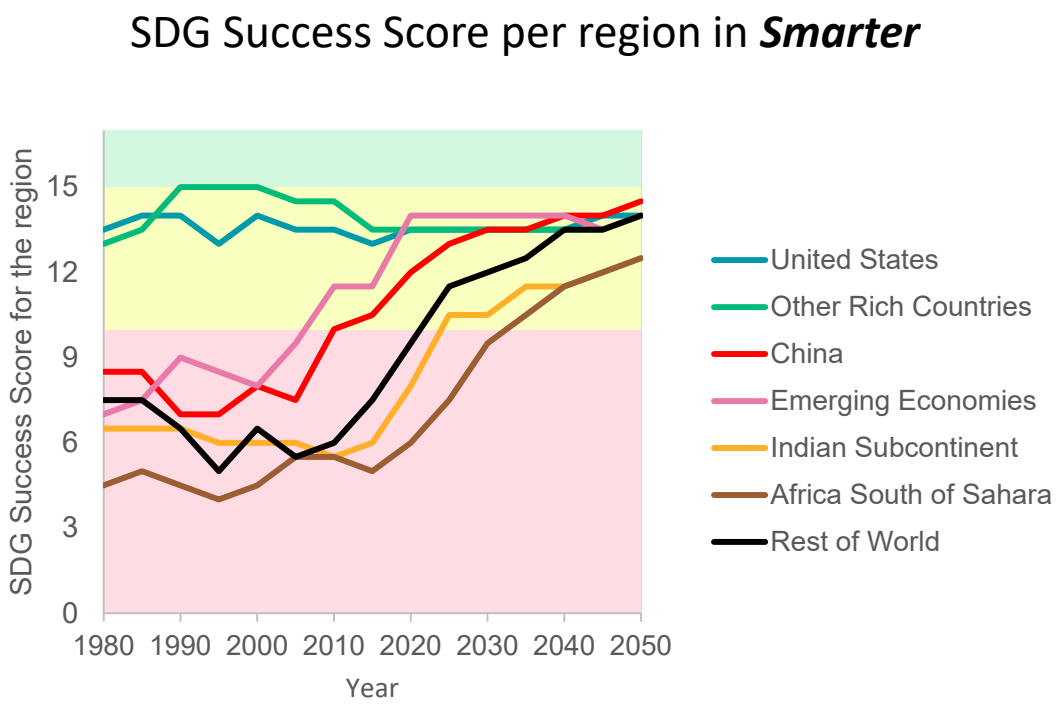
government cause an outspoken opposition to the active planning and government roles key to rolling out the transformative actions. The increased progressive taxation to reduce inequality is also a hotly contested topic for decades.

	Scenario SMARTER overview
Main policies (2020–2040)	Accelerated renewable energy growth, sufficient to halve carbon emissions every decade from 2020. Accelerated productivity in food chains, improving by extra +1%/year. New development models in the poorer countries, following models such as South Korea, China, Ethiopia or Costa Rica. Active inequality reduction, ensuring that the richest 10% take no more than 40% of income. Investment in education for all, gender equality, health, family planning, stabilising the world's population.
Unintended obstacles & challenges (2025–2050)	Distrust of central government roles; More nationalism that discredits global cooperation; Ideological opposition to downward redistribution, particularly in Anglosphere; Market fundamentalism that opposes government work on market design.
Outcomes & consequences (2050 →)	World SDG success score of 14 (out of 17); Safety margin of 7: Zero PBs are in high-risk zones, and four in yellow: Global warming, forest degradation, air pollution, toxics (all at 0.5 pts).

Yet, since there are better redistribution measures in place that large majority groups benefit from, a stronger taxation base, and an international commitment to peace and partnership that remains resilient and responds rapidly, the worst crises are dealt with before descending into full collapse of large cities or more failed states.

Despite such obstacles, there is growing acceptance of the evidence that effective and smarter – rather than just bloated and bigger – governments are a huge boon to all market economies, of whatever culture and ideology. And there is evidence that their functions are indispensable for social stability by reducing inequity, in addition to maintaining law and order. Overall, there is also a growing willingness to invest public funds in repairs and rebuilding of infrastructure. Government oversight also helps to account for the material flows through the economy in real-time. The data is used for optimising a circular economy and resource productivity so that total resource use does not threaten the safe operating space of both local ecosystems and global natural commons.

Figure 6 In this scenario, the poorest catch up earlier than in Same, Faster or Harder. This is the result of the five transformational actions having systemic effects on several SDGs The world's total success score also goes higher.



Increasingly, the financial sector and capital markets start connecting corporate activity to positive Environment, Social and Governance criteria (ESG) for investment. From a feeble start around 2015, ever more of the world's funds start to actively *apply* the Principles of Responsible Investment (PRI). The strength of this connection is priced into security and capital markets, and investors include these considerations in their day-to-day operations. Rather than just subscribing to PRI but doing little in practice (as in ***Same***), in the ***Smarter*** scenario the talk becomes reality, and more than half of the world's wealth gets invested in line with effective PRI and ESG guidelines. This has a large direct effect on how businesses join governments' concern for achieving the SDGs inside Earth's safe operating space.

Smarter delivers results from 2030 to 2050

As 2050 approaches, the ***Smarter*** world sees a rapid trend to job-sharing, fairer wages and extensive redistribution reversing the trend of worsening inequity from the three decades that led up to 2020. More regions also manage to provide equitable access to natural resources and ecosystem services. Both these give a net positive impact on GDP/capita growth, the first by stimulating demand, the second by better resource use.

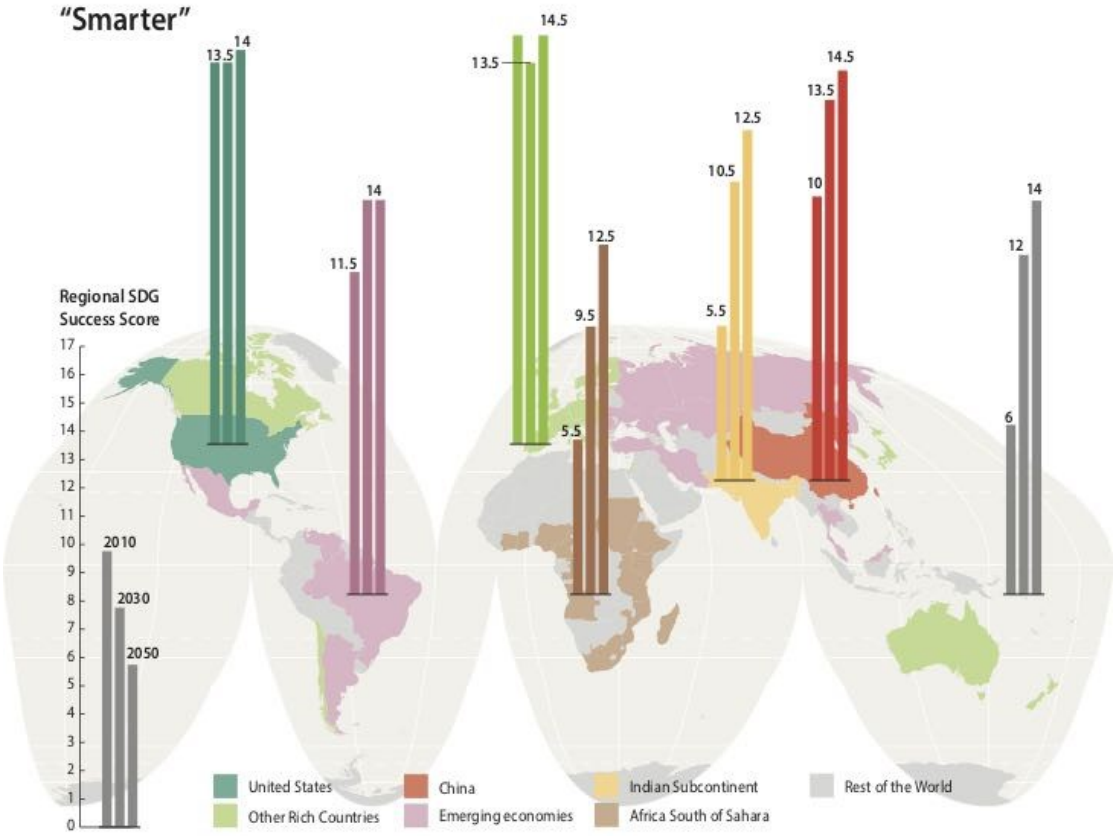
Population stabilizes more quickly as more women get radically better opportunities for education, jobs, economic autonomy, reproductive health and security, particularly in cities.

Among investors and private companies, there is a rapidly growing realization that business cannot succeed in societies that fail. The corollary is also true: societies striving for sustainability require the many opportunities that business can provide. The rationale for

broad business engagement with the SDGs could not be plainer[166]: the smarter solution is when government and businesses mutually reinforce markets and regulations to deliver on the goals that they are (or should be) designed for. The new conventional wisdom in the 2030s is that delivering on the SDGs can happen only if business, governments, and civil society work together; and this is rapidly put into action in transformative ways.

By 2050, most regions of the world are delivering on nearly all SDGs. Both India and Africa South of Sahara has shown tremendous progress (from a 5.5 regional SDG-success score in 2010 to 12.5 in 2050, see figure 7). This ***Smarter*** pathway seems to point the world's economy further toward a prosperous direction within the Earth's safe operating space by 2100.

Figure 7 SDG success score per region in the Smarter scenario. Regional SDG scores for 2010, 2030 and 2050 are shown.



Conclusion: so, will we achieve the SDGs within PBs by 2050?

The results show that while scenarios "Same", "Faster" and "Harder" can somewhat improve on the world's SDG achievement, they tend to do that at high cost to the stability and risk level of Earth's life supporting systems.

[166] UN Global Compact, and DNV GL *Spaceship Earth*, 2016, p.10.

In summary, the analysis shows that – of the four scenarios – only the five actions in the ***Smarter*** scenario can keep developing the world economy in an inclusive manner while staying within planetary boundaries. This type of transformative development seems to be able to secure a safe operating space for all of humanity before mid-century so that the world's societies can continue to flourish into the future beyond 2050 with safe(r) life-supporting systems on Earth.

Figure 8 The world's SDG Success Score for each scenario. The score is calculated as the sum of the regional success indices, weighted by population, for each scenario.

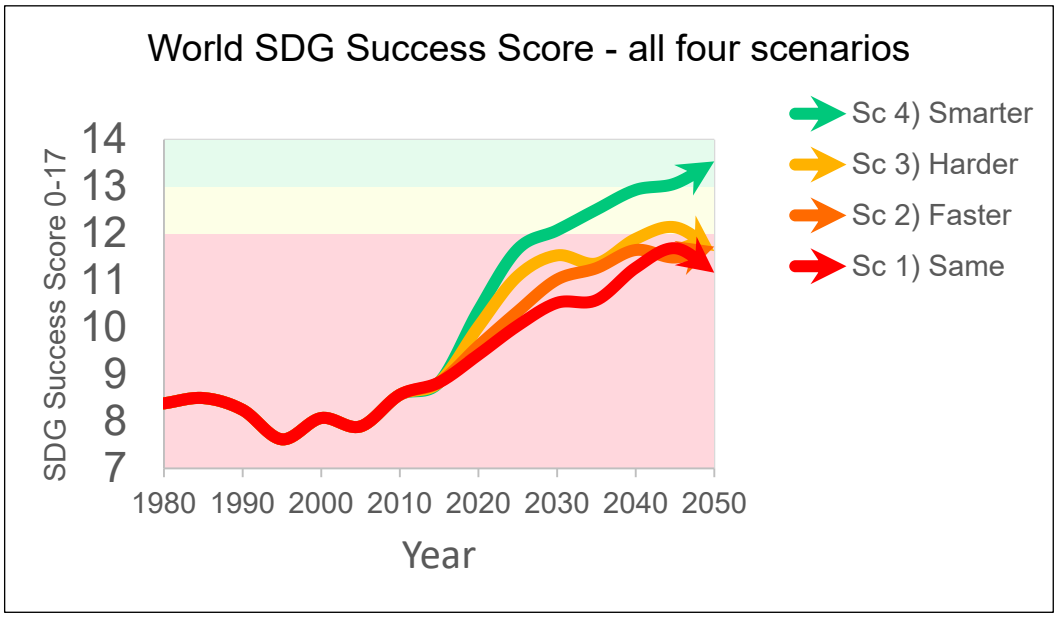


Figure 9 The four scenarios' impact on the Earth's safety margin. The safety margin is determined as the number of Planetary Boundaries that are within their safe operating space.

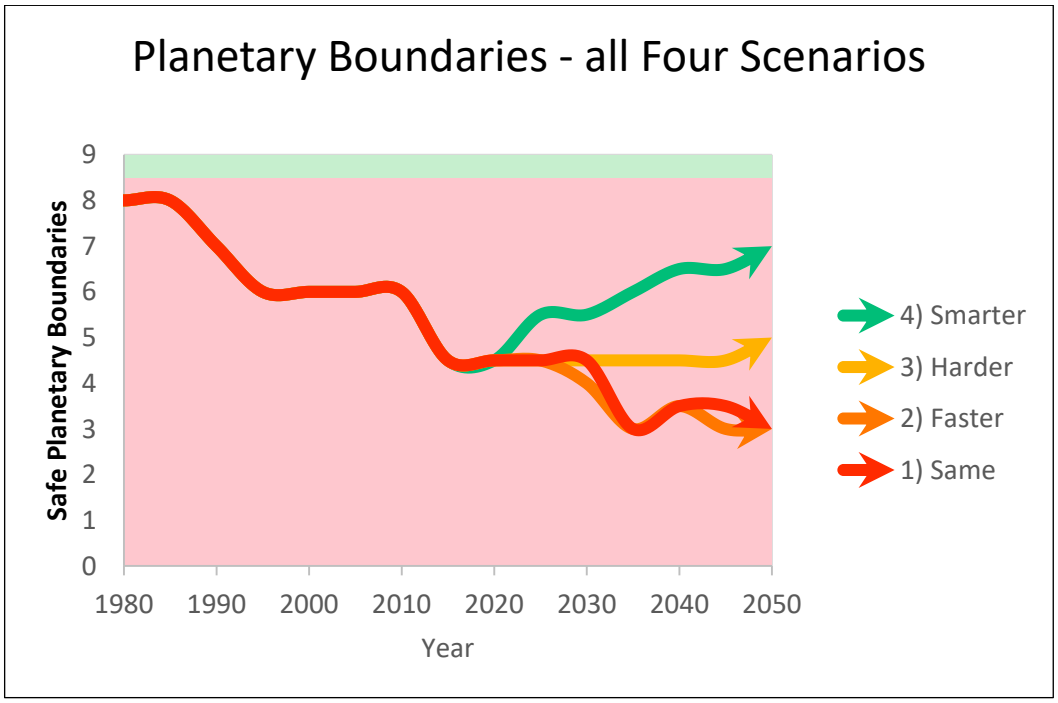
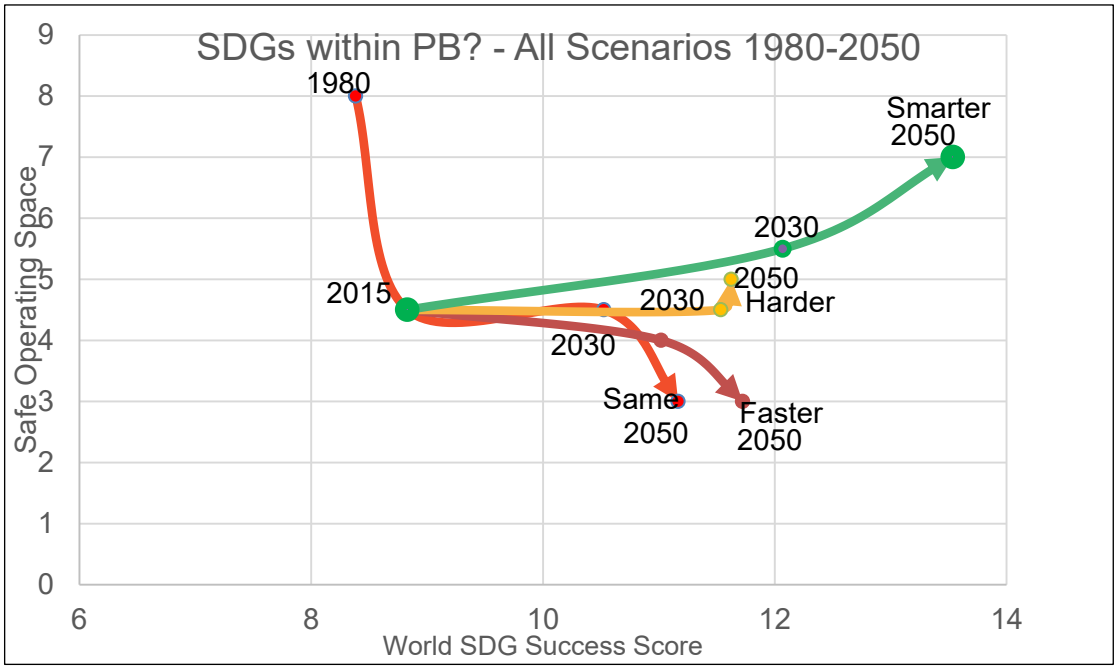


Figure 10 Achieving the SDGs within PBs: Only one of the four scenarios achieves the grand challenge of improving the world's SDG Success Score, without eroding Earth's Safety Margin.



The set of four scenarios together shows the necessity to consider global transformations if we're serious about attaining the SDGs within a stable Earth system.

On closing, we'd like to give two caveats: first, the Earth3 model system has not been developed to analyze and simulate what happens in a dynamic socio-economic transformation at the more detailed levels of real-world decision-making. It has too simple representation of the complex socio-economic feedbacks, such as rising inequality, debt, the long-term effects of education and social responses to crises. A more elaborate global system model for informing decision makers would also include structures linking socio-economics more explicitly with water use, food use, unused biocapacity and emissions, and other resource systems. We therefore aim to develop the model to next version, Earth4,

Our second caveat: the Earth3 model system is not a comprehensive model of all Earth systems. It does have representations of the complex environmental feedbacks between physical and living systems. Some of these feedbacks themselves are changing, such as greenhouse gas emissions from permafrost, ice sheet melting, forest dieback and more. If Earth3 underestimates these effects, then it could mean that failure to meet the SDGs within PBs may have even larger negative environmental social and economic impacts than illustrated in the scenarios, and thus lead to failure in reaching the SDGs in 2050 at all.

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