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Science without borders

Making the SDGs successful

New technological solutions for the Sustainable Development Goals and beyond

Nebojsa Nakicenovic and **Caroline Zimm** discuss how research into innovative technology and support from policy makers is essential for moving towards a more sustainable society.

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Technology in the broader context of science and innovation is central to human and sustainable development. The main drivers of global change and the core resources for addressing sustainability challenges are people, their technology choices and behaviours. These drivers define the relationship amongst all forms of human capital (such as knowledge including know-how and know-why), natural capital (such as land, water, energy, or the atmosphere), and the services they provide (such as food, lighting and clean air) which are essential for wellbeing. Technology is a key determinant for which type of natural resources are used, at what level of efficiency, how the use of one resource affects others positively (through efficiency gains for example), or negatively (through waste or pollution). As such, technology is the main mediator between humanity and the environment.

The Sustainable Development Goals (SDGs, or Goals) unanimously adopted in September 2015 by the United Nation's General Assembly, set a very high ambition for socioeconomic development and environmental sustainability. Their resolution on Transforming our world: the 2030 Agenda for Sustainable Development[1] sets out 17 Goals to be achieved by 2030. The SDGs are the short term goals of the long term aspirational transformation towards prosperity for all within a stable 'Earth-system'. Its 169 targets provide a detailed list of the action areas identified to implement this vision. The World In 2050 (TWI2050)[2] initiative is set to provide the science and policy for achieving all the SDGs in an integrated manner, so as to avoid potential conflicts amongst them and reap the benefits of the potential synergies of achieving them in unison (see **Box 1**).

BOX 1: 'THE WORLD IN 2050' INITIATIVE

'The World in 2050' (TWI2050) is a global research initiative that was launched by the International Institute for Applied Systems Analysis (IIASA), the Sustainable Development Solutions Network (SDSN), and the Stockholm Resilience Center (SRC). The initiative brings together a network of leading policymakers, analysts, modelling and analytical teams, and organisations from around the world to collaborate in developing pathways towards sustainable futures and policy frameworks needed for implementing the SDGs, and more importantly, for achieving much needed transformational change.

TWI2050 aims to demonstrate the feasibility of a sustainable future for all and the role of technology within that future, thus providing urgently needed knowledge on technological behaviour to achieve the SDGs.

More information: www.twi2050.org

TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

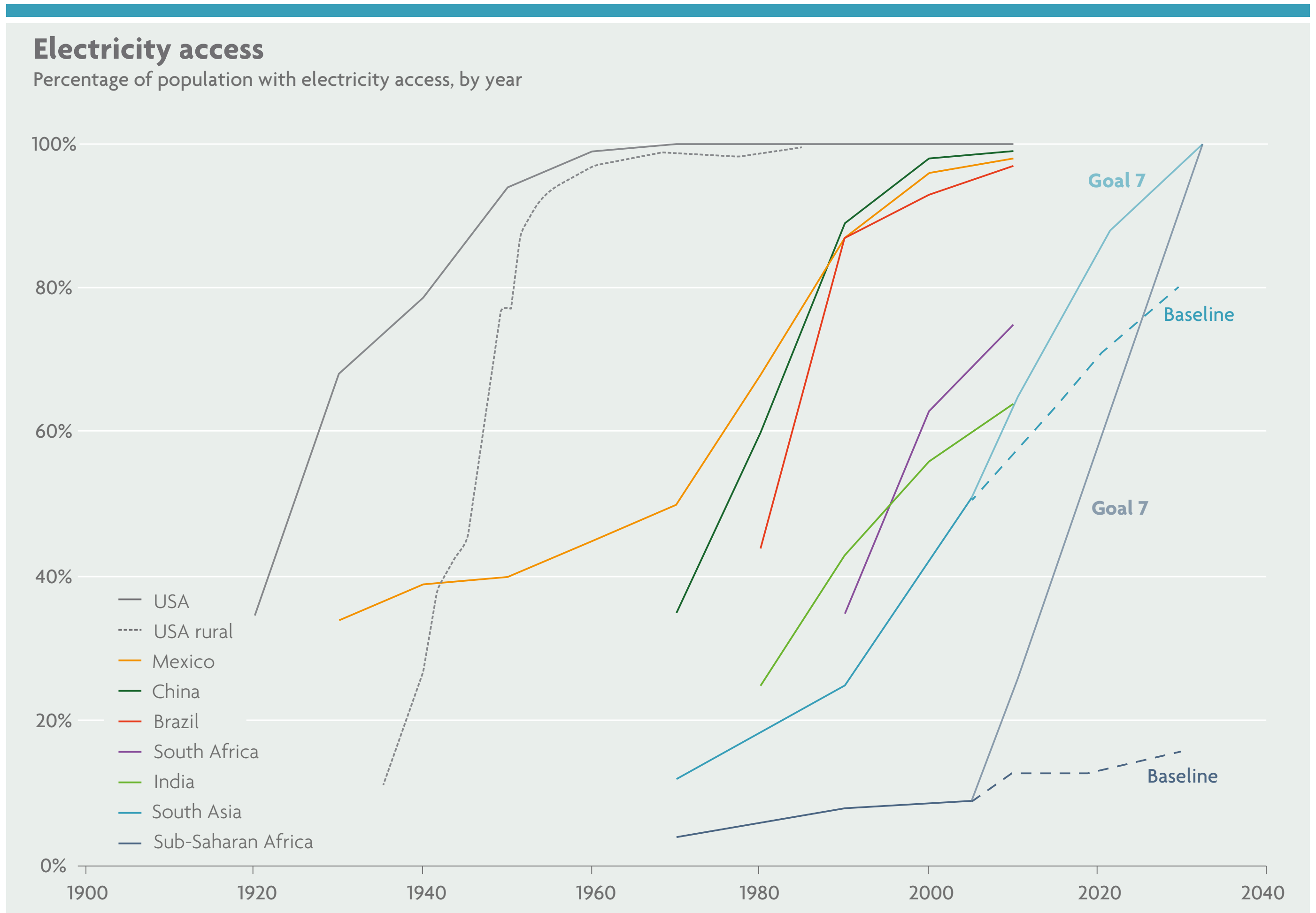
Science, technology and innovation are crucial for achieving the United Nations 2030 Agenda[1]. This Agenda strongly acknowledges the enabling role of technology: the term 'technology' is the fourth most commonly used noun (after 'countries', 'development' and 'access') within the Goals. In addition, technology examples feature prominently in several Goals, such as transport, energy and health, as do the related terms of innovation, science and knowledge.

One key concern addressed in the SDGs is improving access to technologies that satisfy basic human needs. Not only does humanity have to switch to more environmentally sound technology in general, it also has to achieve universal access for those excluded. While technology has provided parts of the global population with ever increasing living standards, about two and half billion people still lack access to clean cooking technologies[3], and another two and half billion do not have access to modern sanitation facilities[4]. Almost 800 million go hungry every night[5] and more than one billion do not have access to electricity[3]. **Figure 1** illustrates the rapid diffusion of access to electricity in a number of developed and developing countries, and the remaining gap (most often in rural areas) to achieve universal access to electricity by 2030 (Goal 7 – Affordable and Clean Energy). The figure shows that rural electrification was achieved very quickly in the USA, indicating that the challenge can be tackled with political will and the right investment environment.

Those lacking access have to bear the brunt of the negative environmental externalities linked to technology use by the affluent, such as air pollution, climate change and ecosystem degradation. This can be attributed to the high consumption and waste intensive patterns of the billion richest people. With the rise in the 'global middle class' from about two billion in 2010 to an estimated five billion by 2030[6], the historical development trajectories stand in direct conflict with the vision of the SDGs. Scaling up of existing advanced technological solutions with low adverse environmental impacts, together with new technologies with close-to-zero impacts, are required at an unprecedented scale for creating future systems that can simultaneously fulfil all 17 Goals.

TECHNOLOGICAL (R)EVOLUTION

Technology comprises both social dimensions (norms and institutions) as well as technological hardware (processes, products, and infrastructures). This is especially relevant for the successful and rapid technology diffusion[7] the SDGs call for. From this perspective, technology transfer of hardware alone is not a sufficient concept because social dimensions are concerned with the skills and institutions that need to be developed in order to benefit from advanced and new technologies. In this regard,



▲ **Figure 1. Diffusion of electricity access for select countries as percentage of population with access. (Adapted from Fig 19.5, Chap. 19, GEA[3])**

technology diffusion is primarily an endogenous process that can be enhanced through cooperation, capacity building and co-financing but not simply 'transferred' like hardware. This relates to adaptation to local circumstances, technology use and the need to develop national innovation ecosystems. Hardware plays a minor role in technology development and transfer; in other words, technology takes the form of disembodied and embodied knowledge and as such is a continuous learning process. It is, together with human knowledge, the only truly renewable resource and is a cumulative process requiring long term commitments and strategies[8,9] – this is exemplified through historical examples of technological 'forgetting' (the TriStar (L-1101) passenger aircraft[10] is one such example).

People develop and use technology in a broader context by way of a learning process. Hardware on its own is meaningless; it has to be assessed and developed in the context of the systems in which it is embedded. The technology system includes people and their institutions, and the knowledge, skills and cultural aspects related to its use and evolutionary history. It also includes the technology's characteristics, such as the resources used, and its direct and indirect impacts – positive and negative – thus providing many entry points for policy makers.

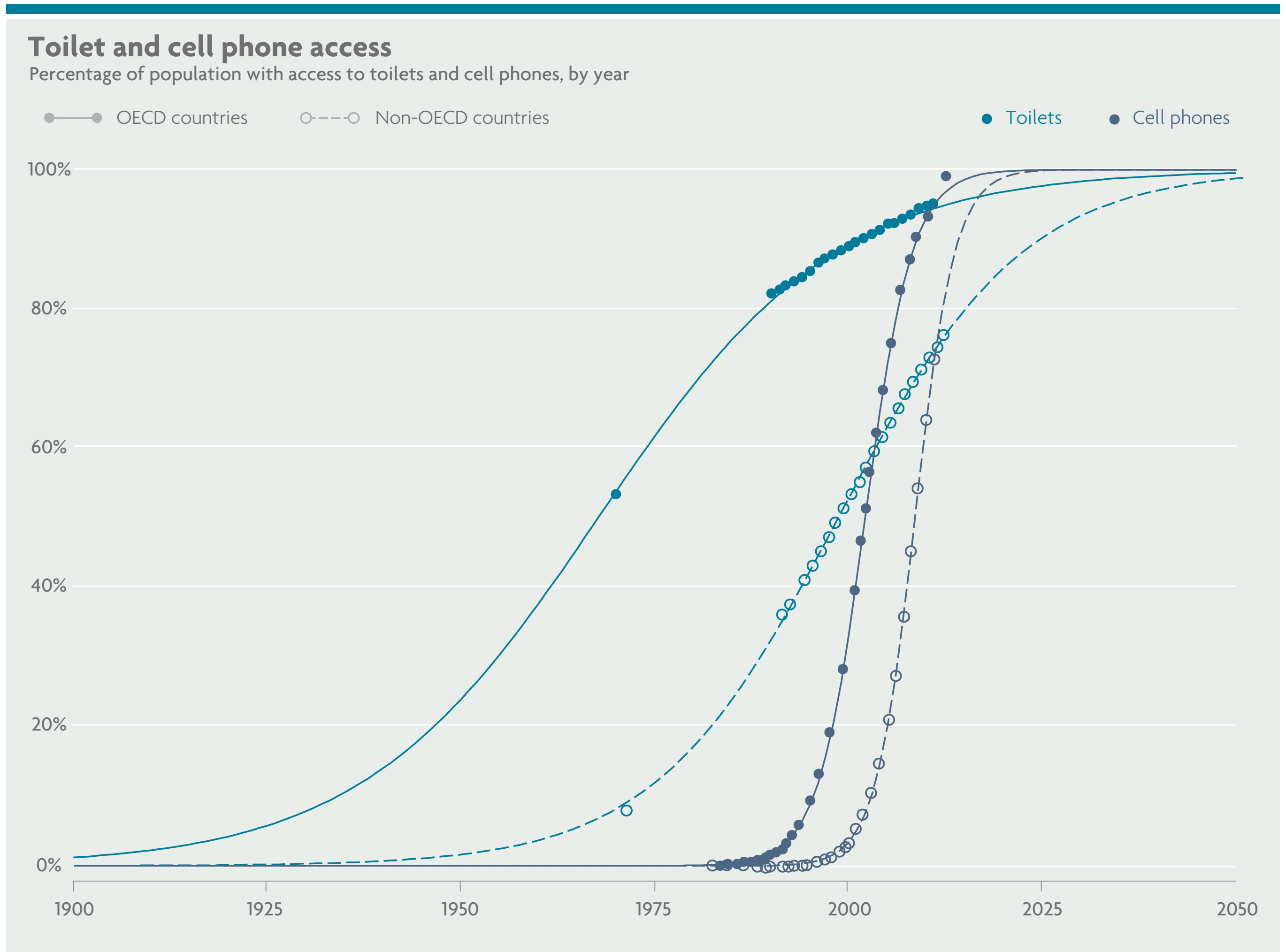
Policy makers have a deep interest in technology as it spurs economic development, but they too need to understand the different technologies within their systems. A key challenge for policy makers lies in creating a level playing field, and ideally accounting for externalities. Simply stated, public decision-makers are no better at identifying technological winners than anyone else. What is required is a competitive environment that nurtures innovations. Novel technologies often compete with well-established technologies supported through subsidies, favourable policies, or simply traditional inertia. Policymakers can alleviate these skewed market conditions and uncertainties by de-risking investments, and ensuring stable economic and institutional circumstances. The private sector is responsible for the largest share in developing and deploying technologies worldwide, but needs appropriate incentives and stable perspectives to invest in.

Research is needed to further the understanding of technology systems; studying the patterns, drivers, constraints, and impacts of technological change is required to identify viable options and policies that will accelerate the transformation of society towards a sustainable future. While technological change will always occur, high uncertainties remain about which technologies succeed. **Figure 2** provides an example of differences in technology diffusion rates, which raises the question why mobile phones have come close to reaching almost seven billion people[11] on the planet within three to four decades (including those without access to electricity), while two and half billion still lack access to safe sanitation after a century[4]. Detailed explanations are possible, but in the deeper sense, we do not have a theory that can capture the essential difference between the two diffusion processes. What can we learn from the success story of mobile phones for the diffusion of other technologies conducive for sustainable development?

To achieve sustainable development, available technologies should not be underestimated, some of which have already been proven and in need of up-scaling, while others are in an earlier diffusion phase. Additionally, incremental improvements alone will not be sufficient and technology revolutions will take over a substantial part in the transformation towards sustainability. It should be remembered that technological change is non-linear and true transitions are radical; disruptive change will therefore occur which will result in some actors leaving the market and for some, loss of investment.

System change is also costly and lock-ins, especially related to larger infrastructures, such as the electricity grid, sewage or transport systems, inhibit change and novel technology diffusion. On the other hand, inertia creates long term path dependencies, which support technological evolution with incremental change, but not revolutions, which can be seen more in end-use technologies.

The digital revolution has surprised society in many ways. It has emphasised the power of granular technologies, which are small scale, divisible, and have low unit cost. They also offer a series of potential benefits for rapid transitions. Novel analysis of historical data shows that granularity enables faster and less risky diffusion outcomes. Granular energy and end-use technologies have higher learning rates – relative unit cost reductions per doubling of cumulative output – than energy supply side technologies[12]. They offer a larger potential for system transformation, and greater equitably distributed



▲ **Figure 2. Technology diffusion compared: Diffusion of cell phones vs. toilets for OECD countries (solid) and non-OECD countries (dashed) (Data source: World Bank WDI, 2016[11] | CC BY. Model fit and graphic courtesy of Arnulf Grubler, IIASA.)**

benefits. In view of the Goals, a paradigm shift in focus from supply to demand can facilitate a rapid transition. In many sectors, such as in the case of energy, household level and distributed electricity generation (such as solar home systems) prove more successful in delivering last-mile electricity access than industry-scale centralised systems feeding the grid.

TECHNOLOGY IS NOT A SILVER BULLET

Technology was at the core of the agricultural, industrial and digital revolution. The next technological revolution towards sustainability will most certainly transform the world again and poses huge opportunities as well as threats for humanity. While technology is indisputably a transformative force, its application does not inherently promote human development. As a paradox, technology is the solution to many problems and simultaneously the cause of others. The power of technology can be deployed to support criminal and harmful activities, such as conflicts and wars as well as human and drug trafficking, thus threatening the achievement of the SDGs. Diesel generators, for example, bring urgently needed energy services to remote villages while emitting greenhouse gases. The internet both democratises information by providing easy access to knowledge, but it also facilitates organised crime; this is not just due to flawed law enforcement or misuse as technology design itself can be a key enabler. While novel technologies and innovations often provide solutions to a pertinent problem, they can come with undesirable side effects, which society sometimes only notices later in time – climate change being a prominent example. For many technologies in use today, humanity is lacking knowledge on their long term negative effects.

TOWARDS A TRANSITION TO KNOWLEDGE SOCIETIES

Technological change plays a key role in long term social transformations. The changes currently underway – such as the digital or sharing economy – are significant. With the advent of 'knowledge societies', many current technological transitions favour non-material benefits that support human wellbeing. Yet still, humanity possesses technology to eradicate itself within hours. At the same time, we have proven the innovative power to fight diseases, overcome man-made global environmental degradation, such as the ozone hole or acid rain, and reach the moon – with the help of technology.

Technological change is crucial for achieving the SDGs and harnessing its full potential will maximise the social, economic, and environmental benefits. The window of opportunity is closing to use innovative power to get on the transformative track toward sustainability as there are only a few years left, which in terms of technological change, is a mere wink. Still, the new global social contract of the SDGs gives hope that humanity has decided to set out on a sustainable development path and technology will be a primary enabler, which needs to be nurtured and developed for the benefit of all. ES

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REFERENCES

1. United Nations (2015) *Transforming our world: the 2030 Agenda for Sustainable Development.* A/RES/70/1. ‹https://sustainabledevelopment.un.org/post2015/transformingourworld›
2. The World in 2050. ‹www.twi2050.org›
3. Global Energy Assessment (2012) *Toward a Sustainable Future.* Cambridge and New York: Cambridge University Press and Laxenburg: International Institute for Applied Systems Analysis.
4. World Health Organization and UNICEF (2015) Lack of sanitation for 2.4 billion people is undermining health improvements. *World Health Organization.* Available at: ‹http://www.who.int/mediacentre/news/releases/2015/jmp-report› [Accessed: 11/07/2017]
5. Food and Agriculture Organization (2015) World hunger falls to under 800 million, eradication is next goal. *Food and Agriculture Organization of the United Nations.* Available at: ‹www.fao.org/news/story/en/item/288229/icode› [Accessed: 11/07/2017]
6. Pezzini, M. (2012) An emerging middle class. *OECD Observer.* Available at: ‹www.oecdobserver.org/news/fullstory.php/aid/3681/An_emerging_middle_class.html› [Accessed: 11/07/2017]
7. Grubler, A. (1998) *Technology and Global Change.* Cambridge: Cambridge University Press.
8. Argote, L. (1999) *Organizational Learning: Creating, Retaining, and Transferring Knowledge.* Norwell: Kluwer.
9. Argote, L. and Epple, D. N (1990) Learning curves in manufacturing. *Science*, 247(4945), pp.920–924.
10. Benkard, C. L. (2000) Learning and forgetting: The dynamics of aircraft production. *American Economic Review*, 90(4), pp.1034–1054.
11. World Bank (2016) *World Development Indicators.* ‹http://data.worldbank.org/data-catalog/world-development-indicators›
12. Wilson C., Grubler A., Gallagher K.S., and Nemet G.F. (2012) Marginalization of end-use technologies in energy innovation for climate protection. *Nature Climate Change*, 2(11), pp.780–788.