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Key technological enablers for ambitious climate goals

Insights from the IPCC Special Report on Global Warming of 1.5°C

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1. Introduction

The Special Report on Global Warming of 1.5°C (SR1.5) by the Intergovernmental Panel on Climate Change (IPCC) shows that achieving greenhouse gas (GHG) emission reductions that can limit warming to 1.5°C requires rapid and far-reaching transitions in energy, land and ecosystems, industry and urban and infrastructure systems (IPCC 2018a).

This paper discusses specifically the robust insights from SR1.5 regarding deployment of the technologies in a 1.5-compatible pathway, acknowledging that it does not make normative statements about the best or most realistic options or technologies – this would not be consistent with IPCC mandate to be "policy-relevant but not policy-prescriptive".

This paper is primarily aimed at ensuring correct interpretation and avoid misunderstandings of the messages emerging from the report. It starts by describing the methodology adopted in the SR1.5 to assess technology enabling conditions, and then summarizes the key robust takeaways on this question from the assessment.

2. Methodology for assessing technology enabling conditions

Three layers of assessment underpin the report's insights on technology.

First, global technology solutions are presented as they emerge from integrated high-level analyses of how the global society can transform towards low-carbon futures, based on Integrated Assessment Modelling exercises, complemented to a limited extent by sectoral and bottom-up studies (Rogelj et al. 2018). Different scenarios, which differ in how GHG emissions and concentrations are reduced over time, inform this question. These scenarios differ specifically in the degree to which CO_2 emissions reductions rely on carbon dioxide removal (CDR) compared to an early phase-out of gross emissions. The portfolio of technologies and practices typically modelled in the literature presenting these pathways is broad but non-exhaustive. For instance, of the CDR approaches, only Afforestation and Reforestation (AR) and Bio-Energy with CO_2 capture and storage (BECCS) are typically included in the pathways in the SR1.5. Also, depending on model characteristics and specific scenario assumptions, pathways can vary in their technological content, for example, in their reliance on nuclear energy, CO_2 capture and storage and behavioural change-related strategies.

The SR1.5 highlights four illustrative modelled pathways. Detailed technological configurations for each of them were presented (see Fig SPM3.b in (IPCC 2018b)). However, these illustrative pathways correspond to an arbitrary choice in the full database of scenarios and they do not span all possible dimensions of variation. An in-depth look into the full scenarios database underlying the assessment (Huppmann et al. 2018) is required to understand the full extent of the technological trends supporting each of these trajectories.

Second, the report assesses the multi-dimensional feasibility of technology options. It identifies which technological options are readily available to decision-makers, context-specificities of this availability, and the changes required to remove barriers and provide a broader context conducive to wider technological deployment (de Coninck et al. 2018). The SR1.5 assessed 28 mitigation (and 25 adaptation) options along six dimensions – economic, technological, institutional, socio-cultural, environmental and geophysical. Each of these dimensions is characterized, using the peer-reviewed literature, through three to five indicators, such as political acceptability, legal and administrative feasibility, institutional capacity, transparency & accountability under the institutional dimension; or social co-benefits (e.g. for health, education), public acceptance, social & regional inclusiveness, intergenerational equity, and human capabilities under the socio-cultural dimension.

Finally, the SR1.5 further broadened its scope by discussing the interplay between different mitigation options and other objectives and goals that society pursues, notably sustainable development (Roy et al. 2018) . This added considerations related to societal and environmental goals other than climate change. The assessment was accomplished by an assessment of the strength of synergies and trade-offs with the Sustainable Development Goals (SDGs), using an SDG-interaction scorecard (McCollum et al. 2018). The analysis provides concrete information for decision-makers to understand how to align mitigation options with sustainable development objectives and therefore improve public support and societal acceptability of measures, encourage faster action, and support the design of equitable mitigation.

These three layers of assessment provide complementary insights on technology development and implementation in 1.5°C-compatible pathways. Global modelling can provide a quantitative and internally consistent view based on techno-economic optimisation (Rogelj et al. 2018), while a more practical perspective on what would be needed for the technological options to come to fruition, including the importance of contextual factors at the regional, national and sub-national levels, is provided by the bottom-up literature (de Coninck et al. 2018). The latter perspective complements the aforementioned quantitative approaches. It notably includes institutional and socio-cultural dimensions, and some technological, economic, geophysical and environmental indicators that are not typically comprehensively captured by modelling studies, such as assessment of risks, distributional aspects, or technical scalability. Several broader conditions that enable systems transitions are also discussed. These are policy instrumentation, finance and investment, behaviour change, technological innovation, multi-level governance and institutional capacity. The two previous perspectives are complemented by the third method, which adds explicit and detailed consideration of a number of key sustainable development objectives for assessment of alternative portfolio of mitigation and adaptation options. The latter takes into account the multiple synergies and trade-offs of mitigation options consistent with 1.5°C pathways across the Sustainable Development Goals (SDGs), and that the net effect will largely depend on the composition of the mitigation portfolio and the management of the transition.

3. Results

Based on the full picture provided by these three layers of assessment, we here provide eight robust conclusions regarding the technological conditions for limiting global warming to 1.5°C in the context of sustainable development.

3.1 Supporting lower energy demand

Technologies that support lower energy demand enable more pronounced synergies and a lower number of trade-offs with respect to sustainable development. This includes notably options for energy efficiency, such as more efficient industrial motors, vehicles, appliances or building envelope. These technologies are generally more technologically mature than other mitigation technologies, and, when appropriately incentivised, ease the deployment of low-carbon supply-side options, because they reduce the absolute value of required production and hence the scale of capacity increase. The societal acceptability and desirability of the reduction of energy demand does depend on the context, as absolute reductions of energy demand for groups that lack access to modern energy does not show such synergies.

3.2 Power generation

By 2050, drastic increases of renewables to 70 to 85% of electricity production and decreases of unabated fossil sources to near-zero in the case of coal are necessary in the power generation sector. The extent of the reliance on other low-emission technologies varies across scenarios and thus reflects an area where choices can be made.

These choices are made at the national, local or individual level and depend upon a number of parameters, among which societal characteristics and preferences, behaviour, institutional capacity and finance. These, for example, partly explain diverging approaches to the deployment of nuclear energy across countries based on a number of conditions such as: different social assessments of risks linked to security or nuclear waste, and different levels of aversion to these risks; human capacity, energy market structure and related consequences for the availability of finance; physical potentials and economic attractiveness of other low- or zero-emission electricity generation technologies.

3.3 Short-term action

Short-term action on technologies should combine the fast deployment of existing low-emission technologies with parallel efforts to develop and already start deploying a wide set of new technologies. The faster and deeper the deployment of existing mitigation technology options in the next decade, the lower the dependence on new and more uncertain technologies in the longer term. However, technologies that are not currently commercially available play an important role to enable low-carbon transitions. Research, development, demonstration and deployment of a wide range of new technologies for the future transition is a key area for international cooperation, in order to benefit from scaled-up learning-by-searching and learning-by-doing, and from sharing tacit knowledge and innovation capabilities when structured collaborations are put in place.

3.4 Non-technology drivers

Non-technology drivers of changes, such as infrastructure or behaviour, condition the feasibility of different technological options. For example, denser urbanisation patterns in cities enable the deployment of non-motorised and public transportation; potential for product substitution in the industrial systems depends on market organisation and government incentivisation; dietary shifts, reduced food wastage and efficient food production largely depend upon changes in the behaviour of both consumers and producers.

3.5 Integration in a consistent strategy

The system-level role and contribution of any given technology option depends on which broader strategy is pursued across sectors. For example, the reliance on carbon dioxide removal (CDR) technologies depends on the deepness of the emission reductions in other sectors, and the feasible CDR options depend on the strategy for supplying emission-free energy – direct air capture (DAC) has higher energy requirements than afforestation and reforestation (AR) or bioenergy and CCS (BECCS) and is only worthwhile when affordable zero-emission energy can be generated at large scale. Another example is renewable electricity, the capacity of which depends on the dynamics of other sectors, in particular transport (electric vehicles and trains), industry (electrification, green hydrogen) and heating of buildings (heat pumps).

3.6 Carbon Dioxide Removal (CDR)

CDR technologies are necessary to achieve 1.5C compatible pathways, but the number and scale varies greatly across different types of pathways; higher near-term emission reductions decrease the need for high scale of deployment for these options. The role and feasibility of a CDR technology in a given sector in the context of keeping global warming to 1.5°C depends on the capacity of other sectors to imagine solutions to decrease their carbon footprint sufficiently. The required scale for these technologies can vary from a couple of Gt negative CO_2 emissions annually from 2050 onwards to as much as 20 Gt. Costs vary greatly per CDR option and are uncertain but are probably below 300 USD/tCO_2 by 2050. Also, it is this total amount of CDR in combination with the type of CDR option used that defines the area of land required, especially in the case of AR and BECCS. This land requirement varies from a few hundred thousand km2 to around 10 Million km2 in the high overshoot scenarios, with strong impacts on land competition and related risk of trade-offs with agriculture and food production.

3.7 Context-specific circumstances

Local and national circumstances, including policies to limit trade-offs, determine whether the synergies with sustainable development can be realised, and therefore which portfolios of technologies will be implemented. Technological choices should be taken according to the specifics of the local context in terms, for example, of resources availability (crucial for the feasibility of renewables), geographical characteristics (a country with lots of remote areas may favour a decentralised electricity system to provide electricity to all people), synergies with other sustainable priorities (improved cook stoves make fuel endowments last longer and hence reduce deforestation, support equal opportunity by reducing school absences due to asthma among children and empower rural and indigenous women).

3.8 Long-term perspective

Any investment done now in zero- or negative-emission technology or infrastructure pays off in the future, also when current markets do not value this benefit, nor the synergies with sustainable development. Conversely, investments done now that enhance CO_2 emissions for decades to come, pose a financial risk. When enabling conditions are not structurally changed, through mixes of policy instruments in combination with behaviour change, technological innovation, building of institutional capacity and multi-level governance, the just systems transitions that are needed globally and locally are unlikely to happen, and sustainable development will be further under pressure.

4.Conclusion

The three layers of assessment described in section 2 should be considered jointly by users of the SR1.5, including those in government, the private sector and civil society, as well as the media that translates the findings to a wider audience. Only together these three layers of assessment provide rounded policy-relevant insights and information, as summarized in section 3. Only together they show what actions are most beneficial and feasible, and need to be done in any case to achieve the required transition to a zero-carbon or negative-carbon world, and where choices should be made because of the potential trade-offs emerging from different technology options and mitigation strategies.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

References

de Coninck, H., and Coauthors, 2018: Strengthening and implementing the global response. *Glob. Warm. 1.5 C an IPCC Spec. Rep. impacts Glob. Warm. 1.5 C above pre-industrial levels Relat. Glob. Greenh. gas Emiss. pathways, Context Strength. Glob. response to Threat Clim. Chang.*,.

Huppmann, D., J. Rogelj, E. Kriegler, V. Krey, and K. Riahi, 2018: A new scenario resource for integrated 1.5 °C research. *Nat. Clim. Chang.*, **8**, 1027–1030, doi:10.1038/s41558-018-0317-4.

IPCC, 2018a: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,*. V. Masson-Delmotte et al., Eds.

——, 2018b: Special Report on 1.5 degrees: Summary for Policymakers. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf.

McCollum, D., and Coauthors, 2018: Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nat. Energy*, **3**, 589–599.

Rogelj, J., and Coauthors, 2018: Mitigation Pathways Compatible With 1.5°C in the Context of Sustainable Development. *Glob. Warm. 1.5°C. An IPCC Spec. Rep. [...]*, 82pp. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chapter2_Low_Res.pdf.

Roy, J., and Coauthors, 2018: Sustainable Development, Poverty Eradication and Reducing Inequalities. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the c. *IPCC Spec. Rep. Glob. Warm. 1.5 °C*,. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter5_Low_Res.pdf.