UN environment

International Resource Panel

Green Technology Choices:

The Environmental and Resource Implications of Low-Carbon Technologies

INTERNATIONAL RESOURCE PANEL REPORT

Acknowledgements

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Preface

Limiting climate change to well below 2°C will require unprecedented aggressive decarbonisation of global electricity generation and deployment of demand-side low-carbon energy technologies in the coming decades. Moreover, meeting Sustainable Development Goal 7 "Ensure access to affordable, reliable, sustainable and modern energy for all" will require substantially increasing the share of renewable energy in the global energy mix and doubling the global rate of improvement in energy efficiency by 2030. Achieving these targets will necessitate a profound transformation of how energy is supplied and used around the world. With this challenge comes the opportunity to design systems and select technologies that will minimize adverse impacts on the environment and climate, as well as address the additional pressure on natural resources.

Energy efficiency and demand-side technologies are often viewed as desirable due to their potential to reduce greenhouse gas emissions while also saving costs. But how much do we know about other environmental impacts of a large-scale deployment of these technologies? What are the benefits (or costs) from the life-cycle perspective? By how much can the gains from energy efficient technologies be multiplied if combined with decarbonisation of electricity production?

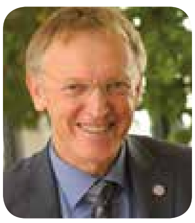
Tasked with building and sharing knowledge on how to improve management of the world's resources, the International Resource Panel (IRP), which provides independent, coherent and authoritative scientific assessments on the use of natural resources, turned its attention to understanding the impacts of such a transformation in energy production and use options, not only on greenhouse gas emissions but also on the environment and natural resources.

With this report, the Working Group on Environmental Impacts of the International Resource Panel provides, for the first time, a comprehensive global-scale assessment of the benefits, risks, and trade-offs of energy efficiency technologies and their combined effects when deployed alongside low-carbon electricity supply technologies.

The results of the report show that the majority of efficiency technologies, used for mobility, buildings and industry, bring environmental co-benefits beyond greenhouse gas mitigation, including reduced impacts on the environment, health and natural resources. However, some technologies may generate higher impacts than the baseline technology for certain regions and for certain years.

The analysis also sheds light on the interactions between supply-side and demand-side low-carbon technologies since without decarbonizing electricity supply, the benefits of some energy efficiency technologies cannot be realized. For example, extensive electrification of passenger transport in the regions that generate electricity from fossil fuels leads to an increase—rather than a decrease—in environmental impacts and natural resource pressures, which illustrates the importance of doing both together.

We are very grateful to Sangwon Suh, Joseph D. Bergesen and other co-authors for their contribution to this extremely important body of work. We would also like to thank the authors of the background studies published in the companion issue of the Journal of Industrial Ecology. We are confident that this report together with another IRP report, *Green Energy Choices: The Benefits, Risks and Trade-Offs of Low-Carbon Technologies for Electricity Production*, will help to design policies for mitigating potential and unintended consequences of large-scale changes towards a low-carbon society.



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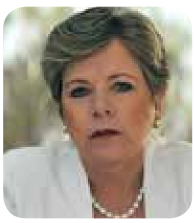

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Foreword

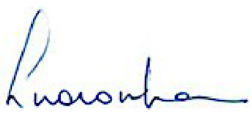
It is sometimes said that the future belongs to electricity. Electricity is clean at the point of consumption, easy to adjust up and down, and incredibly versatile. The key environmental requirement is that the production of electricity is also clean. This was the theme of a previous International Resource Panel report entitled "*Green Energy Choices: The Benefits, Risks and Trade-Offs of Low-Carbon Technologies for Electricity Production*". Because the supply of clean electricity is still limited, it is important also to look at the demand for electricity to ensure that the available supply is stretched as far as possible. Thus, efficient energy technologies are critical in combatting climate change.

That is why different initiatives around the globe have been promoting energy efficient technologies. For example, Southern Africa faces rising energy demands due to economic development and increased use of appliances, increased access to electricity and low availability of energy efficient household appliances on the market. As the region generates 75% of its electricity from fossil fuels, this growing electricity demand will also greatly increase CO_2 emissions. Several Southern African countries are acting collectively to develop an action plan for the region to leapfrog to energy efficient lighting, appliances and equipment. While the energy and climate change benefits of these technologies are clear, the understanding of their impacts on environment, human health, and natural resources has been limited. This new report, produced by the International Resource Panel, closes this knowledge gap by quantifying the environmental and natural resource implications of 60 supply and demand-side technologies in nine regions of the world, and therefore help different regions like Southern Africa make an informed transition.

The report confirms that under a 2-degree Celsius scenario, low-carbon energy technologies alleviate the pressure on both water and land by 2050 when compared to a 6-degree Celsius scenario. Moreover, the introduction of these technologies help by reducing particulate matter, which causes air pollution, as well as toxic emissions, which affect human health. Low-carbon energy technologies however, also require significant volumes of metal resources by 2050 for additional infrastructure and wiring needs. Thus, promoting these technologies would be beneficial not only for climate change mitigation, but also to reduce our impact on health, environment and natural resources use, with the exception of metals consumption.

For the first time, thanks to this report, companies and countries making the decision about which energy efficient technology to use, have clear, comparative, science-based information about not only their greenhouse gas reduction benefits, but also about other positive and negative impacts that these technologies represent. This will allow them to avoid the trade-offs and unintended consequences arising from the large scale deployment of new technologies. Protecting human health and managing the natural resource base while combatting climate change is fundamental to long-term social and economic development, as well as to eradicating poverty and increasing equality. Only with the solid scientific assessments like this one we will be able to build the truly sustainable future to which we aspire.

I would like to express my gratitude to the International Resource Panel, under the leadership of the Co-chairs Alicia Bárcena and Janez Potočnik, for coordinating this significant scientific effort.



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Glossary

air pollution

The introduction into Earth's atmosphere of one or more substances (particulates, gases, biological molecules), or other harmful chemicals, materials or physical conditions (such as excess heat or noise) in high enough concentrations to cause harm to humans, other animals, vegetation or materials. Air pollution may come from anthropogenic or natural sources. (UNFCCC)

anthropogenic emissions

Emissions of pollution associated with human activities, including the burning of fossil fuels, deforestation, land use changes, livestock, fertilization, etc. (IPPC SYR Appendix)

battery electric vehicle (BEV)

Battery electric vehicles (BEVs) in this report refer to passenger vehicles powered entirely by electrically recharged battery packs. Such vehicles use electric motors in place of internal combustion engines.

biomass

Renewable energy from living (or recently living) plants and animals, e.g. wood chippings, crops and manure. Plants store energy from the Sun while animals get their energy from the plants they eat. (IEA)

building energy management system (BEMS)

See **demand-side energy management**

building shell

The building envelope – also known as the building shell, fabric or enclosure – is the boundary between the conditioned interior of a building and the outdoors. The energy performance of building envelope components, including external walls, floors, roofs, ceilings, windows and doors, is critical in determining how much energy is required for heating and cooling. (IEA)

carbon dioxide (CO_2)

A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass and of land use changes and other industrial processes. It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a Global Warming Potential (GWP) of 1. (IPPC SYR Appendix)

carbon [dioxide] capture and storage (CCS)

A process consisting of separation of carbon dioxide from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere. (IPPC SYR Appendix)

carbon dioxide equivalent

A metric measure used to compare the emissions of the different GHGs based upon their GWP. GHG emissions in the United States are most commonly expressed as "carbon dioxide equivalents," which are CO_2 equivalents measured in terms of the mass of carbon and not carbon dioxide. GWPs are used to convert GHGs to carbon dioxide equivalents. (UNFCCC) In this report GWP100 is used for carbon dioxide equivalency. See also **global warming potential**, **greenhouse gas**.

climate change

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. (IPPC SYR Appendix)

coal

Refers to a variety of solid, combustible, sedimentary, organic rocks that are composed mainly of carbon and varying amounts of other components such as hydrogen, oxygen, sulfur and moisture. Coal is formed from vegetation that has been consolidated between other rock strata and altered by the combined effects of pressure and heat over millions of years. Many different classifications of coal are used around the world, reflecting a broad range of ages, compositions and properties. (IEA)

co-generation

The simultaneous generation of both electricity and heat from the same fuel, for useful purposes. The fuel varies greatly and can include coal, biomass, natural gas, nuclear material, the Sun or the heat stored in the Earth. (IEA)

consumption

The use of products and services for (domestic) final demand, i.e. for households, government and investments. The consumption of resources can be calculated by attributing the life cycle-wide resource requirements to those products and services (e.g. by input-output calculation). (IRP)

demand-side technologies

Demand-side technologies are broadly defined to include the following: (1) deploying energy efficient technologies (e.g. using light-emitting diode bulbs) that provide the same service while consuming less energy, (2) the deployment of infrastructure like improved building shell insulation that reduces the need for heating and cooling energy, and (3) fuel and mode switching (e.g. using electric vehicles or public transportation to replace petroleum vehicles).

demand-side energy management

Demand-side energy management in this report refers to a variety of technologies and approaches used to reduce energy demand by consumers. This includes Building Energy Management Systems (BEMS) that can control heating energy consumption at the apartment or room level by adapting to usage patterns, weather predictions and building design. BEMS can also control other building functions such as lighting and ventilation.

ecosystem

A system of living organisms interacting with each other and their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent