Energy Technology Systems Analysis Programme

Workshop Series:
Integrating Sustainable Development Goals Into Energy Systems Models

Project Team:

Dr. Evangelos Panos
PSI, Switzerland

Prof. Nadia Maïzi
Mines Paris – PSL, France

M.Sc. Alice Spasaro
Mines Paris – PSL, France

Prof. Markus Blesl
IER, Germany

M.Sc. Vera Sehn
IER, Germany

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Foreword

This report summarises the talks of three workshops about integrating Sustainable Development Goals into energy systems models. The three workshops organised by Mines Paris – PSL, IER, and PSI. Due to the COVID-19 pandemic, the workshops were delivered as webinars on the 13th of January 2022, 27th of January 2022 and 10th of February 2022.

The three webinars, including presentations and video recordings, are available on the ETSAP website https://www.iea-etsap.org/index.php/workshops/webinars. Below are the links to the recordings:

- First webinar: Resilience and sustainability of power systems with high shares of renewables (13th of January 2022)
- Second webinar: Energy and land-use nexus. (20th of January 2022)
- Third webinar: Energy poverty and energy access (February 2022)

For the webinars a registration was required. The first webinar received about 300 registrations, the second webinar around 120 registrations and the third webinar around 125 registrations. The actual online attendance rate was about 50% of the registrations.

The advertisement of the webinars was made via a flyer (attached to this report) and announcements in the ETSAP and IAMC modelling communities, as well as to other channels available from the organisers.

The report is divided into four chapters. Chapter 1 is the introduction providing insights into the motivation for this workshop series. Chapter 2 contains the main findings regarding the first workshop on Resilience and Sustainability of Power Systems. Chapter 3 presents the main insights from the second workshop on Energy and Land-use Nexus. Chapter 4 discusses the main outcomes from the third workshop on Energy Poverty and Energy Access.

The authors would like to thank the speakers in the three webinars for sharing their experiences and valuable insights. Without **Prof. Kirsten Halsnæs (DTU)**, **Dr. Vincent Mazauric (Schneider Electric), Dr. Gondia Sokhna Seck (IFPEN), Dr. Adriano Vinca (IIASA), Dr. Miodrag Stefanovic (PIK), M.Sc. Vera Sehn (IER), Dr. Shonali Pachauri (IIASA), M. Sc. Gianluca Tonolo (IEA) and Dr. Anteneh Dagnachew (PBL),** these webinars would have never been realised.

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1. INTRODUCTION

As defined by the United Nations, the sustainable development goals represent the "blueprint for achieving a better and more sustainable future for all". Energy and climate are two of the many topics the 17 Sustainable Development Goals (SDGs) refer to. There are interlinkages and trade-offs between several SDGs, which calls for holistic research approaches when investigating these goals. Integrated energy models have proven valuable in analysing the energy sector and related environmental and economic aspects. The IEA-ETSAP community has performed several model developments and knowledge exchanges regarding the integrated assessment of the economic and energy systems given a sustainable development (e.g., through projects linking energy models and macro-economic models, workshops on sustainability modelling, and workshops on water-energy nexus). All these efforts are described in the relevant reports available on the IEA-ETSAP website and aim at expanding the boundaries of energy modelling by incorporating new systemic interdependencies. Hence, they contribute to a more holistic understanding of future development pathways in a broader sense.

The three workshops organised under the topic of "Integrating Sustainable Development Goals Into Energy Systems Models" continue these efforts. They aim to trigger the expansion of TIMES-based energy systems models towards multiple SDGs other than purely related to energy and climate. In particular, they aim to develop and share knowledge on advanced energy and sustainability modelling to facilitate the cross-disciplinary understanding of the different resource and system interactions, including the energy system, water resources, agriculture, land-use, resilience and energy security, but also linkages to energy poverty, food security and health.

The main objectives of the three workshops described in the next three chapters are:

a. To analyse methodologies for integrating sustainable development goals into energy systems modelling
b. To assess needs and requirements in associated data and identify potential data sources
c. To provide insights on the value-added gained for policy analysis by accounting for broader SDGs in the assessment of the energy transition and the instruments that enable it
d. To get insights on state-of-the-art synergies and trade-offs between SDGs and energy transition by exchanging robust evidence and research ideas

1.1 The 17 Sustainable Development Goals

The 2030 Agenda of Sustainable Development calls for urgent action by all countries – developed and developing – in a global partnership across 17 key thematic areas. The 17 Sustainable Development Goals (SDGs), with their 169 targets, balance the economic, social and ecological dimensions of sustainable development.

Figure 1: Overview of the 17 Sustainable Development Goals of the UN

The SDGs are to be achieved worldwide and by all UN member states by 2030. This means that all states are called upon equally to play their part in finding shared solutions to the world's urgent challenges:

- **Goal 1 - No Poverty**: Despite considerable progress in the fight against poverty since 1990, over 800 million people, 70% of whom are women, still live in extreme poverty. The Sustainable Development Agenda aims to eradicate extreme poverty by 2030.

- **Goal 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture**: Although the situation has improved in numerous countries, many people still suffer from hunger and malnutrition worldwide. Undernourishment affects nearly 800 million people worldwide –

most of them women and children. The aim of the 2030 Agenda is to end hunger and all forms of malnutrition around the world.

- **Goal 3 - Ensure healthy lives and promote well-being for all at all ages:** The Millennium Development Goals (MDGs) have made a significant contribution to improving global health. Goal 3 continues along the same lines as the MDGs by setting the target that all people should have access to good-quality healthcare and medicines, including financial risk protection. Also, ensure universal access to sexual and reproductive healthcare, including family planning, information and education.

- **Goal 4 - Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all:** It aims to ensure that all children, adolescents and adults – especially those most marginalised and vulnerable – have access to education and training appropriate to their needs and the context in which they live. This makes education a contributing factor in making the world more secure, sustainable and interdependent.

- **Goal 5 - Achieve gender equality and empower all women and girls:** Gender inequality is one of the biggest obstacles to sustainable development, economic growth and poverty reduction. While progress in enrolling girls into school and integrating women into the job market has been considerable, important issues such as violence against women, economic disparities, and the low participation of women in political decision-making need to be tackled.

- **Goal 6 - Ensure availability and sustainable management of water and sanitation for all:** Access to drinking water and sanitation is a human right and, together with water resources, a key determinant in all aspects of social, economic and environmental development. Goal 6 aims to ensure access to drinking water, sanitation and hygiene for all. In addition, it sets targets such as protecting and restoring water-related ecosystems, improving water quality and reducing water pollution and advocating cross-border cooperation in managing water resources.

- **Goal 7 - Ensure access to affordable, reliable, sustainable and modern energy for all:** In 2019, 771 million people worldwide lack access to electricity. In addition, about 2.6 billion people need improved access to clean and safe cooking fuels and technologies**.** Goal 7 thus advocates universal access to affordable, reliable, modern energy services. Given that sustainable development hinges on climate-friendly economic development, Goal 7 aims for a substantial increase in the share of renewables in the global energy mix and a doubling in the global rate of improvement in energy efficiency. Another target is to promote research in renewable energy and energy efficiency as well as investment in energy infrastructure and clean energy technologies.

- **Goal 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all:** Over 200 million people around the world are unemployed, especially young people. Goal 8 targets sustaining economic growth, increasing economic productivity and creating decent jobs. It envisages combating forced labour and ending modern slavery and human trafficking by 2030. Goal 8 also advocates improved global resource efficiency in consumption and production and decoupling economic growth from environmental degradation.

- **Goal 9 - Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation:** Goal 9 aims to build resilient infrastructure, promote industrialisation and foster innovation. It aims to support technology development, provide greater access to financial services, including affordable credit, and increase the integration of companies into value chains and markets. It also advocates providing universal and affordable access to the internet.

- **Goal 10 - Reduce** inequality **within and among countries:** Global inequalities are massive and present one of the biggest obstacles to sustainable development and the fight against poverty. Inequality within many countries has been rising in recent years. It limits the opportunities for social groups to participate in and make significant contributions to social, cultural, political and economic life. Goal 10 aims to deliver sustained income growth to the poorest 40% of the global population and achieve empowerment and social, economic, and political inclusion for all by 2030. It ensures equal opportunities by eliminating discriminatory laws, policies and practices while facilitating orderly and safe human migration and mobility via the implementation of sound migration policies. It also envisages enhanced representation and a greater voice for developing countries in decision-making within international economic and financial institutions.

- **Goal 11 - Make cities and human settlements inclusive, safe, resilient and sustainable:** More than half of the global population lives in cities, expected to increase to 70% by 2050. Cities concentrate more than 80% of global economic activity, and while they occupy 3% of the world's surface, they are responsible for 75% of global resource consumption and 75% of global emissions. Goal 11 aims to reduce the adverse per capita environmental impact of cities, particularly in terms of air quality and waste management. It calls for more inclusive and sustainable forms of urbanisation based on a participatory, integrated and sustainable approach to urban planning. In addition, it aims to ensure universal access to safe and inclusive green and public spaces and provide access to safe and affordable housing and transport systems.

- **Goal 12 - Ensure sustainable consumption and production patterns:** Goal 12 calls for implementing the UN's ten-year framework of programmes on sustainable consumption and production patterns. It advocates environmentally sound management of chemicals and all waste and a substantial reduction in waste generation through measures such as recycling. Goal 12 also aims to halve food waste, encourage companies to adopt sustainable practices, and promote sustainable public procurement practices.

- **Goal 13 - Take urgent action to combat climate change and its impacts:** Goal 13 calls on countries to incorporate climate protection measures in their national policies and assist each other in responding to the challenges at hand. It acknowledges that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change. Supplementing this dialogue, Goal 13 advocates strengthening resilience to climate-related natural disasters and reaffirms the commitment of developed countries to mobilise each year USD 100 billion jointly from all sources by 2020 to help developing countries adapt to climate change.

- **Goal 14 - Conserve and sustainably use the oceans, seas, and marine resources for sustainable development: Goal 14 advocates significantly reducing marine pollution and minimising ocean acidification by 2025 and sustainably managing and protecting marine and coastal ecosystems by managing and protecting marine and coastal ecosystems** as early as 2020. It also aims, by 2020, to regulate harvesting effectively and to halt overfishing by ending illegal and unregulated fishing and destructive fishing practices. In addition, Goal 14 aims to prohibit specific types of subsidies to fisheries.

- **Goal 15 - Protect, restore and promote sustainable use of terrestrial ecosystems:** Goal 15 calls for the conservation, restoration and sustainable use of ecosystems to halt deforestation, restore degraded forests and substantially increase reforestation by 2020. It also advocates combating desertification by 2030 and restoring land affected by desertification, drought and floods. Goal 15 calls for urgent measures to end poaching and trafficking of protected plant and animal species to protect biodiversity.

- **Goal 16 - Promote peaceful and inclusive societies for sustainable development:** Goal 16 for 2030, therefore, aims to promote peaceful and inclusive societies. It advocates reducing all forms of violence, ending torture, and combating organised crime. In addition, Goal 16 envisages significantly reducing corruption and bribery and illicit financial and arms flows. To ensure that societies are peaceful and inclusive, Goal 16 aims to promote inclusive institutions and the rule of law and guarantee equal access to justice.

- **Goal 17 - Strengthen the means of implementation and revitalise the Global Partnership for Sustainable Development:** Goal 17 calls on developed countries to renew their commitment to allocate 0.7% of their gross national income to official development assistance. It aims to mobilise domestic resources to reduce dependence on foreign support, enhance international science, technology, and innovation collaboration, and promote an equitable multilateral trading system. Goal 17 also advocates enhancing macroeconomic stability and policy coherence in sustainable development.

2. Workshop 1: Resilience and Sustainability

Providing reliable, secure and affordable electricity is essential to power economic growth and development. The drop in the cost of renewable technologies makes them an increasingly viable option. Moving towards a weather-dependent electricity generation raises resilience issues against supply disruptions, while backup storage systems depend on critical supplies of rare-earth materials.

This workshop aims to give a better understanding of how resilience can be achieved in future power systems with high shares of renewables to ensure affordable and sustainable electricity supply while at the same time mitigating criticalities in the supply chains of materials. Three expert modellers share insights on methodologies and data about integrating resilience and sustainability indicators of renewable energy technologies into energy systems models.

Speakers:

- Kirsten HALSNÆS; DTU, IPCC Coordinating Lead Author: *"State of the art on synergies and trade-offs between SDGs and renewable energy implementation – robust evidence and research ideas"* (download)
- Vincent MAZAURIC; Schneider Electric: *"Reconciling reliability and sustainability: some thermodynamics insights dedicated to the integration of renewables in the power system"* (download)
- Gondia Sokhna SECK; IFPEN: *"Raw materials with a high share of low-carbon energy technologies for the energy transition"* (download)

The workshop was moderated by Prof. Nadia Maïzi from Mines Paris – PSL, France.

The webinar video is available here:
https://www.youtube.com/watch?v=e4766aJiwaA&list=PLd4O73HMkP8KDn29LT4t6ouPT6AaHerGF&index=1&t=2126s

2.1 State of the art on synergies and trade-offs between SDGs and renewable energy implementation – robust evidence and research ideas

Presentation from Prof. Kirsten Halsnæs (DTU)

Meeting the objectives of the Paris agreement to stabilise global temperature changes to be below 2°C or 1.5oC will require large and rapid reductions in global Greenhouse Gas (GHG) Emissions, and this can only be realised if all countries in the world at different development stages participate. Climate change mitigation is not a major goal in low-income countries, so ensuring wide participation in GHG emission reduction efforts requires alignment with a broader sustainable development agenda. The AR6 report on mitigation policies includes an assessment of how modelling studies have addressed the links between climate change mitigation and sustainable development with a particular focus on trade-offs and synergies between different policy objectives.

There are important methodological challenges in addressing links between climate change mitigation and sustainable development in energy models. Energy models typically are structured around technologies and systems. Models have widely been used to assess sustainable development impacts in relation to energy access and costs, indirect impacts on air pollution, energy for education, health clinics, industry, etc. Energy modelling studies have also linked land-use models for integrated assessment of trade-offs and synergies between land-use mitigation options and access to food, water, biodiversity and other sustainable development aspects.

The IPCC AR6 WGIII report on mitigation policies includes mapping sectoral mitigation options in relation to the UN 2030 Sustainable Development Goals (SDGs) based on modelling studies. Here, it is concluded that there are potentially many synergies between climate change mitigation and meeting the SDGs. Still, there can also be trade-offs between energy sector options, including large scale applications of bioenergy crops and some renewable energy options with large land requirements, and meeting key SDGs including no poverty, zero hunger, water access, and life on land. There is large agreement across models on these conclusions.

However, there are also a number of important mitigation and SDG links, which are only covered sparely in the literature. These include socioeconomic and human sustainability aspects and specific issues facing the introduction of renewable energy options in low-income countries like access and affordability of energy, local income generation possibilities and international finance. Improved modelling of the economics of implementing renewable energy options in low-income countries could support the development of projects which could be candidates for international green finance.

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2.2 Reconciling reliability and sustainability: some thermodynamics insights dedicated to the integration of renewables in the power system

Presentation from Dr. Vincent Mazauric (Schneider Electric)

Within the context of climate change mitigation, the power grid decarbonisation issue is expected to be tackled through massive renewables integration. Electrical networks will thus evolve towards a more heterogeneous and clustered structure such as micro-grids. This transformation is first appreciated regarding the operating conditions that could be derived from a thermodynamic description of the electromagnetic power flowing throughout the grid. For a given level of reliability, the second principle of thermodynamics provides the trade-offs to consider between the decommissioning of conventional power plants and their subsequent loss of inertia, a significantly higher renewable-induced intermittency, the agility to restore faster supply/demand adequacy along with the management of flexibilities with their extra IT self-consumption, and the materiality of the power system infrastructure. Finally, operation issues were endogenised in the technical optimal TIMES model to design a 40 to 100% renewable power system for France.

Methods:

- A thermodynamic description of the power flowing throughout a power system relies on a reversible interpretation of Faraday's law.
- Justified from the time uniformity, two "constants of motion" are derived on which the stability conditions of the power system before any operation from the dispatch are discussed.
- Long term power system analysis is based on a bottom-up TIMES-FR model providing forthcoming production mixes according to different renewables targets.

Findings

Grid synchronism is a critical issue to correctly aggregate kinetic energy and face to fluctuations:

- Centralised system favours transient stability but needs grid reinforcement for the aggregation of kinetic energy; while
- Decentralised system favours synchronism but jeopardises transient stability by an intrinsic lack of kinetic energy. However, the constraint on synchronism is rejected on the distribution network (with lower voltage and extra losses), inducing investment at this scale.

High variable renewable energy penetration seems technically feasible in electro-intensive countries without jeopardising the reliability.

Insights:

The environmental issue should be deeper assessed regarding:

- The importance of power exchanges with neighbouring countries;
- The carbon neutrality of flexible biomass plants which are functioning in extreme peak;
- The three implemented options of flexibility – Demand-Response, storage technologies and new interconnections – to satisfy the reliability constraint.

Externalities such as:

- digitalisation dedicated to control; and
- extra-materiality of the infrastructure;

of diluted energy sources claim for their endogenisation in planning exercises.

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2.3 Raw materials with a high share of low-carbon energy technologies for the energy transition

Presentation from Dr. Gondia Sokhna Seck (IFPEN)

To curb climate change and mitigate its environmental consequences, a shift towards more sustainable economies is needed. The renewable energy transition and the rise of electric mobility are put forward as key levers to reduce Greenhouse Gases (GHG) emissions and air pollution, with low-carbon technologies becoming increasingly popular. From 2010 to 2018, the average annual growth rate of the supply of renewables was 2.5%. This figure even reaches 14.4% for new renewables capacity for electricity generation, whose growth is driven by solar photovoltaic (PV) (42.8%) and wind power (17.9%) technologies (IEA, 2020a). The same applies to the electric mobility sector. Supported by public policies and technological progress, electric vehicles (EVs) registered an annual average increase of 60% between 2014 and 2019, according to the 2020 Global EV Outlook of the International Energy Agency (IEA, 2020b).

The number of countries that have pledged to reach net-zero emissions by mid-century or soon after continues to grow, but so do global GHG emissions. A considerable number of actions would be needed to turn today's impressive ambitions into reality and tackle the climate crisis, a great challenge of our times. Doing so requires nothing short of a total transformation of the energy systems that underpin our economies (IEA, 2021). These profound transformations and the underlying low-carbon innovations that support them are putting pressure on the consumption of raw materials. Indeed, while dependence on hydrocarbons could be reduced in the future as low-carbon technologies become more widely deployed, trade relationships and the balance of geopolitical power might be redefined by the new dependencies generated by mineral-intensive clean technologies.

The notion of criticality is not universal, and the evaluation that is made depends on the methodology used, and the risks studied. Graedel and Nuss (2014) define criticality as an approach based on an assessment of the risks associated with the production, use, or end-of-life management of a raw material. From one study to another and depending on the prism adopted, a metal can therefore be qualified as critical or not. These can be economic, geopolitical, technological, environmental, or social in nature. Much of the early literature was then dedicated to the criticality of REEs, but in recent years a growing number of other metals have been covered (Hache et al., 2019a).

Therefore, as pointed out by Hache et al. (2019b), long-term energy analyses might not be accurate or might need to be reassessed if the potential future limitations on the supply of materials are not accounted for energy modellers and policymakers. Limiting global warming to below 1.5°C is undoubtedly challenging (IPCC, 2018) and has inspired numerous alternative pathways for meeting the COP21 objectives. A literature review shows that current approaches related to the raw materials demand analysis could rely on snapshot retrospective analyses of the main drivers of supply disruptions and the environmental sustainability of the material flows/production or, lately, on long-term modelling of raw material production and demand. The latter is either based on historical trends or hypotheses on future growth rates based on expert opinion or long-term production modelling via bell-shaped production curves or ultimately using long-term energy models to explore geopolitical supply risk, to analyse vulnerabilities and environmental impacts of mining.

We have developed the first bottom-up long-term energy model TIAM-IFPEN (TIMES Integrated Assessment Model), with endogenous raw material supply chains from the resources to the end-use sectors. By considering climate constraints and the availability of resources, the development of their consuming-sectors and trade balances, the model could be useful to provide unique insights on raw materials. TIAM-IFPEN has been used successfully in analysing the interactions between low-carbon energy transition and raw material criticality, such as the assessment of future risks related solely to the lithium supply chain (Hache et al., 2018, 2019a), the dynamic criticality of copper through to 2050 based on current known resources, urban mining and resource availability (Seck et al., 2020), and the analyses of the rare earth elements demand, and their water stress impacts with the energy transition by 2050 (Guedes et al., 2022), and have enriched the model input database with a more detailed description of battery technologies for EVs to assess the evolution of cobalt criticality as a function of the battery penetration scenario with an accelerated uptake of EVs in stringent climate scenarios (Seck et al., 2022).

References:

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3. Workshop 2: Energy and Land-use Nexus

Land use is central to many environmental and socioeconomic issues. The twin challenge of reversing biodiversity declines and mitigating climate change, while producing sufficient food to ensure zero hunger and providing new land areas for renewable energies, must be tackled together. While a transition towards cleaner, less emission-intensive energy systems has been the focus to date, the role of agriculture in generating GHG emissions is becoming increasingly clear. Further, negative emission technologies or land use types which accumulate carbon are getting more in the focus on achieving the climate neutrality targets and will be even more important in the future.

This webinar aims to provide a deeper understanding of land-use change's role in reducing GHG emissions while contributing to other strategic priorities such as food production and biodiversity. It brings three top modelling teams to share insights on methodologies and data about integrating energy and land systems, identifying suitable sustainable development indicators and discussing required policies and their impacts.

Speakers:

- Dr. Adriano VINCA; IIASA: *"MESSAGEix-GLOBIOM and NEST: modelling land-use, water and energy systems to assess SDGs and climate impacts at the global, national and basin scales"* (download)
- Dr. Miodrag STEVANOVIC; PIK: "*Modeling a sustainable development pathway for climate action with REMIND-MAgPIE integrated assessment framework*" (download)
- M.Sc. Vera SEHN; IER: *"Integrating agriculture and land-use aspects into TIMES Pan-EU"* (download)

The workshop was moderated by Prof. Markus Blesl from IER. Germany.

The webinar video is available here:
https://www.youtube.com/watch?v=EwT9zc7k63E&list=PLd4O73HMkP8KDn29LT4t6ouPT6AaHerGF&index=2&t=2326s

3.1 MESSAGEix-GLOBIOM and NEST: modelling land-use, water and energy systems to assess SDGs and climate impacts at the global, national and basin scales

Presentation from Dr. Adriano Vinca (IIASA)

The tools used at IASA to assess SDGs and climate interactions are MESSAGEix GLOBIOM (IAM model) for modelling the global scale and Nexus Solutions Tool (NEST) for modelling river basin scales. With the multi-sectoral model framework, it is possible to look at resource interactions that would typically be neglected in a single sectoral model. The nexus analysis is quite different for different regional scales. For that reason, two separate nexus models were developed.

Messageix-Globiom is a model framework with an energy system optimisation and Macro model, which is linked to the land use Model GLOBIOM, which models, e.g. forest CO2 Emissions/sinks, forest and cultivated areas. The land-use model simulates land use, forestry, livestock and forestry and balances the uses with the demands from several sectors (food, fibres, energy and industry). The bioenergy requirement, as well as the carbon price, is fed into the land-use model. The land-use model feeds land-use based GHG emissions and bioenergy supply curves for a given carbon price and marginal abatement cost curves conditioned on a given biomass demand back into the MESSAGE module. Both models work with the same scenario assumptions concerning global drivers like population development, GDP and other storylines.

In the study of [Frank et al., 2019], they compared how a full consideration of the land-use related SDG goals would change the results compared to a non-SDG scenario. They discovered that adding the SDGs to the scenario assumptions would result in 30 % lower irrigation water, 19% lower livestock and 10 % higher food demand, while the natural forest area would be 10 % greater. The same approach was taken with the study of [Parkinson et al., 2019], where the key water-energy-climate trade-offs were modelled in a water module and enabled the model to compare climate targets with a composition of climate target and the water-related SDG and identify infrastructure demands to find alternative sources of fresh water supply. In the study of [Vinca et al. 2021], the river basin scale model NEST was used to assess SDG accessibility but also how an optimal cooperation between the countries in the river basin would lead to lower investment expenditures, but also to social and environmental benefits. A finer regional scale is important to answer, especially the question about the interactions with the water sector.

The data requirements as a basis for the presented models are very high. They cover socioeconomic and climate pathways like SSP and RCP, global or national databases coming from IEA, WB or FAO, and other model outputs, especially for the demand projections.

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3.2 Modelling a sustainable development pathway for climate action with REMIND-MAgPIE integrated assessment framework

Presentation from Dr. Miodrag Stefanovic (PIK)

The second presentation focussed on the work with MaGPIE REMIND, which is an integrated assessment framework. REMIND is a modular multiregional model with a detailed representation of the energy sector in the context of long-term macroeconomic developments, where economic activity results in energy demands in different sectors. MaGPIE is a socioeconomic model of land-use and agricultural sector with spatially explicit and dynamic features. The model balances the biophysical aspects like crop yields, carbon stocks, nutrients and water with the economic aspects like costs, prices, demands and policies. It optimises agricultural production under the cost minimisation objective function. Besides the optimised agricultural production system, the model also calculates the agricultural and land-use change emissions. MagPIE communicates in an iterative operation mode. REMIND feeds into MaPGIE the CO2 price and the demand for bioenergy, while MaGPIE supplies that bioenergy demand and feeds back the information on land-use change emissions and biomass prices.

The modelling framework was coupled to several downstream models, e.g. to post-processing models, so that all the SDG indicators or meaningful proxies could be represented. In the study of [Soergel et al., 2021], a current trend scenario was compared to a holistic scenario which includes development interventions, resource efficiency, climate change mitigation, food and energy interventions, global equity and equality and power alleviation. The intervention of food and energy is composed of a food pattern change to zero hunger and healthy diets, a food waste reduction to a maximum of 50% in high-income regions, an energy increase in developing regions, and an energy consumption reduction in high-income regions and additional land system sustainability policies. The effect of the food intervention was that the prevalence of underweight could be substantially reduced by 2050, and the effect of climate policy on food prices could be fully compensated by carbon pricing revenues. The effects of the different interventions on the land system showed that there are large co-benefits of healthy and sustainable nutrition for multiple planetary boundaries like climate, land, water, nitrogen cycle and biodiversity intactness. Overall, there are SDG achievement gaps remaining in 2030, but they could be closed by 2050. If the SDGs should be achieved in 2030, there are more measures and interventions necessary than what was assumed in the scenarios.

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3.3 Integrating agriculture and land-use aspects into TIMES Pan-EU

Presentation from M.Sc. Vera Sehn (IER)

The third presentation focussed on how agricultural and land-use aspects could be integrated into a TIMES energy system model. The TIMES PanEU model was extended with several nexus interactions between the energy and land and water systems [1]. The interactions between the energy and land resource are composed of energy for agriculture processes, agricultural emissions influencing the climate target, land area for biomass and renewable energies, and lignite mining. As a subsystem of the land use categories, the agriculture sector was modelled in more detail, and an irrigation option for biomass irrigation was modelled as a link between the land and water resource. The insights from data assessment to model the interactions were presented for the topics of land-use factors of the renewable energies, modelling of biomass cultivation, and the agriculture sector. The land-use factors to assess land use impacts of the future energy system are easily accessible data, but with a wide range of resulting factors in the literature if several studies are compared. These differences result from the technological development of renewable energies during the last 20 years and the great development of land use efficiency. Therefore, if a new land-use assessment of renewable energies should be set up, then the data on the land use factors should be taken from a very recent study to simulate the near future, and the factors for the remote future should fit the renewable energies potential study. The yield factors and water requirements were adopted from the MaGPIE land use model results in modelling biomass cultivation [2]. To model a simplified agriculture sector with its emissions and land uses, the statical data of the agricultural sector and products can be easily accessed and used to calculate country-based land use and emission factors.

The result insights show that a simple representation of the agriculture sector allows an energy system to explore new research questions, like what happens if food demand reduction measures like the increased usage of alternative meat products or a food waste reduction is applied to the system. The land use assessment of the energy and the agricultural sector together as well as the simulation of future water uses from the energy system and other sectors can identify risks for land area or water scarcity which can be avoided if slightly different energy transformation pathways are chosen. For example the biomass potential should be minimised and adapted to the interplay of different measures of the LULUCF and agriculture sector. To minimise land use even further, dual land use possibilities for renewable energies can be applied like agri PV or swimming PV on renatured lignite mining pits.

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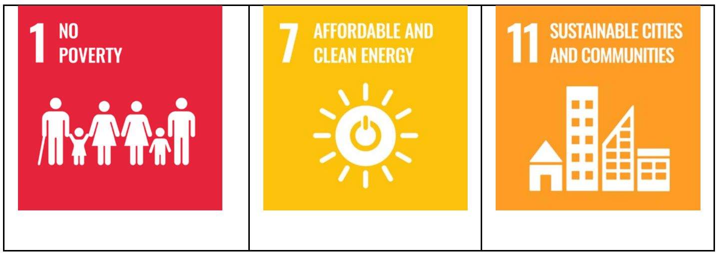
4. WORKSHOP 3: ENERGY POVERTY AND ENERGY ACCESS



In 2019, 771 million people around the world lack access to electricity. In addition, about 2.6 billion people need improved access to clean and safe cooking fuels and technologies. On top of the socioeconomic impacts of energy poverty, achieving ambitious goals for climate change mitigation requires energy services based on clean electricity and cooking fuels. As the COVID-19 pandemic showed, lack of access to energy also hampers efforts to contain diseases across many parts of the world.

This webinar brings together three top modelling teams to share insights on methodologies and data about integrating energy poverty and energy access into energy systems models. Suitable sustainable development Indicators on this topic, e.g. population without access to clean energy or health impacts, will be identified and discussed.

Speakers:

- Dr. Shonali PACHAURI; IIASA, Group leader of Transformative Institutional and Social Solutions: *"Access to modern energy services for all: Climate compatible development opportunity"* (download)
- M. Sc. Gianluca TONOLO; IEA, Leader of the energy access modelling team of the IEA World Energy Model: *"Tracking and modelling access to modern energy, the IEA approach"* (download)
- Dr. Anteneh DAGNACHEW; PBL, Leader of the energy access modelling team of the IMAGE model: *"Universal energy access beyond lighting: modelling demand for productive uses"* (download)

The workshop was moderated by Dr Evangelos Paos from PSI, Switzerland.

The webinar video is available here: https://www.youtube.com/watch?v=-XVUGdbNqeI

4.1 Access to modern energy services for all: Climate compatible development opportunity

Presentation from Dr. Shonali Pachauri (IIASA)

Energy is the engine of the modern world, but its distribution is unequal around the globe. The first goal of SDG 7 is universal access to modern energy services. Nowadays, there is a shift to measure access beyond binary indicators, such as yes/no about electricity connections or access to clean cooking. World bank adopts multi-tier indicators: reliability, affordability, quality, peak capacity, health, safety, legality, and availability. Going beyond the classical approach and adopting a multi-dimensional measure of access to modern energy services is a big step forward. An analysis based on this multi-tier framework [1, 2] showed more people without access if one considers all these different dimensions than what is captured by the official binary indicators.

A recent work [3] looked at scenarios of household access to energy services, using this multi-tier framework for defining and measuring access. The study tried to understand the drivers for energy services and demand preferences that can inform analysis of how these will change in the future across diverse populations. It is based on a highly granular bottom-up residential appliance and energy demand model estimated using microdata from national household surveys to assess changes under different socioeconomic (SSP1, SSP2 & SSP3) and climate policy scenarios (CP2C &CP1.5C). It is impossible to have surveys for every country globally. An effort was made to obtain surveys from key countries representing the different regions identified in the MESSAGE energy system model used in this study. The scenario analysis with MESSAGE regarding the evolution of the household access to energy services to 2050 showed that even under the most optimistic shared socioeconomic pathways, there would be huge inequalities in the amount of energy used across regions. The global South will still have about two-thirds of the population using less than 5 GJ/yr. per capita in 2050, whereas much of the global North will use more than 15 times, i.e. over 50 GJ/yr. per capita. Under stringent climate mitigation scenarios, there is mitigation of the energy poverty, but not elimination. In terms of access to specific services, e.g., thermal comfort, food preparation and conservation, entertainment and cleaning, vast inequalities persist over time, even in optimistic scenarios. Entertainment services showed less unequal access over time than thermal comfort or food preparation and conservation. Looking at the diffusion of appliances that provide energy services in individual homes, there are also huge inequalities, even within the same region. For example, air conditioner ownership in South Asia differs widely between urban and rural areas under the different socioeconomic futures.

Another recent work [4] looked at clean cooking access under post-pandemic scenarios and under climate mitigation futures. The study's objective was to understand the drivers of preferences for cooking stoves and fuels, accounting for the fact that many uses multiple stoves, and there is huge heterogeneity across populations and regions. The study explored a baseline scenario, a slow economic recovery from the COVID-19 pandemic scenario assuming a 20-year recovery period, and ambitious climate mitigation policy scenarios set to limit global warming to below 2 °C by the end century. A key takeaway from this research is that a protracted recession after the pandemic could leave an additional close to 500 million people unable to afford clean cooking services in 2030 relative to a reference scenario with a sort of moderate economic growth and income distribution like under SSP2. Also, ambitious climate mitigation can result in people not able to afford clean cooking, particularly in certain parts of the world. These findings underly immediate acceleration and efforts to make clean cooking accessible and affordable for all. Moreover, the results showed that income poverty and lack of access to clean cooking are correlated, although the degree of correlation differs by region. For instance, in sub-Saharan Africa, income poverty and lack of access to clean cooking fuels are highly correlated. At the same time, in other regions, there are fewer people lacking access to clean cooking compared to those having income poverty due to policies supporting the former.

Finally, one more issue is how much energy requirements are needed to provide a decent life for all. This broad understanding of energy access goes way beyond SDG 7 but is still considered important aspect of energy needs that allow for a good life. Previous attempts estimated them to be around 30 – 100 GJ per capita and year. Recent research [5] took a bottom-up approach by first defining a basket of decent living standards, including direct energy needs in homes and indirect energy needs and infrastructure for providing basic services like healthcare, education, mobility, nutrition, etc. This set of basic needs for decent living was translated to a minimum set of required material satisfiers (e.g., minimum space per capita or litres per day of clean water per capita, or the number of TV sets and cell phones, etc.). The study compared a normative scenario of meeting decent living standards in 2040 with a baseline and climate change mitigation scenarios. The analysis found that there are many more gaps in meeting decent living standards in the global South than in the global North. The energy requirements for meeting decent living standards vary regionally between 9 and 36 GJ/yr. and capita, due to different heating/cooling requirements, energy intensities, etc., in the different regions. However, in the climate change mitigation scenarios, the average final energy needs that are compatible with meeting these goals are way above the estimated energy needed for reaching decent living for all by 2040. In other words, there's more than enough energy globally to meet decent living for all by 2040. Still, there will be much need for increasing energy in certain parts of the world, and there may be a need for redistribution from certain parts of the population to the other – but these are political questions and topics.

The main takeaway from the research presented in this talk is that trickle-down economics do not work. We need explicit policies and efforts to achieve universal access to basic energy services and decent living standards. Also, despite significant growth in energy demand in regions of the global South, inequalities persist, and access for all is not likely without policy. Also, globally we have enough energy to meet universal decent living standards, but redistribution may be necessary. Finally, if the poor and vulnerable are shielded, climate mitigation and universal access goals can be achieved simultaneously.

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4.2 Tracking and modelling access to modern energy, the IEA approach

Presentation from M. Sc. Gianluca Tonolo (IEA)

The presentation gave details regarding the methodology followed in the IEA in integrating into the World Energy Model (WEM) the access to electricity and clean cooking. Insights were given on trends and projection results regarding access to modern energy services, how IEA tracks access, the barriers encountered while tracking access, and the methodologies used.

According to the definitions used in the IEA, electricity access entails a household having initial access to sufficient electricity to power a basic bundle of energy services – at a minimum, several lightbulbs (4 or 5), phone charging, radio and potentially a fan or television – with the level of service capable of growing over time. Besides, connections to small standalone systems, e.g., pico solar or solar lanterns that besides providing very good improvements in the welfare of people like providing for example lights and charging of phones etc., are not considered as access to electricity because they cannot provide other basic and essential energy services, for example having a fun, radio or television. Hence, the IEA definition goes beyond the often by governments definition of having just an electricity connection.

The IEA definition for access to clean cooking facilities means access to (and primary use of) modern fuels and technologies. These include LPG or natural gas and super-efficient new, improved cooking stoves that can burn biomass, but they are not like some stoves today in the market, which are based on biomass and are considered polluting. While the former are accounted for the future, the latter are used for historical reasons. The definitions of access to electricity and clean cooking refer to the residential sector only and exclude productive uses captured by other parts of WEM, namely agriculture or industry.

The latest projections from the IEA show that besides the progress made so far, especially in Asia if no additional efforts in policies and investments are deployed by 2030, more than 2 billion people will continue to use traditional and harmful stoves for cooking. Also, more than 650 million will still lack basic electricity access. The effort for eliminating access to clean cooking is higher than eliminating electricity access because the nature of the problem is different – more decentralised than electricity. Hence, IEA recommends building up some synergies between access to clean cooking and access to electricity. Particularly in Sub-Saharan Africa, the region where most people without access to modern energy services will live by 2030, access rates must increase at an unprecedented pace to achieve SDG7.1.2 goals from a low of 30% today. LPG seems to be a least-cost solution for 1/3 of people gaining access, electricity for 10%, and improved cooking stoves for 40%. In increasing electricity access, off-grid solutions seem to be promising.

IEA uses a combination of methods and tools to collect data on the population with access to electricity and clean cooking fuels: administrative data, business surveys (utilities tracking connections), household surveys, estimations and modelling, and in-situ measurements for grids and mini-grids. The quality of the data obtained from these methods is often poor. For instance, geographical locations are missing, or connection data do not include consumption levels. Rural electrification programmes also have information on the sales of products relevant to electricity grid connection, e.g., solar systems or permits released to construct mini-grids. Surveys, businesses or households have a high potential for good data quality but come at a high cost. As surveys do not run every year, administrative data is used to fill the gaps together with estimations (econometric models). Finally, in-situ measurements involve reading meters and smart meters that directly give data, e.g., for mini grid connections and consumption levels. However, in-situ measurements should be combined with the methods above to have a more holistic tracking of electricity production and consumption and access.

IEA is now working on a project to develop a framework together with experts and governments in order also to understand the barriers and the best practices in tracking access in Africa. This framework is planned to be released by the end of this year. Common barriers in tracking access relate to correctly sampling urban and rural areas and regions (access rates are different, household sizes are different, etc.), and off-grid electricity data are often not metered. At the same time, non-technical losses are high and distort the samples. At the same time, there are always issues related to the definition of the quality or level of the electricity access, the type of access (grid vs mini-grid vs solar systems vs solar lamps, etc.), and what could be a level of power per capita that can be considered as the first access to electricity.

In the IEA's World Energy Model (WEM), the modelling of access to electricity and cooking is connected to the residential sector. First, there is an estimation of country-by-country how many people gain access if policies stay as they are today or how many people need to gain access to achieve SDG 7.1 by country and then all these projects are fed into the residential model, which estimates the electricity or clean fuels demand associated with the increased population access while the rest of the WEM model identifies the options that can provide these additional demands. Such policies accelerating access are part of IEA's scenario development (e.g., are included in STEPS or SDS scenarios or even normative scenarios aiming at universal access). The main questions that are tried to be answered relate to how many people gain access and how demand is supplied, how much investment is needed to deploy the infrastructure and the energy-access related CO2 emissions.

Looking more in-depth at the electricity access model, the projections on people gaining access are based on policies, historical trends, and discount rates. The estimated electricity demand is based on per-capita assumptions depending on the region/country. The electricity demand of the households getting electricity access begins with a small bundle of appliances. Planned improvements to the model are to understand better how people use the energy, consider other public services such as schools and hospitals, etc. The estimated demand is allocated to residential electricity demand for lighting, cooking, appliances, space and water heating. When it comes to identifying power generation options to supply the increased demand, the model considers geospatial data such as population clusters, infrastructure density, field characteristics such as solar radiation levels, distances from existing grids and plants, and other inputs such as prices. Then the model calculates via a least-cost approach how much of the demand could be provided by the grid, from mini-grids or off-grid and other solutions. This aggregates to generation capacities needs and infrastructure investments. At the same time, the related CO2 emissions are calculated.

It should be noted that the IEA estimations on the population gaining access are conservative. It is based on the difference between a scenario with policies promoting access and a baseline projection which assumes the continuation of the existing trends by only considering the population growth. It does not consider that when a household gains access, the children born in this household would also have access.

Finally, regarding the demand modelling of the population gaining access, the approach starts from the average regional electricity demand per capita, increasing in the IEA scenarios. If a person gains access, for example, in 2022, it is assumed that this person will consume 100 kWh (if in an urban area) or 50 kWh (if in rural areas). Then every year, the demand is stepwise increased so that after some time, e.g., 10-12 years reaches the average per capita electricity demand in the region – and this corresponds to a scenario implying that there is full access to electricity. The access to electricity is not therefore achieved at once but gradually in time, with different population segments having at each point different per capita consumption.

4.3 Universal energy access beyond lighting: modelling demand for productive uses

Presentation from Dr. Anteneh Dagnachew (PBL)

The last presentation shared methodologies used or developed in PBL to model the demand for productive energy uses of private households. This complements the presentation from IEA, in which the modelling of access and demand for the unproductive uses of private households was discussed.

Previous work at PBL has shown that about 500 million people will lack access in Sub-Saharan Africa by 2030. The required investments for achieving universal access amount to about 33 billion USD per year until 2030. However, closing this gap requires not only this amount of investment but also an understanding of the technologies, risks and opportunities associated with this effort. Moreover, several studies have shown that it is not enough to provide basic levels of electricity to people to improve their livelihood. Thus, it also needs additional electricity for the productive uses of energy occurring in the household sector, e.g., agricultural uses, agro-processing, milling, and services (e.g., small restaurants or beauty salons), which generate additional income for the households. Most of the economic activity in Sub-Saharan Africa is dominated by activities in the informal sector. Some studies show that about 80% of the labour force is self-employed in the informal sector in some parts of Sub-Saharan Africa. About 42% of rural Sub-Saharan Africa operate micro-enterprises. By providing enough energy to support such productive uses of households, the increase in economic poverty can be avoided.

In modelling the electricity access and demand related to productive uses of households, the main challenge is that there is not much literature on this that shows the role of electricity access in entrepreneurial activity or the performance of an enterprise. As this needs to be done from scratch, additional data collection and quality challenges arise. The model developed in PBL for estimating the electricity access and demand for productive uses of energy in households defines two classes of uses: agro-related and non-agro-related microenterprises.

The modelling of electricity demand for agro-related microenterprises is bottom-up. First, the common crop types are identified, while the IMAGE model provides crop production at 1x1km^2 resolution until 2100. The model identifies over 9000 grid cells. Thus, there is very detailed data in PBL about the types of crops and productivity. In a second step, the crop processing operations are identified, which can be performed at the microenterprise scale and finally, the electricity requirements for these operations.

Modelling the demand for non-agro related microenterprises is more complex, and it is performed top-down. There are four steps/modules involved. The first is to project the entrepreneurial activity via binomial logistic regression on the probability of a household being engaged in such an activity. Then the connection module projects the probability of a household getting access to electricity via a binomial logistic regression. The third module projects the annual sales of a microenterprise via linear regression. Enterprise surveys from the World Bank usually support this regression. Finally, the last module projects the electricity consumption of an enterprise via a linear regression based on surveys from the World Bank. These modules do not distinguish different enterprises but refer to an average enterprise representative at each grid cell. This is because of the lack of data.

There are 23 drivers for these projection modules, including literacy rate, employed men and women, female-headed households, and lending interest rates. The challenge is to find data sources for these data at high resolution. Some data exists at the grid-scale level, and some are country-level data. Additional data are extrapolated or interpolated to fill data gaps. Common data sources are the World Bank Household Survey, World Bank Enterprise Survey, World Bank Development Indicators database, USAID Households Survey, and peer-reviewed literature.

Preliminary results show that in Eastern Africa and Southern Africa, the demand for productive uses of energy at the household level will significantly impact energy planning as the role of centralised systems is accentuated when these uses are accounted for in the analysis. There is a shift from decentralised to centralised systems and from standalone systems to mini-grid systems. This highlights the need for a long-term strategy to integrate decentralised systems into a larger network or forms of swarm electrification.

In conclusion, adding productive uses of households in energy planning considerably changes the landscape. For example, one outcome of the preliminary analysis is that off-grid systems should be designed ready for integration into larger networks. It should be highlighted that a significant amount of work is put into identifying drivers for uptake, performance, and consumption of micro-enterprises. In addition, due to the explorative nature of this study, there are a lot of independent variables that are analysed. At the same time, sensitivity analyses still need to be performed, and more activities like aquaculture and livestock need to be integrated. Finally, electricity system investment and electricity-related emissions need to be further investigated.

Overall, assessing the electricity access and demand for both productive and non-productive uses of households would provide richer insights into the role of the different technologies, systems, and investment requirements for universal access. Including productive uses in the discussion of achieving universal access and energy planning improves the viability of decentralised systems' economic variability in general.

5. CONCLUSIONS

The energy transition needs to include all countries in the world at different development stages. In this regard, energy sector planning must account for impacts of the deployed mitigation options on SDGs.

Together with sustainable development, resilience of the energy system is important. High variable renewable energy penetration seems to be technically feasible, without jeopardising the reliability of the power system when there are conventional power plants (e.g., biomass-fuelled) which can function in extreme peaks, there is enough cross-border capacity to facilitate balancing of the power system via exchanges with neighbouring countries and there is deployment of storage and demand side management schemes. Grid synchronisation is a critical issue and this calls also for grid reinforcement. The future designs of the electricity system should be performed at the largest scale possible to ensure cost-effectiveness, size system adequacy and ancillary services and take externalities into account, such as scarcity of functional material and IT energy footprint. Energy systems models should consider the reliability of the power system when assessing the feasibility of the energy transition and endogenously represent concepts beyond storages, such as demand side management, grid synchronisation and planning, ancillary services, and cross-border trade.

Besides, energy transition could lead to increased material criticality and scarcity, especially ofthose needed for batteries and ICT. Copper, bauxite, cobalt, nickel, lithium and rare earths are some of the materials of which the use could double in a climate change mitigation scenario compared to a baseline. Energy systems models should account for this increase in materials use when assessing the feasibility of the energy transition. This is because there are many forms of vulnerability, economic, industrial and geopolitical in the supply of these materials which are surrounded by uncertainties about the markets' ability to meet the new and growing demand on time or the commercial strategy of large consumers (e.g., China), or even uncertainties about the consequences of national strategies (e.g., high dependence on supplies from a specific region). Besides, there are uncertainties regarding the environmental impact of the material production that call for additional modelling improvements to capture such effects. In this regard, public policy is a key issue and especially those policies promoting recycling and sustainable mobility.

The energy-land-water-food nexus is important for a sustainable energy transition. This calls for improving energy systems models to better represent this nexus in the optimal decisions they take when evaluating climate change mitigation scenarios. Studies have shown that there are clear trade-offs in the use of land and water with the deployment of specific energy sources, such as bioenergy. In this regard, integrated assessment models that capture interlinkages between energy, economy, land-use, water and food become a valuable tool in aiding sustainable policy design. Such models comprise sub models which are soft-linked to perform a cost-optimisation of the interlinked systems.

For example, the MESSAGEix-GLOBIOM is a model framework that couples the energy system optimisation model MESSAGE and its macro sub model with the land-use model GLOBIOM that models forest CO2 emissions/sinks, forest and cultivated areas, land use, forestry, livestock and balances the uses with the demands from several sectors (food, fibres, energy and industry). The bioenergy requirement, as well as the carbon price, is fed from MESSAGE to GLOBIOM. GLOBIOM feeds to MESSAGE land-use based GHG emissions and bioenergy supply curves for a given carbon price and marginal abatement cost curves conditioned on a given biomass demand back.

Another framework operating in a similar way is the REMIND-MagPIE. REMIND is a modular multiregional model with a detailed representation of the energy sector in the context of long-term macroeconomic developments, where economic activity results in energy demands in different sectors. MaGPIE is a socioeconomic model of land-use and agricultural sector with spatially explicit and dynamic features. The model balances the biophysical aspects like crop yields, carbon stocks, nutrients and water with the economic aspects like costs, prices, demands and policies. It optimises agricultural production under the cost minimisation objective function. Besides the optimised agricultural production system, the model also calculates the agricultural and land-use change emissions. MagPIE communicates in an iterative operation mode. REMIND feeds into MaPGIE the CO2 price and the demand for bioenergy, while MaGPIE supplies that bioenergy demand and feeds back the information on land-use change emissions and biomass prices.

Within the TIMES energy system modelling community, there are also attempts to integrate land-use modelling into energy systems models. For example, the TIMES PanEU model has been extended with several nexus interactions between the energy, land and water systems. Energy for agriculture processes, agricultural emissions influencing the climate target, land area for biomass and renewable energies, and lignite mining, are among the topics captured by the interlinked framework. As a subsystem of the land use categories, the agriculture sector was modelled in more detail, and an irrigation option for biomass irrigation was modelled as a link between the land and water resource.

Finally, one important SDG is the access to clean fuels for cooking and electricity. The energy transition needs to be inclusive and socially just and this involves access to affordable modern energy services. Trickle-down economics do not work to achieve this SDG. We need explicit policies and efforts to achieve universal access to basic energy services and decent living standards. Also, despite significant growth in energy demand in regions of the global South, inequalities persist, and access for all is not likely without policy. Globally, we have enough energy to meet universal decent living standards, but redistribution may be necessary. Finally, if the poor and vulnerable are shielded, climate mitigation and universal access goals can be achieved simultaneously.

However, modelling access to electricity and clean fuels is not an easy task. The first challenge is that there is not a commonly used definition of access. Governments use a binary yes/no definition, while academia, IEA and World Bank opt for a multi-tier, multi-dimensional definition. The lack of a uniform definition influences the quality of data, which together with the data scarcity form the second challenge in modelling access. The third major challenge in the modelling of access relates to the inclusion of both productive and non-productive uses of households. Many modelling frameworks focus mostly on the non-productive use of energy in households, e.g., for cooking, lighting, etc. However, in many developing countries, the productive-uses of households, e.g., small agriculture enterprises, or small restaurants and beauty salons operating within the household boundary, form a significant part of the economy. Supporting these uses by providing enough energy to operate them is crucial for fighting poverty. Modelling frameworks that also account for such uses when estimated electricity and clean fuels access have been developed only recently.

Usually, the modelling of electricity and clean fuel access follow a bottom-up approach. First, a basket of basic energy services is defined. This includes energy services for thermal comfort, food preparation and conservation, entertainment, cleaning, etc. To support the provision of these services, the household needs to have a number of bulbs (e.g., 4-5), a fridge, radio, TV set, fan, etc. Based on this bundle of appliances, a minimum electricity and clean fuels consumption is defined per capita, which defines a first access to electricity and clean fuels. The household is considered to have full access when this first demand increases gradually every year to reach the regional average.

When modelling, productive uses of households both bottom-up and top-down approaches are used. For instance, agro-related microenterprises can be modelled bottom-up based on geographical information systems and models, by identifying types of crops, their production levels, associated operations to support cultivation and harvesting and the related energy demand. In contrast, non-agro-related microenterprises can be modelled top-down, via binomial logistic regressions representing the probability that a household develops such a microenterprise, the probability of grid connection and the consumption required to support this activity.

To cope with the data scarcity and quality challenges, several tools and data sources are combined. These include administrative registers, data from rural electrification programmes, business surveys, surveys from the World Bank, household surveys, in-situ measurements (e.g., mini grids) and econometric estimations and modelling to fill gaps.

As noted in the opening presentation of this webinar series from Prof. Halsnæs, the Chapter 17 of IPCC AR6 WGIII report clearly emphasises that "*accelerating climate actions and progress towards a just transition is essential to reducing climate risks and addressing sustainable development priorities, including water, food and human security*". However, understanding the interactions among the policies targeting different SDGs presents a gap in the knowledge. Energy systems models and integrated assessment models need to capture and perform wider analyses of the SDGs, to inform policymaking and close this knowledge gap. In this regard, the current series of webinars presented state-of-the-art methodologies and insights on modelling developments and improvements for representing 9 key SDGs. These webinar series complement the energy-water nexus workshop of ETSAP held in Zurich in 2015. The high rate of attendance achieved in the webinars indicated the need in the TIMES energy systems modelling community to continue such knowledge exchanges and modelling efforts towards holistic assessment of the energy transition beyond the energy system and the GHG emissions.

6. APPENDIX: WEBINAR SERIES FLYER

January – Feburary 2022 **Webinar Series**

Integrating Sustainable Development Goals Into Energy Systems Modelling

etsap ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAM

iea Energy Technology Network

IEA-ETSAP supports the Sustainable Development Goals

As defined by the United Nations, the sustainable development goals represent the “blueprint for achieving a better and more sustainable future for all”. Interlinkages between sustainable development goals, energy, and climate, call for holistic approaches in their assessment.

The ETSAP community has performed several model developments and knowledge exchanges regarding the integrated assessment of the economic and energy systems in view of sustainable development. The aim is to expand the boundaries of energy modelling and incorporate new systemic interdependencies in a broader sense and contribute to a more holistic understanding of future development pathways

In this context, three workshops are organized that address different sustainable development goals and their interaction with the energy system.

The main objectives of the three workshops are:

- To analyze methodologies for integrating sustainable development goals into energy systems modelling
- To assess required associated data
- To provide insights on the value-added gained for policy analysis
- To get insights on state of the art synergies and tradeoffs between SDG’s and energy transition – robust evidence and research ideas

etsap ENERGY TECHNOLOGY SYSTEMS ANALYSIS PROGRAM

iea Energy Technology Network

IEA-ETSAP supports the Sustainable Development Goals

7 AFFORDABLE AND CLEAN ENERGY

11 SUSTAINABLE CITIES AND COMMUNITIES

January 13th 2022, 16:00 – 18:30 CET

Resilience and sustainability of power systems with high shares of renewables

The provision of reliable, secure and affordable electricity is essential to power economic growth and development. The drop in the cost of renewable technologies makes them an increasingly viable option. Moving towards a weather-dependent electricity generation raises resilience issues against supply disruptions, while back up storage systems depend on critical supplies of rare-earth materials.

This webinar aims to give a better understanding of how resilience can be achieved in future power systems with high shares of renewables to ensure affordable and sustainable electricity supply while at the same time mitigating criticalities in supply chains of materials. Three of the top modelling teams share insights on methodologies and data about integrating resilience and sustainability indicators of renewable energy technologies into energy systems models.

Speakers:

Kirsten HALSNÆS; DTU, IPCC Coordinating Lead Author: State of the art on synergies and tradeoffs between SDG's and renewable energy implementation – robust evidence and research ideas

Vincent MAZAURIC; Schneider Electric: Reconciling reliability and sustainability: some thermodynamics insights dedicated to the integration of renewables in the power system

Gondia Sokhna SECK; IFPEN: Raw materials with high share of low-carbon energy technologies for the energy transition

Moderator:
Nadia Maïzi, Mines Paris - PSL

Registration link to this webinar:
https://psich.zoom.us/meeting/register/u5wscOmhqzIiHt20105L_jx1PQ_WPfAcu1aF

2 ZERO HUNGER 6 CLEAN WATER AND SANITATION 15 LIFE ON LAND

January 20th 2022, 16:00-18:30 CET

Energy and land-use nexus

Land use is central to many environmental and socio-economic issues. The twin challenge of reversing biodiversity declines and mitigating climate change, while producing sufficient food to ensure zero hunger and providing new land areas for renewable energies, must be tackled together. While a transition towards cleaner, less emission-intensive energy systems has been the focus to date, the role of agriculture in generating GHG emissions is becoming increasingly clear. Further, negative emission technologies or land use types which accumulate carbon are getting more in the focus with the climate neutrality targets and will be even more important in the future.

This webinar aims at providing a deeper understanding of the role of land-use change to reduce GHG emissions while contributing to other strategic priorities such as food production and biodiversity. It brings three top modelling teams to share insights on methodologies and data about integrating energy and land systems, to identify suitable sustainable development indicators and exchange on required policies and their impacts.

Speakers:

Adriano VINCA; IIASA: MESSAGEix model

Miodrag STEVANOVIC; PIK: MaGPIE-REMIND model coupling

Vera SEHN; IER: Integrating agriculture and land-use aspects into TIMES Pan-EU

Moderator:
Markus Blesl, IER

Registration link to this webinar:
https://psich.zoom.us/meeting/register/u5Avc-6grj0tGNJD5LJhjHkKLQ896C8V7wcP

1 NO POVERTY

7 AFFORDABLE AND CLEAN ENERGY

11 SUSTAINABLE CITIES AND COMMUNITIES

February 10th 2022, 16:00-18:30 CET

Energy poverty and energy access

In 2019, 771 million people around the world lack access to electricity. In addition, about 2.6 billion people need improved access to clean and safe cooking fuels and technologies. On top of the socio-economic impacts of energy poverty, achieving ambitious goals for climate change mitigation requires energy services based on clean electricity and cooking fuels. As the COVID-19 pandemic showed to us, lack of access to energy also hampers efforts to contain diseases across many parts of the world.

This webinar brings together three top modelling teams to share insights on methodologies and data about integrating energy poverty and energy access into energy systems models. Suitable sustainable development Indicators on this topic, e.g. population without access to clean energy or health impacts, will be identified and discussed.

Speakers:

Shonali PACHAURI; IIASA: Group leader of Transformative Insitutional and Social Solutions

Gianluca TONOLO; **IEA Leader of the energy access modelling team of the IEA World Energy Model**: Tracking and modeling access to modern energy, the IEA approach

Anteneh DAGNACHEW; PBL, Leader of the energy access modelling team of the IMAGE model: Universal energy access beyond lighting: modelling demand for productive uses

Moderator:
Evangelos Panos, Paul Scherrer Institute

Registration link to this webinar:
https://psich.zoom.us/meeting/register/u5Ipf-mqpjwuHNVSrGXSohajZwewyizQUb_Y

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