SDSN Global Climate Hub Workshop:

Systematic review on Integrated Assessment Models for decarbonization pathways,

Athens, April 5th 2023

NOTES AND FOLLOW UP ACTIONS

PRESENTATIONS	
Prof. Dogan Keles, Head of section, Department of Technology, Management and Economics, Technical University of Denmark "Balmorel" (v)	
Notes	Prof. Keles presented the BALMOREL model. Balmorel is a partial equilibrium model for analyzing the electricity and combined heat and power sectors in an international perspective. It is highly versatile and may be applied for long range planning as well as shorter time operational analysis. Balmorel is implemented as a mainly linear programming optimization problem. The model is developed in a model language, and the source code is readily available under open-source conditions, thus providing complete documentation of the functionalities. Moreover, the user may modify the model according to specific requirements, making the model suited for any purpose within the focus parts of the energy system. The Balmorel model has been applied in projects or other activities in a number of countries, e.g., in Denmark, Norway, Sweden, Estonia, Latvia, Lithuania, Poland, Germany, Austria, Ghana, Mauritius, Canada and China. It has been used for analyses of, i.a., security of electricity supply, the role of flexible electricity demand, hydrogen technologies, wind power development, the role of natural gas, development of international electricity markets, market power, heat transmission and pricing, expansion of electricity transmission, international markets for green certificates and emission trading, electric vehicles in the energy system, environmental policy evaluation.
Questions	In what extent is Hydrogen demand included in the model and the optimization (chat) - Hydrogen Demand is exogenous to the model while for the Heat sector we allow the model to optimize for the source of heat to use. The Hydrogen demand are currently relied on the European Hydrogen backbone report and similar reports, announced for the decarbonization of the whole sector. Choose a scenario of modest hydrogen report. In principle can it be endogenized? (Prof. Koundouri) - We can do that if we have transport demand instead of fuels demand and let model to optimize for it.

Follow Up Actions	Working on Expanding the model coverage In Balkans
MsMaria Diaz, Manager of the FABLE Consortium&MsClara Douzal,Statistician - FABLE consortium at Sustainable Development Solutions Network,"FABLE: a decentralized approach to model 2050 pathways for the national and global food and land use systems"(v)	
Notes	FABLE consortium focuses on SDG 4, promoting new paradigms that emphasise nutrition security and the need to minimise the environmental footprint of agriculture and food production. For supporting this overarching objective, FABLE proposes models that respect certain requirements (provide a long-term timeframe, allow the simultaneous computation of several objectives, are flexible and transferable, represent the supply and the demand). FABLE has three main lines of work, to build technical capacity to use modeling tools, to develop integrated pathways, and to advise governments on long-term strategies towards sustainable land use. Three models that are used by FABLE have been presented: a. the FABLE calculator b. the Model of Agricultural Production and its Impact on the Environment (MAgPIE), and c. the Global Biosphere Management Model (GLOBIOM). MAgPIE and GLOBIOM are used in certain geographical areas, but the FABLE Calculator is used by all country teams. It is a demand-driven tool with two major constraints (market equilibrium and the land balance) that projects the evolution of several indicators for the assessment of the sustainability of the food and land systems under different assumptions. Historical statistical data are used for calibration. For the 80 products included in the calculator a prediction is possible for the future food, feed and other non-food consumption, losses and waste, imports and exports, production, land use, water use, etc. After each country-team develops each pathway, based on the model, the integration of national and global scales takes place, through an iterative approach called Scenathon, that includes definition of global targets, and agreement on pathways narratives. All the outputs are brought together in a global database to ensure that all assumptions made at national level do make sense on the global scale and are realistic. This allows the formulation of global targets covering the entire land use system, that are to be achieved collectively and their consistency with the SDGs and the Paris Agreement. Two national pathways are created, the current trends / business as usual pathway and the sustainable pathway, based on realistic assumptions in the national context. The FABLE calculator is based on the decentralisation of the modelling activity. As such, this process adds transaction costs but increases realism of global pathways and the likelihood to impact policies. It is an open and transparent tool that can be deployed in several countries and combined with other tools.
Questions	Would more integration with the energy decarbonisation pathways be useful? How do you see the connection between those two? (Prof. Koundouri) - Bioenergy is included, biofuels are included in the model. We also work to make our model more spatial explicit including for example assumptions related to solar or renewable energy and their relation to land use. If you know how much land will be needed for the renewables, then you can add to the model the competition between food and energy. Also, through the collaboration with DDP in India and Mexico, FABLE has started to explore how

	the two models (energy and land use) could complement each other at country level Do you take into account the potential of NBS and the use of land for those? (Prof. Koundouri) - Yes, we are increasing in the model e.g., representation of mitigation options that are nature-based, also making the assumption that agriculture is something that will be more nature-based. The FABLE calculator is based on extensive work on indicators, but the fact that it is an xlsx file, makes it difficult to use it. For ensuring its openness, reusability and user friendliness, complexity should be hidden. A web-based application could be a good solution for both, interested users and the FABLE consortium for maintaining and updating the tool. (Eleni Toli) - We totally agree and are working on an online calculator that will make it easier for our members to use and update. Thereby we would also ensure that all teams have the latest version of other countries, we would not lose the trade consistency of the components and all countries would have easy access to their assumptions and the information from all other countries. Do you look at how production changes, as soil health changes over time? (Prof Leong Yuen YOONG) - Right now, we do not have this component in the model. But we are working on this it will be for example connected the mitigation options (better practices --> better soil quality). But we need the relevant information to be available for all countries, as we work with global databases.
Follow Up Actions	SDSN Climate Hub has a lot of related capacity and can support the creation of this platform, if needed.
Prof Leong Yuen YOONG, Director of Sustainability Studies SDSN Asia Headquarters in Kuala Lumpur Professor at Sunway University in Kuala Lumpur, *"ASEAN Green Future: Net Zero Pathways for Southeast Asia*" (in person)	
Notes	Prof. YOONG presented the ASEAN Green Future project. Objective of the project is to undertake zero pathways analysis to inform policy recommendations. Nine ASEAN country teams (Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand and Vietnam) to design climate action points that build a vibrant and inclusive social and economic future. Two zones of analysis are included, Technology Road (Electricity generation and fuel supply, Surface and Marine transport and Manifacturing) and Ecosystem Growth Mappings (Ocean, Land Use, Land Use Change and forestry, Agriculture and Waste), which refer to decarbonizing Technical Systems and Re-carbonizing ecosystems respectively. Based on the 7nth ASEAN Energy Outlook Report, the most important results are: • the AESEAN member states's fuel switching policies will not significantly change future energy consumption trajectories. • Conventional vehicles still dominate passenger roas transportation fleet into 2050 and Oil continues to be the major transportation fuel • Coal will still dominate energy demand in the industrial sector in 2050 with 34%. So regional optimisation is necessary for deeper decarbonisation of technical systems. Southeast Asia cannot attain net zero by only focussing on decarbonising technical

	systems. Re-carbonisation of natural ecosystems must be worked on as well. Projects regional studies are focused on Regional Power Grid, Regional High-speed Rail as well as Nurturing Forest and Soil as Productive Capital Assets to restore regional biodiversity.
Questions	Whether we can accelerate the regeneration capacity of ecosystems and its services, so for the targets of 2050 to be achieved, and if how much? (Prof. Koundouri) - Yes, it may take a lot of time. Even if the ecosystem is destroyed, it might take more time and resources to restore it. We need to learn from nature and humans may help accelerate its restoration. Is there work on the pace of regeneration capacity or interventions? (Prof. Koundouri) - Many things need to gradually change so for a change to be possible. Consciousness needs to arise and needs to spread.
Follow Up Actions	
Dr. Xavier Garcia Casals, Senior Expert on the Energy Transition at the Policy Unit from IRENA's Knowledge Policy and Finance Centre *"The overlooked socioeconomic layer of the transition: informing scenarios and roadmaps through socioeconomic footprint analysis". (v)*	
Notes	Dr Garcia Casals' presentation focused on the relevenace of measuring the socio-economic impact of the transition, emphasizing the need to incorporate the socio-economic layer of the transition into all scenario work. This is crucial for the necessary buy-in from society that is required to support the transition. Thus far the scientific community has failed to put together a transition narrative that includes everyone often with parts of the world are left behind. IRENA has been working on incorporating this socio-economic layer since 2016. Main points: • There needs to be an acknowledgement of the systemic nature and the feedbacks which we cannot ignore (energy > economy, society > planet) – nested layers. Both systemic and policy layers need to be captured in the analysis. If policy layer is not captured, we are missing the LANGUAGE to communicate with policy makers. • 3 PILLARS of the TRANSITION: Inclusive (no one left behind, Human rights, avoiding the mistakes of the Fossil Fuel era), Equitable (Responsibility and capability to address the transition), Just (how do we take on board all who have been trapped by the FF era and how policies are implemented). • Huge gaps in Mitigation Ambition. Both reality and planning lag behind. Transition planning is not aligned with the needs of all… (very Western-centred, and producing a future that replicates a lot of mistakes of the past.). There is no way to match the required mitigation if we maintain the current Economic system • The disconnect between the carbon requirments layer and the economic layer means we are missing a whole dimension of how we can comply with mitigation targets faster… this is largely to do with how we are constructing our models. • The Scoio-economic footprint refers to the outcome of the implementation of a policy portfolio in order to effect an transition roadmap (GDP, Employment, Welfare). Welfare Index: Economic, Social, Environmental, Distributional, Access. Assessing according to the welfare index helps policy makers recognize areas that need additional policy support, because if the transition is perceived as unfavourable in some aspects then people will find another (path)way.

	• Socio-economic considerations help to create a policy mix that ensures that the benefits of the transition become evident other wise we keep producing roadmaps for transitions that are not accepted and we in effect delay the process of transition. • The tools that we use to produce all these impacts: There is a need for structural change in these layers (energy, economy, social). Equilibrium models are still used (which make implausible assumptions… the economy has never been in equilibrium), and in today's world we are moving even further away from equilibrium. • The value of IAMs is capturing all the feedbacks between the different systemic layers. An effort needs to be made to ensure that the way we capture them are representative of the dynamics we expect within this process. We need to see if the outcomes of non-equilibrium are so far away from the outcomes of equilibrium that they could lead to the wrong policy decisions. Unless we build the relevant models we face the risk of creating ineffective policy mixes.
Questions	*Q: Does the equity translate to the Welfare index? A gen equilibrium model that tries to mitigate the cc effects, we try to identify growth multipliers, job multipliers and equity coefficients for the different regions (mainly Europe). How does this translate in your setting?* A: Equity implications are considered in the distributional element (income and wealth), but mainly in social expenditure. Many historic gaps are associated with lack of public investment in things like education health etc to produce social value. If the transitions only focus on megawatts of deployed capacity, these gaps remain. The economic dimension is also important eg Per capita consumption on investment and allocation to diff parts of the world. Currently historic inequalities in investment within the energy sector are merely projecting into the future leaving very little room for the majority of the world to leapfrog (while they have peak social gaps that need to be plugged). *Q: Would you modeling allow for guidance with regards to fical policy (e.g. a package of measures to allow for financing the transition and supporting the vulnerable)* A: One of the areas that we try to place more emphasis is on the policy layer the which interacts directly with the fiscal layer of countries. All our analyses are global with country level resolution and we focus on the fiscal balances of the countries i.e. how is international collaboration requirements for investment in infrastructure and gaps in areas of social value e.g. access to education, health food, dignified work etc. Fiscal balances are tracked individually with all the associated flows and assessing what needs to be done to support the capability of countries to address these gaps. The technological transition requires less investment than addressing the social gaps in some countries because of the historic cumulative effect. So it is more complex than just the energy transition (which is a false monographic perspective), rather more holistic socio-economic transition which includes the energy transition. A lot of these social gaps
Follow Up Actions	How do we incorporate Ecosystem Services valuation? Particularly in the Global south.
Henri Waisman, Lead Deep Decarbonization Pathways (DDP) initiative Institut du Développement Durable et des relations Internationales (IDDRI), *"Country-driven, country-led and country-owned deep decarbonization pathways: lessons from the DDP initiative". (v)*	

Notes	Mr Waismann presented the IDDRI's work on country-led and country-owned deep decarbonisation pathways. The team are not modelers and do not have a particular model of their own, but work with different models and have derived some criteria on how to best use models to best inform the key policy questions that can be posed by the transition to decarbonisation. Main points: • A network of international research and strategic partners (in-country) since 2013, developing robust decarbonisation pathways by mid century. The analysis is used to support engagement with decision makers to inform their choices (Decision support tool). Analysis is tailor-made to the country-context, providing useful insights on specificities of the transition (no one size fits all solution). International community of practice encourages knowledge sharing across countries and infers lessons for the global scale. • IDDRI builds on the diversity of existing models – from IAMs (most complex and complete), top-down based hybrid models, mixed linked bottom-up/top-down, Bottom-up based hybrid models, bottom-up models, acocunting models (least complex and complete). This is also reflected in levels of transparency. • 3 main criteria in selecting models: 1) Determine Policy Priorities, Reconizing System Characteristics, 3) Evaluating capacity constraints (at country level). There is no one-size-fits-all. • We view modeling as a part of the process, as a way to translate the strategies (narratives) into quantified indicators. Models do not tell the whole story, but inform the story. Narratives are required to capture the broader context. Asking the model to capture everything is arecipee for failure. It is only by identifying where we need models to inform the story in a robust manner, that models can be most useful. • Key challenges of modelling DDPs: 1) it is important to acknowlwedge and manage the complexity of the DD modelling. 2) The model cannot decide policy choices or make decisions FOR the decision makers 3) models provide strategic directions of travel and not as useful for precises numerical evaluation. 4) Socio-economic dimensions are difficult to integrate but important to capture. These can be captured via the narrative. 5) Models are useful tools to engage stakeholders but models/modellers need to speak the language of the stakeholders.
Questions	*Q: these transformations (energy systems, land use) have international value chains with impacts and spillovers between countries. Does IDDRI carry out analysis in terms of this?* A: Our approach is two-fold. We ask the in-country partners to make the boundaries of their analysis explicit. With big countries, e.g. China which have a big international impact, we ask them to be explicit on how their actions affect the outside world. With smaller countries which are usually the 'takers', we ask them to be explicit on the assumptions they make on parameters like technology, trade etc. A new avenue we have started to explore is the development of 'Global Narratives' which look at these international questions from a basis in the reality emerging from the country transitions. We would like to assess a set of countries in terms of the consequences of these countries reaching deep decarbonisation (e.g. what does that mean for

	international parameters like trade?). Our design is iterative driven by in-country directives but can be revised by international paramenters. *Q: Do you have any particular frameworks that you adopt to integrate stakeholders into the narrative building work?* We try to at minimum assess the key questions that SHs ask. Even if we are not directly engaged with SHs, we work with in-country partners who should be aware of the needs and frame the analysis around this. We are currently working in Senegal to undertake a more integrated SH co-creation process, working with diverse groups of SHs (thematic groups), in charge of developing the scenario framing (using LEAP modelling which is useful to have a transparent tool to engage SHs). We want to avoid a mere consultation with SHs. Access to data can be difficult, and engaging with SHs can help overcome that.
Follow Up Actions	How does the work IDDRI is doing at national level feed global/international modelling work? Integration with our approach in calculating value chains of different systems (SDGs) and capturing the socio-economic footprint of the DDPs Discuss collaboration with Participatory Approaches Unit in building 'Global Narratives' Discuss areas of ongoing decarbonisation work in SSA to progress Samuel Hall Proposal
Guenter Conzelmann, senior energy and environmental analyst in Argonne's Energy Systems and Infrastructure Analysis division, "*Net Zero World: Integrated System Analysis to Identify Decarbonization Pathways and No-Regret Investment Strategies to Accelerate Just Transitions toward Clean, Resilient, and Climate-neutral Energy Systems"(v)*	
Notes	Mr. Conzelmann presented the Net Zero World Initiative. The initiative refers to an Integrated Systems analysis to identify decarbonization pathways and investment strategies to accelerate just transition of energy systems. The initiative target to make available labs and resources from the US government, to develop robust net zero pathways and technical Investment plans and to accelerate transition by investment mobilizing. In project, 8 countries and US participate and collaborate in key energy topics and sectors, developing collaborative Action Plans. Each country is modelled using an economy-wide model across all fuels/sectors analyzing and country-specific policy and technology scenarios. The Results identified 4 common essential mechanisms to drive carbon reduction in each country: • Fuel efficiency in all end-use sectors. • Fuel Switching to clean energy carriers (electricity or hydrogen). • Greening electric power supply with large deployments of renewable. • Carbon capture and storage of remaining fossil-based system. System Wide Modeling includes LEAP, GCAM, TIMES, MESSAGE and other models. They are leveraging on available models in each country. Next Steps will be to perform a Sector-Specific (Transportation, Buildings, Industry and Power) Deep Dive Analysis. The end Goal is to also perform an investment analysis and pre-feasibility Conceptual Design and Deployment of projects (solutions). National All sectors Modeling – Decab strategies is based on LEAP and TIMES models. This is connected to a PLEXOS model to Accelerate Coal Power Phase-out Strategies (as a case study in Indonesia).

	Next Step will be to enhance In-country Modeling Capabilities. Mainly this consists od 3 basic steps : 1. Performing Standard Scenario Analysis, perform an expanded uncertainty and risk exploration and finally conducting a stohastic analysis to determine Robust Investment Hedging Strategies.
Questions	Note that we follow the same approach in ERC Water Futures (Prof. Koundouri) In Denmark they have a capacity building program in BALMOREL and LEAP models (which is more user friendly), and maybe this is something to work together. And investment decision analysis in renewables under uncertainty, less ambiguity and more probabilistic and can explore synergies (Prof. Keles) - Highly welcome to explore synergies to leverage of work done and not re-invent the weel.
Follow Up Actions	Synergies can be explored between DTU team and the Net Zero World Initiative.
Dr. Oleg Lugovoy, Lead Senior Economist Economics and Global Climate Cooperation, *"Open source models to support action". (v)*	
Notes	Presentation refers to open-source models to inform action as the Pilot Project: Multi-Country Electricity Transition Potential and Challenges. Open-Source increase transparency and credibility and the goal of this project is to facilitate reuse and application of open energy models and help in developing more and better decarbonization studies. Open Mode has grown during the decade already supports 50 models and data for the models become more accessible. Some important recent studies are a feasibility study of Chinas electric power sector transition to zero emissions by 2050 and main results were that China can produce 5x electricity just from renewable sources and the models give a demand-side flexibility which can produce robust energy pathways and estimates. Other Studies were developed for India and USA, providing decarbonization scenarios. The pilot project aims at increasing the reuse/re-application of models and scenarios and contribute to capacity building, extend the network and result to better informed action. The main tools are SWITCH, PyPSA and energyRt. The Team consists of Instructors/developers of the shared models, modeling teams in 8 countries, policy experts and scenario building writers. Next steps will be to develop concept of “Network of modelers and policy makers” and expand analysis to more countries and studies.
Questions	How do you engage the countries or teams working with different countries (Prof. Koundouri) - Regular meetings/ Trainings to showcase models and provide help the local teams.
Follow Up Actions	
Charlie Heaps, tentative title “Overview of SEI's LEAP planning framework- use in low carbon modeling”, Senior Scientist at Stockholm Environment Institute -US	
Notes	Mr Heaps presented the Low Emissions Analysis Platform (LEAP) developed by the Stockholm Environment Institute (SEI), is a windows-based tool for energy, climate mitigation, and air pollution mitigation planning. LEAP itself is not a model but a model-building tool. It is widely applied with appx 60 countries using it to develop their NDCs. While it is quite user-friendly, it does not go into as much detail as BALMOREL, so integration between tools is

	encouraged. It can be linked to other tools that conduct Montecarlo analysis. There is no one-size-fits-all. Main points: - Focus is on making relatively complex modeling as easy as possible. Designed for planners and decision-makers: not just for expert modelers. Important also for capacity building in many countries. Aside from its modeling capabilities, LEAP supports data management & documentation, results visualization & stakeholder engagement. • LEAP itself is not open source, but most of the models are. Available at no charge to governments, NGOs, and academics in low-income and lower-middle-income countries and at low cost in upper-middle-income countries. Free to students worldwide. • Regularly updated with support available via the LEAP web forum. Comprehensive training materials are available on the LEAP YouTube channel. There is a vibrant community of practice with peer-to-peer learning. • LEAP tries to put the users in control of what methods are suitable for them by providing a framework with a choice of methods to account for diverse modelling needs and data availability. Allowing users to mix and match methods. • There are a choice of methods: 1) Demand methods include top-down econometric, bottom-up end-use-oriented models, and detailed stock-turnover modeling (e.g. for transport modeling). 2) Transformation methods range from simple accounting-based models to advanced least-cost optimization of capacity expansion and dispatch including energy storage and sub-annual time slices. Full energy system optimization modeling coming later this year. 3) Optimization modeling utilizes NEMO: a high-performance, open-source optimization framework supporting multiple free and commercial solvers. 4) The Integrated Debugging Environment (IDE) makes it easy to edit, import, and process data, visualize results, and systematically debug models. • The expression-based data definition language (DDL) allows input variables to themselves be modeled. E.G.: technology penetration can be specified exogenously or made a function of other variables such as fuel price, device cost, income, etc. • To minimize data entry, LEAP's expressions are inherited across hierarchies of scenarios. Multiple scenario inheritance allows individual "mini" scenarios describing individual policy measures to be packaged into overall integrated strategies. • Provides a wide range of results and visualisations which lends itself to SH engagement • Additional functionality to be incorporated into LEAP in the short and medium term includes: LEAP Plugins, Cloud-based Data, Energy System Optimization Modeling, Energy Affordability, Better Accessibility, more detailed modeling of the GHG emissions implications for land-use
Questions	
Follow Up Actions	Explore various avenues for collaboration and integration into our work engaging country leaders

SDSN Global Climate Hub

SDSN Global Climate Hub IAMs Workshop Model Matrix								
MODEL	LEAD INSTITUTION	CURRENT INTEGRATION WITH OTHER MODELS	MODEL PARAMETERS					
			ENERGY	LAND USE	WATER	CO2	Market Equilibrium	Comments
FABLE	SDSN	No, amenable for combination with Energy Models (IDDRI/DDP suggestion)		X	X	X	X	Tool with ready-to-use data from FAO – amenable to edits/additions from national sources in each country's Calculator
LEAP	SEI	Part of the NZWI along TIMES, GCAM, PLEXOS, MESSAGE	X	X		X		Complemented with IIASA's ECLIPSE scenarios. Typically, at national scale but can be used at a regional/city level
BALMOREL	DTU		X					Balmorel is a partial equilibrium model for analyzing the electricity and combined heat and power sectors in an international perspectiv e
GCAM	U.S. Department of Energy	Part of the NZWI along TIMES, LEAP, PLEXOS, MESSAGE	X		X		X	Part of the Net Zero World Strategy of the NET-ZERO WORLD INITIATIVE
TIMES	IEA -ETSAP	Part of the NZWI	X					Part of the Net Zero World Strategy of the NET-ZERO WORLD INITIATIVE
PLEXOS		Part of the NZWI Part of the NZWI along TIMES, LEAP, GCAM, MESSAGE	X					Part of the Net Zero World Strategy of the NET-ZERO WORLD INITIATIVE
MESSAGE	IIASA	Part of the NZWI Part of the NZWI along TIMES, LEAP, GCAM, PLEXOS	X			X		
SWITCH		Part of EDF Open Decarbonization Project	X					Open Source
PyPSA	Technical University of Berlin	Part of EDF Open Decarbonization Project	X					Open Source in Python
enrgyRT	EDF	Part of EDF Open Decarbonization Project	X					Open-Source Modelling Toolbox in R – GAMS or GLPK or

								Python or Julia to solve the model