LOCOMOTION

LOCOMOTION Massive Open On-line Course (MOOC)

Dates: 3rd -13th November

LOW-CARBON SOCIETY: AN ENHANCED MODELLING TOOL FOR THE TRANSITION TO SUSTAINABILITY (LOCOMOTION)
H2020-LC-CLA-2018-2

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INTRODUCTION

The main aim of the LOCOMOTION MOOC is to understand how improved integrated assessment models (IAMs) can support policy decisions towards social and environmental sustainability. The course will present the main structure and features of WILIAM (Within Limits Integrated Assessment Model) developed by the Horizon 2020 project LOCOMOTION (https://www.locomotion-h2020.eu/). The model runs at three geographical levels – global, European and national for the 27 EU member states from 2005 to 2050-2100. A special focus will be on the improvement in the integration among energy, resource, economy, society and environment modules, with improved data management, policy and scenario assessment, as well as systematic dynamic modelling of relevant variables of each module.

WILIAM offers a data-driven environment to compare policy interventions in the different modules, by simulating alternative scenarios. The model addresses key pervasive limitations of most IAMs such as: the simplistic representation of the economic processes, assumptions of technical renewable potentials without considering material limits, energy return of investment or other accessibility constraints, and key sustainability dimensions other than climate change. Therefore, by introducing WILIAM to students, LOCOMOTION MOOC provides an introduction to the complex interactions between environment and economic spheres, mapping its interrelations and feedback effects following system dynamics methods. Current developments on WILIAM study the impact and constraints to many different policies on energy, transport, land use, climate damage mitigation, as well as social policies. However, the analytical framework is versatile and open to new policy and academic oriented analysis, leaving an open room for future studies based on this or related methodologies.

The course is online and comprises a mix of lectures and workshops, with case analyses, exercises and group activities to stimulate the participants' ability to analyse and understand the challenges posed by the climate crisis and the proposals to counter it. The subject areas of the project work will be identified by the lecturers and communicated at the beginning of the course. Participants will acquire the ability to programme and analyse scenarios with the software Vensim.

The course will be divided into different modules, each of them will focus on a specific field. The first day will be devoted to a general introduction of MOOC, IAMs and System Dynamics, and the WILIAM model (Modules 1, 2, 3). The second day will be centered on the Resource, Environmental and Energy debate, (Modules 4, 5, 6). The third day will focus on the Economy and Society and Demography components, as well as the integration of all the different components of the model (Modules 7, 8, 9). Finally, the last day will be dedicated to an overall analysis of policies scenarios and WILIAM toolkit, and a final lab dedicated to the analysis of policy impact which will form the basis of trainees' final project work (Modules 10, 11, 12).

OBJECTIVE

The primary objective of the LOCOMOTION MOOC is to explore how enhanced integrated assessment models (IAMs) can aid in making policy choices that promote social and environmental sustainability. A particular emphasis will be placed on how WILIAM improves the coordination between the various components related to energy, resources, economy, society, and the environment. This improvement involves better data handling, policy evaluation, and scenario analysis, along with the systematic and dynamic modeling of key environmental, economic, social, technological, and biophysical factors.
Specific aims are the following:

- Acquiring the skills to utilize diagnostic and scenario assessment tools for the analysis of a shift towards a sustainable low-carbon society.
- Developing integrated policy analysis to evaluate environmental and social sustainability.
- Improving simulation and analysis methods with the Vensim software.
- Fostering multi-disciplinarity in policy analysis and design.

TRAINEES

The LOCOMOTION MOOC is designed to support policy decisions towards social and environmental sustainability. It is directed at both academic and institutional researchers who may be interested in studying such topics through simulations withIntegrated Assessment Models.
In particular, the course might be useful for young researchers, such as doctoral and postdoctoral researchers, research scientists, assistant professors, master students, research associates, lab and data analysts working in sustainability, just transition, and related fields..
Besides, technicians working both for institutional and private organizations can benefit from policy analysis instruments.

SCHEDULE

The full training will be delivered from 3rd until 13th November. This course has been designed with 12 learning modules and a maximum total duration of 3 hours per day of the trainees work (including the synchronous lectures, discussions and lab activities).

Each module presentation will last between 30 and 45 minutes and each of them will be followed by 10 minutes of Q&A sessions.

DAY	DATE	MODULE	ORGANIZER/ COORDINATOR
SYSTEM DYNAMICS INTRODUCTION AND MODELLING	**Nov 2/3**	**General Introduction of MOOC**	UNIPI
		IAMs and System Dynamics	UVA
		Introduction to the WILIAM model	UVA
ENVIRONMENTAL SUSTAINABILITY	**Nov 6**	**The Resource Module**	INN
		The Environment Module	UVA
		The Energy Module	AEA
SOCIAL SUSTAINABILITY	**Nov 10**	**The Economy Module**	BC3
		The Social and Demographic Module	ONU
POLICY SCENARIOS	**Nov 13**	**Baseline and Policy scenarios**	UVA
		The WILIAM Toolkit	CARTIF
		Policy impact and scenarios - project work	UNIPI

TEACHING METHODS

The course is free of charge. It will be delivered online through ZOOM platform and the lectures will be at the following link https://us02web.zoom.us/j/82130670389. Each module will start with a synchronous session. Participation is subject to prior registration. Registration form is available at https://iscrizioni.aicgroup.it/Login.asp?IDcommessa=A23064&Lang=EN.

Each day will consist of synchronous presentations of modules, Q&A sessions and comprehensive labs with the application of the discussed topics through exercises of system dynamics modelling and simulations using Vensim PLE software (freely available at the following link https://vensim.com/free-downloads/).

Complementary material (activities, reading, video, recorded lectures, link to web pages, etc.) will be at participants' disposal on the repository https://drive.google.com/drive/folders/1nJmT8sUsG9Jej-rfGd3Uvl_d1HcGV_2Z. Additional material can be provided to trainees including additional readings, a list of suggested resources to consult, a PPT of the training, and some video-pills on very specific topics.

This material will be helpful for the final assignment. Indeed, the final phase will consist of detailed study of the policy impact and scenarios from the last project work.
The submission of this project will guarantee the certificate released by LOCOMOTION.

MODULE DESCRIPTION

DAY 1 - SYSTEM DYNAMICS INTRODUCTION AND MODELING

1
General Introduction of MOOC

- **Introduction to the problem**. The global climate is heating up. Species are dying out at unprecedented speed. Many of the world's finite resources are being overexploited. At the center of this worldwide crisis stands humanity. Citizens are demanding change, while civil society and policymakers are seeking sustainable alternatives for a low-carbon, net zero-emissions future. How can we evaluate the ramifications and consequences of the various options so as to make informed and wise decisions?
- **Introduction to the course.** The WILIAM model is an Integrated Assessment Model (IAMs), which links socioeconomic, energy and environmental models into a single modeling framework to assess the feasibility and effectiveness of different sustainability policy options. In this MOOC you learn how to use WILIAM as a robust, usable and transparent (open source) diagnostic and scenario assessment tool for analyzing a sustainable transition towards a low-carbon society.

The lecture aims to motivate and empower students to evaluate and assess various sustainability policy options using the WILIAM model, with the ultimate goal of making informed and wise decisions to address the pressing global issues mentioned in the course description.

2
IAMs and System Dynamics

- **Introduction to IAMs**. Although Integrated Assessment Models (IAMs) have advanced significantly in recent years, the very structure and techniques of currently existing IAMs pose great barriers to the modelling of dynamic, complex, biophysically grounded and social futures.

- **Introduction to modelling and simulation with system dynamics.** A promising method to lower these barriers is to use System Dynamics to build IAMs, as was done in the development of WILIAM.

- **Dynamic models, feedbacks, stocks and flows, dynamic patterns. Structure and behaviour of dynamic systems.** System Dynamics enables modelers to combine variables of different character (economic and technological, but also biophysical and social), to build models based on the principle of modularity, and to integrate various modeling

techniques, all of which facilitates interdisciplinary work. Other strengths of the approach include the clear graphical representation of causal relationships, the exploration of dynamic changes of the socio-ecological system over time and the modelling of non-linear causality. The broad and flexible range of tools System Dynamics offers will facilitate the adaptation of WILIAM to fit the requirements of new scenarios and policies that will be developed in the project.

The primary learning objective of this lecture is to equip students with the knowledge and skills needed to address the limitations of existing IAMs and explore the potential of System Dynamics as a method to enhance their modeling capabilities for complex socio-ecological systems.

3 Introduction to the WILIAM model

- **Introduction to WILIAM.** WILIAM is a system dynamics simulation model that is equipped to capture complex feedback loops and nonlinear relationships between different social, economic and environmental variables. It has been designed to explore the social, economic and environmental implications of long-term socio-ecological transition pathways, taking into account planetary limits and socio-economic constraints.

- **General overview of the model, modules and interactions.** WILIAM consists of a set of fully-integrated modules of the earth and human systems (economy and finance, energy, materials, land, water and climate, society and demographics). The economic module of WILIAM is a Dynamic Econometric Multi-regional Input-Output model which represents the interactions between firms, households and governments. It covers 62 sectors, with a detailed representation of decarbonisation-related sectors such as mining industries, transportation, and energy transformation. The environmental module includes land use, water and climate, and represents the interactions of these biophysical dimensions with energy and economy. The energy modules includ renewable and fossil energy generation and transmission capacities, taking into account intermittencies, as well as a submodule on the use and availability of critical minerals and other material resources. The society module models demographic dynamics, including migration flows and education, and uses the human development index as a measure of human well-being.

The learning objective of this lecture is to provide a comprehensive understanding of the WILIAM system dynamics simulation model, its modules, and their interactions. By the end of the presentation, students should be able to effectively use WILIAM to analyze and simulate complex feedback loops and nonlinear relationships among social, economic, and environmental variables.

4
The Resource Module

This module will focus on the following main topics: energy resources, resource reserves, TRE, need for minerals from renewables. It provides a comprehensive understanding of material and hydrocarbon models and their applications in the context of low-carbon transitions. It will be structured as follows:

- It begins by focusing on hydrocarbon models. Participants will gain insights into WILIAM and its integrated modules, which represent the resources, reserves, supply, demand, and prices of oil, coal, and gas. Through expert-led video lectures, learners will explore the intricate relationship between macroeconomics, energy systems, and hydrocarbon dynamics. They will examine how pricing mechanisms, demand-supply gaps, and investments impact hydrocarbon production, resource availability, and economic outcomes. The module will also highlight the influence of hydrocarbon prices on consumption, investment, and global dynamics, providing a comprehensive framework for analyzing long-term climate change scenarios.

- In the second part of the module, the focus shifts to material models within the low-carbon transition. Learners will gain a deep understanding of the role of metals and critical minerals in clean energy technologies. The video lectures will cover topics such as supply-demand dynamics, ore grades, extraction requirements, refining processes, and their economic implications. Participants will explore the relationships between metal prices, consumption patterns, and the feasibility of low-carbon scenarios. The module will also delve into uranium availability and its impact on nuclear utilization and capacity expansion. Through interactive exercises, learners will apply their knowledge to analyze material requirements for specific green energy technologies.

The learning objective of this lecture is to equip learners with a comprehensive understanding of energy resource modeling, including hydrocarbon models and material models, and their practical applications in the context of low-carbon transitions.

5
The Environment Module

- **Land modelling, the role of land use in the energy transition, land use competition issues, and global trade of land use products**. The Land module is in charge of allocating the land among several uses (rainfed and irrigated cropland, managed forest, primary forest, and tree plantations, grasslands, urban, solar land for energy, and other uses) by taking the demands for land use changes coming from the population demand for food (diets and land products demand sub-module), for urban land (land-use sub-module), and for solar energy or for biomass (energy module). It uses signals such as the shortage of land products and

energies that allow it to calculate the land stress for several uses and also calculates the loss of agricultural land due to sea level rise.

- **Water demand and supply**. The Water submodule depends on the water demand and water availability to compute the water stress in the future climate. We computed the relation between precipitation and evapotranspiration, that influences the available water, depending on the radiative forcing. This submodule has links with economy, population, energy and land submodules.

- **Human interference in the climate system, Land Use, Land-Use Change and Forestry (LULUCF) emissions, and climate modelling in IAMs.** The Climate submodule simulates the cycles of the main greenhouse gases (GHG) according to the emissions and absorptions coming from the rest of the submodules, including estimated land use, land use change and agriculture emissions. This allows us to obtain the variation of the concentration of these GHGs and its effects on radiative forcing and the mean global temperature. Climate change impacts on global sea level rise and in ocean acidification are also estimated. Finally, regional temperature value is obtained, and specific biophysical climate change impacts on 1) water availability, 2) land use and 3) crop yields are estimated. Additionally, we had the probability of crossing several tipping points, with more emphasis on the AMOC weakening, including some possible consequences in the northern hemisphere climate.

By the end of this lecture, students should be proficient in using integrated assessment models (IAMs) to assess the impacts of land use decisions, water availability, and climate change on various aspects of the environment, society, and the economy. They should also be able to analyze and estimate regional and global climate change impacts, including the effects on sea level rise, ocean acidification, and temperature variations, as well as the potential for crossing critical tipping points in the climate system.

6
The Energy Module

- **Introduction to Energy Modelling:** Energy stands at the core of our modern society, and fossil energy consumption is the major source of GHG emissions, so transitioning to a post-fossil energy system is one of the obvious policy choices to address climate change. The introduction will tackle the basics of energy statistics, the energy conversion chain and different types of energy models.

- **Overview of WILIAM energy module:** Overview of the most important variables and feedback of the energy module with other modules; Overview and description of the main sub-modules (Energy End-Use, transformation, capacity, variability management).

- **Main energy policies:** Overview of the currently implemented policies; Demonstration of model mechanics.

By the end of the course, students should be able to comprehend energy statistics, the energy conversion chain, and different types of energy models. Additionally, they should gain an in-depth

understanding of the WILIAM energy module, including its key variables, feedback mechanisms, and sub-modules related to energy end-use, transformation, capacity, and variability management. Students should also be equipped to analyze and evaluate existing energy policies and understand the mechanics of how these policies interact with energy models.

DAY 3 – SOCIAL SUSTAINABILITY

7
The Economy Module

Theoretical explanation of the economic module of WILIAM (main features of the WILIAM economic module). At the core of WILIAM economic module lies a dynamic econometric multi-regional Input-Output model that has been extended by endogenous final demand and by mutual feedbacks between quantities and prices. WILIAM comprises a high level of disaggregation of economic sectors (62 industries), households (60 types) and regions (35) and captures the interplay between consumer demand, induced investment, government and exports demand, on the one side, and production and income generation and distribution on the other. The model has New Keynesian features, as markets are not generally cleared by the price mechanism, but effective demand under supply constraints determines the outcome for the different industries. The macroeconomic IO model in WILIAM is especially designed for incorporating feedbacks between the economy and nature, in particular resources constraints and climate change impacts.

In summary, the course aims to help students gain both a theoretical understanding of the economic module within WILIAM and the practical skills to work with this module effectively for analyzing complex economic and ecological systems and their interactions.

8
The Social and Demographic Module

- **Conceptualising Society and Demography (Social and Demographic Indicators): Consequences of climate change and energy transition in the society: general presentation and major challenges**. This module outlines why and how people are represented in Integrated Assessment Models (IAMs) and sets out the need for improved inclusion of society and demography. Until now most IAMs have included humanity within the economy. However, people are the conduit through which the economy and environment interact. Therefore any model which does not (meaningfully) include people does not fully represent the system.

- **Identification of the variables explaining the dynamics (population-health education-migration-social indicators)**. This module describes how to better represent humanity by looking at two closely related spheres. Demography considers the size and composition of the population. An improved demographic understanding in WILIAM with an endogenous population is vital as the scale and make-up of the population has implications for how the economy and society interact and the demands placed upon the environment. On the other hand, the economy and environment also condition demography, through their impacts on demographic indicators such as life expectancy. This suggests the need to investigate different

aspects of society. The wellbeing, health and migration of people also affect the economy and environment and in turn, the form of transition taken can also have an effect on society. In so doing, WILIAM will contribute to humanising IAMS.

By the end of the course, trainees should be able to identify and analyze the key variables that explain the dynamics of society, including population, health, education, migration, and social indicators. They should also gain insight into the interconnectedness of these variables with the economy and the environment within IAMs.

DAY 4 – SIMULATION BY TOOLKIT

9
Baseline and Policy scenarios

- **Presentation of the four scenarios parameterized for WILIAM in the LOCOMOTION project.** A baseline scenario, which assumes a continuation of past trends, and three policy-action scenarios: Green Growth, Green Deal and Postgrowth.

- **Paths towards sustainability, are they possible? Is green growth feasible?** The policy action scenarios have shared environmental objectives (i.e. climate, land, water, energy and mineral depletion), but differ in their socio-economic goals (economic growth objectives, social well-being, equity and participation). Different policies are modeled per scenario in pursuit of the objectives. Simulation results are able to pinpoint objectives which are incompatible or unfeasible due to biophysical and technical limits.

By the end of this lecture, students should be able to evaluate the feasibility of paths towards sustainability and critically assess the potential for green growth. They should gain insight into how different policy actions and objectives impact the environment, economic growth, social well-being, equity, and participation.

10
The WILIAM Toolkit

- The **Model Analyzer** is a desktop application, which allows users to configure scenarios and run them using the WILIAM model. There are two scenario options to chose from: the Full scenario, which allows a degree of parametrization similar to that of the original WILIAM model, and the Simplified scenario which, as the name implies, corresponds to an attempt to make the scenario configuration easier. In both cases, default values for all scenario parameters are provided, which allows users to focus exclusively on those they are interested in. The expected target audience for this application are modellers and experts on the energy transition, and policy makers including their advisors.
- The **Global Sustainability Crossroads II Game** is a cooperative and social role-playing game played in groups using electronic devices thanks to a web implementation of the tool. Designed for the educational community, the main idea behind the Crossroads II Game is to raise awareness about the climate transition and streamline player interaction in decision-making on the implementation of climate change policies through gamification.

- The **Model Explorer** is a user-friendly and easy-to-use web application to explore WILIAM without needing to be a modelling expert. With reduced functionality, its main goal is to increase the awareness of civil society in terms of climate change, helping in the definition of more sustainable future scenarios.
- **How does it work?** Demonstration on the use of each tool and how you can implement your own scenarios. 2-3 minutes allocated for each tool presenting the general aspects to parametrize policies and visualize results. We will include where you can find the tools.
- **Main assumptions** for the tools development (simplified scenario), final indicators and results from different configured scenarios. Data download, graphs and how you can create, save and visualize scenarios.
- **Implemented policies**, parameterization methods and available policy options.

By the end of this lecture, participants should be able to configure scenarios, run models, and utilize the Model Analyzer for in-depth modeling and analysis. They should also be proficient in using the Global Sustainability Crossroads II Game for educational and decision-making purposes in the context of climate change policies.

11
Policy impact and scenarios - Project work

The project work will be introduced in the final lab of the course, where participants are expected to implement notions and tool knowledge acquired during the lectures. In particular they will configure and analyze policy scenarios, making evaluations of results from an interdisciplinary perspective. The course should have enabled trainees to utilize WILIAM for a comprehensive assessment of the ecological transition, including the evaluation of alternative policy scenarios and the consideration of economic, ecological, and social outcomes. Trainees can also choose to work divided into groups or individually.

LAB SESSIONS AND FINAL PROJECT

LABS

Each day, lectures will be followed by a lab session, designed according to the topics discussed in the modules.

- The first day the lab activity will consist of an exercise to practically introduce participants to the System Dynamics reasoning underlying IAMs. The hands-on session will involve an introductory use of the Vensim PLE software, serving as a basis for the lab activities of the following days.
- The second day the lab activity will be devoted to practice exercises, concerning one of the modules discussed in day 2: environmental, material resources, and energy. The objective is to test comprehension of skills necessary to model and analyze the complex relationships between energy resources, materials, and low-carbon transitions.
- The third day lab will be focused on model integration of socio-economic analysis, to understand how the integration with other modules (e.g., environment, resources) can deeply affect the results. Instructors will provide a simple socio-economic model in Vensim and

students will be invited to identify key parameters and potential structural changes that simultaneously improve the economic and environmental outcomes of the model.

- The last lab will be dedicated to policy impact. Trainees will work on the introduction of a few policies for social and ecological sustainability, properly modelling the given set of policies accounting for the interactions and feedbacks in different parts of the model. This lab will also introduce the project work required for trainees to get the certificate.