# ece-teaching

**IIASA**

**Jul 25, 2024**

# WORKSHOPS AND TUTORIALS

The IIASA Energy, Climate, and Environment (ECE) Program and its staff are involved in many activities to support learning about model-based E/C/E research, especially using software and tools such as the MESSAGEix framework that we use ourselves. This page outlines and links to some of these activities & opportunities, and also the teaching & learning materials and resources used in those activities.

Learning can take place in many ways, from self-directed study by individuals to for-credit courses at degree-granting institutions taught by a knowledgeable instructor. The right materials and venue for learning depends on factors including your current level of knowledge, learning goals, and time and resources you have available. The aim of this page is to clearly describe all the activities and materials so you can make an appropriate choice for your needs.

This website is generated from https://github.com/iiasa/ece-teaching using Sphinx.

The source code of the website is released under the MIT License.

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# ONE

# WORKSHOPS AND TUTORIALS ORGANISED BY ECE

Our recorded workshops and tutorials are particularly suitable for dealing intensively with a topic in a defined time frame. The synergy of lecture and practice gives you the chance to apply what you have learned directly - and of course to rewind as often as you like and need.

## 1.1 MESSAGEix Community Meeting

The Community Meeting aims to bring together researchers working on integrated assessment and/or energy system modeling using open source software.

It is a platform for showcasing new developments and features of the MESSAGEix modeling framework, sharing knowledge on various modeling approaches and applications of the framework, and discussing best practices in model-based policy analysis. The meeting is a place for facilitating collaboration between MESSAGEix users from around the world, by creating a forum where users can share their latest research outcomes and modeling experiences.

The Community Meeting also aims to inspire new users of the MESSAGEix framework on the range of available possibilities and link them with other users in order to help them advance their modeling work. For information about the modeling framework, its structure, mathematical formulation, installation, and much more, please see the documentation.

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### 1.1.1 Upcoming events

- 28-29 May 2024 - MESSAGEix Community Meeting (more info and the agenda)

### 1.1.2 Past events

- 24-25 May 2023 - MESSAGEix Community Meeting (more info and the agenda)
- 7-8 May 2022 - 1st Annual MESSAGEix Community Meeting (more info and the agenda)

### 1.1.3 Objectives of the community meeting

The objectives of the community meeting are the following:

- Connecting with other community members
- Showcasing new applications of MESSAGEix
- Exploring recent advances and new features of MESSAGEix
- Understanding more complex analyses within the scope of MESSAGEix
- Gaining insights on coupling possibilities with other tools/modules

### 1.1.4 Agenda

Please see the current Community Meeting page for the agenda. Kindly note that the agenda is subject to change until a month before the meeting.

## 1.2 MESSAGEix Workshops

The aim of the workshops is to help new users of the MESSAGEix modelling framework getting started with their modelling work. The main features of the "framework" are introduced, and the use cases of some features are shown. The users can learn how to build an energy model and how to represent some policy constraints in their energy scenarios. For information about the model, its structure, mathematical formulation and much more, please see the documentation.

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- *Upcoming events*
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### 1.2.1 Upcoming events

- 5-6 and 10-12 June 2024 - MESSAGEix Workshop

### 1.2.2 Past workshops and seminars

- 5-7 and 12-13 June 2023 - MESSAGEix Workshop

- 7-13 June 2022

- 7-11 June 2021 (download)

- 7-10 September 2020

- 8-12 June 2020

### 1.2.3 Learning objectives

The learning objectives of the workshops are the following:

- Gaining a good understanding of energy systems modelling.

- Getting to know the main features of MESSAGEix.

- Demand estimation, renewable potential and investment cost representation

- Building an energy model and solving it.

- Applying further policy constraints to the model.

- Getting insights on version control, testing and documentation in software development.

- Understanding collaborative model development and continuous integration (GitHub).

### 1.2.4 Needed requirements

Each workshop is designed to be accessible for users with different backgrounds and levels of experience with the modelling. However, there are some pre-requisite knowledge and skills which you should go through before getting started, including:

- Elementary computer programming (preferably in the Python or R language);

- Fundamental concepts of mathematical modelling, optimization, and data analysis; and

- Energy systems (e.g., energy supply, energy conversion technologies, and demand sectors and their linkages).

For a complete list, plus links to learning resources, see "Pre-requisite knowledge & skills" repo in the documentation.

### 1.2.5 Installation of MESSAGEix

Installing MESSAGEix before you're getting started with the workshop is highly recommended. Complete instructions are provided in the documentation on the "Installation" page of the documentation.

To successfully work through this workshop, we emphasize a few points from the instructions:

- If you are not already familiar with the other installation methods, you should use Anaconda to install the framework.

- Under the "Tutorials" page, you can download some simple models developed using MESSAGEix. To run these sample models, you need to install the Jupyter notebook software from Anaconda Navigator.

You can check our GitHub pages, where common issues and solutions are discussed: https://github.com/iiasa/message_ix/discussions

### 1.2.6 General Agenda

**Section I: Introduction to MESSAGEix modelling framework**

- Introduction to the MESSAGEix modelling framework and its components.
- Troubleshooting of the installation.

**Section II: Building a simple MESSAGEix model**

- Brief introduction to linear optimization.
- A review of energy systems modelling.
- Building a simple model of a coffee machine from scratch using MESSAGEix (step-by-step hands on guide).
- Discussing some main parameters/equations of the mathematical model.

**Section III: Energy system modelling with MESSAGEix**

- Building a single region energy model using MESSAGEix (step-by-step guide, going through MESSAGEix online tutorial: Westeros Baseline)
- Modelling some energy and environmental policies (share of renewables and emission targets).
- Discussing dynamic constraints and related parameters/equations in MESSAGEix.

**Section IV: Postprocessing and model software development**

- Introduction to MESSAGEix reporting and post-processing tools.
- Version control, testing, documentation in software development.
- Brief intro to collaborative model development and continuous integration (GitHub).

**Section V: Modelling forum**

In this free-format session, different modelling topics asked by the latest workshop participants will be discussed.

## 1.3 GAINS Workshops

The aim of the workshop is to help new users of the GAINS modelling framework getting started with their modelling work. The main features of the "framework" are introduced, and the use cases of some features are shown. The user can learn how to build their own emission scenarios, adjust and create new policy constraints and run analysis on costs and co-benefits. For information about the model, its structure, mathematical formulation and much more, please see the documentation.

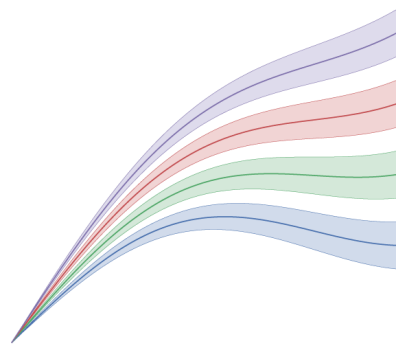**Table of Content**

- *Recent workshops*

### 1.3.1 Recent workshops

- GEIDCO workshop July 2021
- SPIPA workshop March 2021 http://gains.iiasa.ac.at/SPIPA/
- IGP workshop Oct 2020 http://gains.iiasa.ac.at/IGP/

## 1.4 The pyam package



*pyam*: analysis and visualization of integrated assessment scenarios

This page collects tutorials and presentations related to the open-source Python package **pyam** for scenario analysis & visualization.

Read the docs to learn more about the package.

### 1.4.1 Intro video about the pyam package

This video is part of the IAMC Youtube channel.

### 1.4.2 NAVIGATE-ENGAGE Summer School on Integrated Assessment Modeling (July 4, 2023)

Daniel Huppmann presented an overview and live demo of the **pyam** package at the NAVIGATE-ENGAGE Summer School on Integrated Assessment Modeling (July 2023).

- Presentation slides: https://doi.org/10.5281/zenodo.8112529
- Tutorial notebook: https://github.com/danielhuppmann/ENGAGE-pyam-tutorial (release 2.0)

### 1.4.3 European Climate and Energy Modelling Platform 2022 (October 6, 2022)

This "Skills Workshop" at the European Climate and Energy Modelling Platform 2022 conference (ECEMP) covered how to use the pyam package for simple scenario analysis, data visualization and computation of derived indicators. In addition, it was shown how to load scenario data directly from an IIASA Scenario Explorer instance (e.g., the scenario ensemble supporting the IPCC AR6 WG3 report) into a Python computing environment for processing and analysis.

**Related material:**

- Presentation slides: https://zenodo.org/record/7150257 and

- Tutorial notebook: https://github.com/phackstock/ECEMP-pyam-tutorial

### 1.4.4 ENGAGE Capacity Building Workshop (February 1, 2022)

At a capacity-building workshop on good modeling practices organized by the Horizon 2020 project ENGAGE on February 1, 2022, Daniel Huppmann and Philip Hackstock presented an overview and live demo of the **pyam** package.

- Presentation slides: https://pure.iiasa.ac.at/id/eprint/17783

- Tutorial notebook: https://github.com/danielhuppmann/ENGAGE-pyam-tutorial (release 1.0)

### 1.4.5 Presentation at the *Strommarkttreffen* (July 14, 2021)

At an online meeting of the Strommarkttreffen on July 14, 2021, Daniel Huppmann presented an overview and live demo of the **pyam** package.

- Presentation slides (german/english): https://pure.iiasa.ac.at/id/eprint/17319

- Tutorial notebook (english): https://github.com/danielhuppmann/strommarkttreffen-pyam

- *MESSAGEix Community Meeting*

- *MESSAGEix Workshops*

- *GAINS Workshops*

- *The pyam package*

# UNIVERSITY COURSES AND LECTURES

In this section, you find a collection of university lectures given by the ECE staff. Take a look - no need to enroll!

## 2.1 Open Source Energy System Modeling @ TU Wien

Lecture by Daniel Huppmann held in the summer semester since 2019.
Link to the lecture page on TISS.

### 2.1.1 Scope

This lecture introduces key concepts of open-source modelling to better understand the energy system and assessing the transition to renewable sources in the context of climate change mitigation and sustainable development.

We discuss the role of quantitative, model-based pathways in international and national climate mitigation policy, in particular the reports by the Intergovernmental Panel on Climate Change (IPCC), and the students will learn how to develop scenarios of the energy transition using open-source tools and readily available data.

### 2.1.2 Summer semester 2023 (370.062)

**Lecture 1**:

Principles of open, collaborative scientific programming for energy modelling
pdf (2.7MB) | pptx (4.5MB)

**Lecture 2**:

A hands-on example of working with git
pdf (0.9MB) | pptx (1.6MB)

The repository created as part of the hands-on exercise is available at https://github.com/danielhuppmann/lecture-spring-2023.

**Lecture 3**:

Integrated assessment of climate change

and sustainable development | pdf (6.4MB)

     pptx (10.7MB)

**Lecture 4**:

Developing your own energy system scenarios using the MESSAGEix framework
pdf (4.7MB) | pptx (6.2MB)

**Lecture 5**:

What's next?
pdf (3.9MB) | pptx (8.9MB)

### 2.1.3  Summer semester 2021 (370.062)

**Lecture 1**:

Principles of open, collaborative scientific programming for energy modelling
pdf (5.9MB) | pptx (4.2MB) | recordings of this lecture (2020)

**Lecture 2**:

A hands-on example of working with git
pdf (1.0MB) | pptx (1.6MB) | recordings of this lecture (2020)

The repository created as part of the hands-on exercise is available at https://github.com/danielhuppmann/lecture_spring_2021.

**Lecture 3**:

Integrated assessment of climate change

and sustainable development | pdf (5.1MB)

     pptx (6.2MB)

**Lecture 4**:

Developing your own energy system scenarios using the MESSAGEix framework
pdf (5.6MB) | pptx (6.0MB)

**Lecture 5**:

Developing your own energy system scenarios using the MESSAGEix framework
pdf (1.5MB) | pptx (6.8MB)

## 2.1.4 Overview of recording sub-pages

### Recording of lecture 1

These recordings were made in the lecture held via Zoom on April 21, 2020.
All participants agreed to the recording of the lecture.

### Part 0 - Introduction

> **ⓘ Note**
>
> This was the first online lecture, so I forgot to hit the "Record" button. The video of the Introduction shown here
> is a shortened, re-recorded version of the actual lecture. It excludes in particular the interactive opening to get an
> overview of the background and knowledge of participating students.

### Part 1 - Open-source licenses

### Part 2 - The FAIR principles

### Part 3 - Misconceptions about open(-source) research

### Part 4 - Working with git

### Recording of lecture 2

These recordings were made in the lecture held via Zoom on May 5, 2020.
All participants agreed to the recording of the lecture.

**Part 1 - Setting up a git repository from scratch**

The second part of the hands-on exercise (see slide 4) was done by the students in break-out groups and then discussed with the entire class. This part of the recording is not available.

**Part 2 - Practical considerations**

### 2.1.5 Acknowledgement

Thanks to Matthew Gidden (@gidden) and Paul Natsuo Kishimoto (@khaeru) for providing valuable input and sharing their own teaching material.

## 2.2 Integrated Assessment Modeling @ NTNU

Lecture by Volker Krey held on a biannual basis since the academic year 2019/2020. Link to the lecture page at NTNU.

### 2.2.1 Scope

Integrated Assessment Models (IAMs) are extensively used in the analysis of climate change mitigation and are informing national decision makers as well as contribute to international assessments such as those of the Intergovernmental Panel on Climate Change (IPCC). The objective of this course is to provide an overview of the field of integrated assessment modeling, including a characterization of different types of IAMs, their methodological basis and applications of IAMs. The field started emerging in the 1970's, based on research by 2018 Nobel laureate William D. Nordhaus and others, and has undergone a dynamic development to the present. The course introduces important concepts in the field of climate change research, including the Shared Socio-economic Pathways (SSPs) and the Representative Concentration Pathways (RCPs) that link integrated assessment modeling with climate and earth systems modeling as well as climate change impacts, adaptation and vulnerability research.

Applying IAMs to analyze the potential role of individual technologies and different policies in mitigation of climate change is studied from a systemic perspective which is becoming increasingly important with the increasing connections between regions and parts of human and natural systems. A recent expansion of IAM research therefore deals with putting climate change mitigation and policy into the context of broader sustainable development objectives, including air quality, water management, energy security or resource efficiency. The linkage of IAMs with methods and tools from other disciplines such as atmospheric chemistry and health research related to air pollution or industrial ecology research (e.g., lifecycle assessment) is discussed.

The course also provides an introduction to state-of-the-art modeling techniques, including methods to ensure reproducibility of results, such as version control and usage of tools for collaborative model development and quality control. This will be achieved through exercises that require the operation and modification of an existing IAM framework to analyze different types of scenarios. Finally, studying current applications and methodological expansions of IAMs in a seminar part of the course will deepen the understanding of IAM applications at the research frontier.

## 2.2.2 Academic year 2019/2020 (EP8900)

**Day 1**:

A short history of IAMs, different modeling paradigms and system boundaries
Good modeling practice and collaborative tools for model development
Hands-on session: Installation of MESSAGEix and tutorial(s)

**Day 2**:

Historical overview of IPCC scenarios
Representative Concentration Pathways (RCPs)
Shared Socio-economic Pathways (SSPs)
Hands-on session: MESSAGEix South Africa
Group work: SSP variants for South Africa

**Day 3**:

Technology assessment using IAMs: "If-then" vs. "reverse engineering" approach
Comparative assessment of value of technology
Model evaluation of IAMs
Group work (continued): SSP variants for South Africa

**Day 4**:

Consumer heterogeneity in IAMs: Energy access, Transportation
Policy analysis: assessing current policies and NDCs
Group work (continued): SSP variants for South Africa

**Day 5**:

Coupling IAMs to disciplinary models for assessing broader SDG implications
Using IAMs for assessing SDG interactions
Group work (continued): SSP variants for South Africa

### 2.2.3 Acknowledgement

This lecture is based on ongoing research and capacity building activities. It builds on material from a number people, in particular: Shinichiro Fujimori, Matthew Gidden, Arnulf Grübler, Daniel Huppmann, Paul Kishimoto, Gunnar Luderer, David McCollum, Haewon McJeon, Clara Orthofer, Shonali Pachauri, Simon Parkinson, Peter Rafaj, Keywan Riahi, Heleen van Soest, Charlie Wilson, Behnam Zakeri

## 2.3 Global Energy Transitions and Climate Policy @ TU Wien

This course is part of the Master's degree program in Environmental Technology & International Affairs held at the Technical University Vienna (TU Wien). The course is designed and delivered by Dr. Behnam Zakeri, including several lectures by guest speakers/lecturers.

### 2.3.1 Scope

The course offers a general overview on drivers of and barriers to global energy transitions. Governing principles of international energy markets are reviewed briefly, with a view on the geopolitics of energy transitions. The role of technological innovations, socio-behavioral dimensions, and economic/political perspectives are discussed. Some contemporary topics in global energy transitions, such as, energy access and poverty, and energy and digitalization are reviewed. The role of modeling and scenario development in energy and climate policy design is another topic of the course. International environmental and climate agreements are reviewed, with a view on successful examples and lessons learned. The course is multi-disciplinary, suitable for students with different backgrounds, including but not limited to engineering, science, economics, and politics.

### 2.3.2 Course material

**Lecture 1: Global energy resources and markets** | pdf (2.4MB)

A short note on energy and development
World energy mix
Fossil energy resources and reserves
International energy markets

**Lecture 2: Energy transitions: Societal and behavioral perspectives** | pdf (2.0MB)

Energy poverty and justice
Societal and behavioural aspects of energy use
Climate change and behaviour
Digitalization and energy use

**Lecture 3-1: Energy transitions: Technological perspectives** | pdf (1.2MB)

Technological challenges in energy transitions

Solar PV as a successful example (see Lecture 3-2 for more details)

Transition in mobility: Electric vehicles

Energy storage systems (see Lecture 4 for more details)

**Lecture 3-2: Energy innovation and energy transitions (by Dr. Kavita Surana) |** pdf (9.8MB)

Technological change in the energy sector

Energy technology innovation process

Potentials and barriers of energy innovation

Global energy transitions: case of solar PV

**Lecture 4: Integration of renewable energy sources: Energy storage systems |** pdf (2.9MB)

Energy and climate change

Global trends in renewable energy

Potentials and challenges of variable renewables

Energy storage systems

Economics of energy storage

**Lecture 5: Modeling of energy transition: Pathways, scenarios and planning tools |** pdf (1.3MB)

Time and energy targets

Energy Pathways and scenarios

Tools for modeling the energy transition

Modeling for policy making

**Lecture 6-1: International environmental and climate agreements (co-lectured with Franziska Menten (MSc))
|** pdf (12.7MB)

History of climate agreements

Montreal Protocol: A successful international environmental agreement

International organizations and development

Project implementation and monitoring

**Lecture 6-2: EU energy and climate policy (by Dr. Samuel Cross) |** pdf (1.9MB)

Introduction to EU Legislation

Past: Where we are coming from, 2020 Objectives

Present: Where we are, 2030 Objectives in legislation

Future: Where we are going, EU Green Deal Fit for 55 proposals

Exercise on making policy: Saving natural gas in a hurry

### 2.3.3 Acknowledgement

The material for Lecture 2 is in parts adopted from the course "Multidisciplinary Perspectives on Energy", lectured by Prof. Peter Lund, Aalto University, Finland. Many thanks to invited speakers Dr. Kavita Surana, School of Public Policy, University of Maryland, Franziska Menten (MSc), United Nations Industrial Development Organization (UNIDO), and Dr. Samuel Cross, Networking Platform, Aalto University. Also, special thanks to Isabelle Starlinger (MSc) (Program Coordinator) and Prof. Hans Puxbaum (Program Director) for their support for this course at TU Wien.

- *Open Source Energy System Modeling @ TU Wien* by Daniel Huppmann (2019-ongoing)

- *Integrated Assessment Modeling @ NTNU* by Volker Krey (2019/2020-ongoing)

- *Global Energy Transitions and Climate Policy @ TU Wien* by Behnam Zakeri (2020/2021-ongoing)

# TALKS, CONFERENCE PRESENTATIONS, SUMMER SCHOOL MATERIAL

In this section you will find a collection of talks, conference presentations or similar formats related to teaching and/or learning by ECE staff, such as those given as part of summer schools or individual lectures.

## 3.1 The NExus Solutions Tool

The NExus Solutions Tool (NEST) is an open modeling platform that integrates multi-scale energy–water–land resource optimization with distributed hydrological modeling. The approach provides insights into the vulnerability of water, energy and land resources to future socioeconomic and climatic change and how multi-sectoral policies, technological solutions and investments can improve the resilience and sustainability of transformation pathways while avoiding counterproductive interactions among sectors. NEST can be applied at different spatial and temporal resolutions, and is designed specifically to tap into the growing body of open-access geospatial data available through national inventories and the Earth system modeling community. A case study analysis of the Indus River basin in South Asia demonstrates the capability of the model to capture important interlinkages across system transformation pathways towards the United Nations' Sustainable Development Goals, including the intersections between local and regional transboundary policies and incremental investment costs from rapidly increasing regional consumption projected over the coming decades. The documentation and code for the initial case studies is published by Vinca et al., 2020, and can be found online.

Github repository

**Documentation paper:**

The NExus Solutions Tool (NEST) v1.0: an open platform for optimizing multi-scale energy–water–land system transformations

A newer version of NEST has been developed, and also referred to as the "MESSAGEix-Nexus" module. This uses the MESSAGEix framework ( see *MESSAGEix Workshops* ) developed at IIASA and allows the generation of country models with representation of the Energy-water-land system similar to the previously developed NEST model in Vinca et al., 2020. Most of the development is currently under submission and not yet public.

The following presentation introduces the first version of NEST and the MESSAGEix-Nexus module:

- NEST and MESSAGEix-Nexus module. September 2022, IAMs workshop at the Lahore University of Management Sciences (LUMS) and October 2022 Engage Stakeholder workshop (link to the PURE IIASA database)

## 3.2 Coding culture at EEG

This talk was given by Philip Hackstock on the 17th of January 2022 for the Energy Economics Group (EEG) group at the TU Vienna.

Presentation slides (.pptx & .pdf, english):

- DOI: 10.5281/zenodo.5881657

Example repositories:

- eeg_demonstration
- eeg_live_demonstration
- *The NExus Solutions Tool*
- *Coding culture at EEG*

# USEFUL RESOURCES

This section contains a collection of various teaching and learning materials in different formats.

- A code-and-tell repo with helpful tips and tricks for your daily programming life, based on presentations during the weekly MESSAGEix meetings

- A template repo for IIASA Python projects