EPFL

Group project
Material Flow Analysis and Resource Management

ENV-501, Fall 2024

Modeling and managing resource flows in cities

Introduction

The goal of this project is to give you the opportunity to **apply the principles and methodological approaches introduced in the course** and show us how you can improve material and resource use in urban systems. The mayors of the **city of Lausanne and Geneva** would like to better understand how they could reduce the ecological footprint and CO_2 emissions of their cities. They are interested in the evolution and possible future scenarios for the building stock and the transportation infrastructure (i.e. vehicles, road and railway networks). They need your support to evaluate what measures are most effective to achieve their sustainability goals set for 2050.

Your role in this project is therefore to (i) develop a dynamic and/or potentially spatial-explicit **Material Flow Analysis (MFA) model** of the system; (ii) look into the **data** needed to represent the current state and possible future scenarios of the system (e.g. development of population, amount of new buildings or refurbishment of building stock, and vehicles); (iii) develop **assessment criteria** and assess the scenarios regarding the developed criteria (e.g. circularity, scope one and scope two emissions); and (iv) test **measures** based on the dynamic model that are promising to achieve the goals. As a basic underlying framework, you will use the Material-Stock-Flow Service Nexus introduced during the lecture.

Guidelines

The following steps will help you organize your work, and as shown in the course, several iterations might be necessary:

1. Familiarize yourself with the case you selected and formulate a first **problem definition and goals**. Align this problem definition in discussion with the project partners (e.g. representatives of the city of Lausanne and Geneva).

2. Set the **boundaries of your system** (time and space), include **processes and flows** which are relevant from an energy and material perspective. Select the most relevant substances, materials or energy sources. These can be e.g. materials, energy, emissions, etc.

3. Based on your system model, **define the data needed and the potential sources** they can be elicited from.

4. Collect the data and structure it in a database necessary to **quantify material and energy flows, stocks and their changes.** We provide you with generic data and you might identify additional or missing data. Refine your system according to data

availability and quality. Make simplifying assumptions if needed and document them clearly.

5. Simulate different future **scenarios** based on the goals presented above and make a **sensitivity** analysis to check the robustness of your results.

6. Identify and quantify measures for more **resource efficiency and savings** in these activities over conventional ones in the perspective of the decarbonization goals set for 2050.

Project sessions

Support for the project will be provided by the lecturers and teaching assistants during the semester in **weekly project sessions**. In each session, **specific tasks and guiding questions** to work on will be provided to the students. Students present their insights at the beginning of each project session which will be followed by a **Q&A discussion**. For more specific inquiries, students are invited to use the Moodle forum.

Deliverables

The project accounts for **40% of the final grade** (report 70% and presentation 30%). The project team consists of 4 students. Students in the same team will get the same grade. Should the work be uneven among the team members, please inform us before the final lecture. The project must include the following deliverables:

1. A **final report** of no more than 25 pages describing the problem, the methodological approach, the model results, as well as the interpretation and discussion of the results. Emphasis will be put on the results and especially their interpretation and relevance for the chosen case. The report must be submitted by **January 10, 2025, at 12am**.

2. The **MFA model** developed using generic (Python) or specific software packages (Umberto or STAN) and used to derive the main results of the project. Please submit the file together with the final report.

3. A **15-minute presentation** delivering the key results of your MFA and your suggestions for policy measures in a convincing way to win further contracts, followed by a 10-minute Q&A session. The presentations take place on **December 12/19, 2024**.

Report structure

The report should have no more than 25 pages (11pt, Arial, line spacing single) including references and annex with the following chapters and elements:

1. **Title page**, table of contents, table of figures and tables.

2. **Introduction** comprises the main motivation of your project with the problem definition, previous research conducted in this area with research gaps, the overall goal of your work and specific research questions.

3. **Methods and material** include case study description with system boundaries (time and space), data sources used (e.g. tables in annex if needed), calculations and assumptions for unknown quantities, and description of the scenarios.

4. **Results** representing main findings of your MFA model with results for each scenario.

5. **Discussion** with the interpretation of your MFA results and recommendations for most effective decarbonization measures, critical reflection on the robustness of your results (sensitivity analysis), strengths and limitations of your methodological approach, and main contribution to the research field introduced above (can potentially be combined with results chapter if preferred).

6. **Conclusion** summarizes the main goal of your project, methods used, main findings and recommendations for policy measures.

7. **References** with literature references and data sources used.

8. **Annex** with e.g. tables for data sources, calculations, figures, etc.

Disclaimer

When preparing the report, ensure clarity, accuracy, and proper citation of all sources. Authors should provide clear and concise explanations of methodologies, results, and interpretations. The report must adhere to ethical writing standards, including transparency regarding the use of **generative AI tools**. If AI was utilized during the report's development, a **disclaimer** must be included, specifying its role. For example, indicate whether AI was used for grammar checking, code development, data analysis, drafting sections (e.g., discussion or conclusions), or formatting. Clearly identify the specific sections or tasks where AI tools were applied and verify that all AI-generated content has been reviewed and appropriately integrated by the authors. This ensures accountability and maintains the integrity of the report.

Contributions to the report

All contributors to the report should be acknowledged, with their specific roles clearly defined in a dedicated section. To standardize this process, you may use the **Contributor Roles Taxonomy (CRediT)**, which categorizes contributions into roles such as conceptualization, data collection, methodology design, formal analysis, software development, drafting, review, editing, project administration, and more. Each contributor's role should be explicitly detailed to reflect their unique input to the report's development. Transparency in contributions ensures proper recognition and accountability, fostering collaborative integrity and fairness in the reporting process.

Data sources

Building infrastructure:

- Footprints (geometry): SwissTopo; OpenSource data
- Building addresses: SwissTopo
- Other building statistics: RegBL

Transportation infrastructure:

- Footprints (geometry): SwissTopo; OpenSource data roads; OpenSource data railways
- Other statistics: Swiss Federal Statistical Office
- Vehicles: Key figures

Readings

Case study documents:

- République et canton de Genève (2021). « Mise à jour du plan directeur communal Ville de Genève »

- République et canton de Genève (2021) « Plan climat cantonal 2030 »

- Ville de Lausanne (2021). « Lausanne 2030. Plan Directeur communal, une vision pour la ville de demain »

- Ville de Lausanne (2021). « Plan climat Lausannois »

Urban metabolism (buildings, roads, and vehicles):

- Heeren and Hellweg (2018). Tracking construction material over space and time: Prospective and geo-referenced modeling of building stocks and construction material flows. Journal of Industrial Ecology 23(1), 253-267.

- Martin del Campo, Singh, Fishman, Thomas and Drescher (2023). The Bahamas at risk: Material stocks, sea-level rise, and the implications for development. Journal of Industrial Ecology 27(4), 1165-1183.

- Wiedenhofer, Steinberger, Eisenmenger, Haas (2015). Maintenance and expansion: Modeling material stocks and flows for residential buildings and transportation networks in the EU25. Journal of Industrial Ecology 19(4), 538-551.

- Haberl et al. (2019). High-resolution maps of material stocks in buildings and infrastructures in Austria and Germany. Environmental Science and Technology 55(5), 3368-3379.

- [Gassner, Lederer, Kovacic, Mollay, Schremmer, Fellner (2021). Projection of material flows and stocks in the urban transport sector until 2050: A scenario-based analysis for the city of Vienna. Journal of Cleaner Production 311, 127591.]

- [Gassner, Lederer, Fellner (2020). Material stock development of the transport sector in the city of Vienna. Journal of Industrial Ecology, 24(6), 1364-1378.]

Material-stock-flow-service nexus:

- [Kalt, Wiedenhofer, Görg, and Haberl (2019). Conceptualizing energy services: A review of energy and well-being along the Energy Service Cascade. Energy Research and Social Science 53, 47–58.]

- [Haberl, Wiedenhofer, Erb, Görg and Krausmann (2017). The material stock-flow-service nexus: A new approach for tackling the decoupling conundrum. Sustainability 9, 1049.]