Guidelines for group project: Modeling and managing resource flows in cities

ENV-501

Material Flow Analysis and Resource Management

Fall 2025

Laboratory on Human-Environment Relations in Urban Systems

SDGs and natural resources

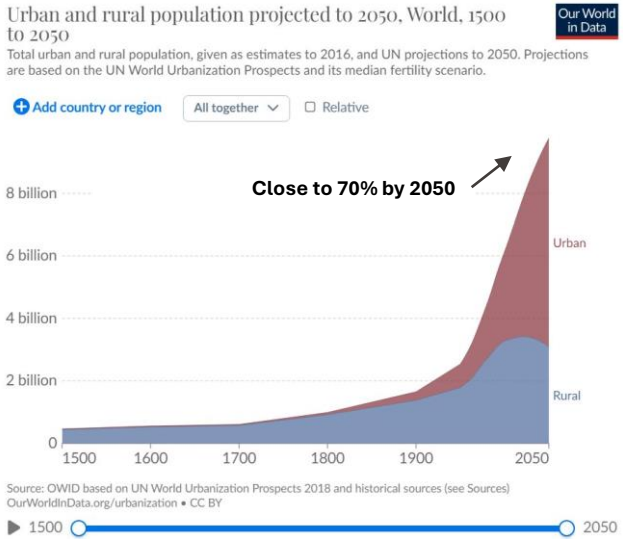
Direct and indirect relationship of natural resources to the three dimensions of sustainability in relation to the Sustainable Development Goals (SDGs)

Adapted from: IRP (2019)

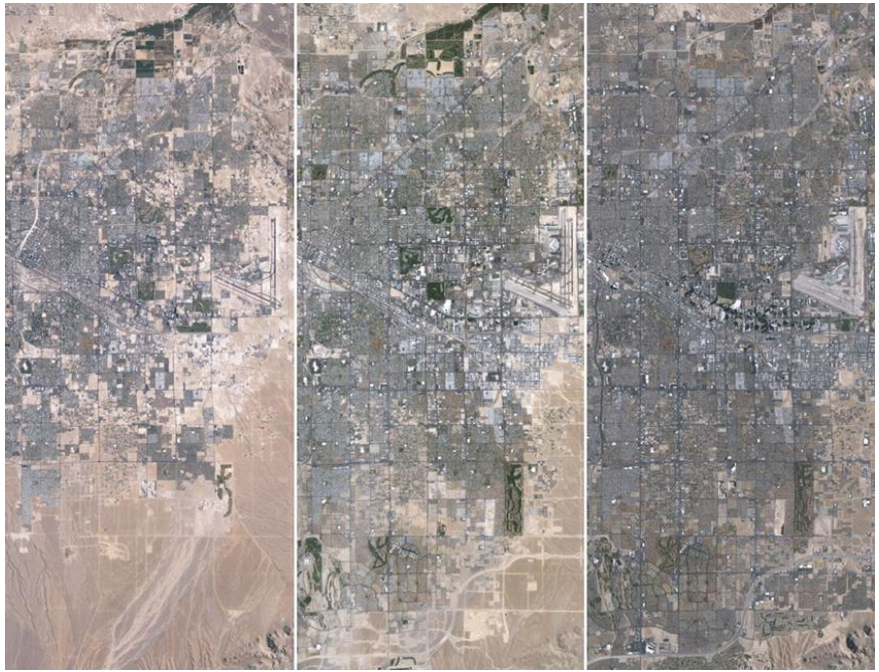
SDGs and natural resources

- Equal rights to economic resources, access to basic services, ownership and control over land and other forms of property, inheritance, ***natural resources.*** *[SDG1]*
- Ensure ***sustainable food production systems*** and implement resilient agricultural practices. *[SDG2]*
- Directly linked to the protection and improvement in the use of ***water, energy, marine resources, and land resources*** respectively. *[SDG 6,7,14,15]*
- Industry, innovation and ***infrastructure***; sustainable **cities** and communities; responsible ***consumption*** and ***production.*** *[SDG 9,11,12]*

Cities: Materials are at the basis of modern urban expansion



	2023	%	2050	%
Urban	4.62	58	6.67	68
Rural	3.42	42	3.09	32
Total	8.03	100	9.76	100



Source: Our World in Data (2023)

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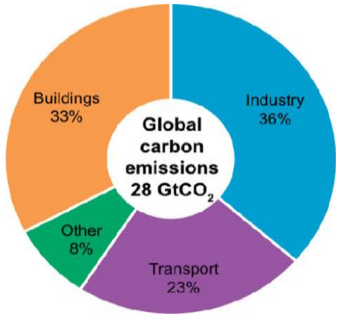
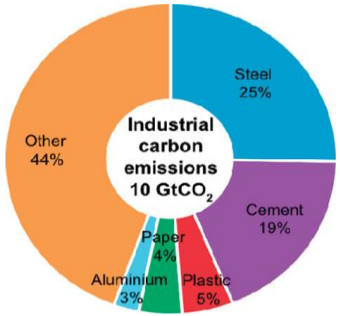
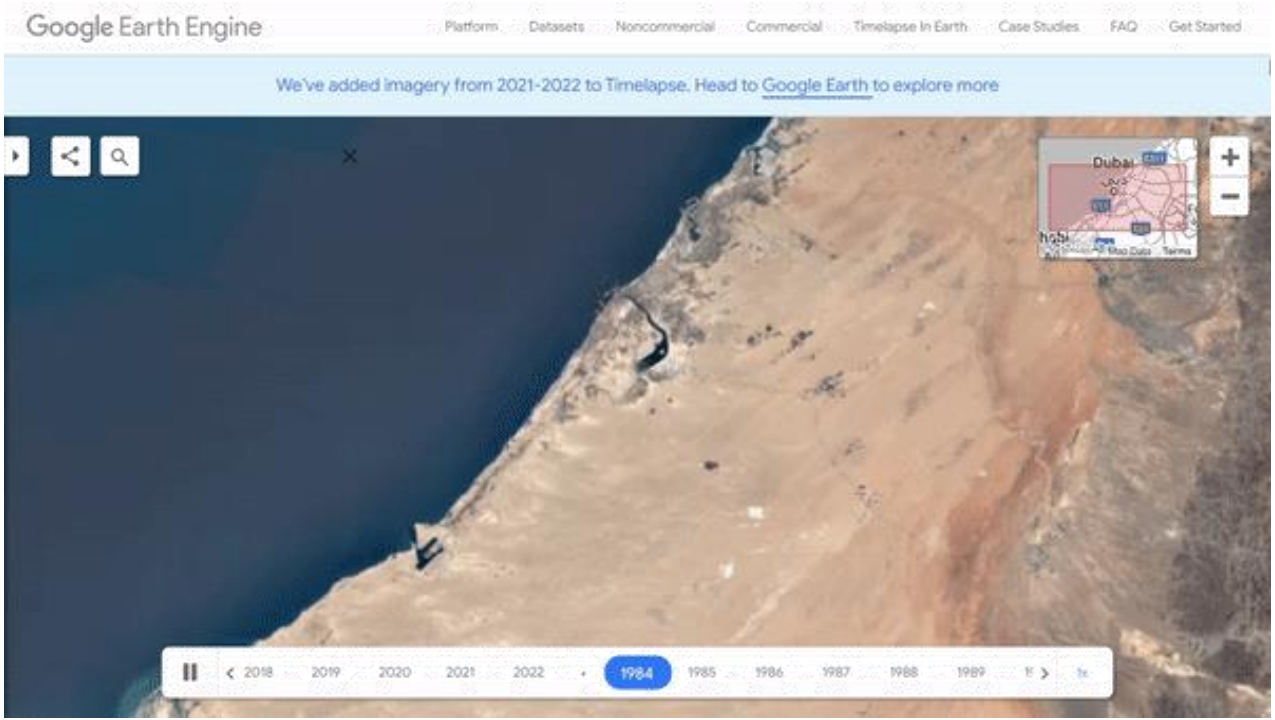
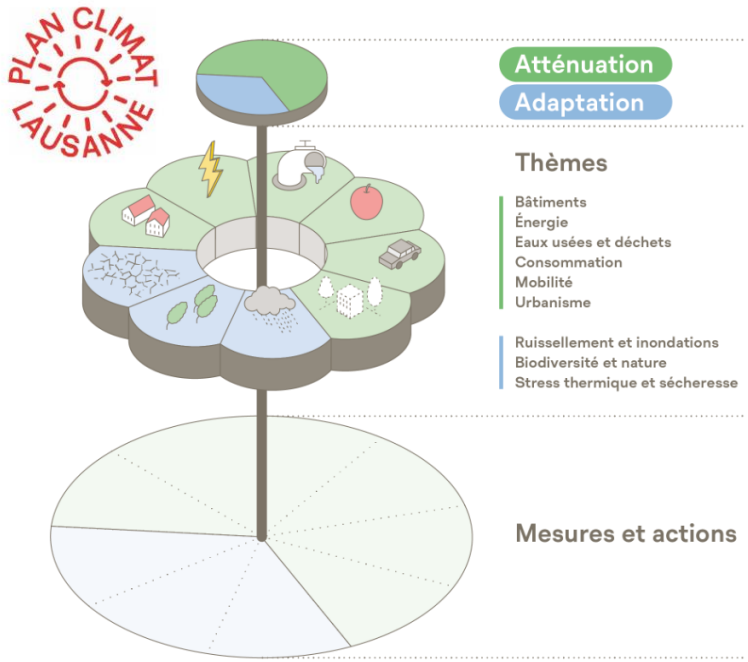






Source: Allwood et al. (2010); Google earth (2023)

Lausanne: Carbon neutrality by 2050



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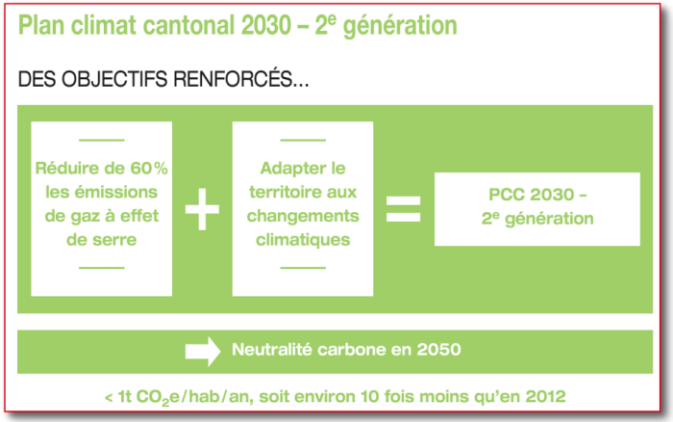
Geneva: Carbon neutrality by 2050

PLAN CLIMAT CANTONAL 2030
2e GÉNÉRATION

genève
PLAN DIRECTEUR COMMUNAL 2020
Renouvellement durable d'une ville-centre



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Group projects: Modelling and managing resource flows in cities

- **Apply methods and approaches** to the city of Lausanne and Geneva
- Develop dynamic **material flow analysis (MFA) model**
- **Collect data** for scenario development and analysis
- Develop **assessment criteria**
- Develop and test **measures** for more resource efficiency and savings

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Group projects

Please, choose and form your group here! until Sept 19

- **40 % of the final grade** (report 70%; presentation 30%)
- **4 students** per group

	LAUSANNE	GENEVA
Residential buildings	*Project 1*	*Project 6*
Non-residential buildings	*Project 2*	*Project 7*
Road network	*Project 3*	*Project 8*
Tracks/railways network	*Project 4*	*Project 9*
Vehicles	*Project 5*	*Project 10*

Departure point: 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 »

Learn from the best: Urban metabolism studies

Buildings

- 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.

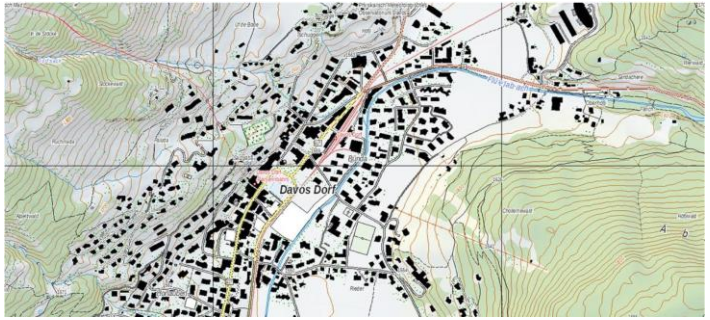
Buildings and roads

- 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.

Vehicles

- 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.

Dive into the data: Data sources



- **Building infrastructure**

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

- **Transportation infrastucture**

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

Departure point: Case study documents

TASK

Specific guiding questions for starting your journey (please prepare for next week Sep 19, 2024)

- Which **goals** do the cities specify and in how far do they quantify them?
- Which **sectors** do they target to reach these goals?
- Which **strategies and specific measures** are mentioned and how do they **assess and monitor** them?
- Is there any **spatial component** in these strategies?
- Which **actors** are relevant and can influence the success in reaching these goals?
- Which **role could material flow analysis play** in supporting the cities to reach their goals?

Project guideline

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- Familiarize yourself with the selected case and create a **first problem definition and goals.**
- Set the **boundaries** of your system, in time and space.
- Identify the most relevant **substances, materials or energy sources.**
- Identify the **necessary data and potential sources.**
- **Collect and structure the data** (material and energy flows, stocks and their changes) and refine the system, making simplifying assumptions as needed.
- Propose and analyze **scenarios** based on the defined goals (including sensitivity).
- Identify and quantify **measures for resource efficiency,** considering long-term goals.

General guiding questions for defining your project

- What is the **current demand** for buildings, roads, and other urban infrastructures?
- What are the **dynamics of the system** in terms of past and future trends?
- What are the **potential impacts** of these trends (land use, energy, emissions, raw materials)?
- How to **spatially arrange the different functions** of a city (buildings, roads, other infrastructures) to improve the provisioning of essential services?
- Who are the **key actors** involved in a city's sustainable development and what roles do they play in influencing decisions and outcomes?
- What **regulatory frameworks, economic incentives, and policies** shape the development and management of urban infrastructure?

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Course outline

		8:15 - 9:00 and 9:15 - 10:00		13:15 - 14:00	14:15 - 15:00
Block I: EW-MFA global / national	W1 - Sep 12	Introduction to the course and general concepts	All	Exercise	Project
	W2 - Sep 19	EW – MFA and EW – MFA in different countries	FMC	Exercise	Project
	W3 – Sep 26	EW – MFA in the Swiss context, Urban Metabolism	External Guest – Florian Kohler	Exercise	Project
	W4 - Oct 03	EW – MFA in the Swiss context: Cantons and Circular Economy	FMC	Exercise	Project
Block II: MFA regional / urban	W5 - Oct 10	The Service-Stock-Flows Nexus	CRB	Exercise	Project
	W6 - Oct 17	Dynamic MFA	External Guest – Stefan Pauliuk	Exercise	Project
	Oct 24	Autumn break			
	W7 - Oct 31	Spatial MFA	FMC	Exercise	Project
	W8 - Nov 07	Input-Output Analysis and Material Flow Cost Accounting	External Guest – Vincent Moreau	Exercise	Project
	W9 - Nov 14	MFA and Uncertainty	External guest – Stefan Pauliuk	Exercise	Project
	W10 - Nov 21	Case studies: Waste management in Indonesia / Critical Raw Materials in the Swiss context	GF & FMC	Exercise	Project
Block III: Social sciences and public policy	W11 - Nov 28	Social Metabolism	CRB	Exercise	Project
	W12 - Dec 05	Agent-based model	CRB, FMC, MAH, SLC	Past exam	Project
	W13 - Dec 12	Group Project Presentation	CRB, FMC, MAH	Project	Project
	W14 - Dec 19	Group Project Presentation	CRB, FMC, MAH	Project	Project

Project sessions

		8:15 - 9:00 and 9:15 - 10:00	14:15 - 15:00
Block I: EW-MFA global / national	W1 - Sep 12	Introduction to the course and general concepts	Project presentation, guidelines, objectives
	W2 - Sep 19	EW – MFA and EW – MFA in different countries	Project definition & goals
	W3 – Sep 26	EW – MFA in the Swiss context, Urban Metabolism	System boundaries & data collection
	W4 - Oct 03	EW – MFA in the Swiss context: Cantons and Circular Economy	System boundaries & data collection
Block II: MFA regional / urban	W5 - Oct 10	The Service-Stock-Flows Nexus	Nexus approach & application for project
	W6 - Oct 17	Dynamic MFA	Dynamics of the system: past & future trends
	Oct 24	Autumn break	
	W7 - Oct 31	Spatial MFA	Spatial perspective & data availability
	W8 - Nov 07	Input-Output Analysis and Material Flow Cost Accounting	Open session with reflections & discussion
	W9 - Nov 14	MFA and Uncertainty	Scenarios development & uncertainty
	W10 - Nov 21	Case studies: Waste management in Indonesia / Critical Raw Materials in the Swiss context	Scenarios development & uncertainty
Block III: Social sciences and public policy	W11 - Nov 28	Social Metabolism	Measures & recommendations
	W12 - Dec 05	Agent-based model	Measures & recommendations
	W13 - Dec 12	Group project presentation	Group project presentation
	W14 - Dec 19	Group project presentation	Group project presentation

Project sessions

- **Weekly** sessions
- **Specific tasks and guiding questions** to work on
- **Students present** their insights at the beginning of each session
- **Q&A** discussion
- For further questions,
  please use **Moodle forum**

Deliverables

- **Final report** until Jan 10, 2025, 12am

  Report with maximum 25 pages including problem description, methodological approach, model results, interpretation and discussion of results.

- **MFA model** together with the final report

  Developed model using generic (Python) or specific software packages (Umberto or STAN).

- **15-min presentation with 10-min discussion** on Dec 12/19, 2025

  Presentation of key results of your model and suggestions for policy measures.

Report structure

- **Title page**

  Include title, table of contents, table of figures and tables.

- **Introduction**

  Main motivation of your project and problem definition, previous research, research gaps, overall goal and specific research questions of your project.

- **Methods and material**

  Case study description with system boundaries in time and space, data sources used with tables (in the annex if needed), calculations, assumptions, and description of scenarios.

- **Results**

  Main findings of your MFA model with results for each scenario.

Report structure

- **Discussion**

  Interpretion of MFA results and recommendations for policy measures, critical reflection on robustness of results (sensitivity analysis), strengths and limitations of your methodological approach, main contribution of your research to the field (can be combined with the results chapter if preferred).

- **Conclusion**

  Summary of main goal of your project, methods used, findings and recommendations for policy measures.

- **References**

  List of literature references and data sources.

- **Annex**

  Additional tables with data sources, calculations, figures, etc.

Guideline: How to write a research paper

Structure

Shape like an hour glass (broad - narrow - broad)

- Introduction
- Method
- Results
- Discussion
- Conclusion

Sections have different **purposes** and **linguistic characteristics!**

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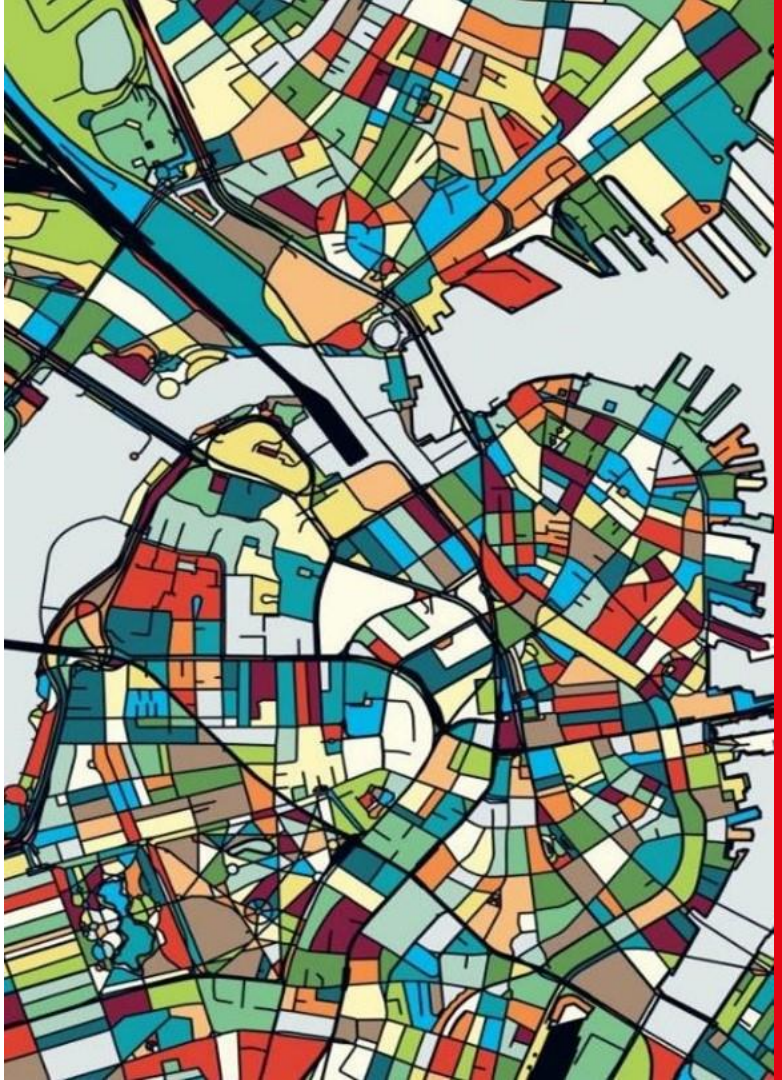

Thanks for your attention!