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

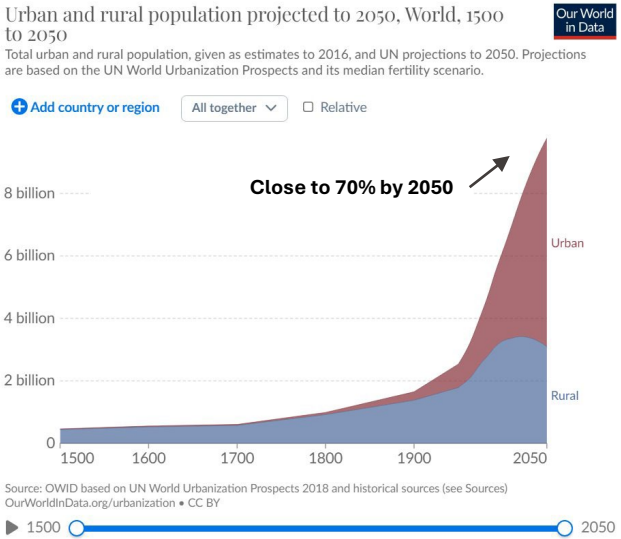
Direct and indirect relationship of natural resources to the three dimensions of sustainability in relation to the Sustainable Development Goals (SDGs)

Adapted from: IRP (2019)

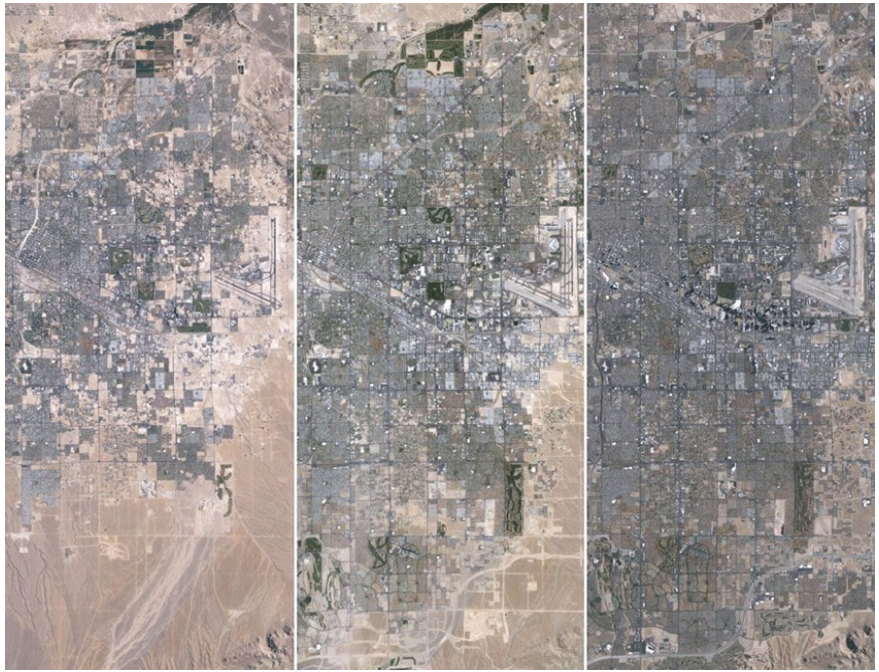
SDGs and natural resources

- 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

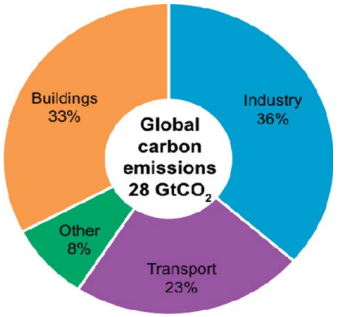


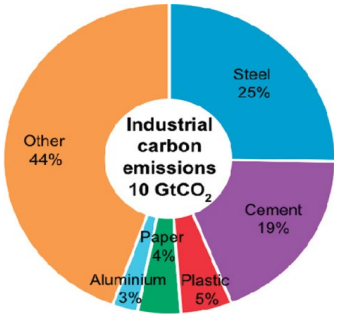
	2023	%	2050	%
Urban	4.62	58	6.67	68
Rural	3.42	42	3.09	32
Total	8.03	100	9.76	100

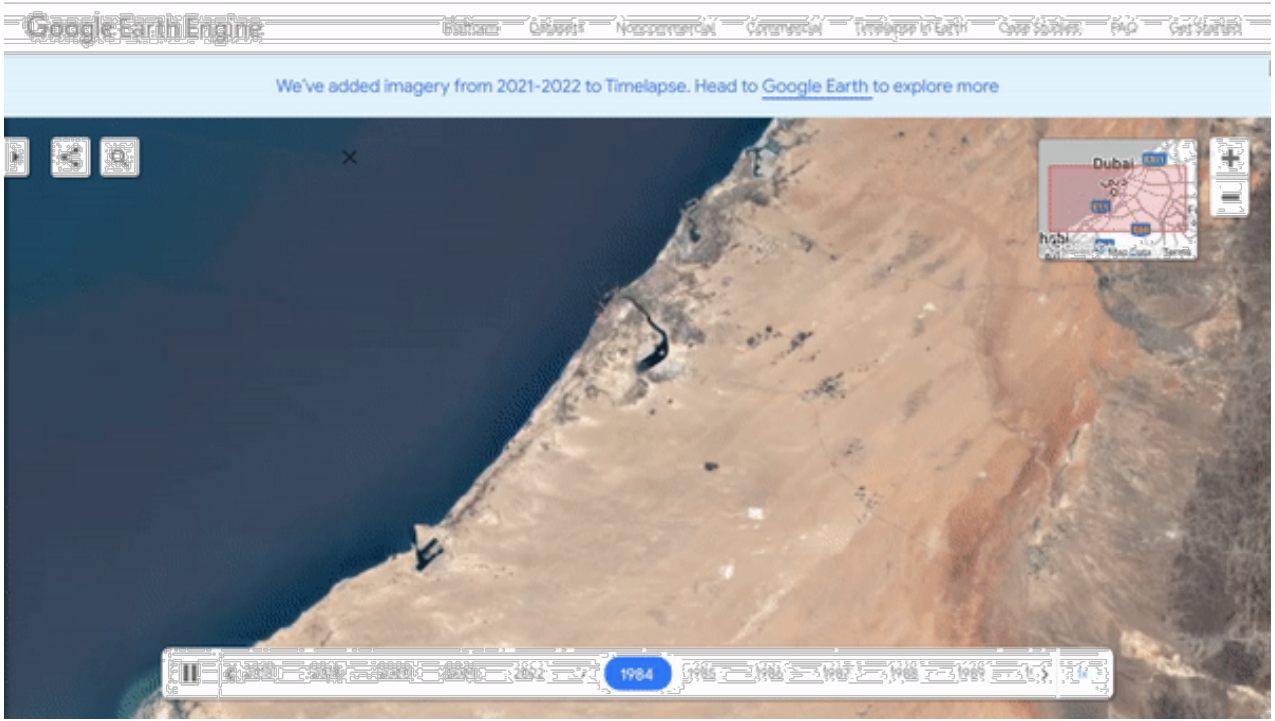


Source: Our World in Data (2023)

Cities: Materials are at the basis of modern urban expansion

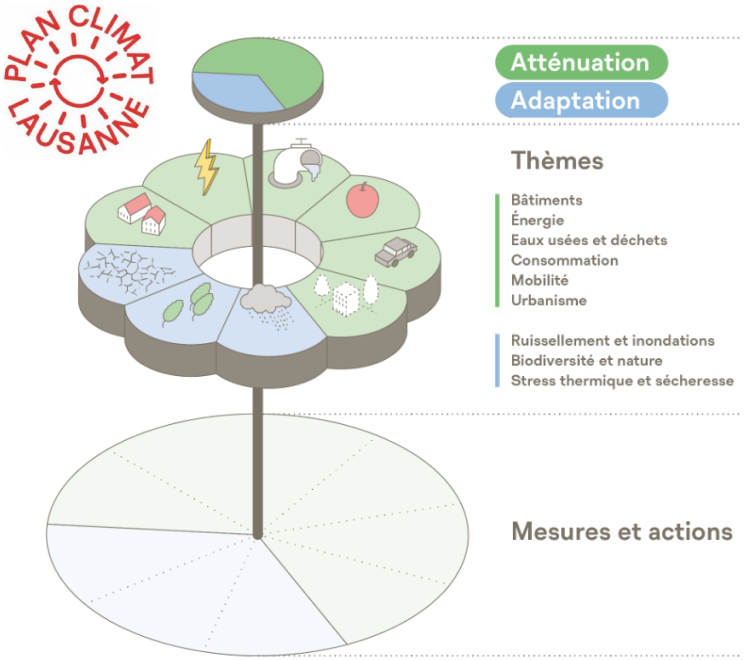






Source: Allwood et al. (2010); Google earth (2023)

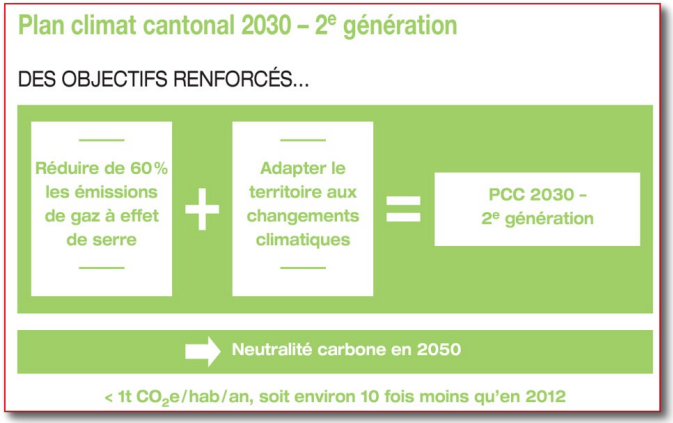
Example of policies: Carbon neutrality by 2050



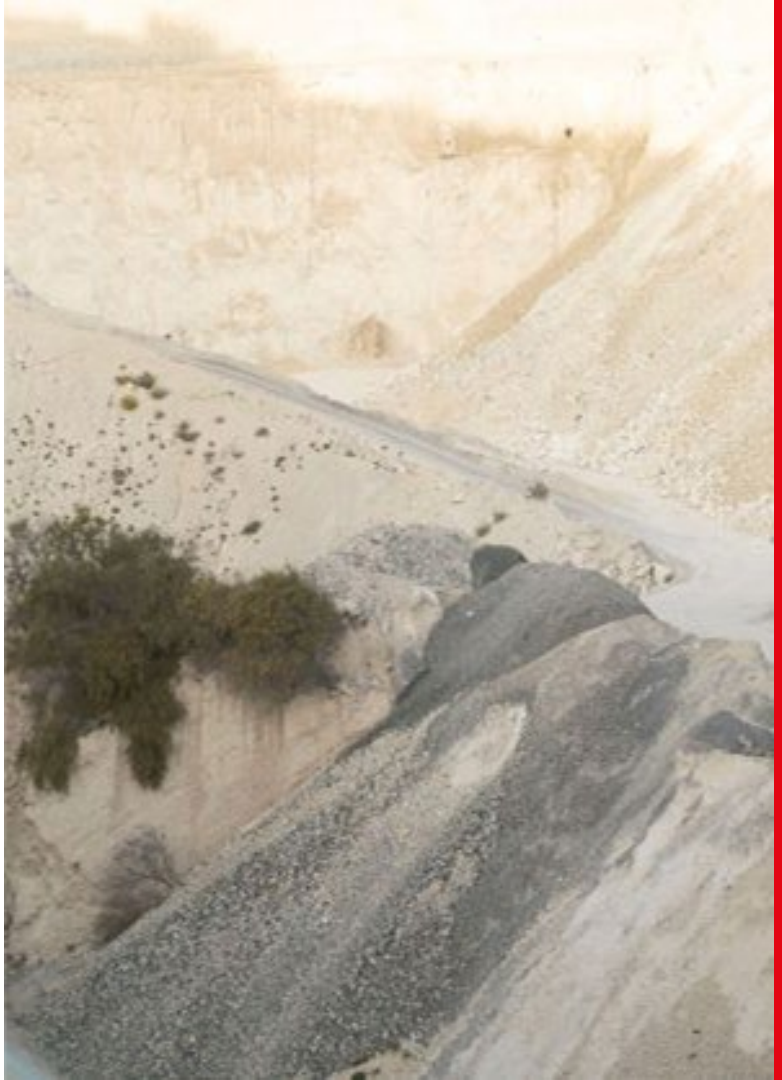
Example of policies: Carbon neutrality by 2050

PLAN CLIMAT CANTONAL 2030
2e GÉNÉRATION

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



Speaker



Deep dive Lausanne, plan climat

Laboratory on Human-Environment Relations in Urban Systems

What is it?

- Basis of the City of **Lausanne's climate policy**
- Objectives:
  - Achieve **zero direct greenhouse gas emissions by 2050**
  - **Adapt the city** to cope with climate change
  - **Raise awareness** among the population and encourage them to take action
- Where to find it: https://www.lausanne.ch/portrait/climat/plan-climat.htm

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Current direct emissions:

0.48 Mio t CO2eq, or 3.3 t CO2eq/Habitant and year

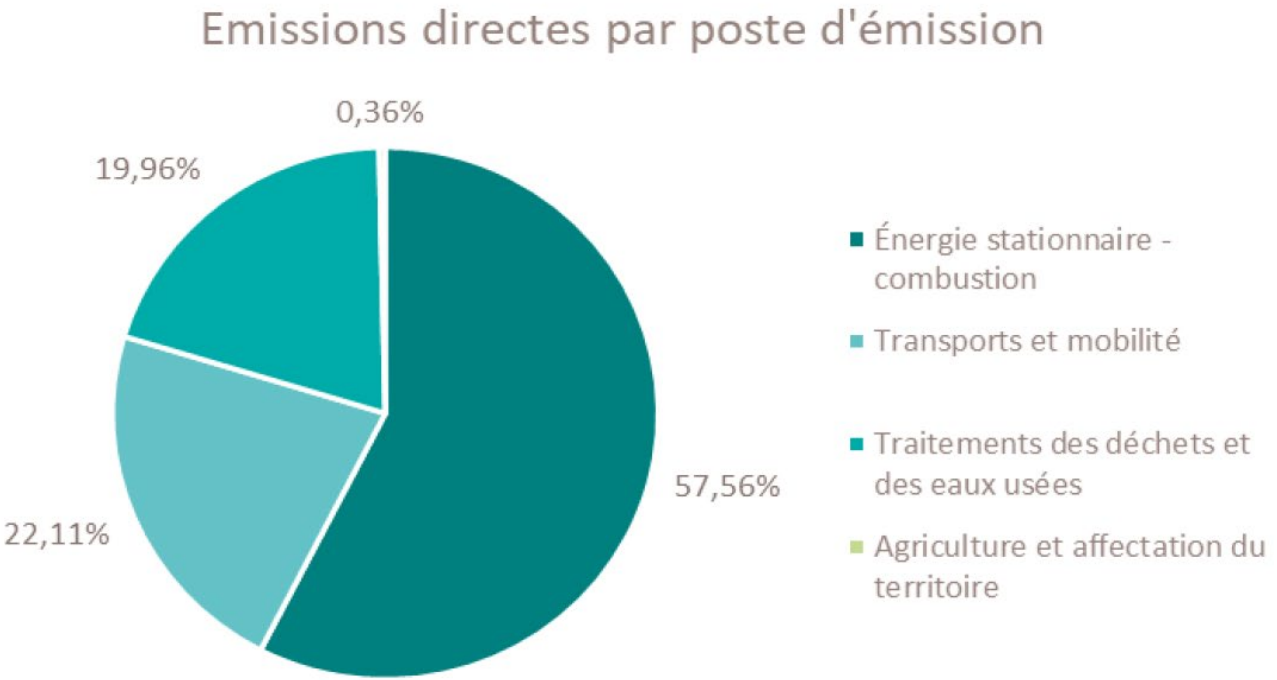

Figure 3 : répartition des émissions directes de 2019 par poste d'émission.

Source: Plan climate de Lausanne 2021, pg.11

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Current indirect emissions:

1.5 Mio t CO2eq, or 10.6 t CO2eq/habitant and year

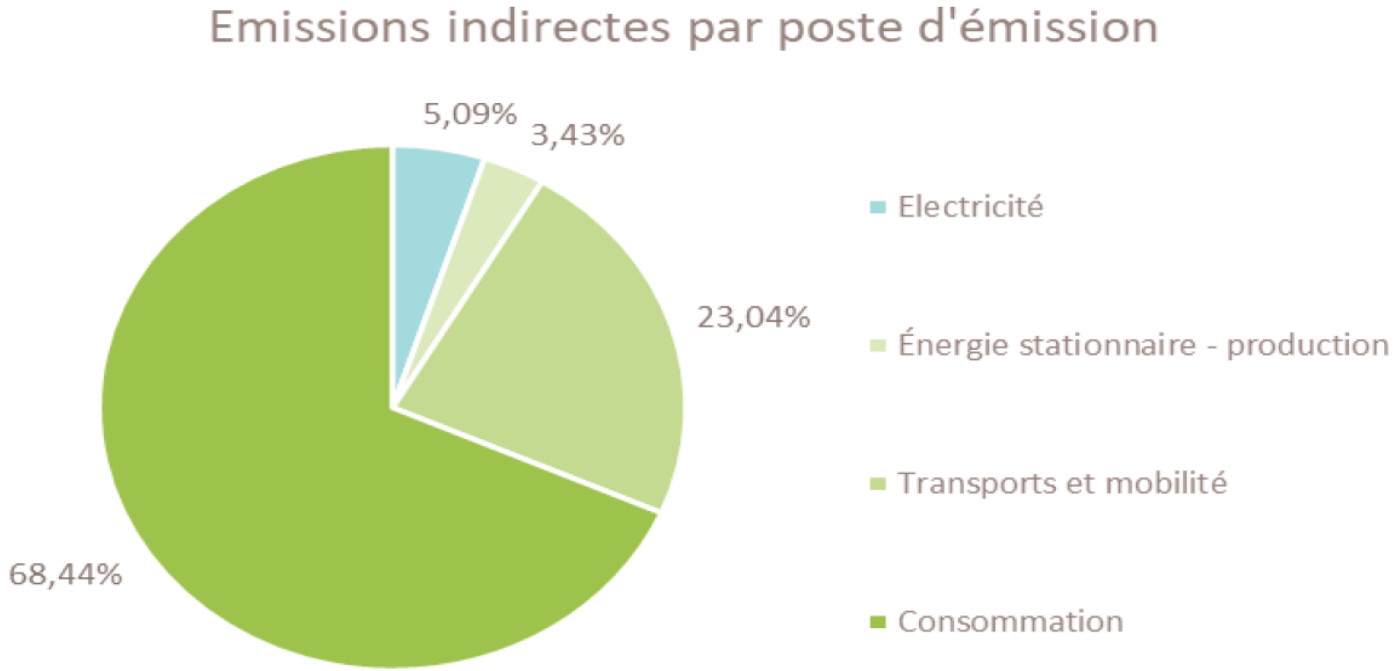


Figure 4 : répartition des émissions indirectes de 2019 par poste d'émission.

Source: Plan climate de Lausanne 2021, pg.13

Decarbonization scenario

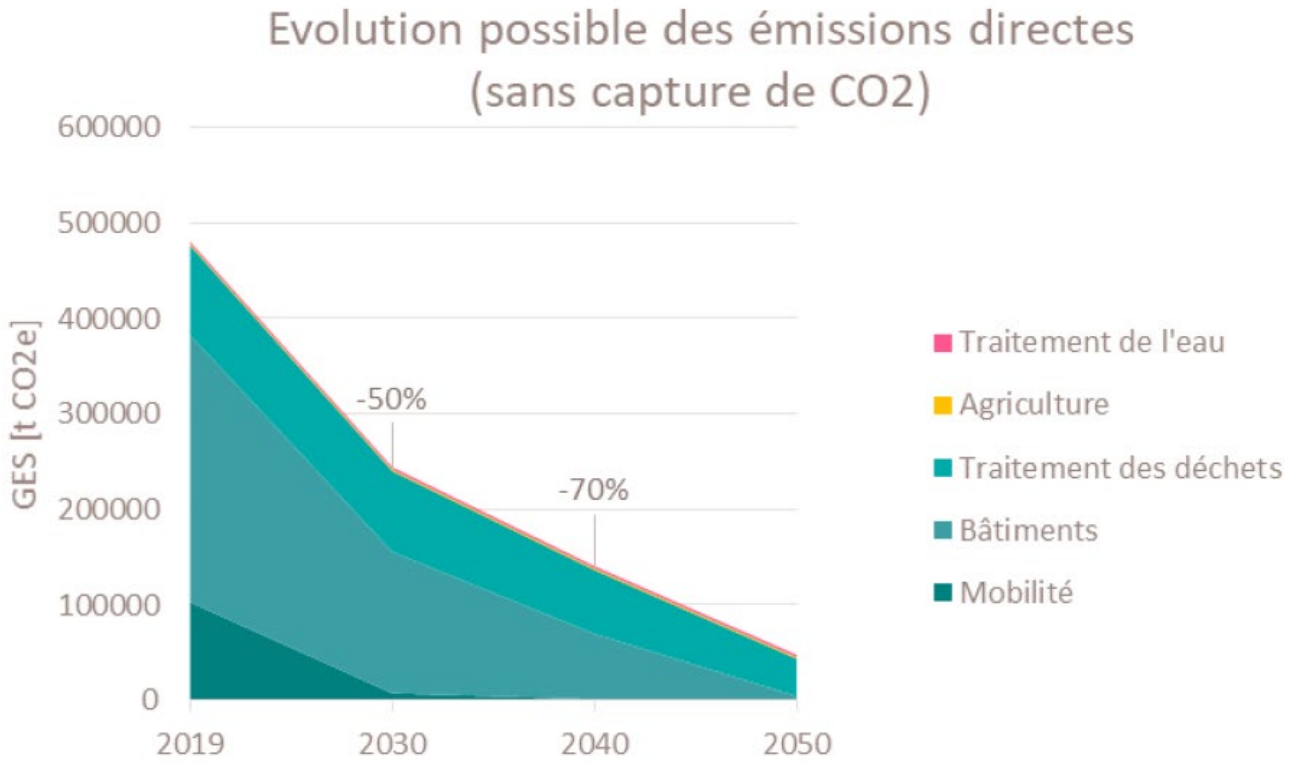


Figure 6 : Evolution escomptée des émissions directes (courbes indicatives).

Source: Plan climate de Lausanne 2021

Main themes

Volets

Atténuation

Adaptation

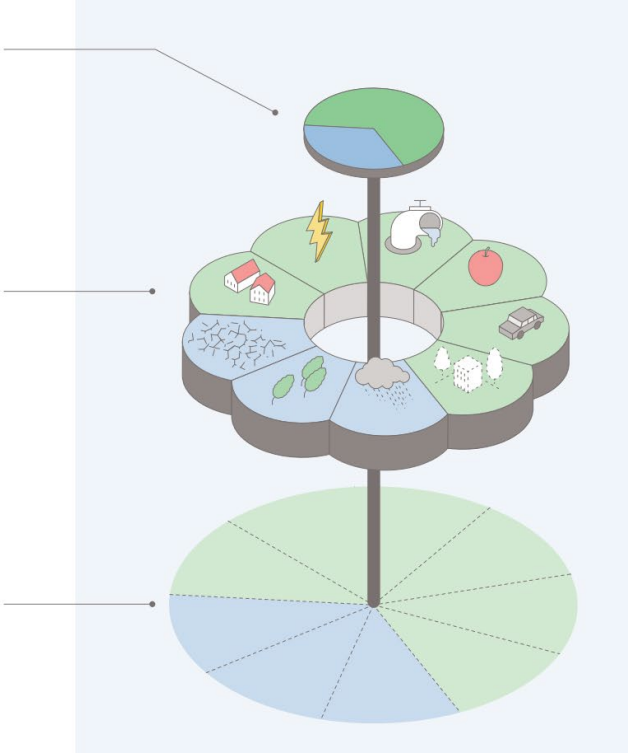
Thèmes

Bâtiments
Énergie
Eaux usées et déchets
Consommation
Mobilité
Urbanisme

Ruissellement et inondations
Biodiversité et nature
Stress thermique et sécheresse

Mesures et actions

De nombreuses mesures et actions sont prévues dans les différents thèmes recensés par le Plan climat. Les projets continuent d'être développés au fur et à mesure de leur mise en œuvre.



Source: https://www.lausanne.ch/dam/jcr:6a0e5b43-b420-4884-8364-f818ee6bbdac/240408-PLAN-CLIMAT-PUBLICATION_WEB.pdf

Main themes for **mitigation**:

- Buildings
- Energy
- Mobility
- Others

Main themes for **adaptation**:

- Flooding
- Biodiversity
- Heat stress

→ measures

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170 measures in 12 domains

Examples:

- Replace heating systems with low-carbon alternatives in municipal buildings
- Contribute to the transition of all public transport (buses, trains, boats, etc.) toward low-carbon propulsion systems
- Renovate the entire municipal building stock by 2050
- Promote refurbishment of electronic devices

Source: https://www.lausanne.ch/portrait/climat/publications/catalogue-mesures.html

Questions related to MFA- project

- Which are the “screws” we can turn (MFA perspective)?
  - Direct/ indirect emissions
  - Resources
  - Energy demand
- Which measures are promising to moving into the right direction?
  - CO_2 emissions
  - Energy demand
  - Resource demand
- What are the «rebound» effects and trade-offs?
  - Are critical materials involved?
  - What are the associated embodied emissions?
  - What waste streams result from replacement?
- What synergies exist between the measures?

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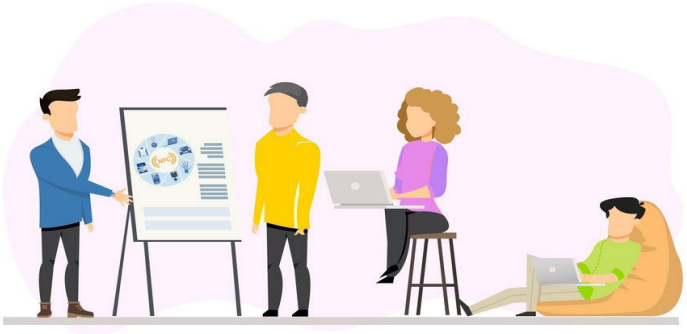
Group projects

Group projects: Modelling and managing resource flows in cities

- **Apply methods and approaches** to the case studies
- 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



Group projects

Please, choose and form your group here! until Sept 25

- **50% of the final grade** (report 70%; presentation 30%)
- **3-4 students** max per group

Exploring mobility flows in the Lémanique area	*Project 1*
Exploring heating technology substitution scenarios	*Project 2*
Household appliances and embodied energy (Part I – White goods)	*Project 3, Project 4*
Household appliances and embodied energy (Part II – Electronics)	*Project 5, Project 6*

Departure point: Case study documents

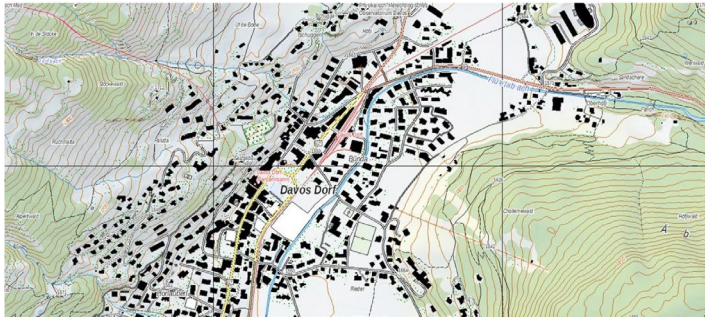
- République et canton de Genève (2021). « Mise à jour du plan directeur communal Ville de Genève »
- République et canton de Genève (2021). « Plan climat cantonal 2030 »
- Ville de Lausanne (2021). « Lausanne 2030: Plan Directeur communal, une vision pour la ville de demain »
- Ville de Lausanne (2021). « Plan climat Lausannois »

Learn from the best: Urban metabolism studies

Urban metabolism (GIS applications, buildings, infrastructure, vehicles, appliances):

- 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.
- 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.
- Matasci, C., Gauch, M., & Böni, H. (2019) – Material and energy flow analysis and associated environmental impacts of Swiss mobility. In C. Ludwig & S. Valdivia (Eds.), *Progress Towards the Resource Revolution*. (Chapter 11, pp. 84-89). A World Resources Forum Production
- Golev et al. (2016) - Product flow analysis using trade statistics and consumer survey data: a case study of mobile phones in Australia. Journal of Cleaner Production, 133 (2016), pp. 262-271
- Jian et al. (2022) - Material flow analysis of China's five commodity plastics urges radical waste infrastructure improvement. Environmental research: Infrastructure and sustainability, 2 025002
- Nausamm et al. (2022) - Life Cycle Assessment of an Air-Source Heat Pump and a Condensing Gas Boiler Using an Attributional and a Consequential Approach. Procedia CIRP, 105 (2022), pp. 351-356

Dive into the data: Data sources



- **Building infrastructure + heating**
  - 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

- **Appliances**
  - Surveys: Panel Lémanique data
  - Other statistics: Swiss Federal Statistical Office

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 11	Introduction to the course and general concepts	All	Exercise	Project
	W2 - Sep 18	EW – MFA and EW – MFA in the Swiss context	External Guest – Florian Kohler	Exercise	Project
	W3 – Sep 25	Examples of EW – MFA. Scaling EW-MFA to Cantons	FMC	Exercise	Project
	W4 - Oct 02	Urban Metabolism and Circular Economy	FMC	Exercise	Project
Block II: MFA regional / urban	W5 - Oct 09	MFA method and the Stock-Flows-Service Nexus	CRB	Exercise	Project
	W6 - Oct 16	Dynamic MFA	External Guest – Stefan Pauliuk	Exercise	Project
	Oct 23	Autumn break			
	W7 - Oct 30	Applications of MFA – case study	External Guest – Guillaume Massard	Exercise	Project
	W8 - Nov 06	Input-Output Analysis and Material Flow Cost Accounting	External Guest – Vincent Moreau	Exercise	Project
	W9 - Nov 13	Spatial MFA	FMC	Exercise	Project
	W10 - Nov 20	Combined approaches: MFA + LCA; MFA + sociodemographics.	AS & FMC	Exercise	Project
Block III: Social sciences and public policy	W11 - Nov 27	Combined approaches: MFA + surveys; Quasi-dynamic MFA	GF & FMC	Exercise	Project
	W12 - Dec 04	Social metabolism	CRB	Past exam	Project
	W13 - Dec 11	Agent-based model	CRB, FMC, MAH, SLC	Project	Project
	W14 - Dec 18	Group Project Presentation	All	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 11	Introduction to the course and general concepts	Project presentation, guidelines, objectives
	W2 - Sep 18	EW – MFA and EW – MFA in the Swiss context	Project definition, goals & measures: interactive session, short project proposal
	W3 – Sep 25	Examples of EW – MFA. Scaling EW	System boundaries & data collection: key flows, stocks & processes
	W4 - Oct 02	Urban Metabolism and Circular Ec	Strategies for data collection: preliminary data sources
Block II: MFA regional / urban	W5 - Oct 09	MFA method and the Stock-Flows-Service Nexus	Nexus thinking & application for project: services provided, impacts
	W6 - Oct 16	Dynamic MFA	Dynamics of the system: drawing the MFA diagram, ID stocks & flows over time
	Oct 23	Autumn break	
	W7 - Oct 30	Applications of MFA – case study	Sensitivity: changes in parameters and impacts on results
	W8 - Nov 06	Input-Output Analysis and Material	Group consultations, reflections on difficulties: submission of project outline (abstract)
	W9 - Nov 13	Spatial MFA	Reflection: trends and projections, spatiality of flows & stocks
	W10 - Nov 20	Combined approaches: MFA + LCA; MFA + sociodemographics	Group consultations, reflections on difficulties: policy goals + scenarios
Block III: Social sciences and public policy	W11 - Nov 27	Combined approaches: MFA + surveys; Quasi-dynamic MFA	Group consultations, reflections on difficulties: how to present results / tables / figures
	W12 - Dec 04	Social metabolism	The social component in MFA: behavioral aspects
	W13 - Dec 11	Agent-based model	Policy measures & recommendations: to discuss during session
	W14 - Dec 18	Group Project Presentation	Group project presentation

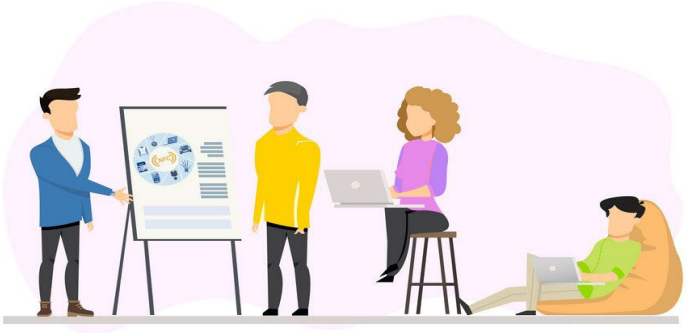
Project framing & system design

Model building & simulation

Interpretation & recommendations

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

Important dates

Dec 18	Group project presentation	In class
Jan 9	Group project report	Upload Moodle

- **Final report** until Jan 9, 2026, 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 18, 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!