Projeter un avenir durable

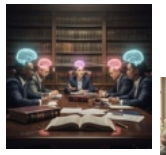
L'AI pour aider à la transition ?

Prof. François Marechal
EPFL
319 → 431 ppm CO2
Industrial process and energy systems engineering
Valais-Wallis

Intelligence humaine ?

Données

Processeur



Cerveaux

Mémoire
Modèles
Instructions/croyances

"C'est trop cher ! Crois-moi !"

Intelligence artificielle ?

Données

Processeur

Cerveaux

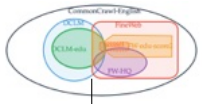
Mémoire
Modèles
Instructions

Processeurs

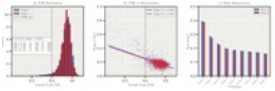
"C'est possible, La preuve !"

Intelligence générative: Large Language models

Données



Entrainement



Generation

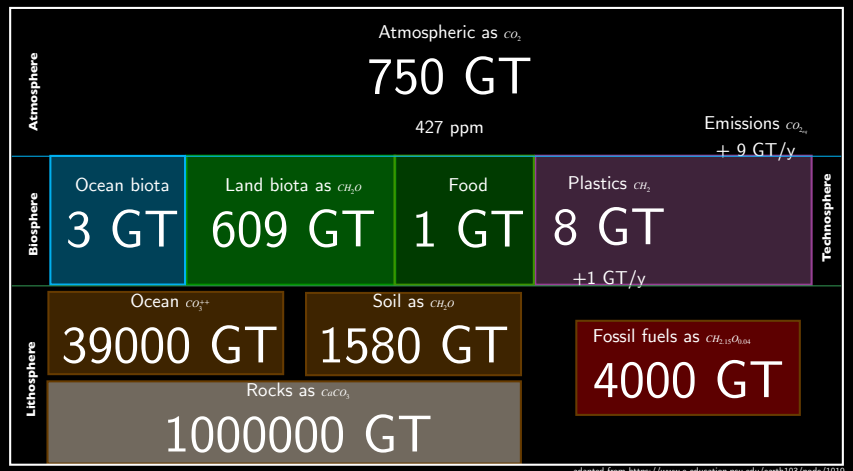
Le mot suivant le plus probable

THE SWISS AI CHARTER

Prompt : instructions

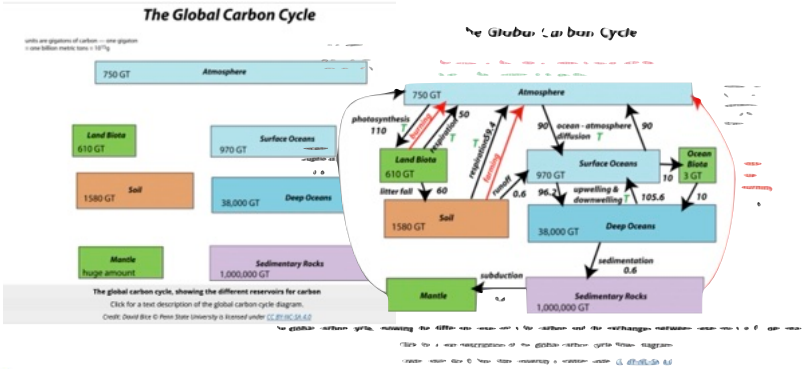
APERTUS V0.1 TECHNICAL REPORT

EARTH CARBON BALANCE



D'où viennent ces données ?

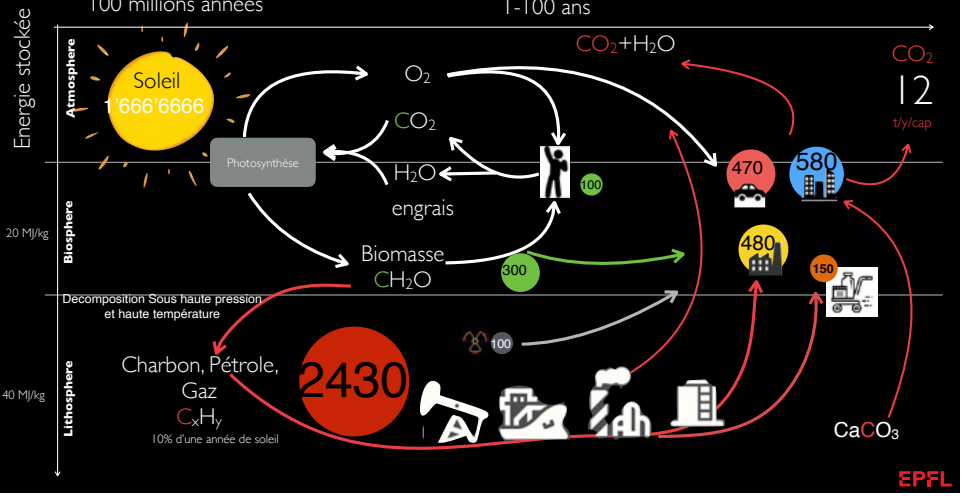
- Mistral : quelles sont les quantité de carbon en GT dans l'atmosphere, la bioshpere et la litosphere ?



LE CYCLE DU CARBONE AUJOURD'HUI

100 millions années — 1-100 ans

100 | Oil/an/cap



CONSÉQUENCES…

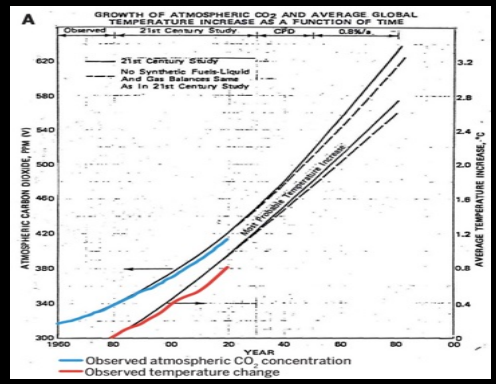
- Svante Arrhenius (1896)

doubling CO2 concentration = +2.5 C

- Exxon study (1982) -> Models

Exxon's private prediction of the future growth of carbon dioxide levels (left axis) and global temperature relative to 1982 (right axis). Elsewhere in its report, Exxon noted that the most widely accepted science at the time indicated that doubling carbon dioxide levels would cause a global warming of 3°C. Illustration: 1982 Exxon internal briefing document

Supran et al., Science 379, 153 (2023) 13 January 2023



EPFL

CO2 EMISSIONS CONSEQUENCES

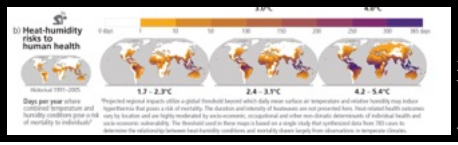
Floodings

Greece 2023
Spain 2023
China 2023
Sierre 2024

+ 2°C
In Switzerland

Heat waves

Fires and Droughts



Migration
Zones in the world where the bulb temperature is higher than the cooling temperature of the body

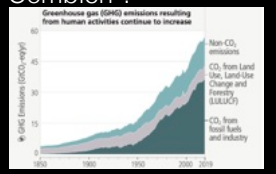
AR6 Synthesis Report (SYR)

EPFL

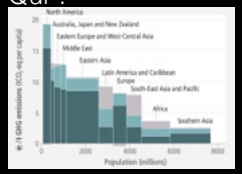
UNE COMMUNAUTÉ SCIENTIFIQUE (e.g. IPCC)

Observations
Statistiques

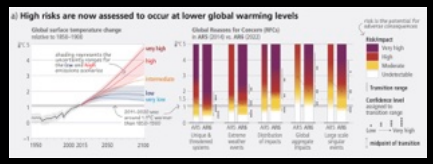
Combien ?



Qui ?



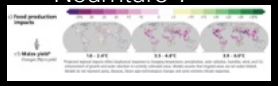
Modèles Prospectifs
- Scénarios
- Probabilité
- Incertitudes



Evénements
Extrêmes ?

Vivable ?

Nourriture ?



IPCC , R6 doi: 10.59327/IPCC/AR6-9789291691647

EPFL **Le coût de la réparation**

De : “c’est papa qui paie” à “on laissera payer l’fiston”

Polleur-payeur : dispense CO_2 (CH= 30-90 Milliards/an)

Notre dette: le coût de la réparation :

200 - 600 USD/ton CO2

Coût social : ≈ 400 CHF/ton co_2 (confédération Suisse, 2025)

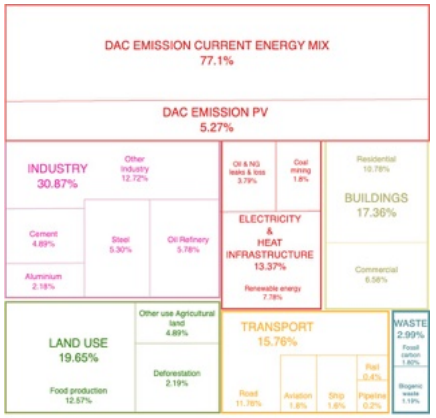
Pour la Suisse : **15** $ton_{CO_2}/an/cap$ (base consommation)=> **30-90** Millards/ans

“On laissera payer fiston” : 1.25 ton/mois/cap = 250-750 CHF/mois

EPA (2023)

EPFL **Industrial Direct Air Capture illusion**

-3500 kJ/kg CO2
374 €/ton CO2
6.4 m3/ton CO2




Current energy mix

DAC


PV

82901 TWh/year

Electricity consumption (TWh/year)
Current world consumption is- 28660 TWh/year

51186 TWh/year

547.8 km^3/year

Volume of carbon dioxide to be stored (km^3/year)
6 X the leman lake

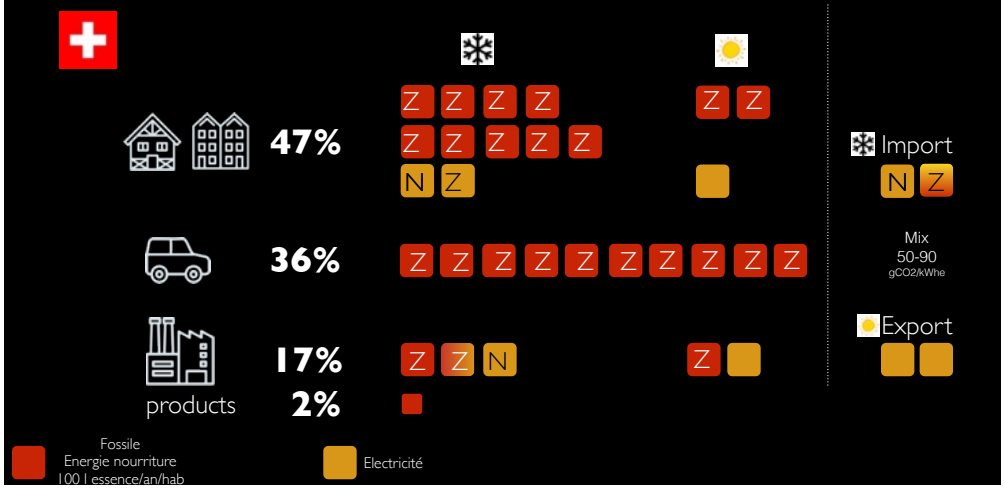
338.4 km^3/year

2.2 times EU Economy
32’000 Milliards/an

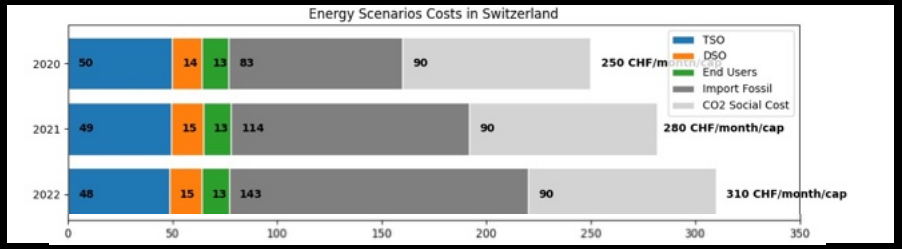
Cost of capturing CO2 (EU Economy/year)
EU Economy - $145000000000

1.36 times EU Economy
20’000 Milliards/an

L'IMAGE ENERGETIQUE DE LA SUISSE 2024



UNE SUISSE DÉPENDANTE QUI CHOISI QUI ELLE RESPECTE



Investissement : **80** CHF/mois/hab: infrastructure et conversion

Import : **80 - 140** CHF/mois/hab: achats d'énergie, Effet Poutine

-> 30/mois/cap (3 milliard ! pour armer Poutine + 5 milliard pour s'en protéger ?)

Dette : **90** CHF/mois/hab (200 CHF/ton CO2)

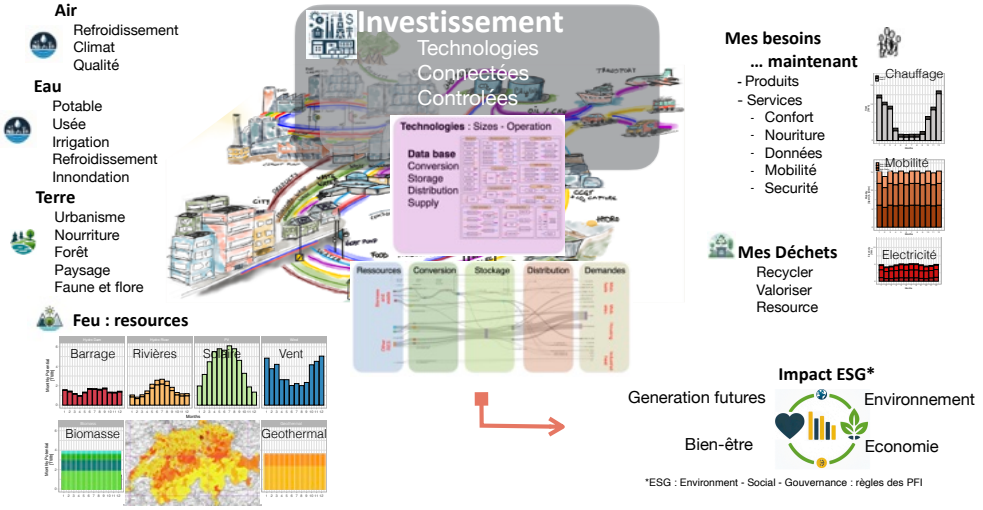
*10 CHF/mois/cap = 1 milliard CHF/an

EPFL

Une Suisse indépendante et neutre ? Est-ce trop cher ?

EPFL

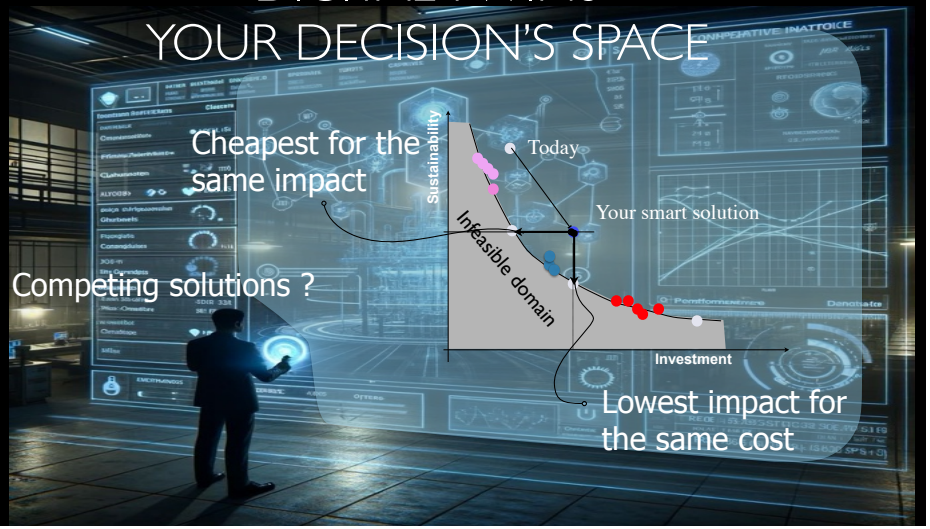
Le système énergétique du futur !



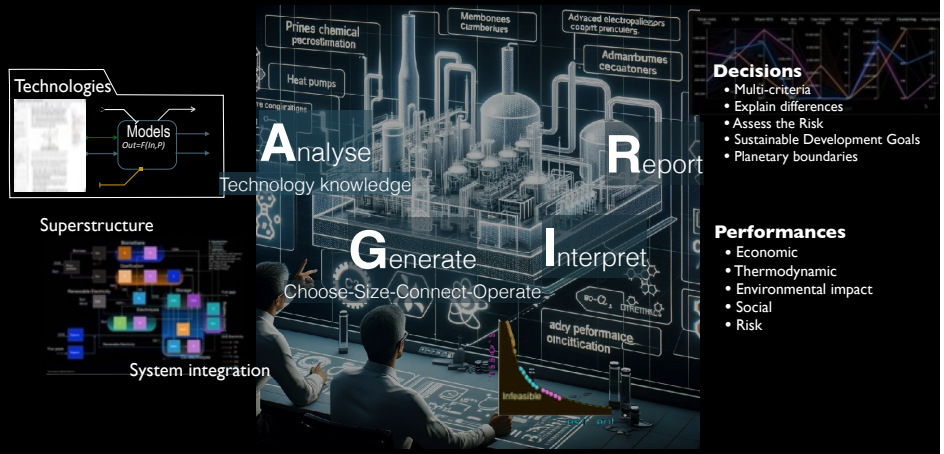
*ESG : Environment - Social - Gouvernance : règles des PFI

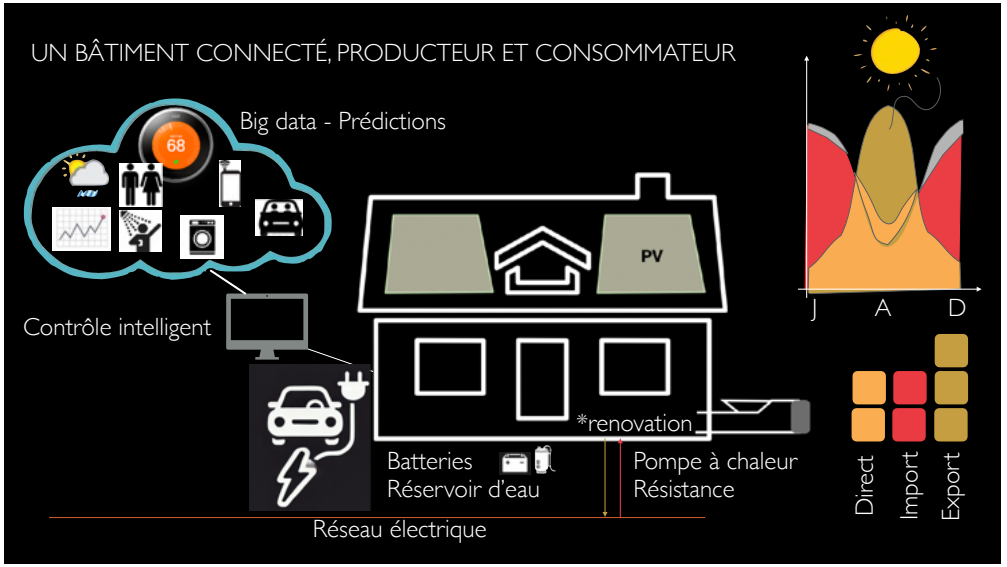
INTÉGRER L'INNOVATION

DIGITAL TWINS
YOUR DECISION'S SPACE



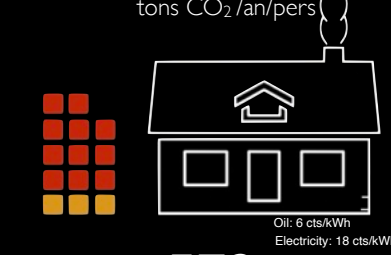
EPFL Our research : Digital Twins for process and energy systems engineering





MODÈLE : HUB ENERGIE RENOUVELABLE
90+ % REDUCTION DES EMISSIONS DE CO2

2.20
tons CO_2 /an/pers



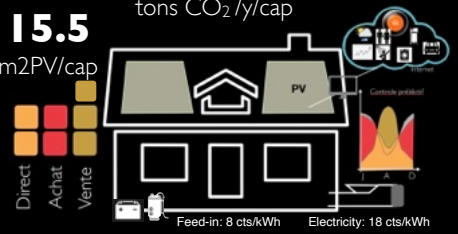
572
CHF/y/cap

Energy : **542** CHF/y/cap
Investment : **30** CHF/y/cap

2021

0.25 - 0.04
tons CO_2 /y/cap

15.5
m2PV/cap

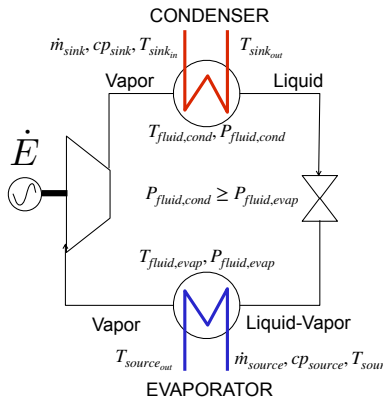


209
CHF/y/cap

PV feed-in : **-139** CHF/y/cap
Energy : **118** CHF/y/cap
Investment : **230** CHF/y/cap (x8)

EPFL **Calculating** $i_{u_{Q_{u,max}}}$ $[CHF/kW]$ **for a heat pump** 22

Sizing : condenser, evaporator & compressor



$$\dot{Q}_{u,t} = \dot{Q}_{sink,t} = \dot{m}_{sink,t} \cdot cp_{sink} \cdot (T_{sink_{out},t} - T_{sink_{in},t})$$

$$\dot{Q}_{sink,t} = \dot{m}_{fluid,t} \cdot (h(T_{fluid,cond_{in}}, P_{fluid,cond_{in},t} - h(T_{fluid,cond_{out}}, P_{fluid,cond_{out},t})$$

$$A_{condenser} = \max_{t \in lifetime} \left(\left(\frac{1}{u_{sink}} + \frac{1}{u_{fluid,cond}} \right) \frac{\dot{Q}_{sink,t}}{\frac{(T_{fluid,cond,t} - T_{sink_{in},t}) - (T_{fluid,cond,t} - T_{sink_{out},t})}{ln(T_{fluid,cond,t} - T_{sink_{in},t}) - ln(T_{fluid,cond,t} - T_{sink_{out},t})}} \right)$$

$$A_{evaporator} = \max_{t \in lifetime} \left(\left(\frac{1}{u_{source}} + \frac{1}{u_{fluid,evap}} \right) \frac{\dot{Q}_{source,t}}{\frac{(T_{source_{out},t} - T_{fluid,evap,t}) - (T_{source_{in},t} - (T_{fluid,evap,t})}{ln(T_{source_{out},t} - T_{fluid,evap,t}) - ln(T_{source_{in},t} - T_{fluid,evap,t})}} \right)$$

$$\dot{E}_{max} = \max_{t \in lifetime} \left(\frac{\dot{Q}_{u,t}}{COP_{u,t}} \right)$$

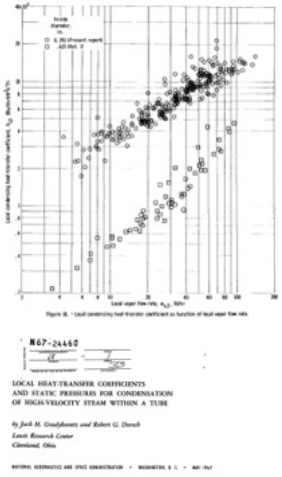
$$\dot{Q}_{source,t} = \dot{m}_{source,t} \cdot cp_{source} \cdot (T_{source_{in},t} - T_{source_{out},t})$$

$$\dot{Q}_{source,t} = \dot{m}_{fluid,t} \cdot (h(T_{fluid,evap_{out},t}, P_{fluid,evap_{out},t} - h(T_{fluid,evap_{in},t}, P_{fluid,evap_{in},t})$$

$$\dot{Q}_{source,t} = \dot{Q}_{sink,t} - \dot{E}_{u,t}$$

$$CAPEX_u = \frac{1}{\tau}(I_{HTX}(A_{condenser}) + I_{HTX}(A_{Evaporator}) + I_{compressor}(\dot{E}_{max}))$$

Nombres addimentionnels et coefficient de transfert



Données synthétisées dans un modèle

$$Nu = C \cdot Re^n \cdot Pr^m$$

où :

- $Nu = \frac{h \cdot L}{k_l}$
- $Re = \frac{4\Gamma}{\mu_l}$ (avec Γ : débit massique par unité de largeur $[kg/m \cdot s]$)
- $Pr = \frac{c_{p,l} \cdot \mu_l}{k_l}$

Les constantes C, n, et m dépendent de la géométrie et du régime d'écoulement (laminaire ou turbulent).

Exemple de corrélation pour un film laminaire sur une plaque verticale

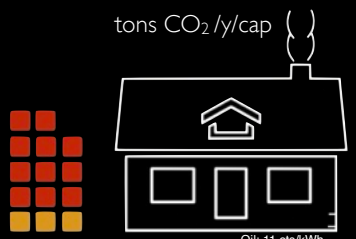
$$Nu = 0.943 \left(\frac{Re \cdot Pr}{4 + 9.66 \cdot \sqrt{Pr} + 10 \cdot Pr} \right)^{1/6}$$

Propriétés par modèles thermodynamiques

MODÈLE HUB ENERGIE RENOUVELABLE
90+ % REDUCTION DES EMISSIONS DE CO2

reho.readthedocs.ch

2.20
tons CO_2 /y/cap



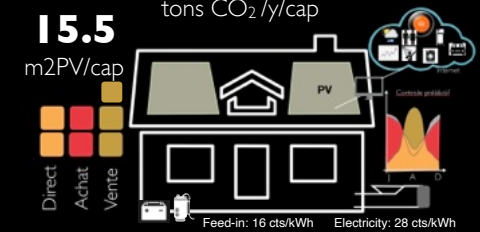
1132
CHF/y/cap

Energy : **1102** CHF/y/cap
Investment : **30** CHF/y/cap

2023

0.25 - 0.04
tons CO_2 /y/cap

15.5
m2PV/cap

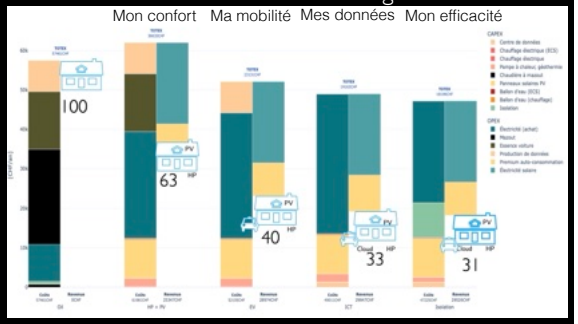


138
CHF/y/cap

PV feed-in : **-278** CHF/y/cap
Energy : **184** CHF/y/cap
Investment : **230** CHF/y/cap

GÉNÉRER DES OPTIONS

Utilisation sobre et efficace de l'énergie

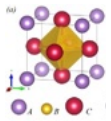


Producteur - Consommateur - Investisseur - Acteur

Data-driven fabrication of sustainable perovskite solar cells (PSCs)

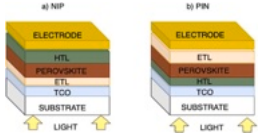
From molecules to layers to complete device

Molecules

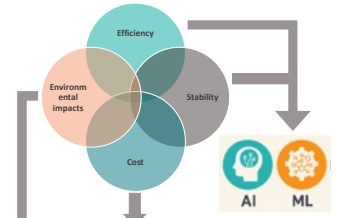


Fabrication process

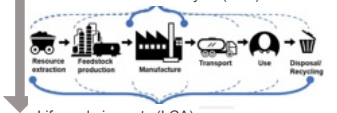
Layers



Models to evaluate
Multiple Key performance indicators



Techno-economic analysis (TEA)

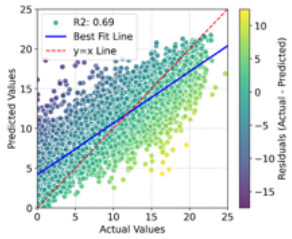


Life cycle impacts (LCA)

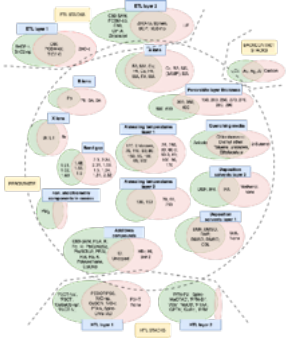
AI for PV fabrication

Predicting the key performance indicators

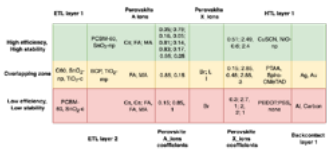
Predicting target indicators with LLMs



Analysing the decision variables affecting performances



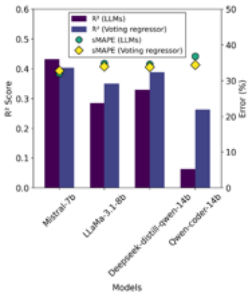
Clustering decision variables affecting multiple performances indicators



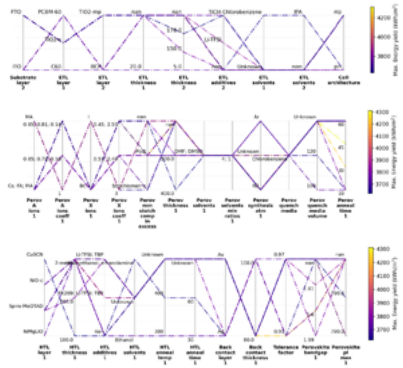
AI for PV fabrication

Inverse designing of procedures based on key performance indicators

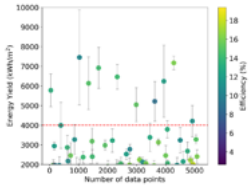
Reverse models



Recipe and fabrication procedure generation

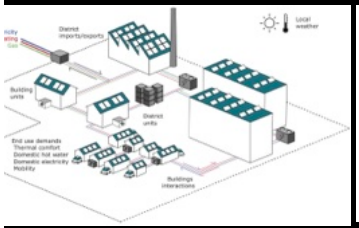


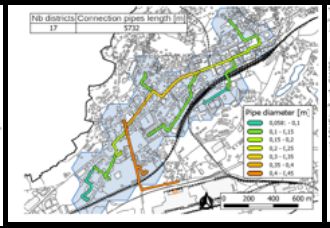
New recipes

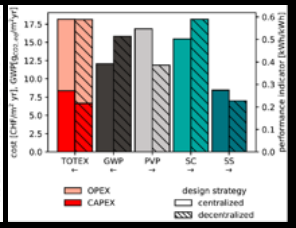


APPROCHE QUARTIER : L'OPTIMUM EST MIEUX QUE LA SOMME DES OPTIMUMS

Communautés d'énergie locales : synergie et mutualisation multi-énergie







Energie Renouvelable Chauffage urbain - Chaleur fatale - Déchet biomasse

→Coûts opérationnels: -9%

→Auto-consommation: +34%

→Investissement "prosumer": + 30%

SYSTEMS IN SYSTEMS

Dantzig-Wolf Decomposition

System problem

$$\min_{x_{b_o}} \sum_{b=1}^{n_b} \sum_{r=1}^{n_r} \sum_{t=1}^{n_t} \dot{m}^+_{b,r,t} \cdot c^+_{r,t} + \frac{1}{\tau} \cdot I_b$$

$$I_b = \sum_{o=1}^{n_o} x_{b_o} \cdot I_{b_o} \qquad \forall b \in \{1..n_b\}$$

$$\dot{m}_{b,r,t} = \sum_{o=1}^{n_o} x_{b_o} \cdot \dot{m}_{b_o,r,t} \qquad \forall b \in \{1..n_b\}$$

$$\sum_{o=1}^{n_o} x_{b_o} = 1 \qquad b \in \{1..n_b\}$$

Duality

$$c^+_{b_o,t} = f(x_{b_o})$$

Convergence

$$|c^+_{b_o,t} - c^+_{b_{o-1},t}| \leq \epsilon ?$$

yes = solution

$n_o = n_o + 1$

Sub-system problems

$\forall b \in \{1..n_b\}$ solve

$$\min_{\dot{m}^+_{b_o,r,t} I_{b_o}} \sum_{b=1}^{n_b} \sum_{r=1}^{n_r} \sum_{t=1}^{n_t} \dot{m}^+_{b_o,r,t} \cdot c^+_{b_o,t} + \frac{1}{\tau} \cdot I_{b_o}$$

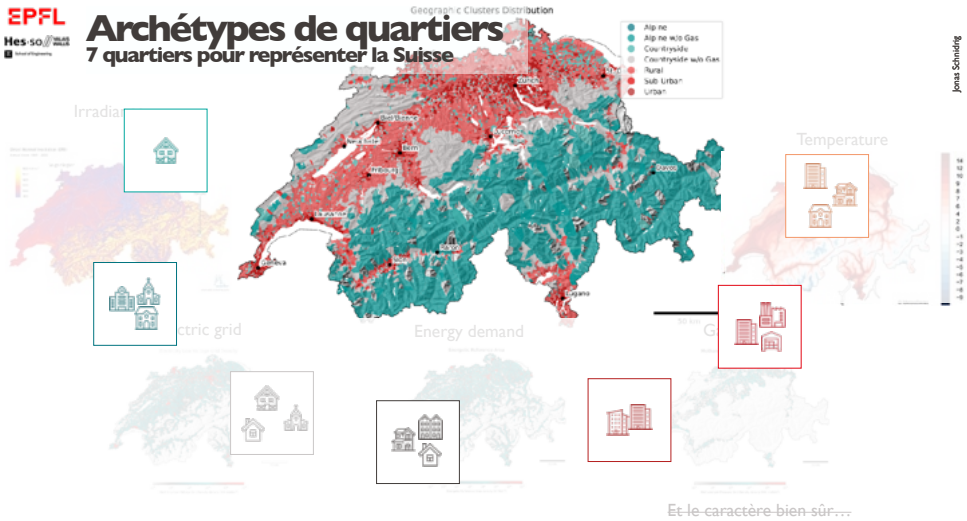
s.t. $F(\dot{m}^+_{b_o,r,t}, I_{b_o}) = 0$

$G(\dot{m}^+_{b_o,r,t}, I_{b_o}) \geq 0$

EPFL

Archétypes de quartiers

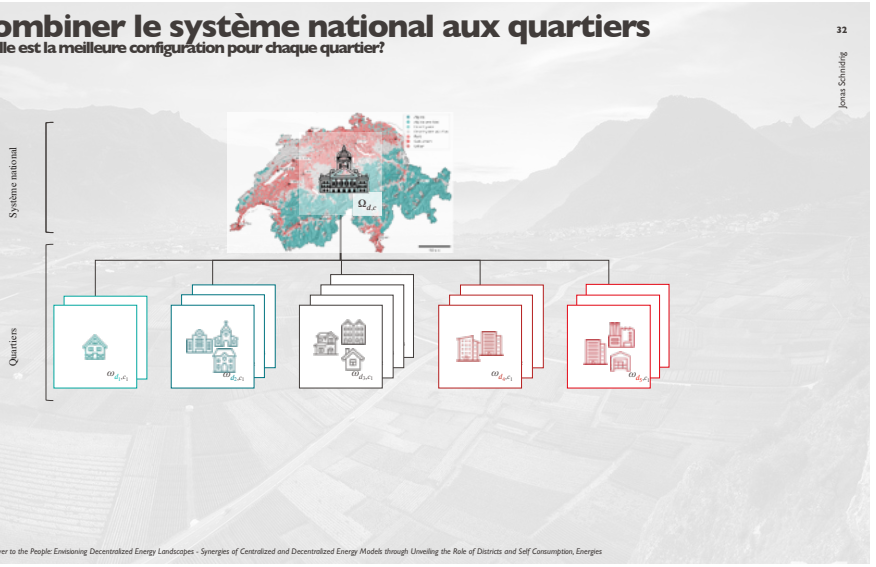
7 quartiers pour représenter la Suisse



Schnidrig et al. 2024, *Power to the People: Envisioning Decentralized Energy Landscapes - Synergies of Centralized and Decentralized Energy Models through Unveiling the Role of Districts and Self Consumption, Energies*

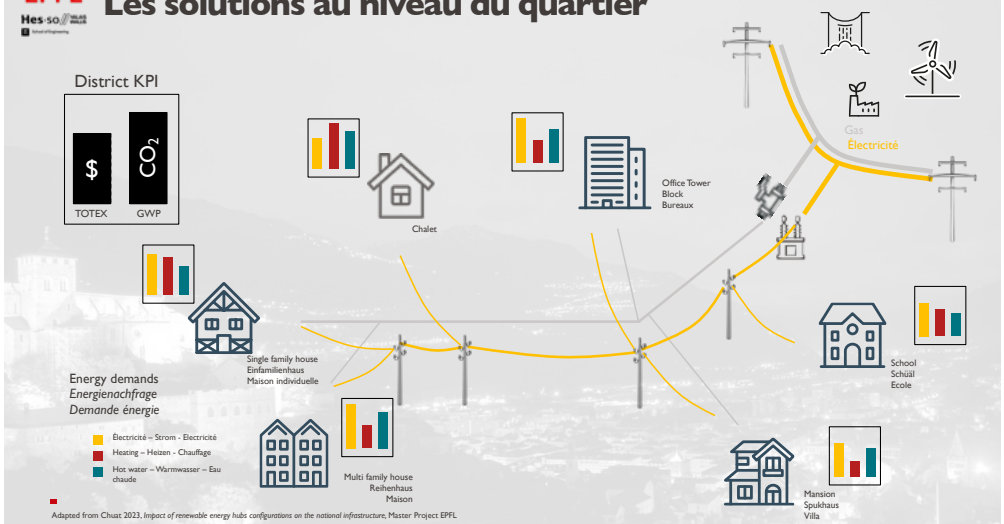
Combiner le système national aux quartiers

Quelle est la meilleure configuration pour chaque quartier?



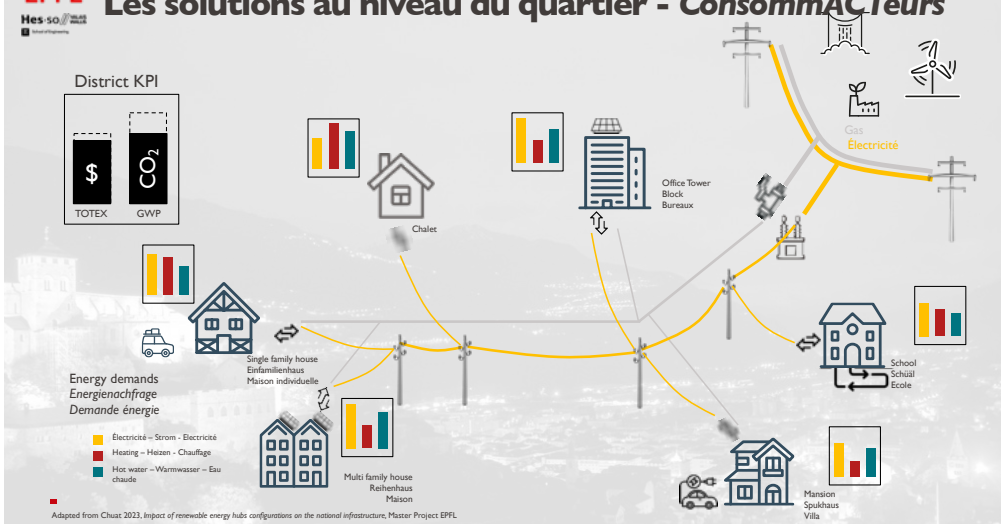
Schnidrig et al. 2024, *Power to the People: Envisioning Decentralized Energy Landscapes - Synergies of Centralized and Decentralized Energy Models through Unveiling the Role of Districts and Self Consumption, Energies*

Les solutions au niveau du quartier



Adapted from Chuat 2023, *Impact of renewable energy hubs configurations on the national infrastructure*, Master Project EPFL

Les solutions au niveau du quartier - *ConsommACTeurs*



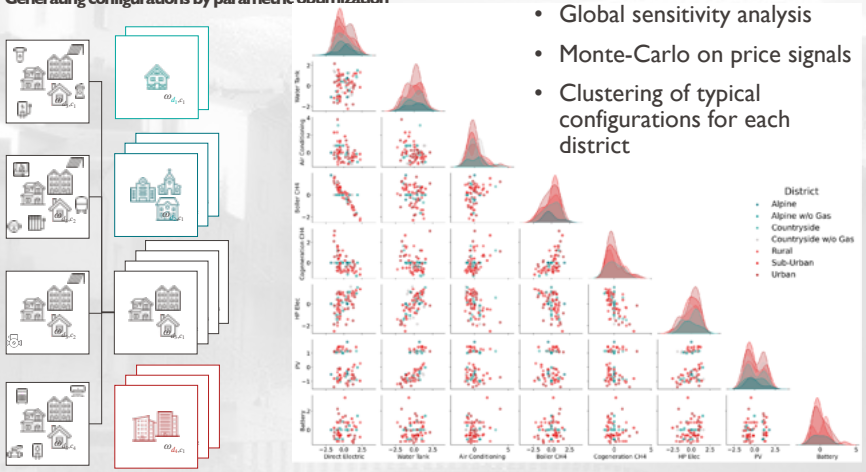
Adapted from Chuat 2023, *Impact of renewable energy hubs configurations on the national infrastructure*, Master Project EPFL

Jonas Schnidrig

District energy system archetypes

Generating configurations by parametric optimization

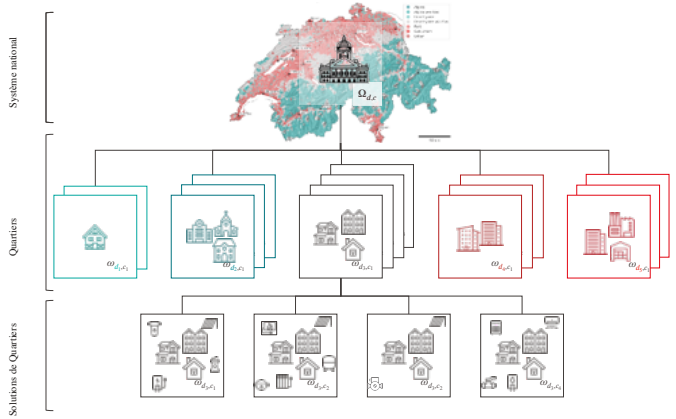
- Global sensitivity analysis
- Monte-Carlo on price signals
- Clustering of typical configurations for each district



Schnidrig et al. 2024, *Power to the People: Envisioning Decentralized Energy Landscapes - Synergies of Centralized and Decentralized Energy Models through Unveiling the Role of Districts and Self Consumption, Energies*

Jonas Schnidrig

Intégrer les technologies futures dans le système énergétique local et national

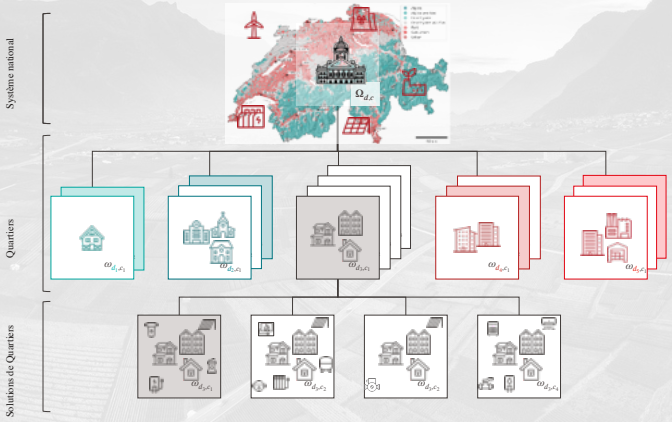


Schnidrig et al. 2024, *Power to the People: Envisioning Decentralized Energy Landscapes - Synergies of Centralized and Decentralized Energy Models through Unveiling the Role of Districts and Self Consumption, Energies*

Combiner le système national aux quartiers

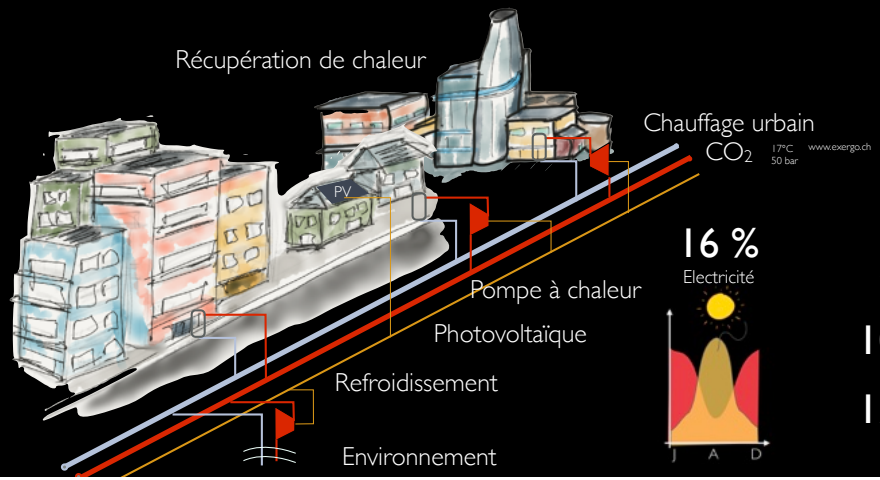
Un équilibre entre solutions régionales et nationales

Jonas Schnidrig



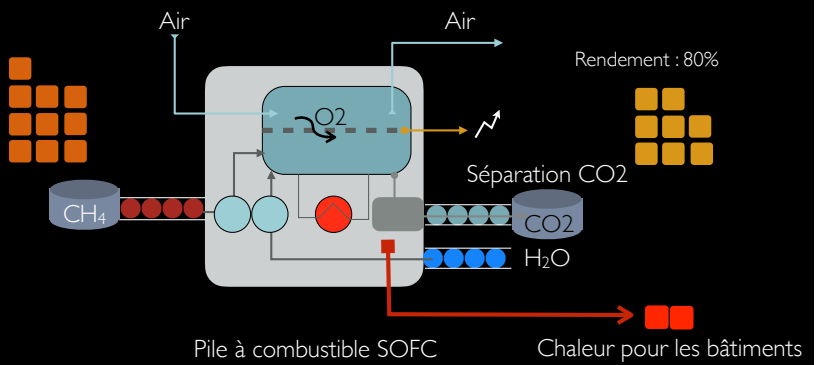
Schnidrig et al. 2024, *Power to the People: Envisioning Decentralized Energy Landscapes - Synergies of Centralized and Decentralized Energy Models through Unveiling the Role of Districts and Self Consumption, Energies*

POMPE À CHALEUR URBAINE ET PHOTOVOLTAÏQUE



10% IMPORT : PILE À COMBUSTIBLE

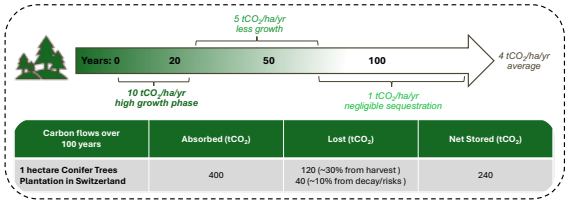
Import



Direct Air Capture by Nature

- **LCA approach** for Carbon Sequestration:
  - Time horizon: 100 years
  - Forest management practices, including harvests
  - Natural decay (e.g., deadwood, fires, pests, etc.)

Net CO2 Sequestered = Carbon absorbed by forest growth - Harvest - Decay/risks



Carbon flows over 100 years	Absorbed (tCO_2)	Lost (tCO_2)	Net Stored (tCO_2)
1 hectare Conifer Trees Plantation in Switzerland	400	120 (~30% from harvest) 40 (~10% from decay/risks)	240

Direct air capture by nature

- 0.52 $[kg_{dry}/kg_{CO2}]$
- $\dot{E}^{-}_{LHV} = +10.4$ $[MJ/kg_{CO_2}]$
- $\dot{E}^{-}_{LHV} = +41.6$ $[GJ/ha/year]$
  or 1300 $[W/ha]$

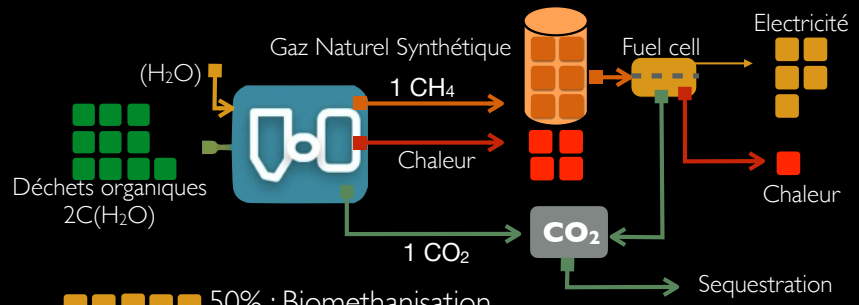
compare with Direct Air Capture

- $\dot{Q}^{-}_{th} = -(4.4 - 5.4)$ $[MJ/kg_{CO_2}]$
- $\dot{E}^{-} = -(0.36 - 1.0)$ $[MJ/kg_{CO_2}]$

0.1-0.2 % photosynthesis efficiency

Dardor D, Flórez-Orrego D, Ribeiro Domingos ME, Germanier R, Margni M, Maréchal F. CO2 Capture and Management Strategies for Decarbonizing Secondary Aluminium Production. ESCAPE 2024 - 34th European Symposium on Computer Aided Process Engineering [Internet]. Florence, Italy; 2024. https://infoscience.epfl.ch/record/311522?&ln=en

LA RESSOURCE BIOMASSE



50% : Biomethanisation
70% : Gasification Hydrothermale (trea-tech.com)
70% : Gasification et gaz naturel de synthèse

Gassner et al., Energy & Environmental Science 4, no. 5 (2011): 1742. Gassner et al., Energy and Environmental Science 5, no. 2 (2012):

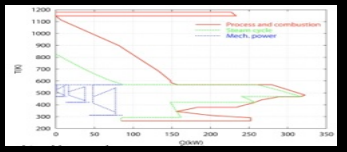
EPFL

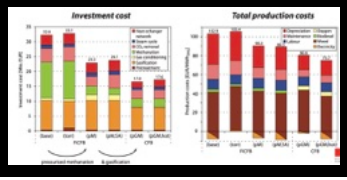
PROCESS DESIGN MODELS

Super-Structure
- Flowsheeting models
- Process unit model data base

System integration
- Heat recovery
- Energy conversion
- Waste + Water

Performances
- OPEX
- CAPEX
- LCA
- Thermodynamic





Gassner, M.; Maréchal, F. Thermo-Economic Optimisation of the Polygeneration of Synthetic Natural Gas (SNG), Power and Heat from Lignocellulosic Biomass by Gasification and Methanation. *Energy Environ. Sci.* **2012**, *5* (2), 5768–5789. https://doi.org/10.1039/c1ee02565d

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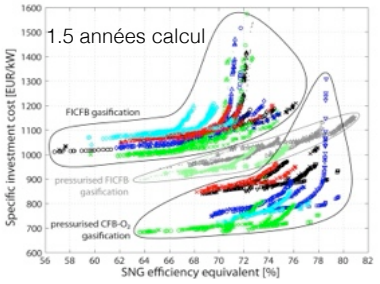
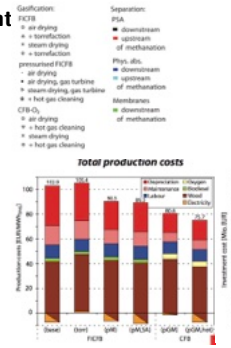
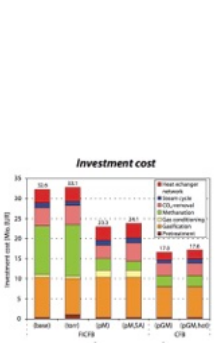
BIOMASS TO SYNTHETIC NATURAL GAS

Thermo-economic Pareto front (cost vs efficiency):







Gassner, M.; Maréchal, F. Thermo-Economic Optimisation of the Polygeneration of Synthetic Natural Gas (SNG), Power and Heat from Lignocellulosic Biomass by Gasification and Methanation. *Energy Environ. Sci.* **2012**, *5* (2), 5768–5789. https://doi.org/10.1039/c1ee02565d

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DEALING WITH UNCERTAINTIES

Taking decision — Generating solutions — What are the most probable best solutions

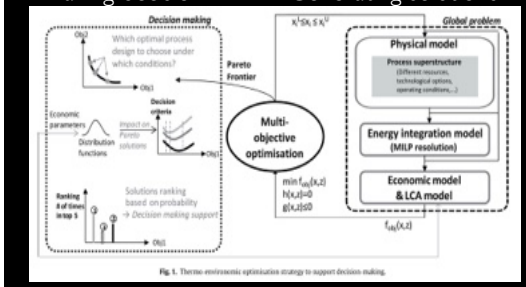
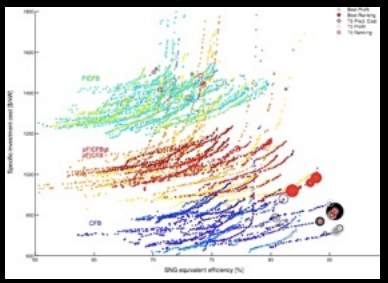
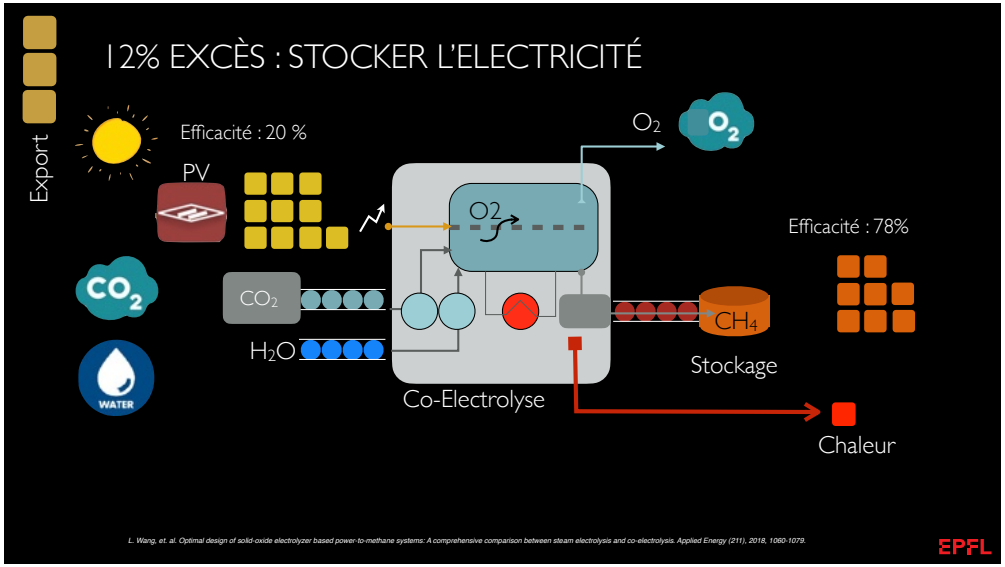


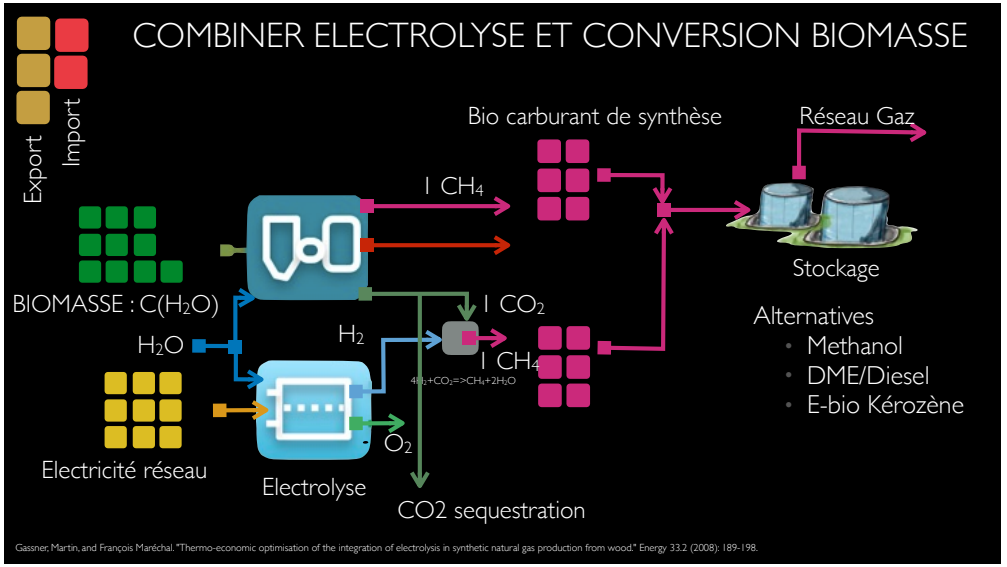
Fig. 1. Thermo-environomic optimization strategy to support decision making.



Teck, L.; Maréchal, F. Decision Support for Ranking Pareto Optimal Process Designs under Uncertain Market Conditions. Computers & Chemical Engineering 2015, 83, 165–175. https://doi.org/10.1016/j.compchemeng.2015.06.009

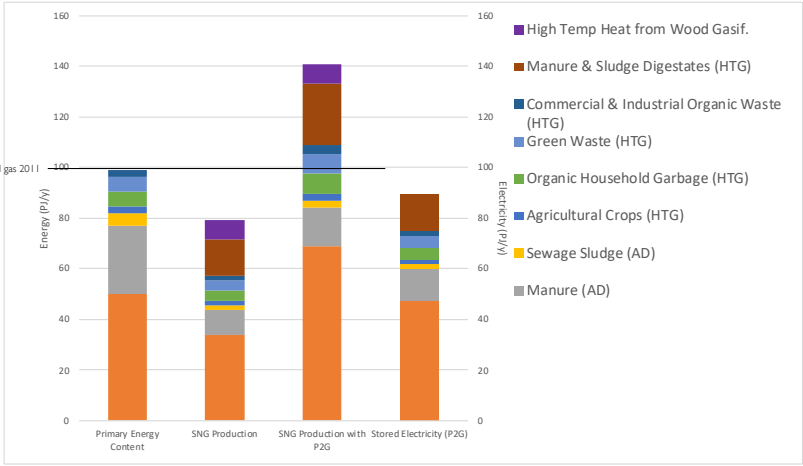
EPFL



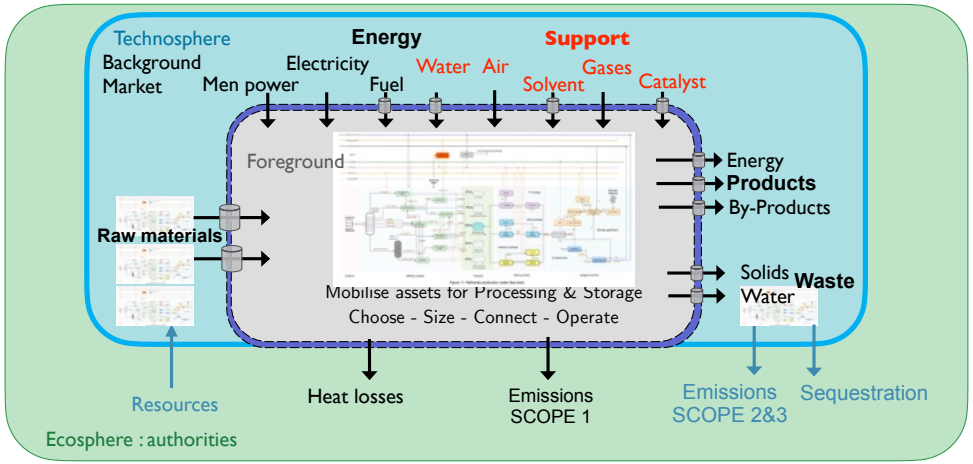


SNG from biomass: potential in Switzerland

IPESE EPFL



EPFL L'industrie et l'innovation

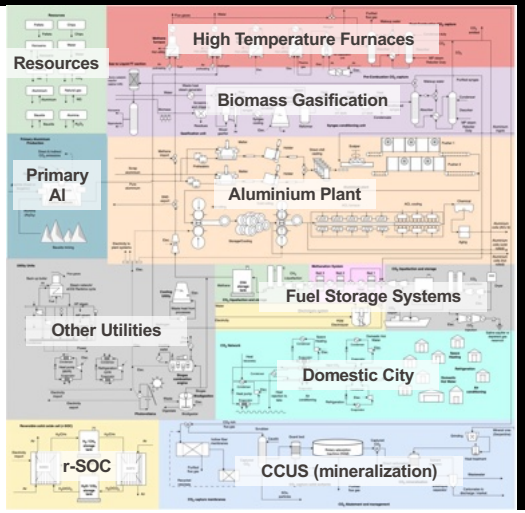


IPESE

INNOVATION ?

Process routes
+
decarbonisation
technologies

Novelis Sierre & Oiken



[1] Flórez-Orrego D., Dardor D., Maréchal F. et al. 2023. "A Systemic Study for Enhanced Waste Heat Recovery and Renewable Energy Integration towards Decarbonizing the Aluminium Industry." ECOS 2023.

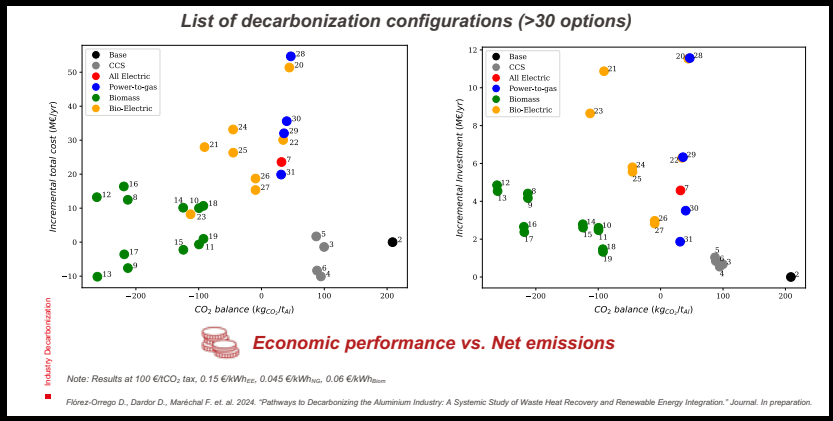
[2] Dardor D., Flórez-Orrego D., Maréchal F. et al. "CO2 Capture and Management Strategies for Decarbonizing Secondary Aluminium Production". ESCAPE34, 2024.

[3] Flórez-Orrego D., Dardor D., Maréchal F. et al. "Renewable Energy Integration and Waste Heat Recovery for the Production of Sustainable Jet Fuel and Decarbonization of Industrial Heating Applications." AIChE 2023.

[4] Dardor, D., Flórez-Orrego D., Maréchal F. et al. "Decarbonizing the Production of Primary Aluminium Using Renewable Resource." AIChE 2023.

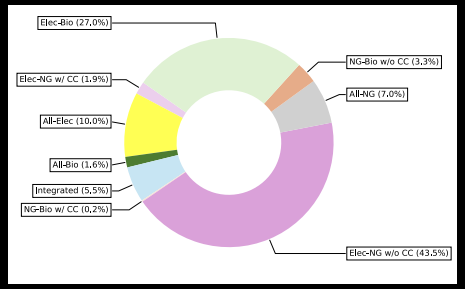
Industry Decarbonization

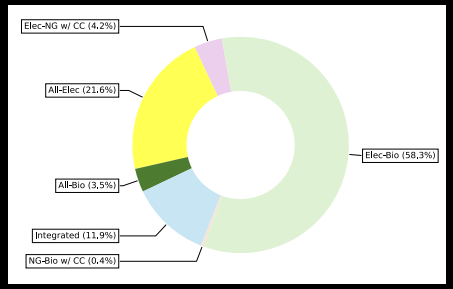
GÉNÉRER LES OPTIONS ET LES COMPARER



Industry Decarbonization

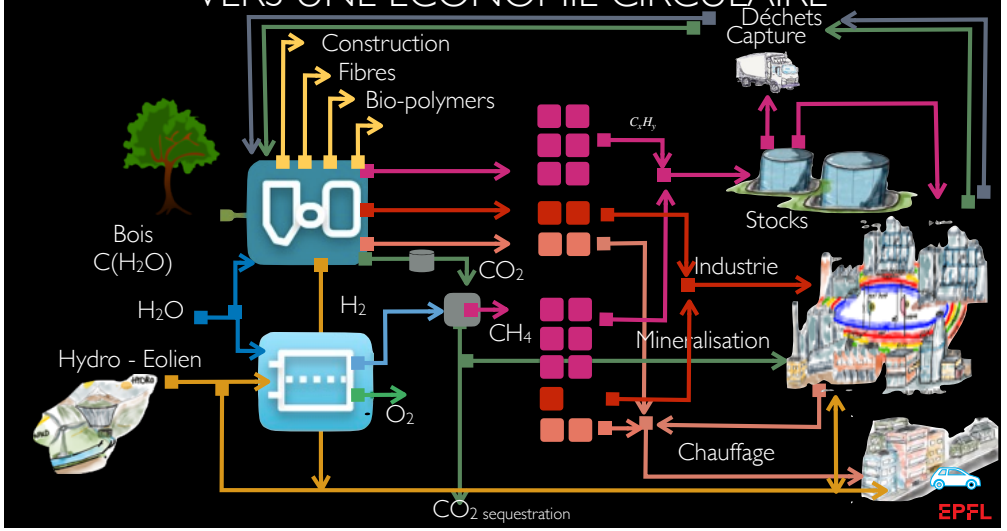
QUELLES SONT LES PLUS PROBABLES DANS CE MONDE INCERTAIN ?



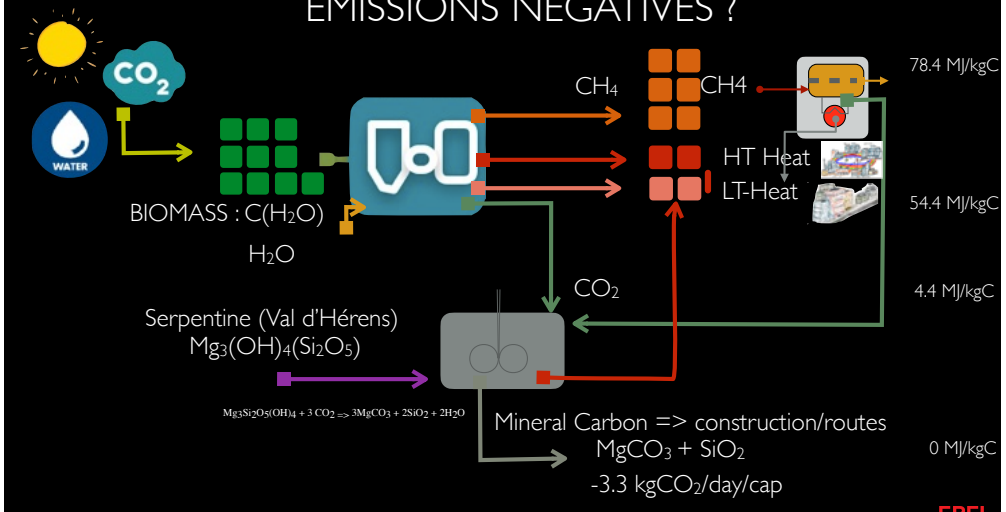


Dareen Dardor et al., ECOS 2024, EC&M under revision

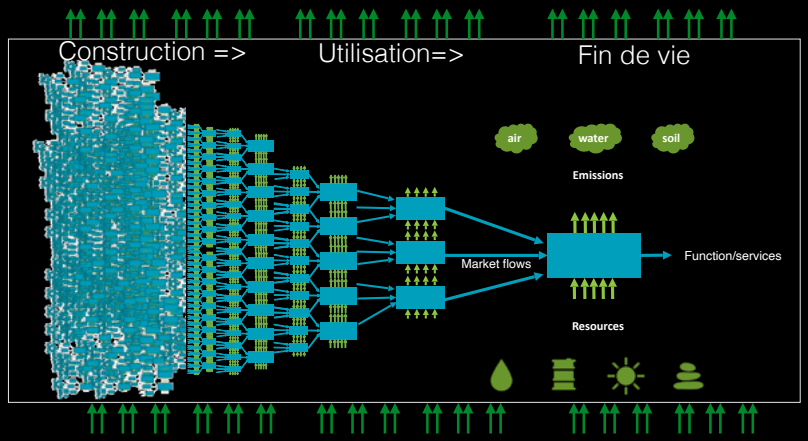
VERS UNE ÉCONOMIE CIRCULAIRE



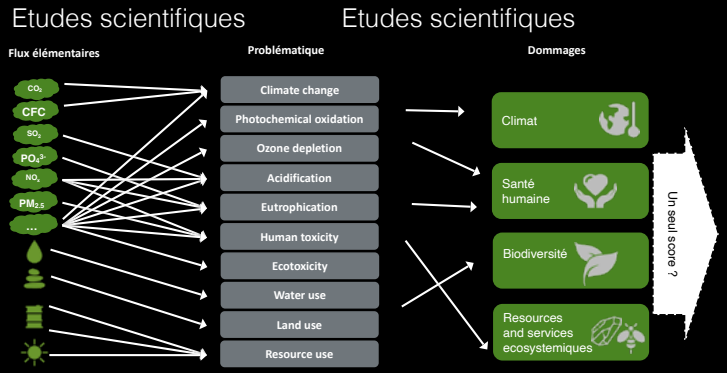
EMISSIONS NÉGATIVES ?



L'IMPACT DES SOLUTIONS



DÉVELOPPEMENT DURABLE: PERFORMANCES

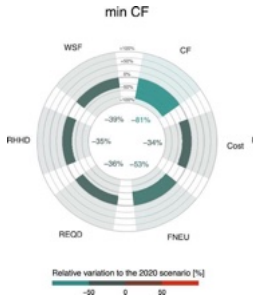


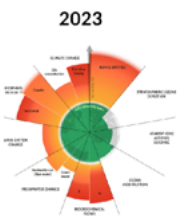
Absolute Environmental Sustainability Assessment (AESA)

SOS : Safe Operating Space

Whole life cycle

Multiple indicators



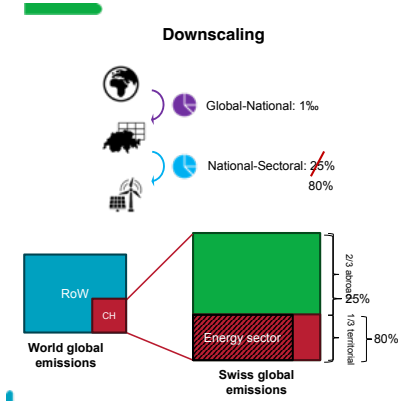


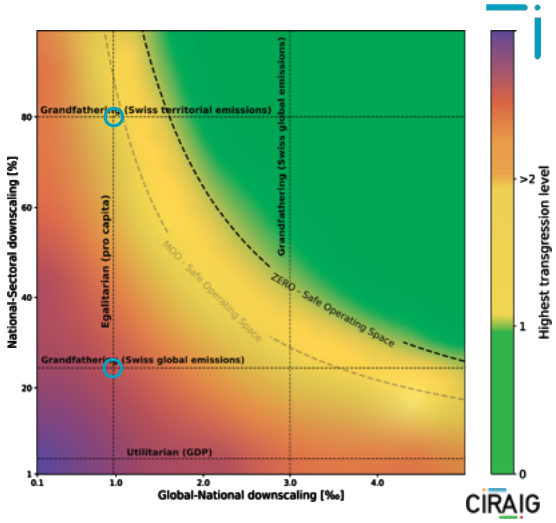
9 boundaries assessed, 6 crossed

Schnidrig, J., Souttre, M., Chuat, A., Maréchal, F., & Margni, M. (2024). Between green hills and green bills: Unveiling the green shades of sustainability and burden shifting through multi-objective. *Journal of Environmental Management*
Stockholm Resilience Centre (2025). Planetary boundaries. Stockholm University.

CIRAIG

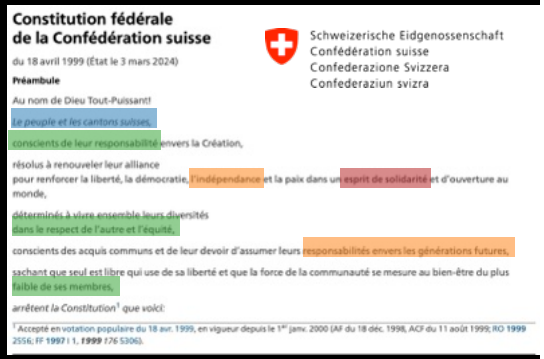
Impact of downscaling methods





QUI PREND LES DÉCISIONS?
MODÉLISATION D'UN DICTATEUR BIENVEILLANT

- Quelles contraintes :
  - Sécurité d'approvisionnement
  - Indépendance
  - Neutralité en CO2
- Quel objectif :
  - Moindres coûts pour la société en bon père de famille
- Quels critères :
  - Impact environnemental - social - bien-être



Constitution fédérale de la Confédération suisse

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

du 18 avril 1999 (État le 3 mars 2024)

Préambule

Au nom de Dieu Tout-Puissant!

Le peuple et les cantons suisses,

conscients de leur responsabilité envers la Création,

résolus à renouveler leur alliance
pour renforcer la liberté, la démocratie, l'indépendance et la paix dans un esprit de solidarité et d'ouverture au monde,

déterminés à vivre ensemble leurs diversités
dans le respect de l'autre et l'équité,

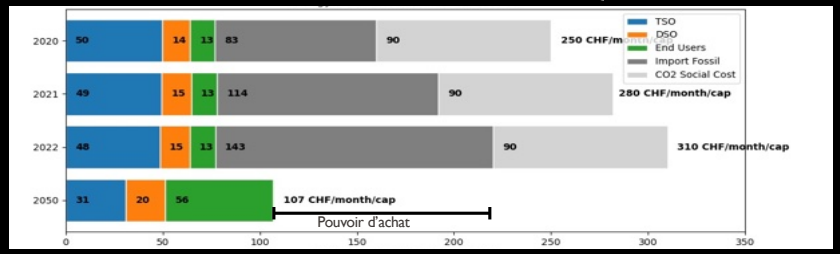
conscients des acquis communs et de leur devoir d'assumer leurs responsabilités envers les générations futures,

sachant que seul est libre qui use de sa liberté et que la force de la communauté se mesure au bien-être du plus faible de ses membres,

arrêtent la Constitution[1] *que voici:*

[1] Accepté en votation populaire du 18 avr. 1999, en vigueur depuis le 1er janv. 2000 (AF du 18 déc. 1998, ACF du 11 août 1999; RO 1999 2556; FF 1997 I 1, 1999 I 76 5306).

LE SYSTÈME ÉNERGÉTIQUE SUISSE



x 5 : Investissement **quartiers (communautés d'énergie locales)**
Remplace **66%** des **achats fossiles**

x 1.8 Augmentation des investissements distribution **(DSO)** : gestion locale

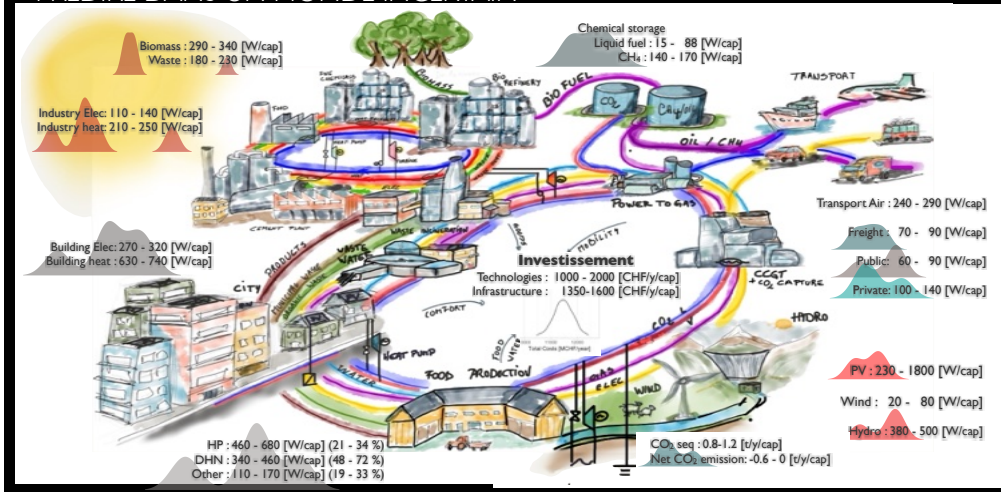
-40% : Réduction des investissements transmission **TSO)**

33% à 50% : pouvoir d'achat

✓ **Frein à l'endettement:** Dettes sociales des **émissions de CO2**

✓Stabilité des prix et sécurité d'approvisionnement (indépendance)

PRÉDIRE DANS UN MONDE INCERTAIN

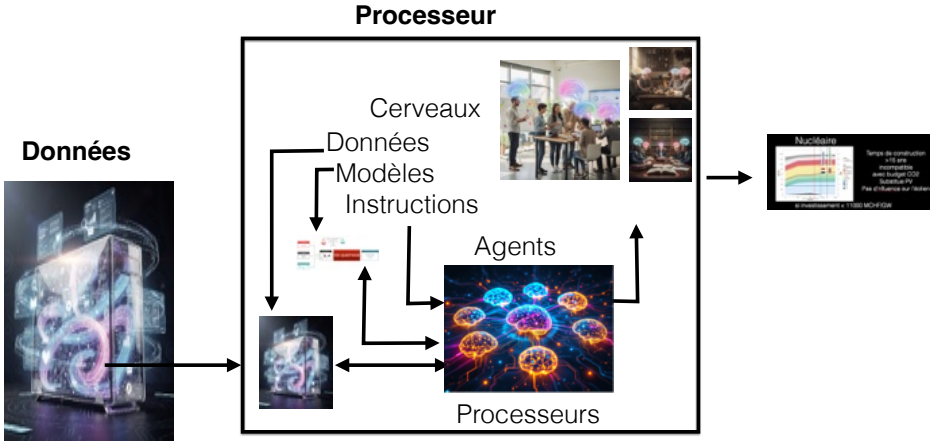


Energyscope
Jumeau numérique du système énergétique

Jonas Schnidrig

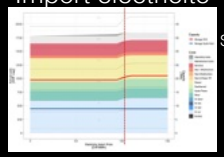
Large Language Models

- Quel est le prix du nucléaire pour que la solution nucléaire soit moins chère pour la suisse ?



INTELLIGENCE ?

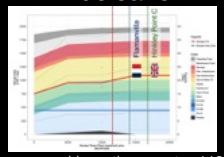
Import électricité



Services réseaux possibles

si <105 CHF/MWh

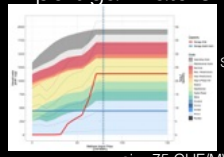
Nucléaire



Temps de construction
>15 ans
incompatible
avec budget CO2
Substitue PV
Pas d'nfluence sur l'éolien

si investissement < 11000 MCHF/GW

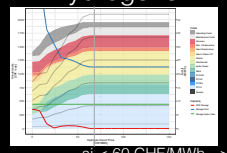
Import gaz naturel



Emissions CO2
Scope 2 à compenser

si < 75 CHF/MWh

Hydrogène



Infrastructure à développer
Pas de besoins de H2 molecule

si < 60 CHF/MWh => elec < 4 cts/kWh !

Intelligence politique ?

Knowing the repartition of political parties in Switzerland what is to your opinion the probability of each of those scenarios

In summary:
- Most likely: SSP4-CH - The Divided Track (35%)
- Moderately likely: SSP1-CH - The Electric Track (30%)
- Less likely: SSP3-CH - The Downhill Road (20%) and SSP5-CH - The Highway (15%)

For each of the scenarios, write a one o po age proposal for an initiative that would allow people to accept and realise the selected scenarios

RÉPONDRE À VOS QUESTIONS

EnergyScope
(Open source)

Master of Advanced Studies
Sustainable Energy Systems Engineering
(Formation continue)

REHO
(Open - Source)