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Prof. Dr. Regina Betz: Subproject 3 Lead: CEE/ZHAW

What are «hard-to-abate emissions» or “remaining emissions” in Switzerland?

Disentis Energieforschungsgespräche 2025, Disentis, 31.1.2025

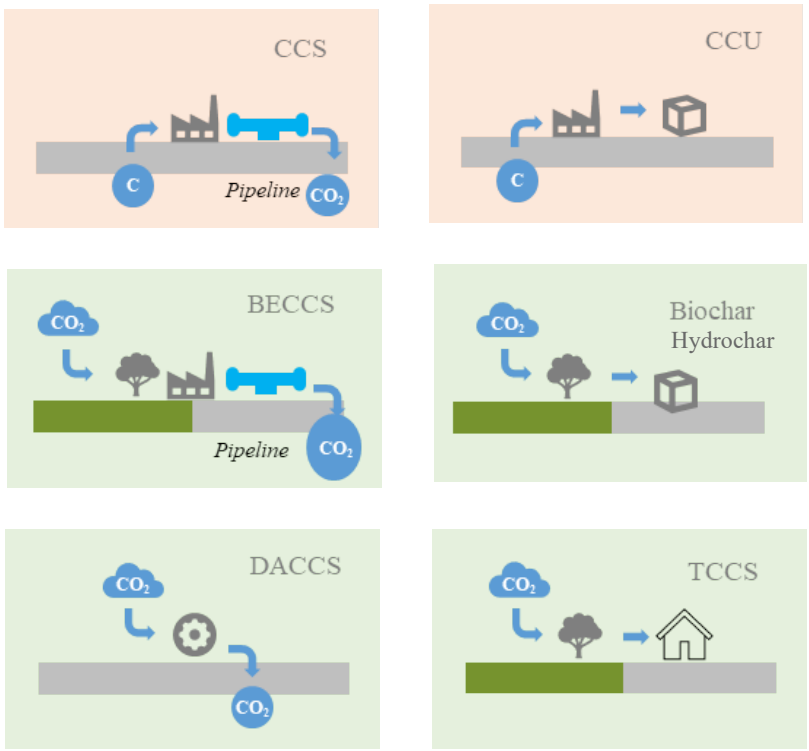
DeCIRRA: Decarbonisation of CIties and Regions with Renewable gAses

Overview of thematic session

Time	Topic	Presenter
14:30	What are “hard-to-abate emissions” or “remaining emissions” in Switzerland?	Regina Betz
14:40	Which scenarios were analysed and what are the major outcomes?	Christina Marchand
15:00	What policies are necessary to achieve the net-zero target of Switzerland?	Paula Castro
15:10	How are the distributional effects of the policies analysed?	Florian Landis
15:20	Discussion Roundtables • What is the probability for the different scenarios? • What is the strategy for Switzerland to buy necessary international offsets? • What policies are missing in the analysis?	Christina / Florian Regina / Raphaela Paula / David
15:50	Final discussion	
16:00	End	

CCUS Ansätze und Ziel des SP3

CCS: Carbon Capture and Storage
CCU: Carbon Capture and Use
BECCS: Bioenergy with CCS
TCCS: Timber with CCS



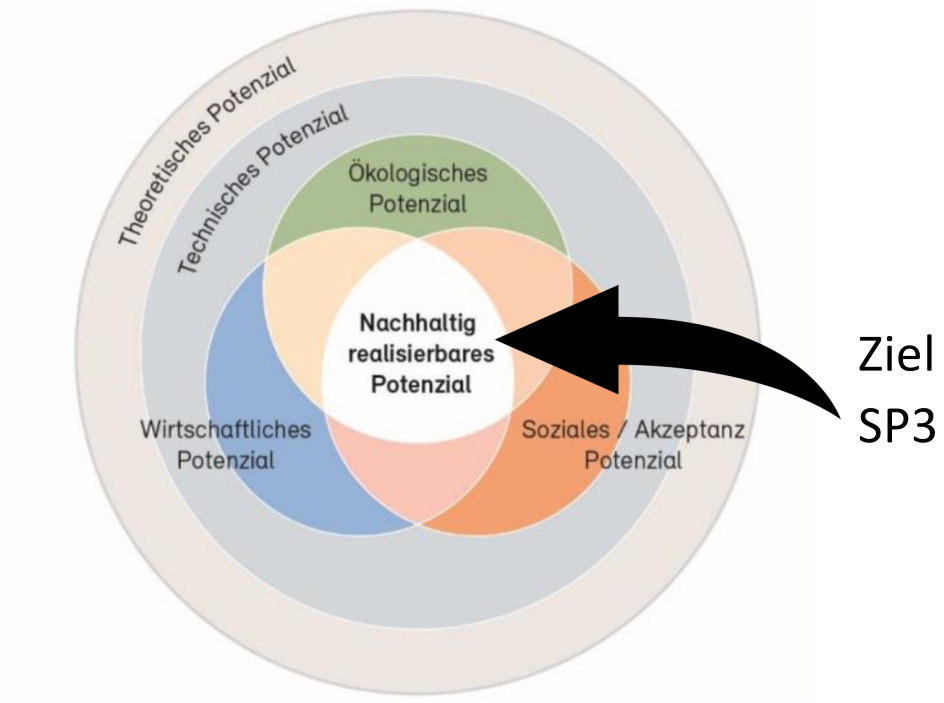


Abbildung 1: Definition des nachhaltig realisierbaren Potenzials

Bundesrat. (2020). *Von welcher Bedeutung könnten negative CO_2-Emissionen für die künftigen klimapolitischen Massnahmen der Schweiz sein? Bericht des Bundesrates in Erfüllung des Postulates 18.4211 Thorens Goumaz vom 12. Dezember 2018*. Bern

Vorstellung Implementierungspartner SP3

Akademische Partner

ETH zürich

zhaw (SP3 Lead)

PAUL SCHERRER INSTITUT PSI

Unterauf-trag

perspectives climate group public sector

Haupt-implemen-tierungspartner

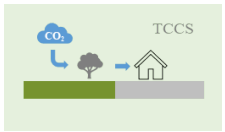
TIMBER FINANCE INITIATIVE

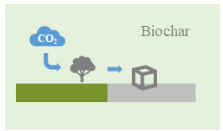
S-WIN Swiss • Wood • Innovation • Network

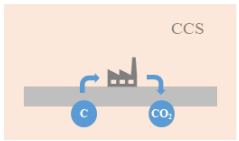
cemsuisse

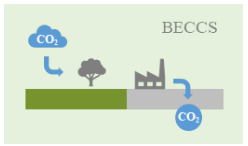
renergia

energie ausserschwyz



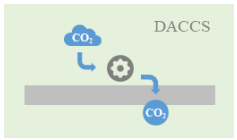




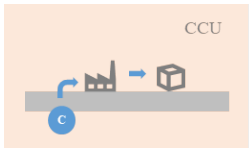


Weitere Implemen-tierungs-partner

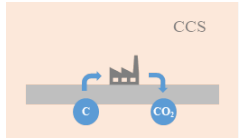
CLIMEWORKS



NeoCarbons Innovate for Prosperity



QAPTIS



Stiftung Klimarappen
Fondation Centime Climatique
Fondazione Centesimo per il Clima
Climate Cent Foundation

WWF

Definitions «hard-to-abate emissions» & «remaining emissions»

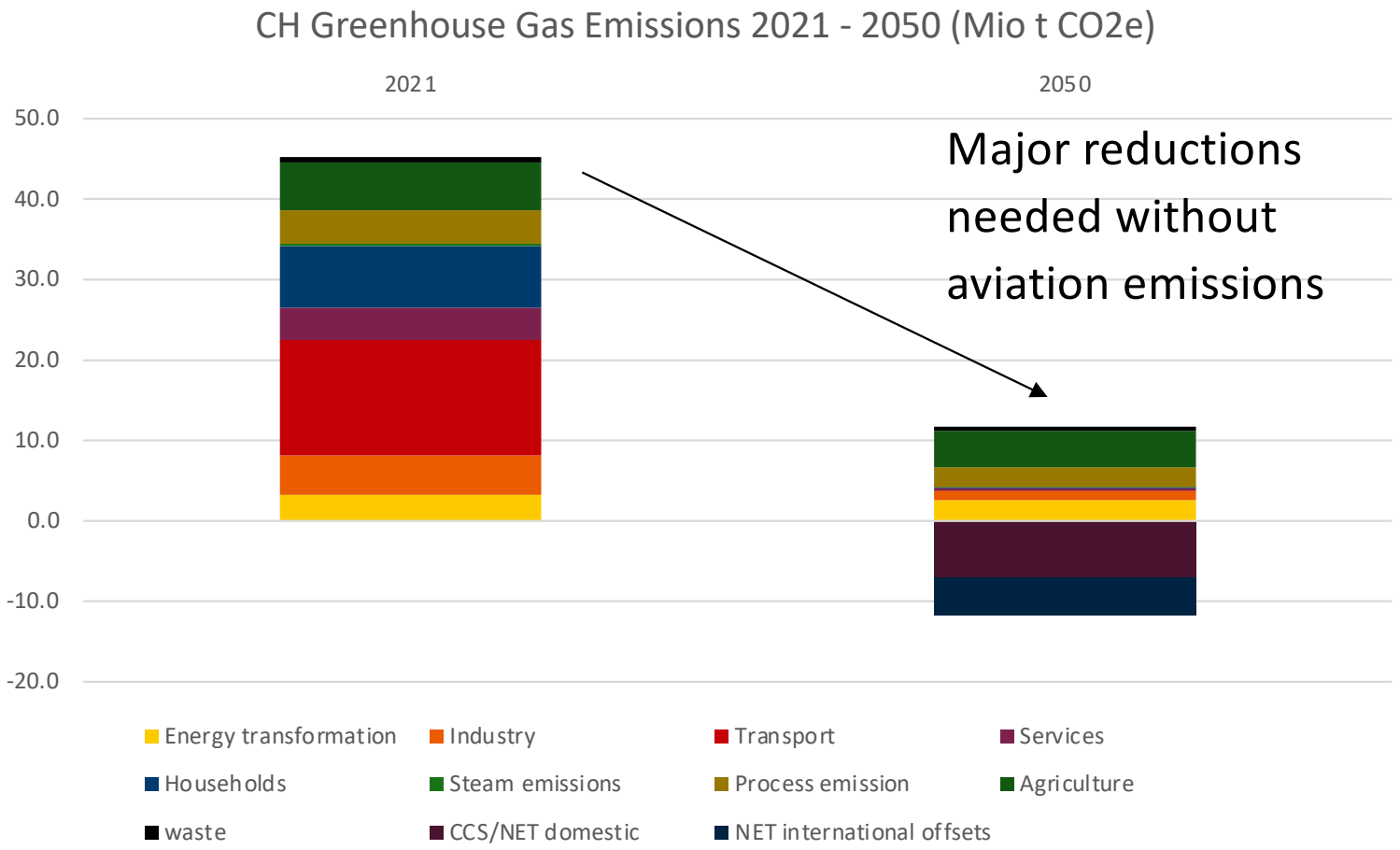
Hard-to-abate-emissions are either:

1. prohibitively costly
2. politically unpopular
3. impossible to reduce with current technology

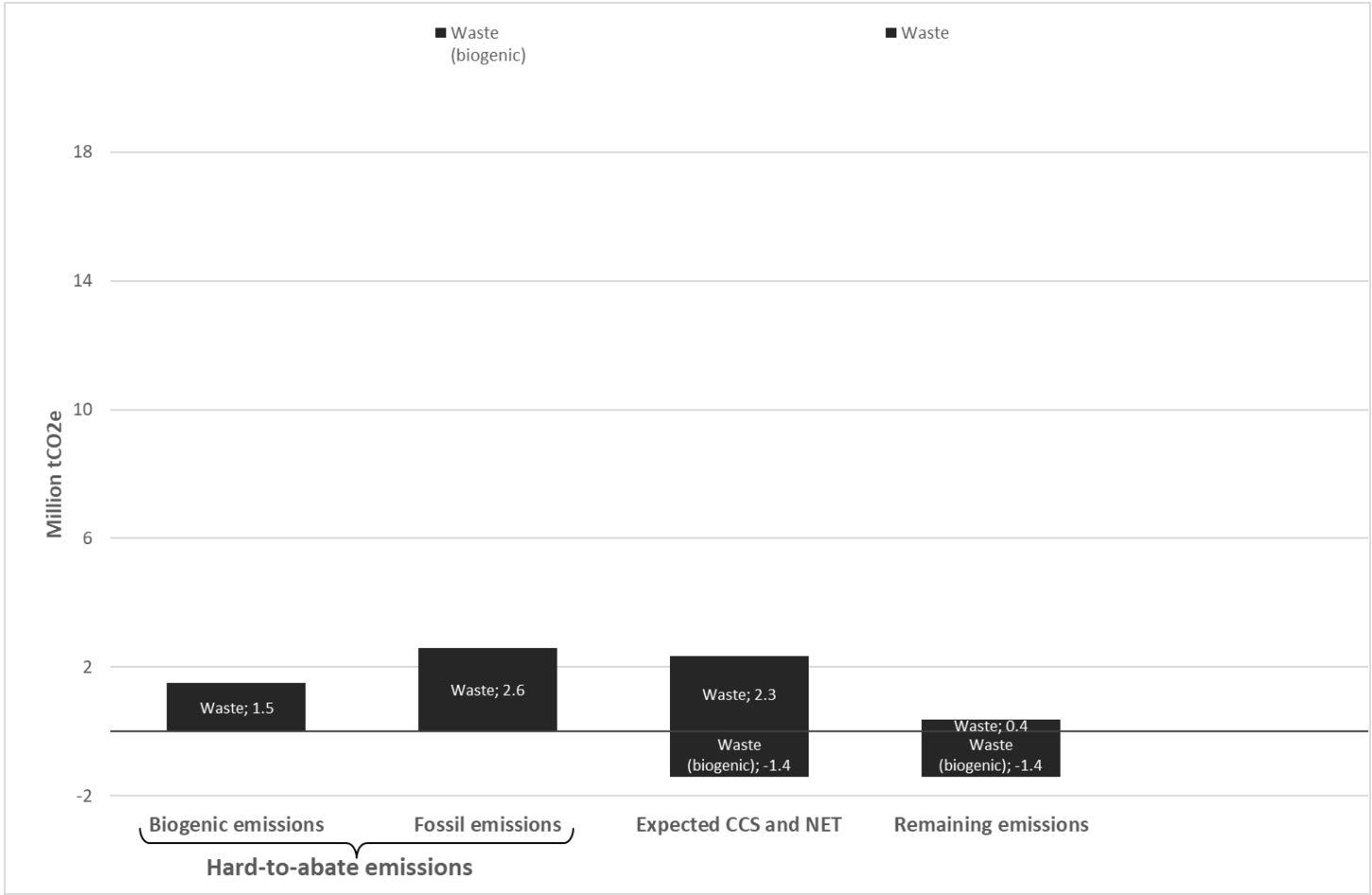
"Hard-to-abate emissions" **can only be avoided with Carbon Capture and Storage or compensated with negative emissions technology (NET) or reduced if high costs and political difficulties are accepted**.

Remaining emissions are emissions **after CCS**, which need to be compensated with NET.

Greenhouse Gas Emissions 2021 vs 2050

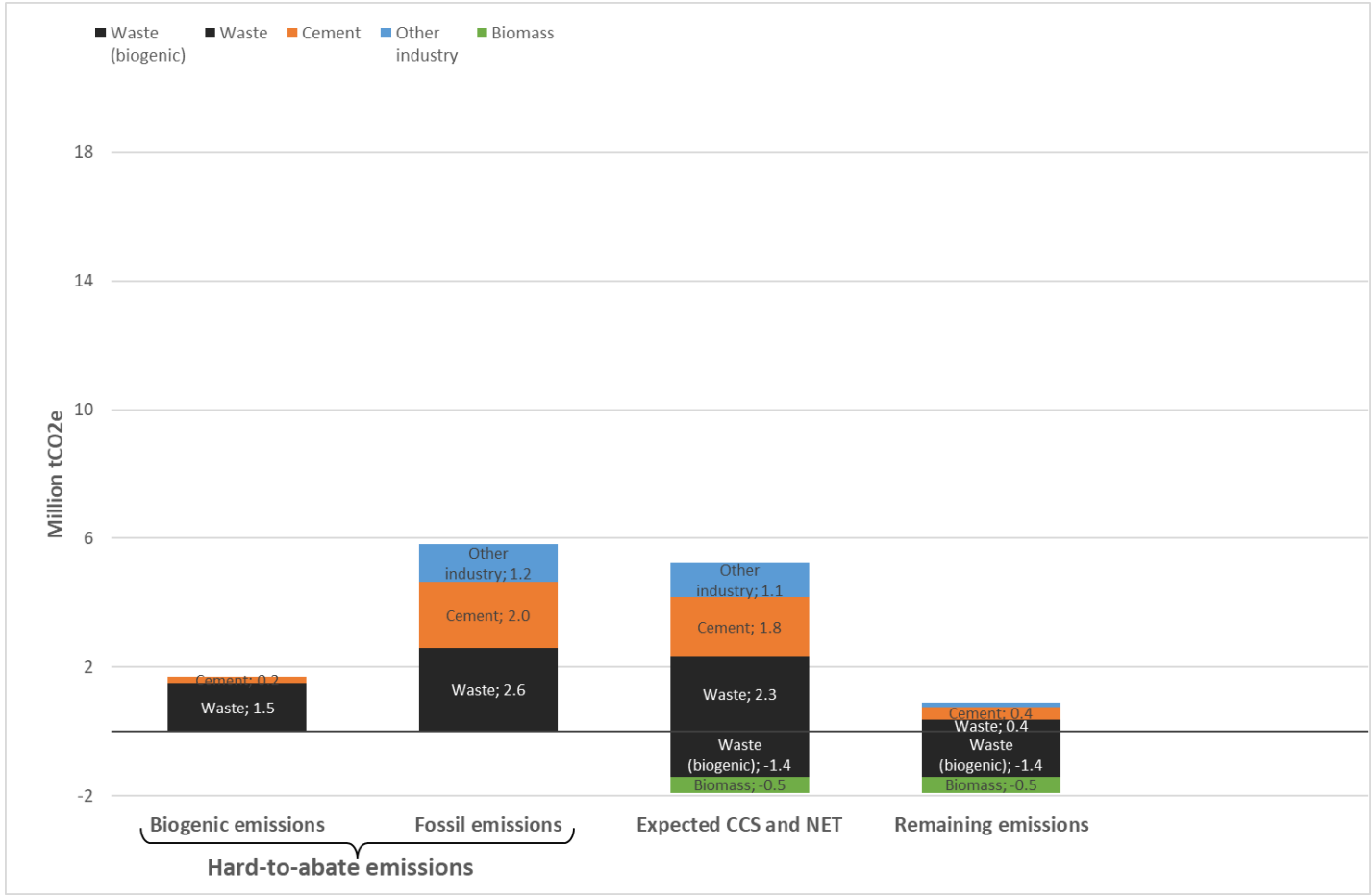


Waste incineration (without landfill) sector in 2050



https://decirra.ch/download/decirra-sp3-scenario-report-dec-2024/

Waste & Cement & other industries in 2050



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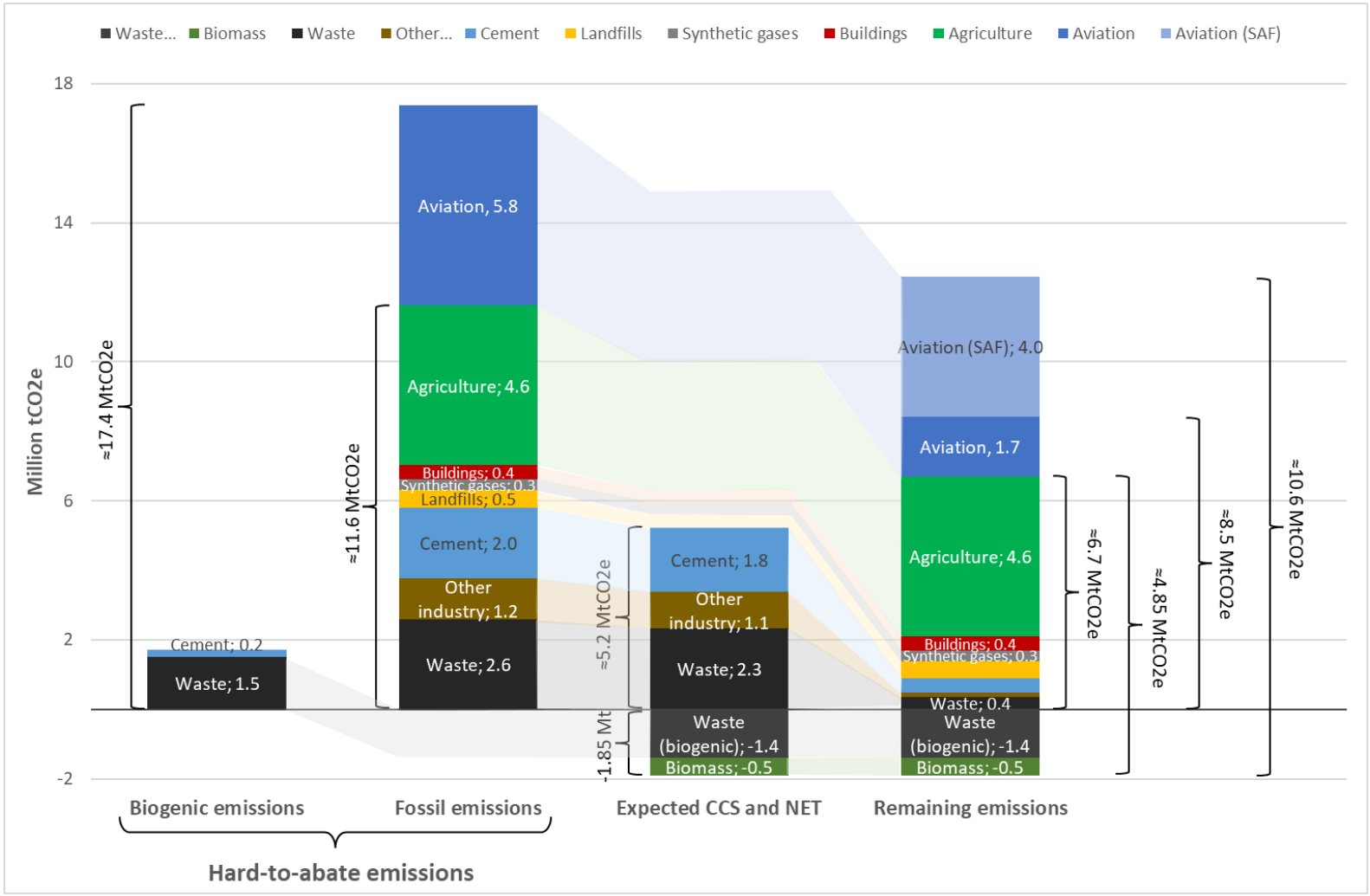
All sectors in 2050



https://decirra.ch/download/decirra-sp3-scenario-report-dec-2024/

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Barriers for Abatement

Source	Abatement option	Barriers		
		technical	economic	political
Waste (biogenic and fossil)	CCS, circular economy		X	(x)
Biomass energy tailpipe emissions	CCS		X	
Other industry	CCS		X	
Cement	CCS or substitution with timber construction		X	
Landfills	Capturing CH_4		X	
Synthetic gases	Substitution	X	X	
Buildings	Biofuel		X	
Agriculture	Shift in diet			X
	Climate-smart agriculture (e.g. nitrification inhibitors; improved manure management; feed additives to reduce methane from enteric fermentation)		X	
	Agricultural carbon sinks: Soil carbon sequestration, agroforestry	X	X	X
Aviation	Sustainable Aviation Fuels		X	
	H_2 or electric airplanes	X		
	Sufficiency			X

https://decirra.ch/download/decirra-sp3-scenario-report-dec-2024/

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Dr. Christina Marchand: Subproject 3 IIE/ZHAW

Future use of Carbon Management to achieve Emissions Reductions and Removals in Switzerland: Scenario and Modeling Analysis

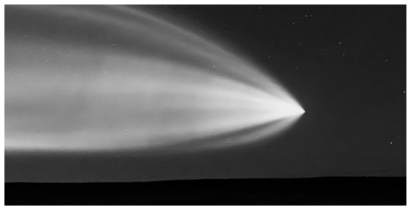
Storylines and Modelling

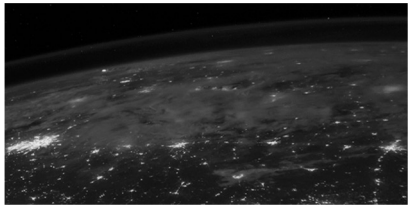
Disentis Input Energieforschungsgespräche 2025, Disentis, 31.1.2025

DeCIRRA: Decarbonisation of CIties and Regions with Renewable gAses

Institute of Innovation & Entrepreneurship
Forschungs- und Arbeitsfelder

IIE Forschungs- und Arbeitsfelder





Fachstelle

Branchenfelder/-themen

- **Energie**
- **Digital/Media**
- **Mobilität**
- …

Entrepreneurship

- Start-up Training und Coaching
- Startup Incubation
- Startup Acceleration
- Business Scale-up
- Neue Formen selbstständigen Unternehmertums

Business Innovation

- Business Model Innovation
- Disruptive Technologien und Innovation
- Corporate Innovation Management
- Strategic & Technology Foresight

Innovation Systems

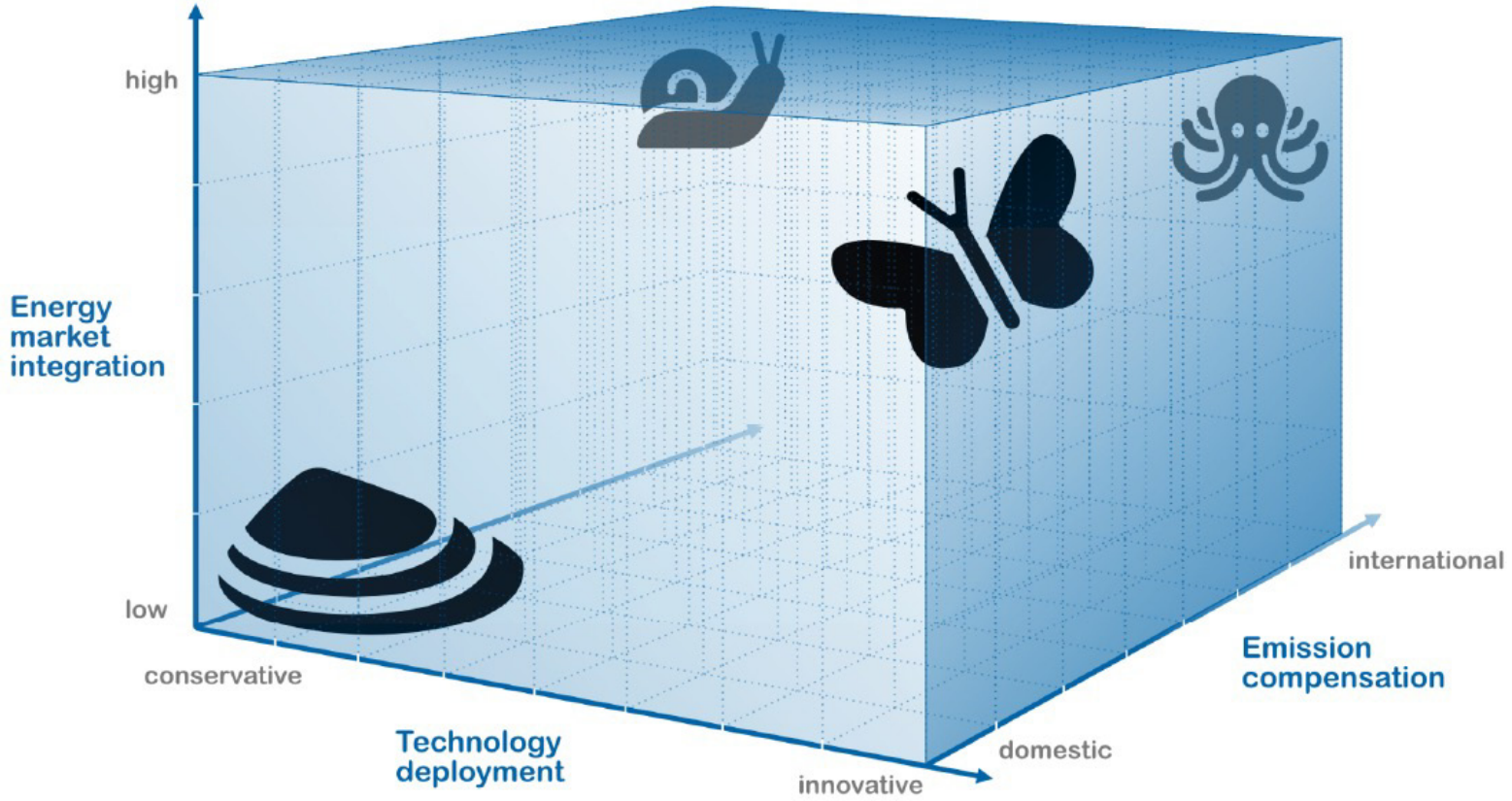
- Business & Innovation Ecosystems
- Wechselwirkungen & Transformation von Technologien und Organisationen
- Zukunftsszenarien
- Akzeptanz neuer Technologien

Entrepreneurial Innovation & Leadership

DeCIRRA Szenario Report (published Dec 2024)

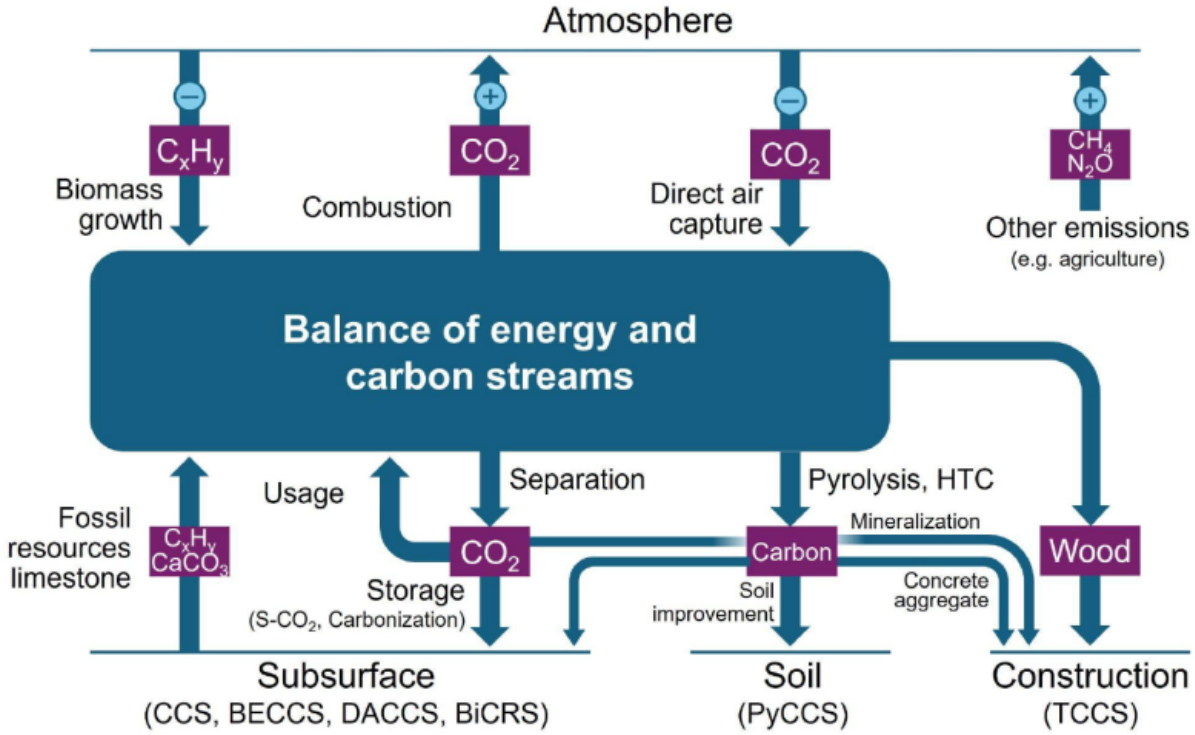
Future use of Carbon Management to achieve Emission Reductions and Removals in Switzerland: Scenario and Modeling Analysis

Using the Swiss Energyscope Model (SES-ETH) from ETH Zurich, the study analyzes four different narratives and their key challenges and opportunities for Switzerland's path to net-zero emissions. The model calculation was done by Gianfranco Guidati (ETHZ)

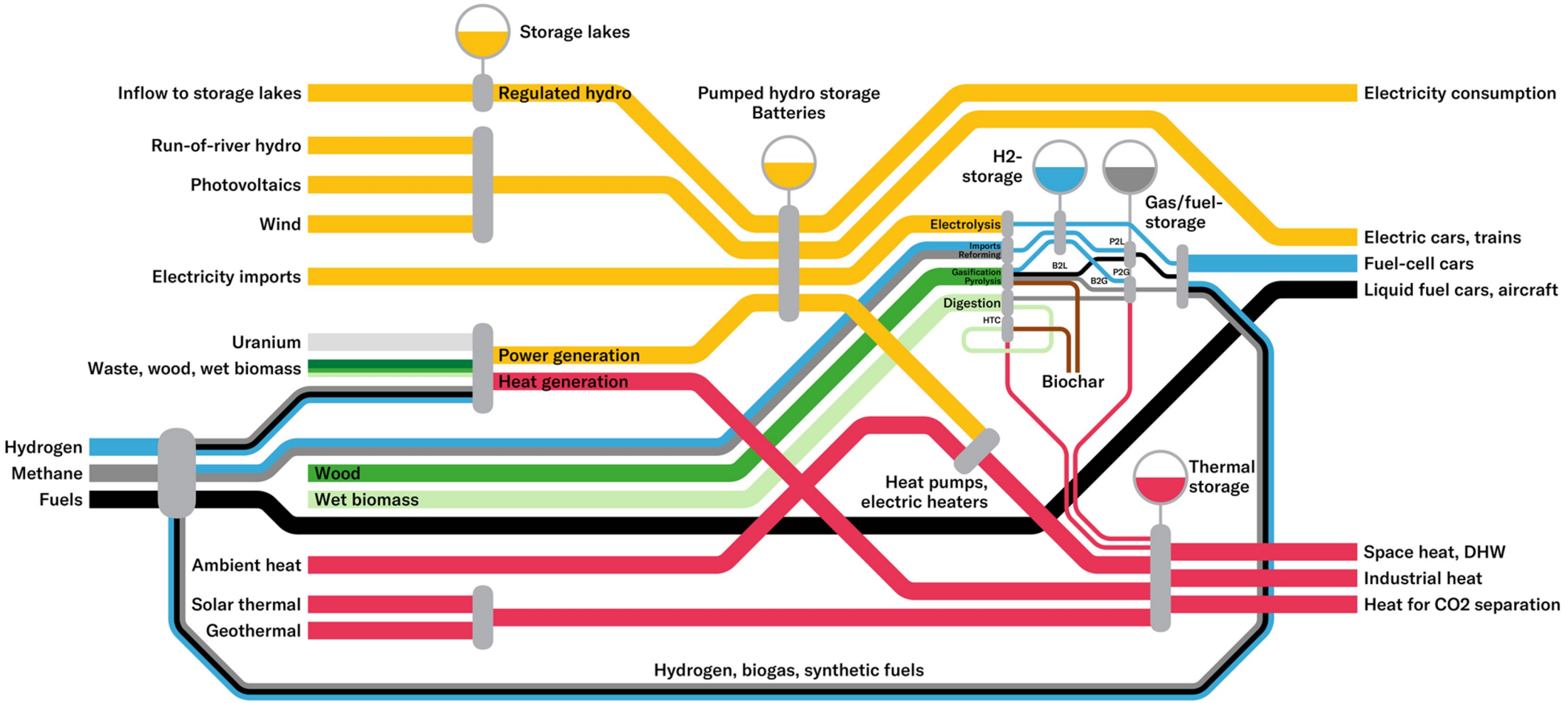


Objectives and approach

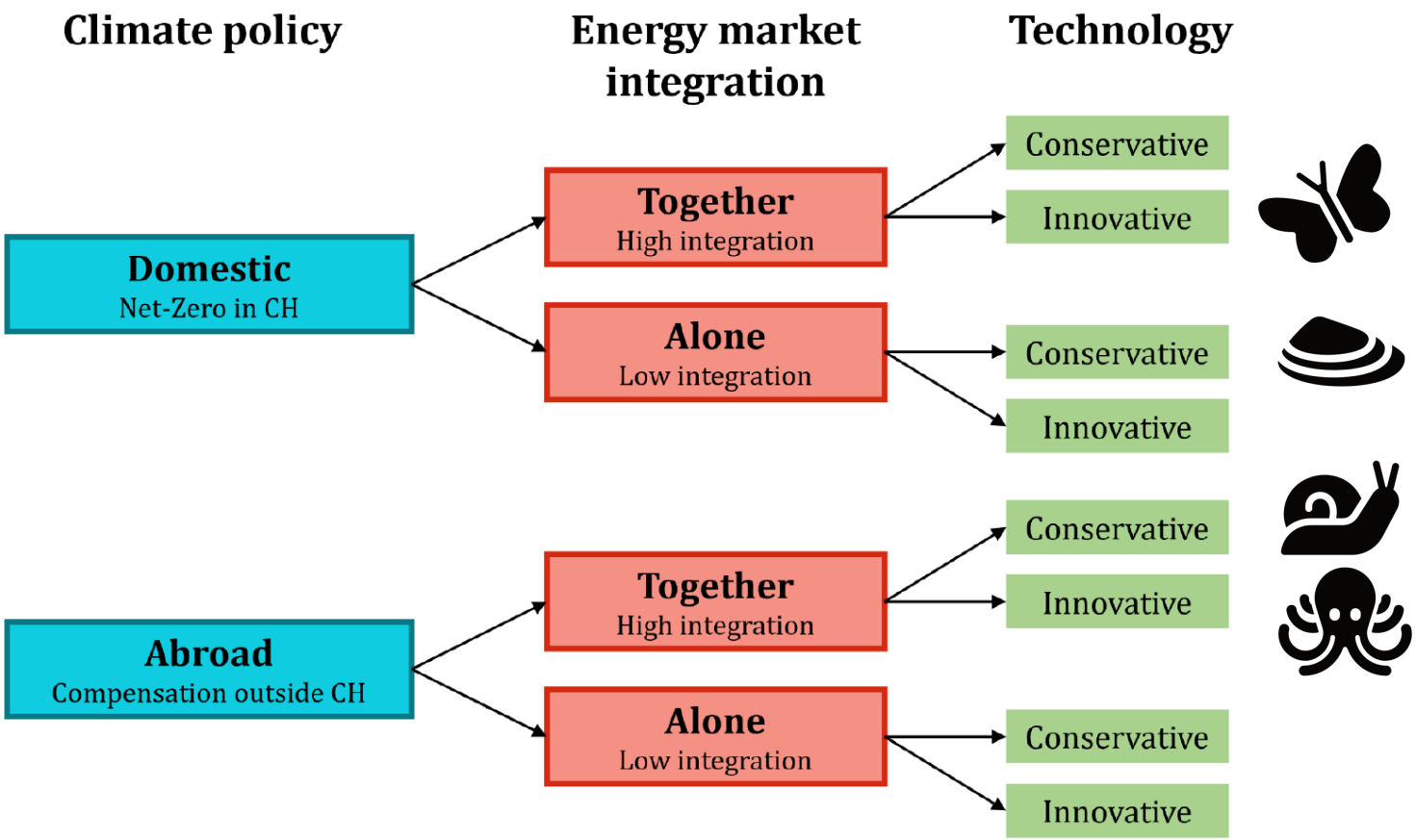
- A variety of Carbon Management Technologies are available
- Their value for achieving the net-zero goal needs to be assessed
- This is achieved by using an energy system model that optimizes energy and carbon flows for a target year 2050
- The results allow to derive priorities for technological and regulatory development



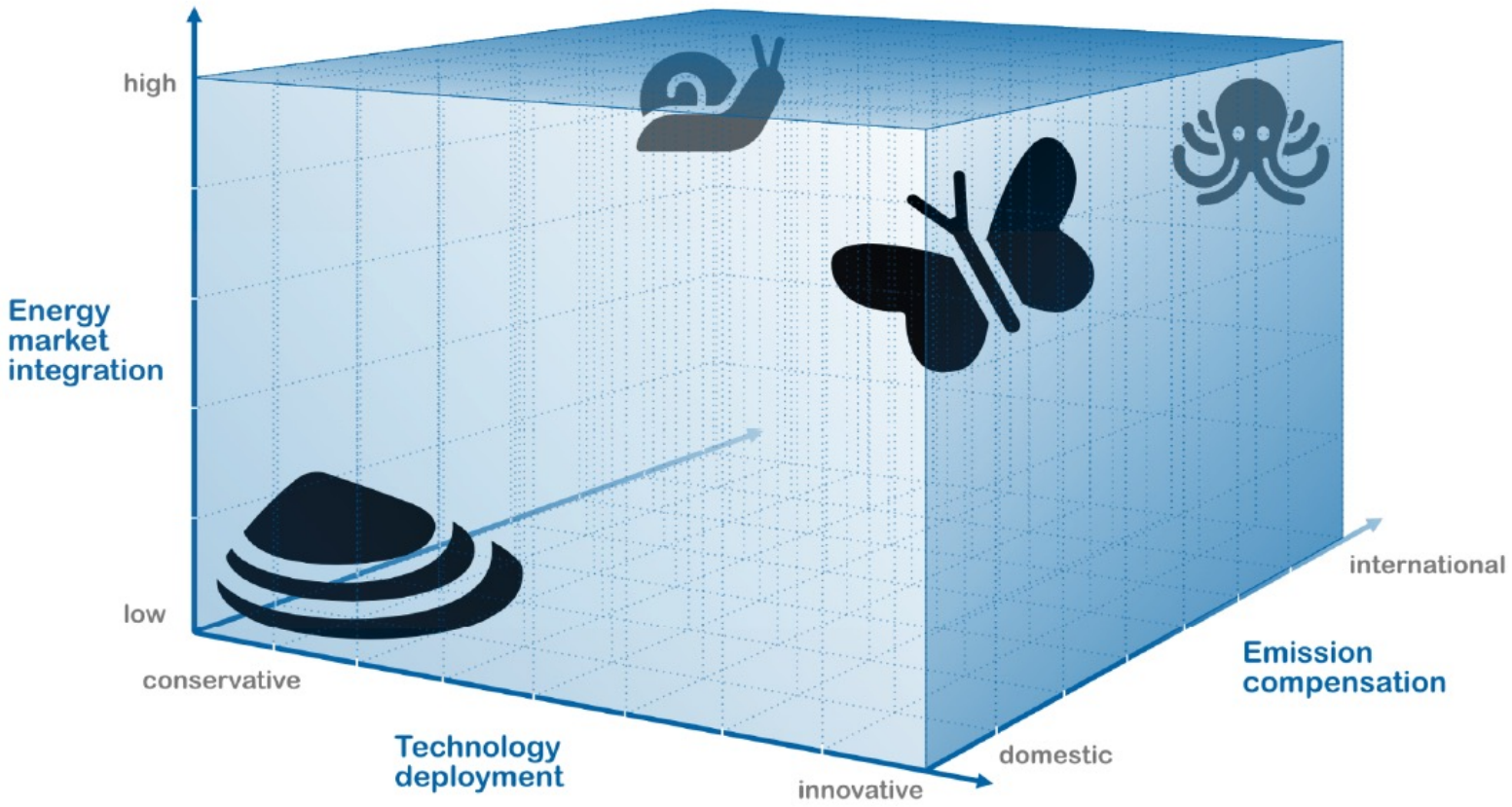
Swiss Energyscope (ETH) model



Scenarios aligned with SWEET-CROSS



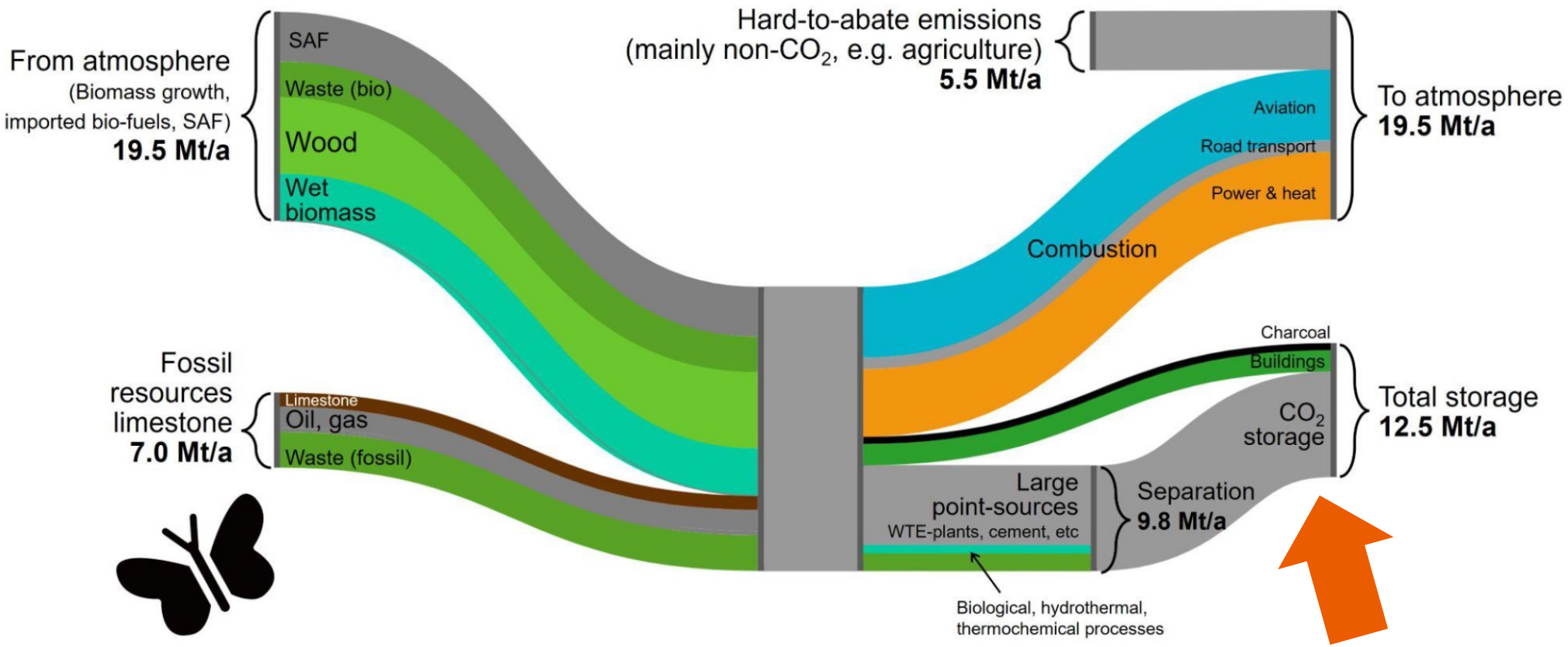
DeCIRRA Szenario Report (published Dec 2024)

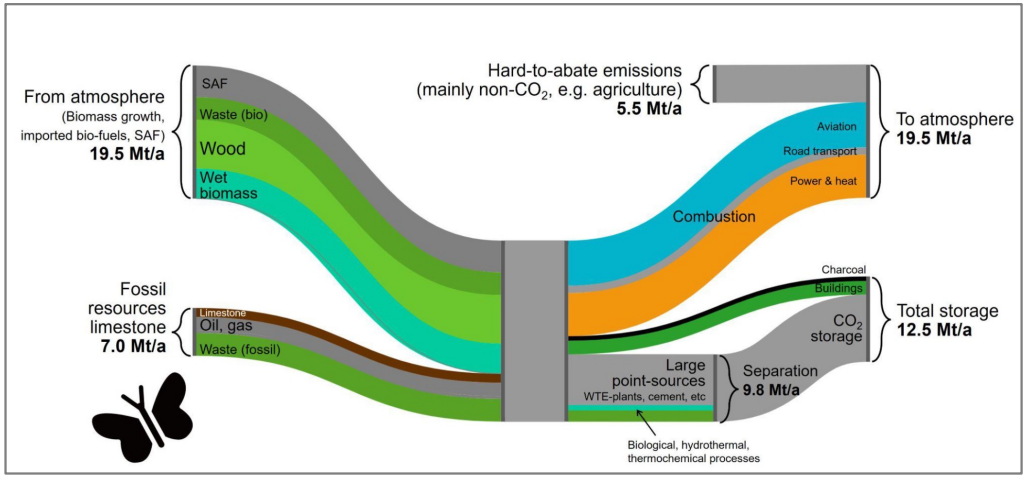


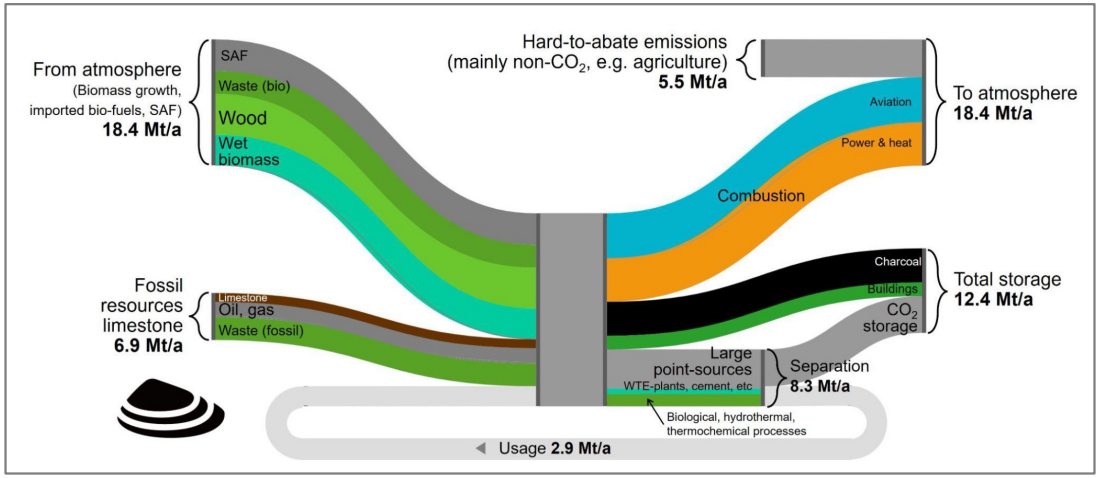
Key modelling assumptions of four narratives

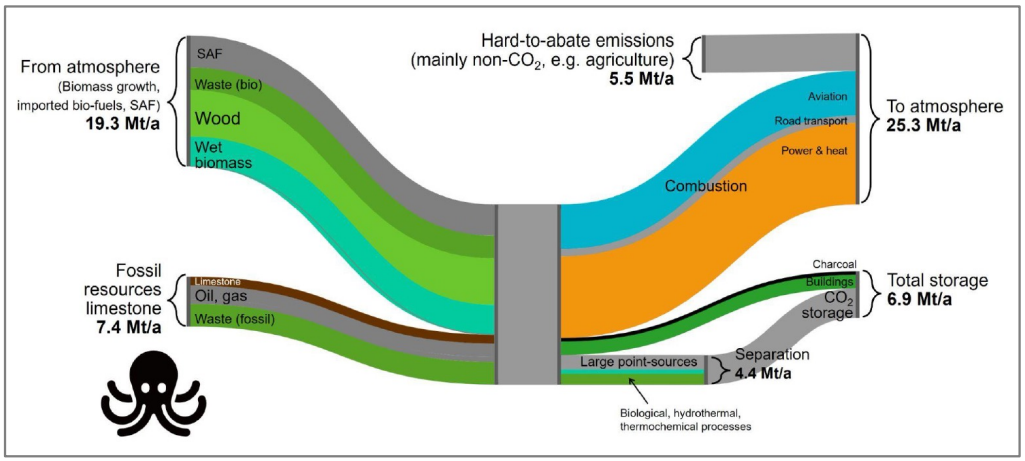
Narrative	Octopus	Butterfly	Clam	Snail
Domestic emissions in 2050: to be compensated with international offsets	6$MtCO_2e$/year	0 $MtCO_2e$/year	0 $MtCO_2e$/year	6$MtCO_2e$/year
Cost of CO_2 transport and storage abroad	100 - 200 CHF/tCO_2	100 - 200 CHF/tCO_2	800 - 1600 CHF/tCO_2	400 - 800 CHF/tCO_2
Limit to wood storage	2 $MtCO_2$/year	2 $MtCO_2$/year	2 $MtCO_2$/year	2 $MtCO_2$/year
Limit to biochar use	5 $MtCO_2$/year	5 $MtCO_2$/year	5 $MtCO_2$/year	5 $MtCO_2$/year
Innovation	Innovative	Innovative	Conservative	Conservative
Market access	Together	Together	Alone	Together

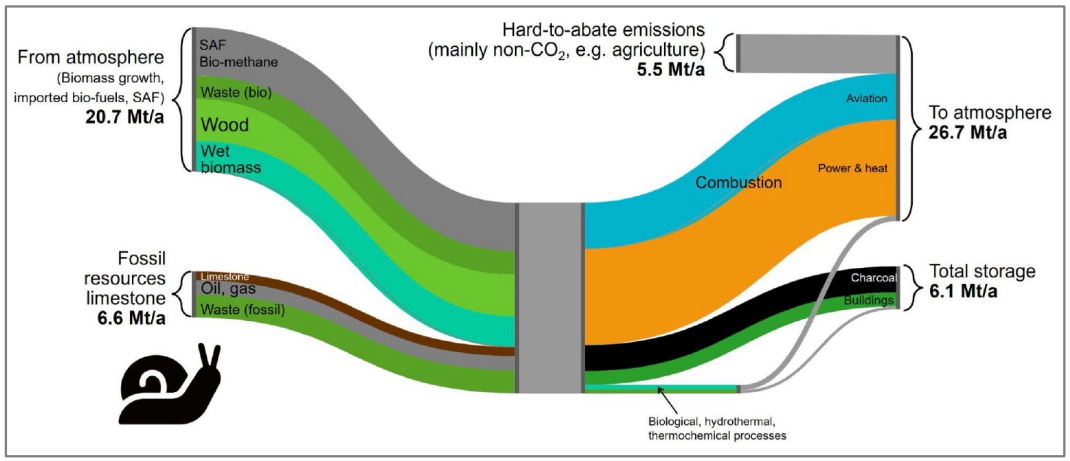
Butterfly narrative: dominated by CO2 storage




From atmosphere
(Biomass growth,
imported bio-fuels, SAF)
19.5 Mt/a
SAF
Waste (bio)
Wood
Wet
biomass
Fossil
resources
limestone
7.0 Mt/a
Limestone
Oil, gas
Waste (fossil)
Hard-to-abate emissions
(mainly non-CO2, e.g. agriculture)
5.5 Mt/a
Combustion
Aviation
Road transport
Power & heat
To atmosphere
19.5 Mt/a
Charcoal
Buildings
CO2
storage
Total storage
12.5 Mt/a
Large
point-sources
WTE-plants, cement, etc
Separation
9.8 Mt/a
Biological, hydrothermal,
thermochemical processes


From atmosphere
(Biomass growth,
imported bio-fuels, SAF)
18.4 Mt/a
SAF
Waste (bio)
Wood
Wet
biomass
Fossil
resources
limestone
6.9 Mt/a
Limestone
Oil, gas
Waste (fossil)
Hard-to-abate emissions
(mainly non-CO2, e.g. agriculture)
5.5 Mt/a
Combustion
Aviation
Power & heat
To atmosphere
18.4 Mt/a
Charcoal
Buildings
CO2
storage
Total storage
12.4 Mt/a
Large
point-sources
WTE-plants, cement, etc
Separation
8.3 Mt/a
Biological, hydrothermal,
thermochemical processes
Usage 2.9 Mt/a


From atmosphere
(Biomass growth,
imported bio-fuels, SAF)
19.3 Mt/a
SAF
Waste (bio)
Wood
Wet
biomass
Fossil
resources
limestone
7.4 Mt/a
Limestone
Oil, gas
Waste (fossil)
Hard-to-abate emissions
(mainly non-CO2, e.g. agriculture)
5.5 Mt/a
Combustion
Aviation
Road transport
Power & heat
To atmosphere
25.3 Mt/a
Charcoal
Buildings
CO2
storage
Total storage
6.9 Mt/a
Large point-sources
Separation
4.4 Mt/a
Biological, hydrothermal,
thermochemical processes


From atmosphere
(Biomass growth,
imported bio-fuels, SAF)
20.7 Mt/a
SAF
Bio-methane
Waste (bio)
Wood
Wet
biomass
Fossil
resources
limestone
6.6 Mt/a
Limestone
Oil, gas
Waste (fossil)
Hard-to-abate emissions
(mainly non-CO2, e.g. agriculture)
5.5 Mt/a
Combustion
Aviation
Power & heat
To atmosphere
26.7 Mt/a
Charcoal
Buildings
Total storage
6.1 Mt/a
Biological, hydrothermal,
thermochemical processes

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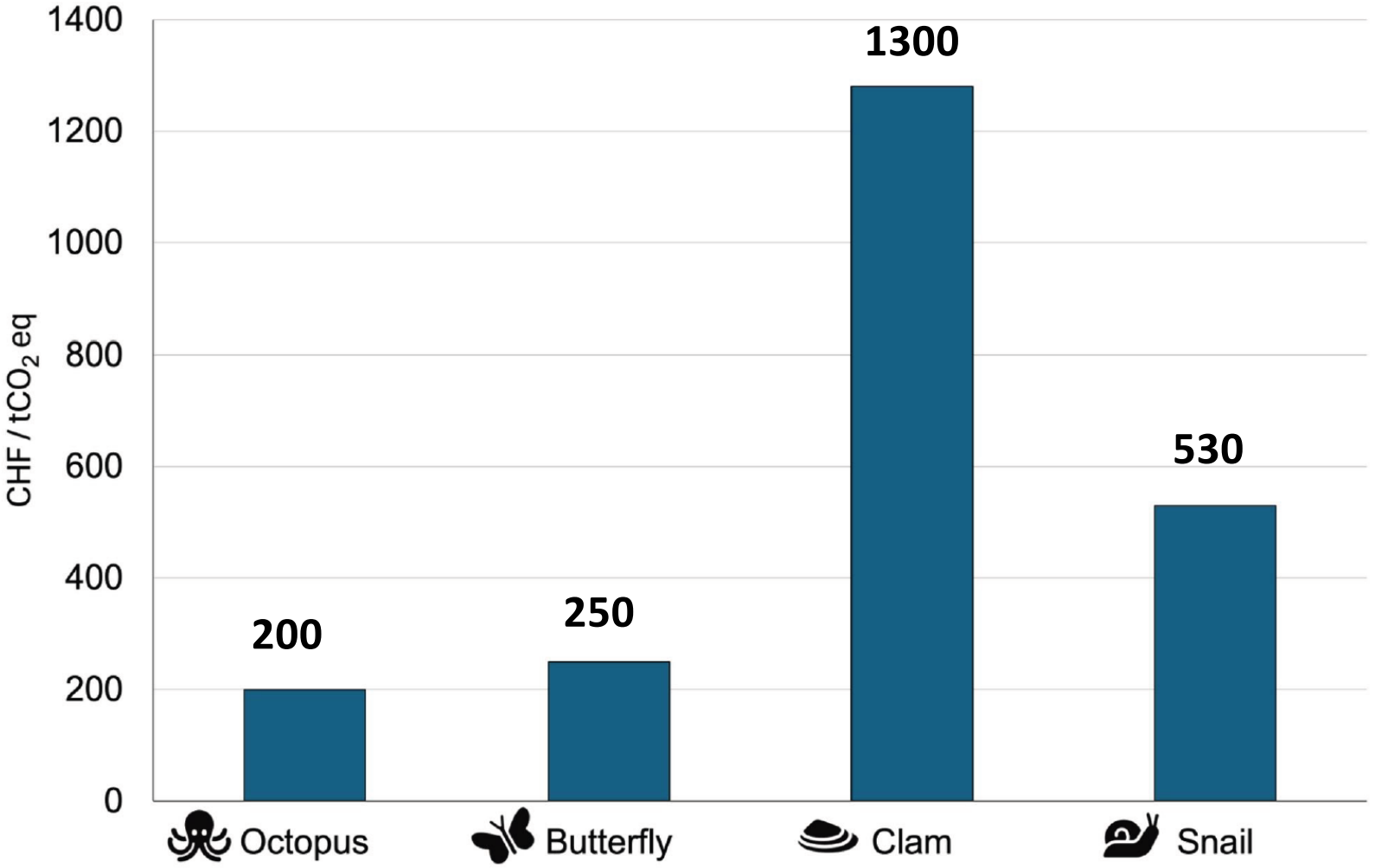
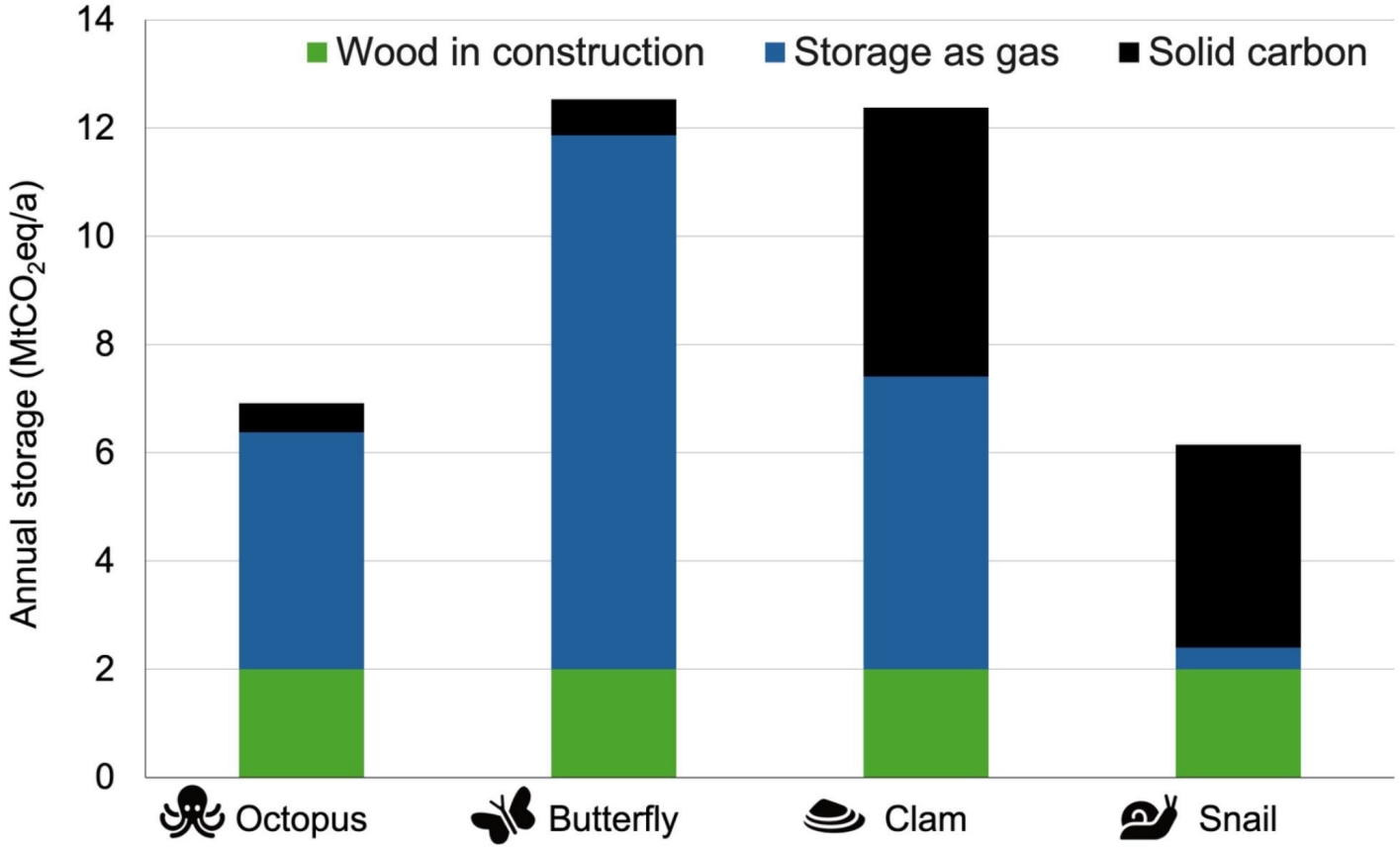
Marginal CO2 avoidance costs in 2050 under the four narratives

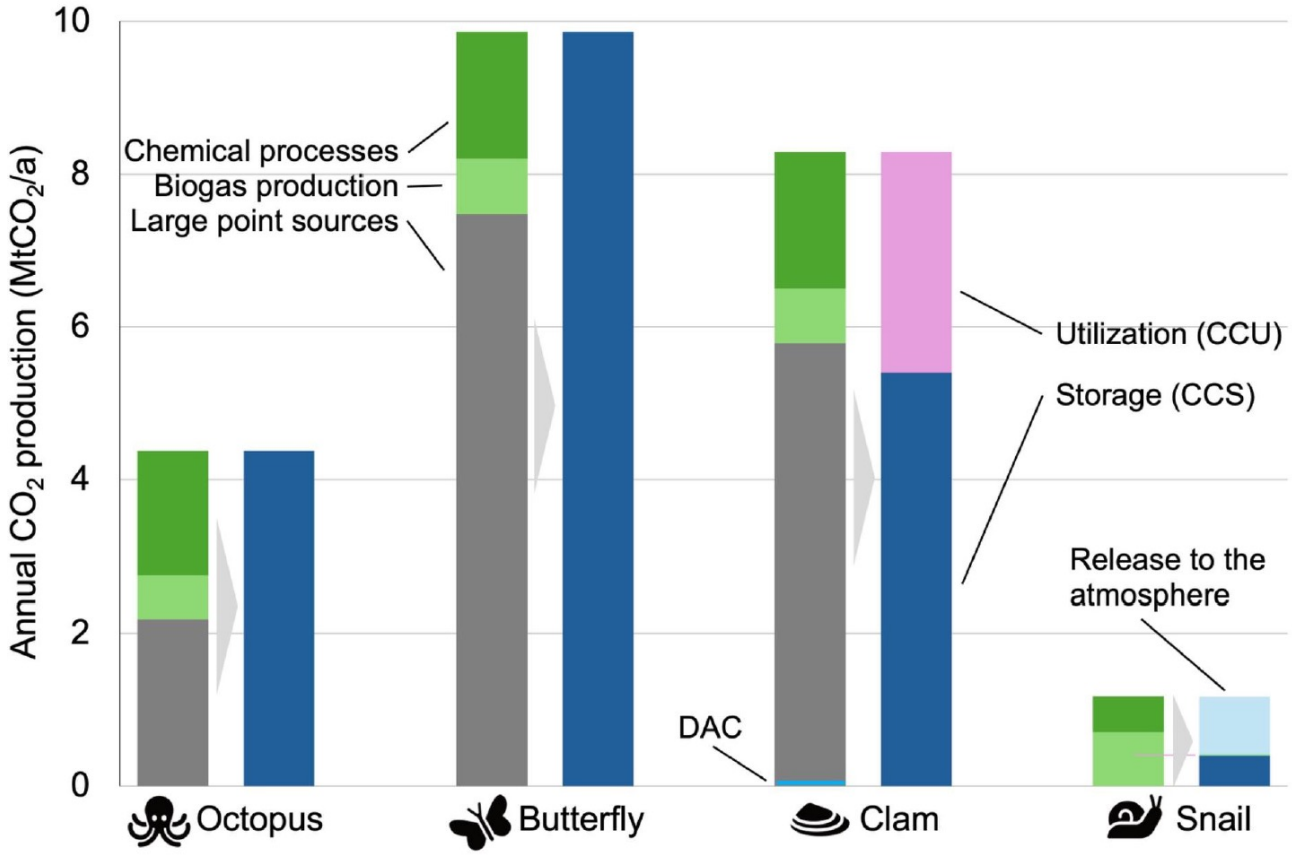


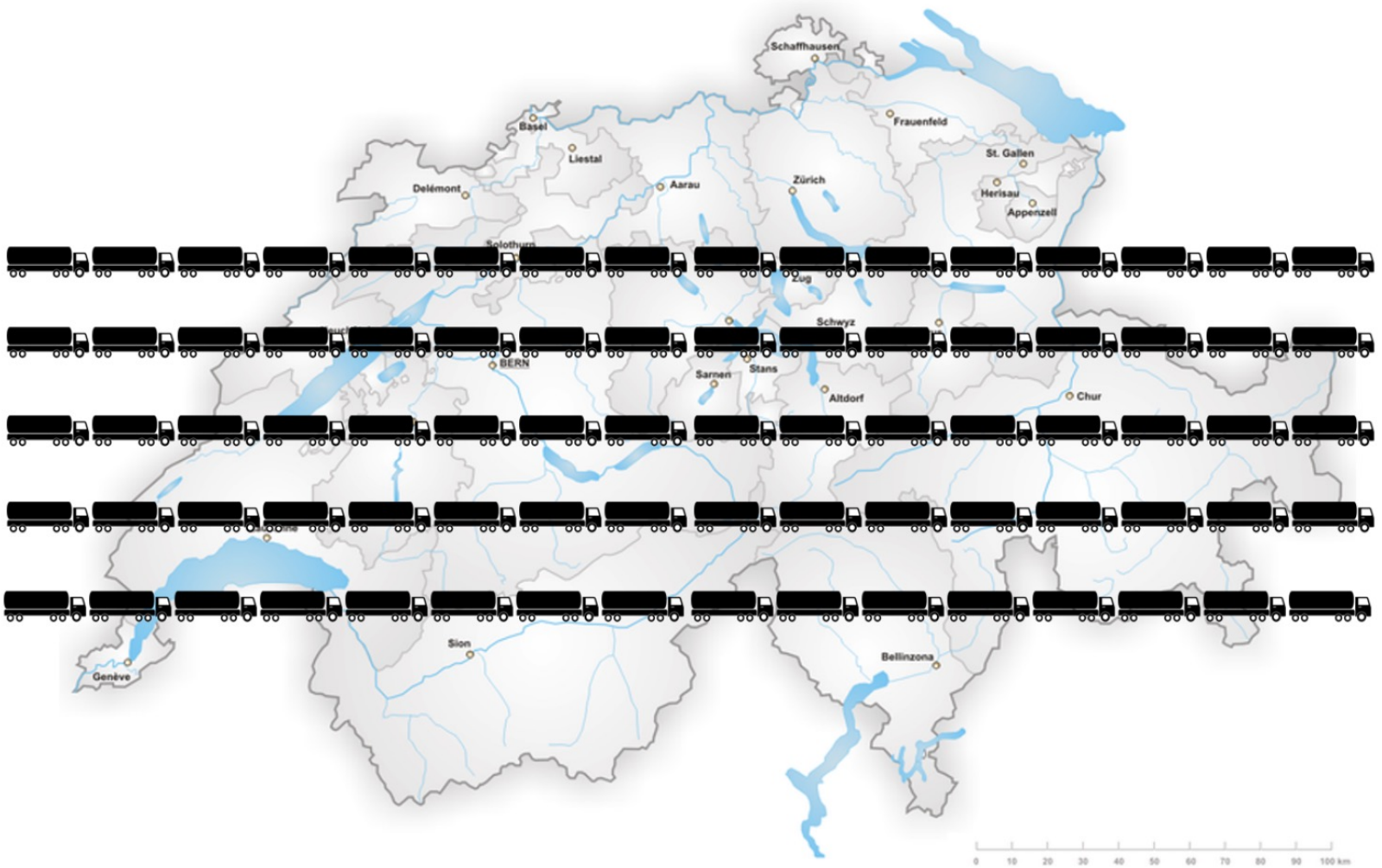
Takeaway from scenario analysis



- Storage of CO2 as gas is always present, and it is the preferred solution provided that transport costs are low (100-200 CHF/t_{CO2})
- For higher costs there is a shift to storage in form of charcoal and to CO2 utilization
- Storage in wood buildings is always part of the optimal mix

Optimal gaseous CO_2 capture sources and destinations in 2050





Visualisation of the annual CO_2 transport volume from carbon capture at Swiss waste incineration plants. It would take more than 100’000 tanker trucks which could form five lines across Switzerland each year to transport the estimated over 4 million tonnes of CO_2

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Prof. Dr. Paula Castro, DeCIRRA Team: CEE/ZHAW

What policies are needed to achieve net zero?

Disentis Energieforschungsgespräche 2025, Disentis, 31.1.2025

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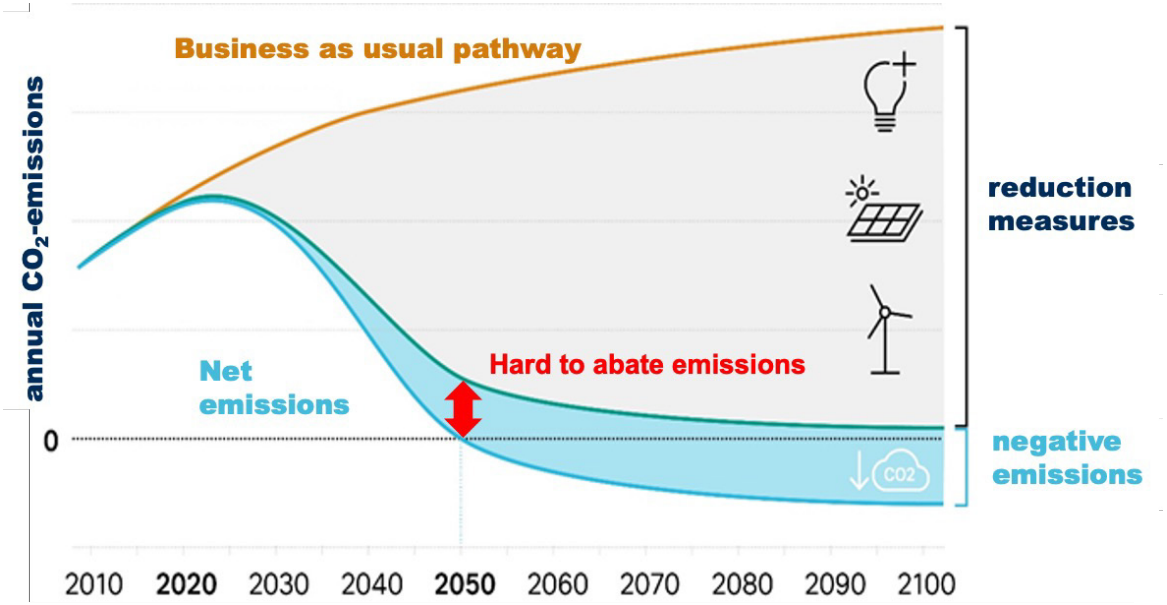
Policies to address hard-to-abate emissions

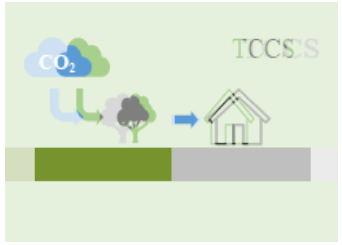
Not covered: What is needed to achieve what can be directly reduced!

→Policies for CCUS and NET solutions

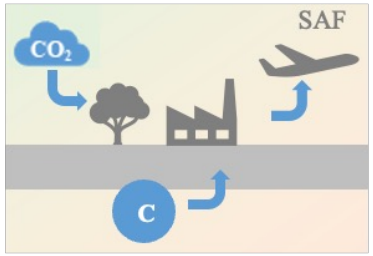
- Embedded in / compatible with **current** policy **framework**
- Various **alternatives**, to be assessed in next step through economic modelling
- **Exclude** increasing biomass growth



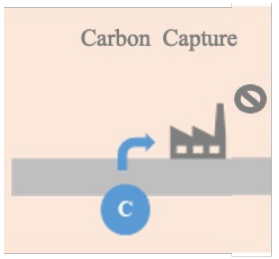
Policies to address hard-to-abate emissions



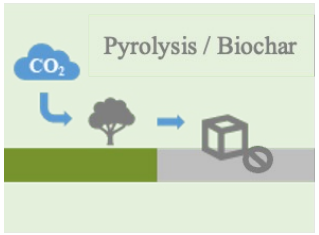
Wood in construction



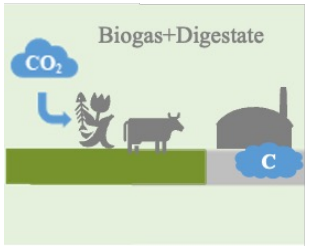
Sustainable aviation fuels



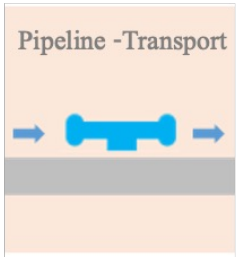
CC from point sources



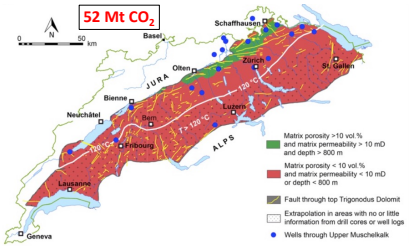
Biochar



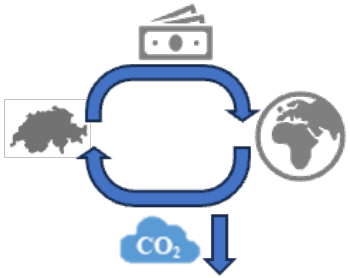
Biological, hydrothermal, thermochemical processes



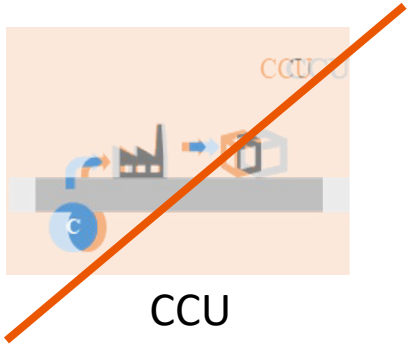
CO_2 pipeline



CO_2 storage



International carbon credits



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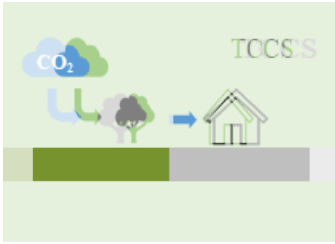
Wood in construction



- **Technology reaches its maximum potential on all 4 scenarios → important**

- New **framework**: Amended **Swiss Environmental Protection Act**
  - Resource-conserving construction requirements (Art. 10h)
  - Option to set limits for life cycle emissions for new buildings (Art. 35j)
  - Standard for reporting on timber (Art. 35g)
- **Climate and Innovation Act**: role model of federal and cantonal administrations (Art. 10)
  - Potentially important role of **public procurement rules** for buildings

- **Still needed**
  - **Certification framework** for using timber in construction that allows access to carbon markets (e.g. EU Carbon Removals and Carbon Farming regulation)
    - To cover not just the **construction** part, but sustainable **forestry** practices
  - Rules to incentivize **cascading use** of wood

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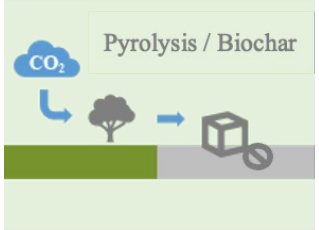
DeCIRRA Biochar



- **Used in all scenarios**
- **Current framework**
  - **Chemical Risk Reduction Ordinance**: permits use of biochar in agriculture, with limits
    - Designed to protect soil from contamination
  - **Ordinance on CO_2 Reduction**: recognizes use in agriculture and construction materials
    - Use for mitigation needs to be registered in the land register (additional costs)
  - No **recognized methodology** for calculating and certifying negative emissions
  - No concrete **support** mechanisms
    - Instead: certification for use and sale in the **voluntary carbon market**
- **Policy options**
  - **Financial support** through carbon removal credits, subsidies or tax credits
  - Adoption of **European Biochar Certificate** for MRV methodologies
  - Incentives for **farmers** to apply biochar to soils
  - Reduction of **regulatory barriers** (land register, limitations on source materials)

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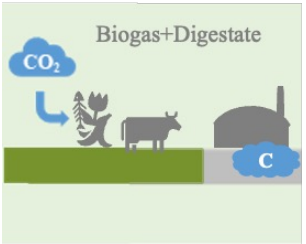
Biological, hydrothermal, thermochemical processes



- For sewage and waste treatment, or agriculture (biogas) → Cost-effective, but small amount
  - Obtained CH_4 can be supplied to biogas networks for further use
  - Requires washing of CO_2 to separate it from the CH_4 → for storage or use

- **Policy options**:
  - **Increasing value** of biogas
    - From 2025, obligation to record production and import of renewable gases (guarantees of origin)
      → allows distinguishing biogas from natural gas
      → value under ETS or CO_2 levy
    - Quotas for biogas use
  - **Or: Mandatory washing** and feed-in of biogas → eliminate flaring, allow use

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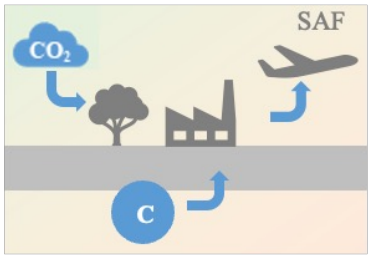
DeCIRRA Sustainable Aviation Fuels



- **SAF imports** required to meet necessary reductions in all scenarios → **important**
- Revised **CO_2 Act** from 2024 mirrors the **ReFuelEU Aviation** regulation
  - Quotas for SAF blending (both generally, and specifically for e-fuels)
  - In 2050: 70% quota

- **Needed**
  - Support for **technology providers** and international knowledge transfer
  - Financial **incentives** to narrow cost differential btw kerosene and SAF
    - 400 million CHF available until 2030 from CH aviation ETS revenues
    - High penalties for fuel suppliers that fail to achieve quotas → revenues earmarked
    - Still: reluctance of private sector to invest → **future policy uncertainty**
    - → more certainty, longer-term perspective needed

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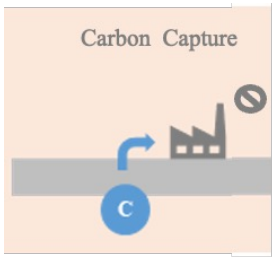
Carbon capture from point sources



- **CCS** mostly in cement and waste incineration → **important**
- **Cement** sector: covered by **Swiss ETS**
  - Investment in CCS depends on **allowance price** under the ETS → not yet high enough
  - **Needed**: Achieving **cost reductions** for CCS technology early on
    - E.g. carbon contracts for difference (Δ (price-cost) paid out from public budgets)
    - Funding e.g. from ETS auctioning revenues, or from **KIG** (just now: interpelation)
- **Waste-to-energy**: **agreement with VBSA** exempting from ETS if one CCS plant till 2030
  - Some plans already there: Werdhözli (ZH), KVA Linth
  - Strong acceleration needed after 2030
  - **Needed**: Either very ambitious **follow-up agreement** or other policies
    - Participation in **ETS**? Fear: increased costs from buying allowances
      - Less capacity to invest in CCS? Costs passed to consumers? Distributional effects?
      - Timing: if erly CCS investment, possibility to sell allowances

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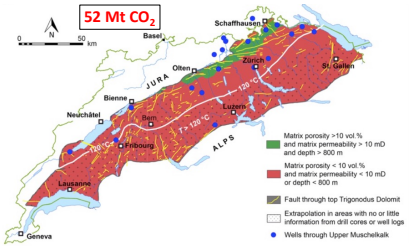
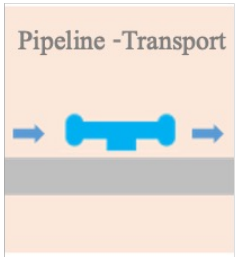
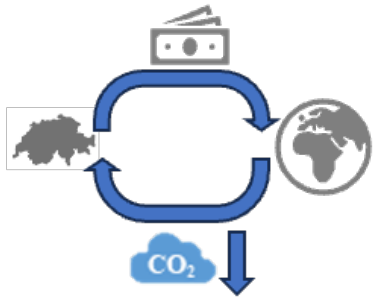
CO_2 pipeline network and domestic storage





- Least-cost option for transporting large amounts of CO_2 to storage sites abroad
- Action needed soon to enable affordable transport and storage
- **Current developments**
  - **Motion** from the UREK-S (Commission on Environment, Planning and Energy) to the government to draw up **framework legislation** including:
    - Harmonized regulations for CO_2 pipelines and underground CO_2 storage
    - Simplified approval procedures
    - Financing solutions
  - **Opinion**: following EU framework makes international coordination easier
  - **Study**: transferring competence for pipeline from cantonal to federal level
  - International storage: **agreements** with Norway, Sweden, Iceland, Netherlands
- **Policy options** for financing pipeline construction
  - **Levies** on **emitters** or producers of carbon in waste (plastic importers)
  - Revenues from Swiss **ETS auctions** → unclear whether applicable to pipeline

Use of international carbon credits



- Only in scenarios that allow for compensating emissions abroad
- **Current framework**
  - Swiss **NDC** foresees about 1/3 of Swiss mitigation to be realized abroad in 2030
  - Use of carbon market mechanisms under **Paris Agreement's Article 6**
    - Switzerland currently a frontrunner, having closed bilateral cooperative agreements with 14 partner countries
  - **KliK** currently tasked to manage such trading, but only for compensating emissions from transport sector → may need to be expanded
  - **Risks**:
    - Competition with demand from other countries
    - Supply could decrease, as host countries need to decarbonize themselves
    - → scarcity and high costs on the long term
    - Public rejection of international offsetting

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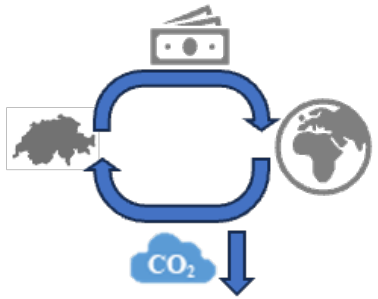
Use of international carbon credits



- **Policy options**
  - Increase **availability**
    - Linking with further ETS (New Zealand or California) to get access to further supply
  - International offsetting should be used **only to compensate** for those emissions that are **hardest** to abate domestically
    - Restrict offset use to certain sectors (distributional effects!)
    - Establish maximum shares of emissions from each sector allowed to be compensated internationally
  - Address public backlash
    - Ensure only **high-quality credits** with positive sustainability co-benefits are allowed
    - Ensure that only credits from CDR activities (removals) are **allowed**

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DeCIRRA Conclusions

- **Rapidly developing and changing regulatory framework**
  – New developments almost every week

- Still, **regulatory gaps** remain

- Various **policy options** suggested to address those gaps
  – Next step: assessing their impacts → see following presentation by Florian!

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Dr. Nina Boogen: DeCIRRA Team: CEE/ZHAW

How can the public perception of CO_2 infrastructure be investigated?

Disentis Energieforschungsgespräche 2025, Disentis, 31.1.2025

DeCIRRA: Decarbonisation of CIties and Regions with Renewable gAses

Public perception

- Direct democracy means that the interests of the population are particularly important, as they can lead to delays and a high degree of uncertainty.
- Studies on high-voltage power lines (Stadelmann-Steffen 2019), among other things, have made it clear that the public perception of energy infrastructure is influenced by
  – diffuse fears,
  – potential health risks (e.g. noise, radiation, air pollution) and the
  – effects on the image of the landscape.
- It was also shown that the distance to the planned infrastructure or whether there is already experience with similar infrastructure (*familiarity*) can have an influence on perception (see e.g. Firestone & Kirk, 2019).

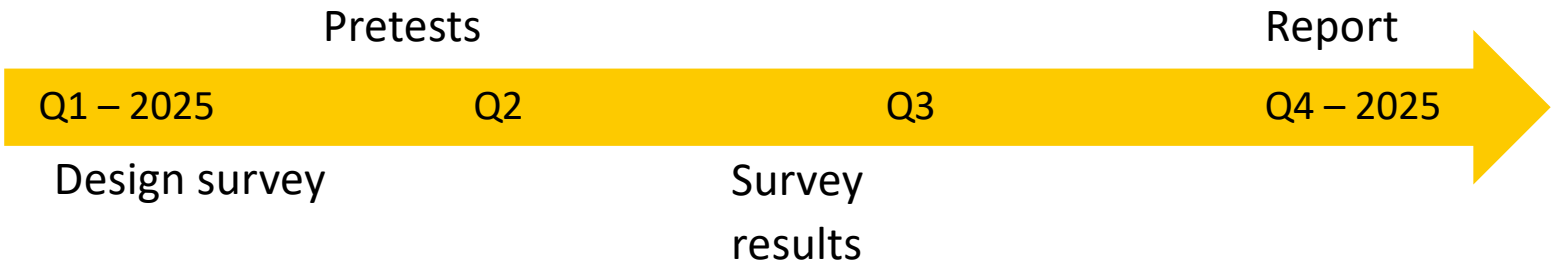
Current situation in Switzerland

- DemoUpCARMA Study (Dallo et al., 2024)
  - Focus groups and survey (with information experiment) in Switzerland (N =503)
  - two specific pathways: (i) CO2 utilization and permanent storage in recycled concrete in Switzerland and (ii) CO2 transport and permanent storage in geological reservoirs in Iceland
- Results show, that:
  - the public is not familiar with CCT(U)S (*familiarity*);
  - public acceptance and support depends on various personal factors (e.g. concern about climate change)
  - perceived benefits and risks depend on the specific capture, transportation and storage processes; and
  - infographics are preferred over plain text to learn more about CCT(U)S options.

Representative survey

- Representative survey on the perception of CO2 infrastructure (N=2,000-4,000)
  - Risk perception in relation to a CO_2 infrastructure
  - Level of knowledge on the topic
  - Perceived benefits,
  - Fairness assessments (storage abroad vs. storage in Switzerland)

- Experiment: information framing with narratives, e.g. benefit framing, cost/fairness framing
- Survey design process: Exchange with practice partners in the



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DeCIRRA

Dr. Florian Landis: DeCIRRA Team: CEE/ZHAW

Analysis of the distribution of policy impacts across the Swiss population (an outlook)

Disentis Energieforschungsgespräche 2025, Disentis, 31.1.2025

DeCIRRA: Decarbonisation of CIties and Regions with Renewable gAses

Numerical modelling

- Analyze economic interaction between energy sector and other economic sectors in a Computable General Equilibrium (CGE) model
- Use results from scenario modelling of Swiss Energyscope – ETH (SES-ETH) to recalibrate CGE model of Switzerland
- (Model coupling presented on Thursday morning)
- Compare a Business-as-Usual (BaU) scenario (current policies; no net-zero) with different policy scenarios that reach net-zero -> comparative statics

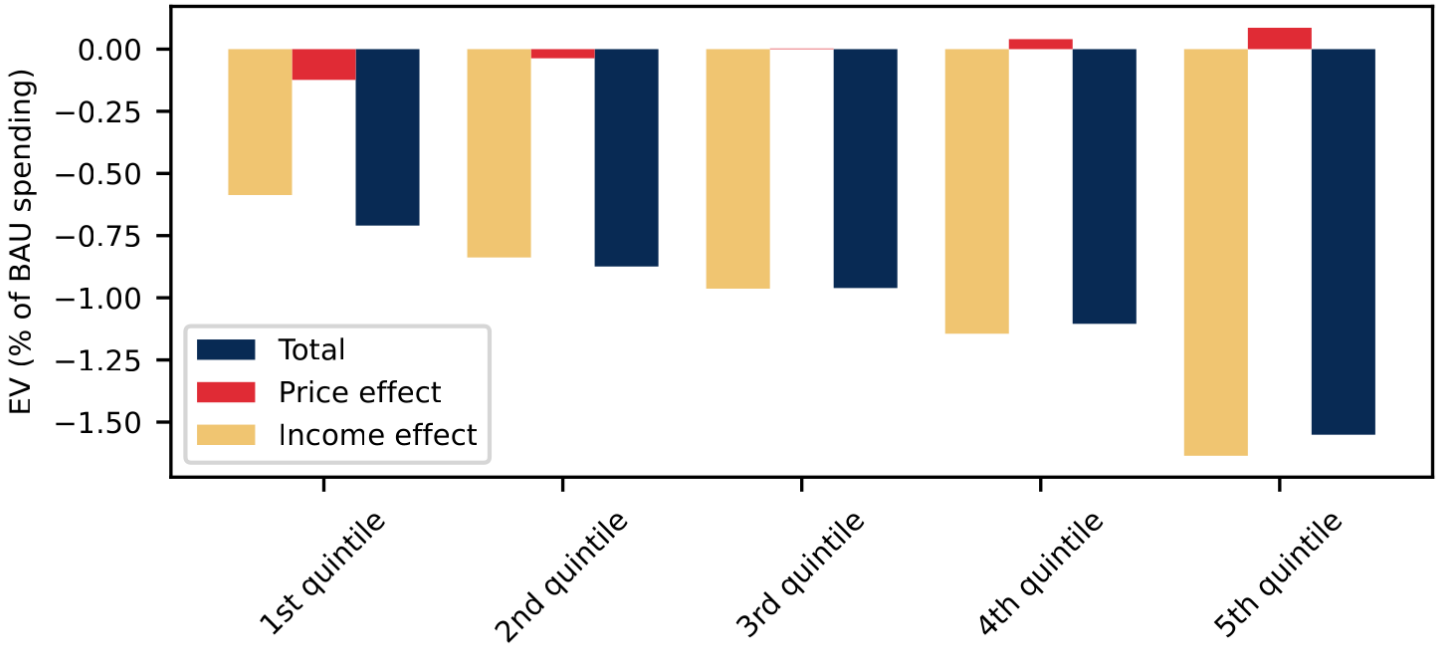
DeCIRRA Policies

Different policy instruments can have different impacts on consumers, workers, and investors. By and large:

- **Subsidies** cost the state, but make consumption more affordable and investments more viable, wages increase
- **Standards and mandates** increase technology costs; this makes consumption more expensive and investments less viable, wages decrease; approximately neutral for government budgets
- **Pigou taxes/Carbon pricing** increase cost of consumption through both technology cost and carbon price; investments less viable, wages decrease. Raises state revenue, but in the case of the CO_2 levy, state revenue cannot used freely but must be recycled to households or used for climate issues.

Impacts on households (illustrative preview)

Change in consumer welfare measured in equivalent variation (EV) relative to households' BaU expenditure budgets.



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Impacts on sectors (illustrative preview)