



Renewable **Fuels** and **Chemicals** for Switzerland*

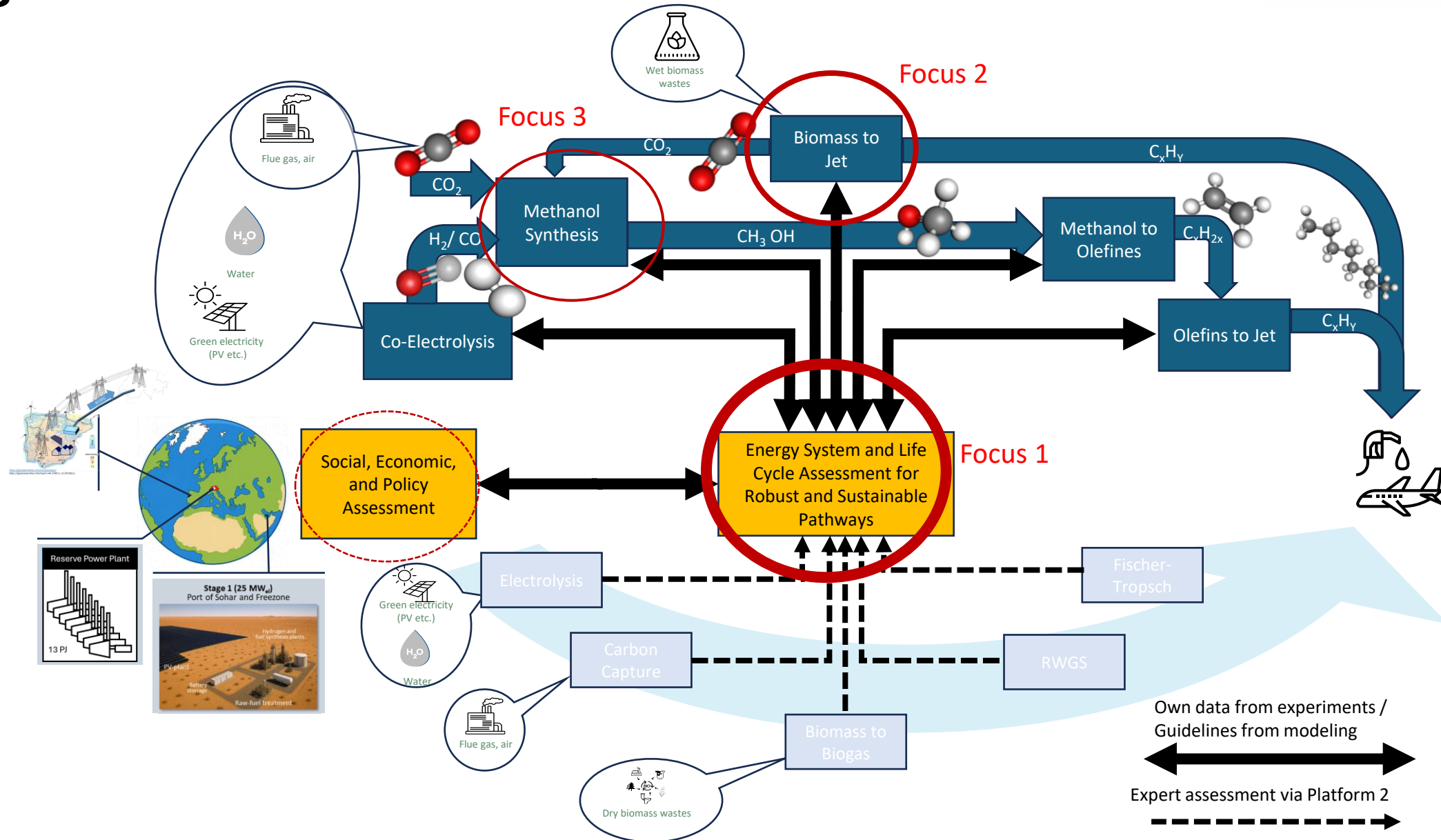
Unlocking manure's biogas potential from local to national scale: A case study of Switzerland

Sandrine Werner
3rd ReFuel.ch Annual Conference
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WP6

*reFuel.ch is a consortium sponsored by the Swiss Federal Office of Energy's SWEET programme and coordinated by Empa.



High-level introduction & link to consortium



1

Introduction

Manure as an underused biomass resource and the gap this study addresses

2

Methodology

A GIS-integrated life cycle GHG framework

3

Results

Energy potential, climate impacts, and spatial trade-offs

4

Discussion

Key levers for climate mitigation, and limitations

5

Take-home messages

Manure Is an Underused Bioenergy Resource



of Swiss renewable final energy consumption is already bioenergy
→ Energy Strategy 2050 calls for further expansion.



of fresh manure produced by Swiss livestock every year
→ equal to 48 PJ of theoretical primary energy.



of that potential is currently used for energy generation.
The rest is stored and applied to fields as fertilizer.



of Switzerland's agricultural greenhouse gas emissions
come from manure management.

Why Isn't Manure's Potential Already Used?



Small, decentralized farms

Average Swiss livestock farm holds ~34 Livestock Units (LSU); standalone biogas plants need ~75 LSU
→ Most farms are too small alone and must cooperate.



Legal & technical constraints

Building restrictions and maximum legally allowed manure transport distances limit where plants can be sited.



End-use limits infrastructure

CHP needs nearby heat demand; upgrading needs gas-grid access.
→ Both are geographically limited.

→ Lack of a spatial assessment integrating legal, technical, feedstock, siting, and climate-impact factors
→ **no integrated decision tool**

Three Objectives



Life cycle GHG analysis

Evaluate the climate change impacts of different manure-to-energy pathways.



National-scale spatial assessment

Quantify the energy potential and climate impacts across Switzerland, accounting for legal and technical restrictions.



Decision-support tool

Build an interactive, regionalized tool so farmers and municipalities can evaluate feasibility and climate impact locally.

Three Manure Management Pathways

Baseline

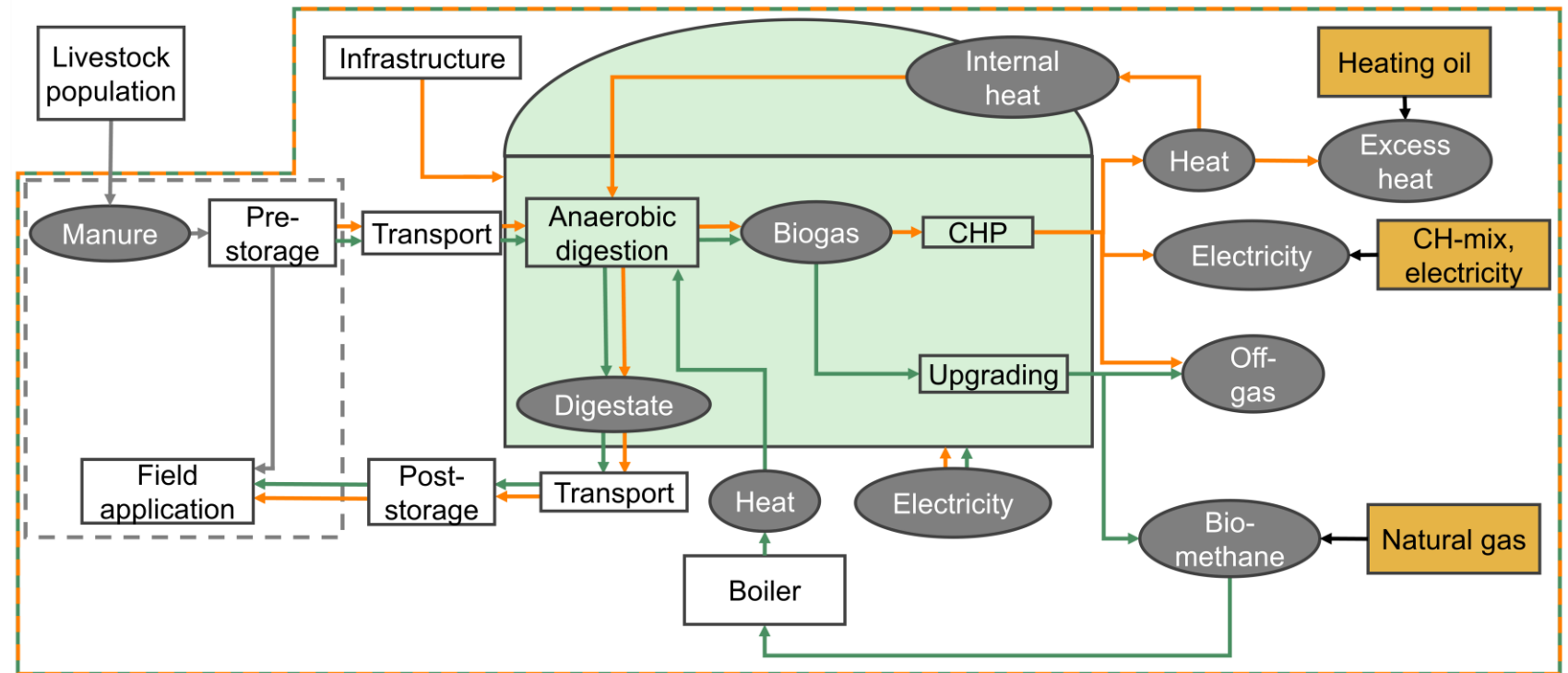
No energy recovery: manure stored on-farm & applied to fields

CHP

Anaerobic digestion → combined heat & power, substituting grid electricity and heating oil.

Upgrading

Biogas purified to biomethane → injected into the gas grid, substituting natural gas.



Legend:

Processes

Resources/products

Reference substitution products

Baseline flows

Additional flows for energy generation (CHP)

Additional flows for energy generation (Biogas upgrading)

System boundary: Baseline pathway

System boundary: Manure-to-energy pathways

Life Cycle GHG Analysis: Storage emissions

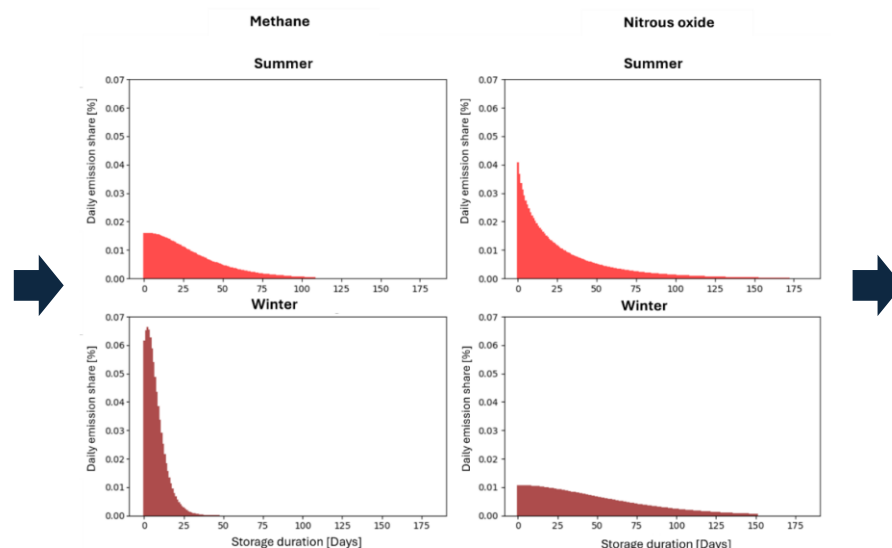
Functional unit: 1 tonne of fresh manure (FM) treated
Impact category: Climate change (GWP100, IPCC 2021)
Manure type: Solid and liquid of 5 manure types (cattle, horses, sheep/goats, pigs, poultry) + weighted Swiss mix

Methane (CH₄)

1. Estimation of the total annual emission potential from manure storage
2. Temporal disaggregation of annual emission potential into a daily time series

Nitrous oxide (N₂O)

1. Estimation of total nitrogen excreted in manure
2. Storage- and climate-zone-specific N₂O emission factor applied
3. Temporal disaggregation of annual emission potential into a daily time series



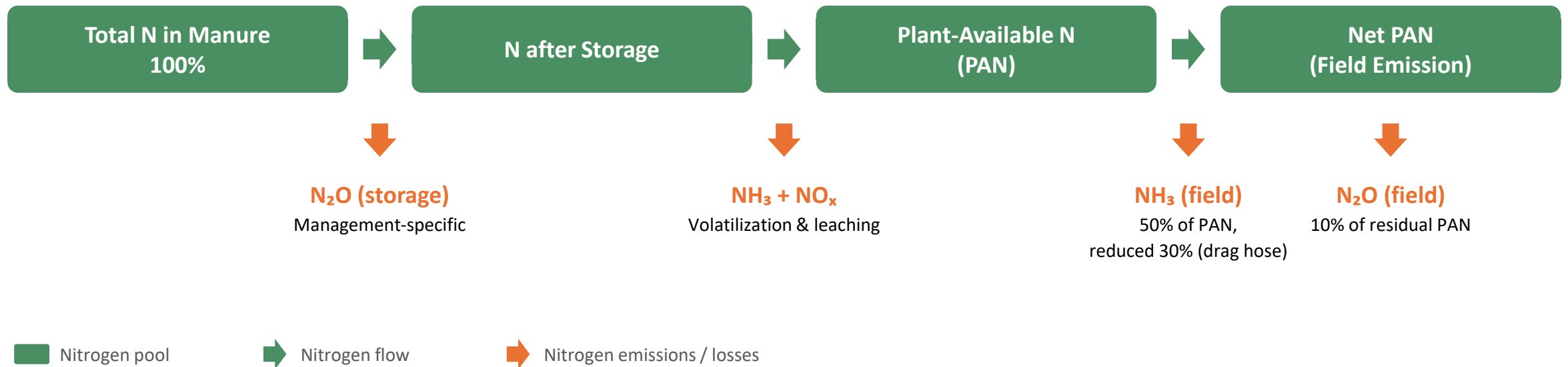
Modelling

- 4 storage systems
- 5 climate zones
- Daily resolution

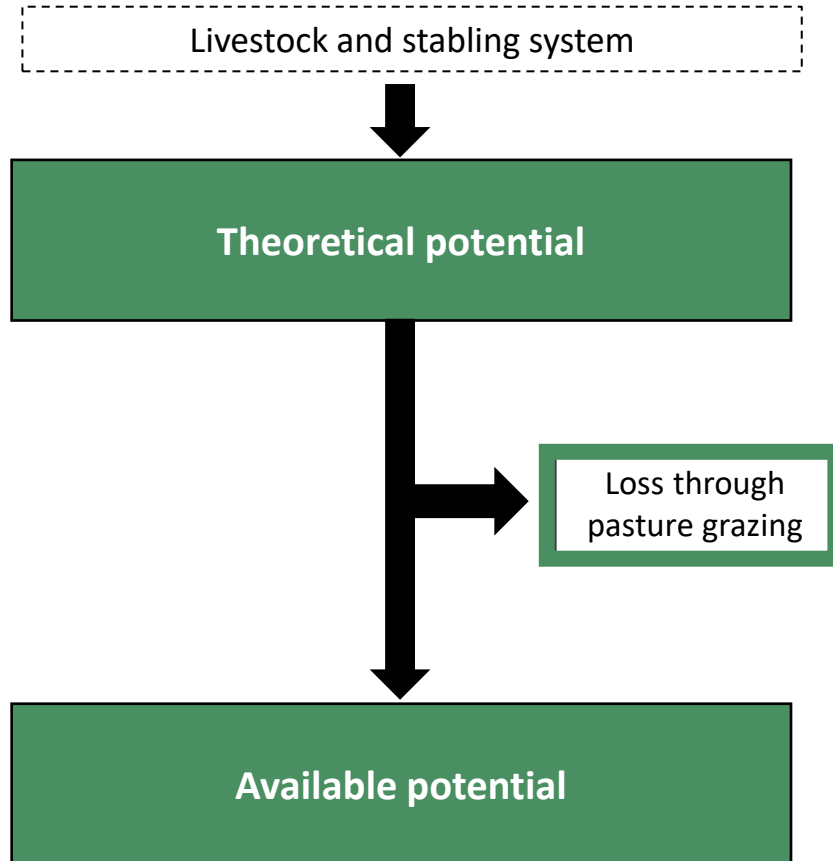
Aggregated over each pathway's storage duration

Life Cycle GHG Analysis: Field application emissions

Functional unit: 1 tonne of fresh manure (FM) treated
 Impact category: Climate change (GWP100, IPCC 2021)
 Manure type: Solid and liquid of 5 manure types (cattle, horses, sheep/goats, pigs, poultry) + weighted Swiss mix



Energy Potential Assessment



- Calculation of available agricultural potential with livestock population data of 2021.
- Considered livestock: cattle, pigs, horses, sheep, goats, and poultry.
- Primary energy content.
- Potential biomethane yield.

Burg et al. (2018). Analyzing the potential of domestic biomass resources for the energy transition in Switzerland.

Werner, S. et al. (2027). Unlocking manure's biogas potential from local to national scale: A case study of Switzerland. *Biomass and Bioenergy*, 217.

From Farm-Level Data to a National GIS Assessment



Farm-level input

48,344 georeferenced Swiss farms (2021); 42,059 with livestock and manure.



Legal siting rules

Mapped in GIS to exclude non-compliant land (buffer zones, building restrictions).



Transport constraint

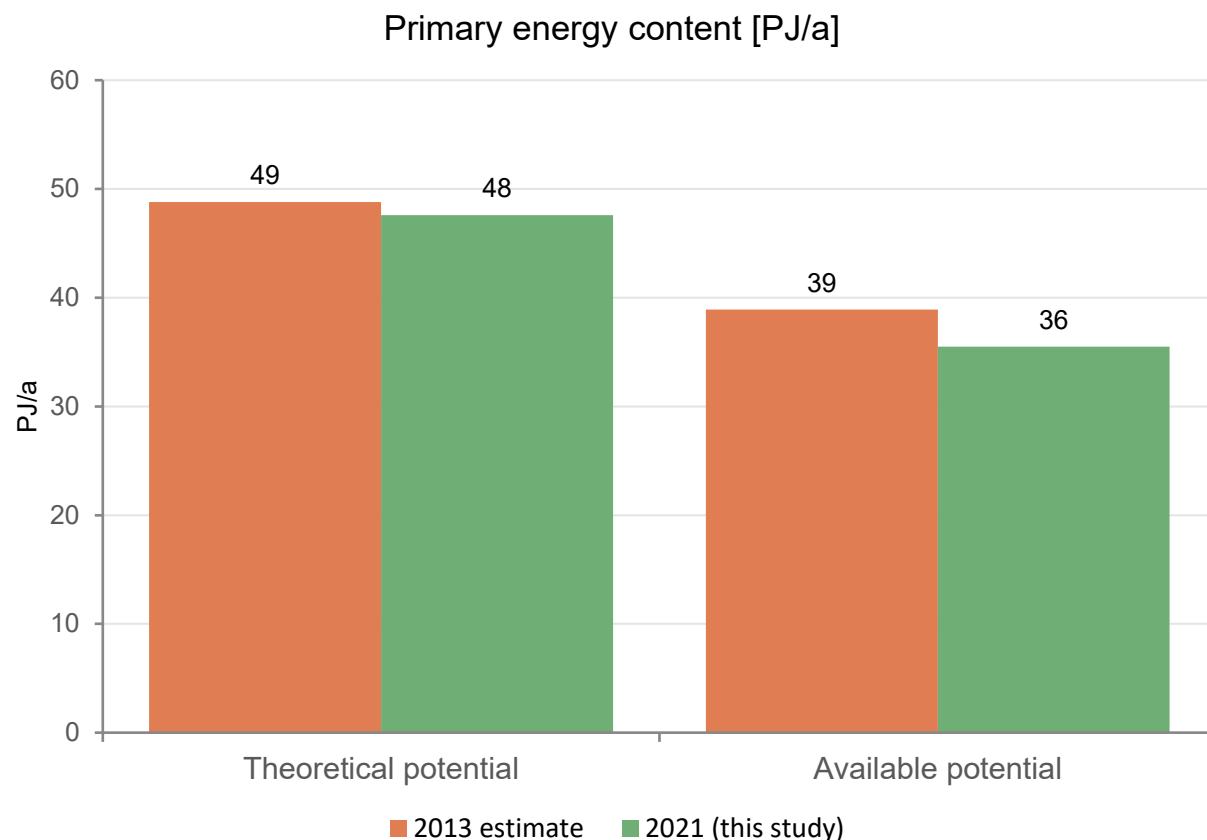
Maximum manure transport distance.



Plant-size thresholds

Minimum plant sizes for CHP and Upgrading.

Available Energy Potential Has Slightly Declined Since 2013



-2.5%

decline in theoretical primary energy potential

-8.8%

decline in available primary energy potential



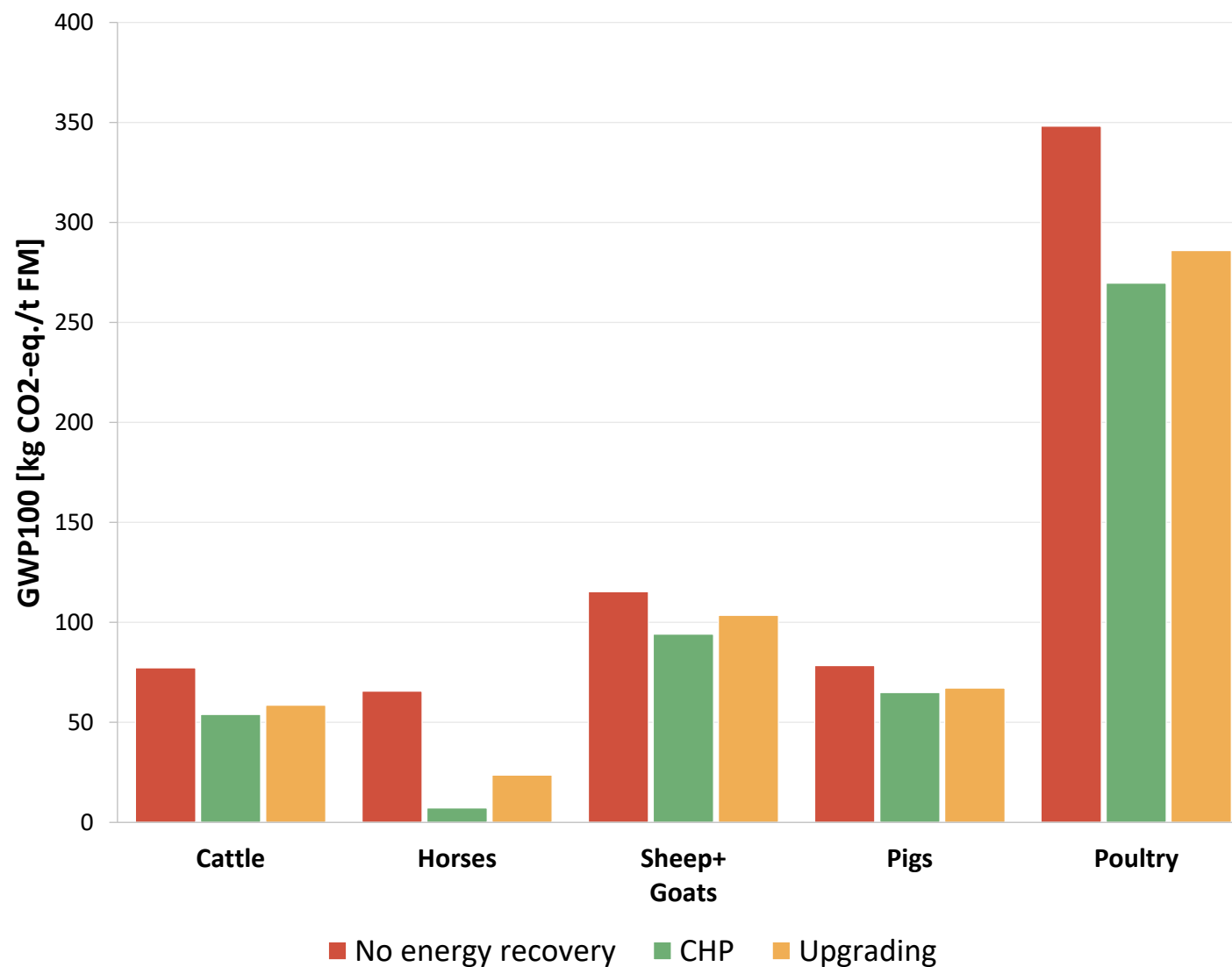
Driven mainly by
more pasture grazing, which increases manure losses outdoors

Burg et al. (2018). Analyzing the potential of domestic biomass resources for the energy transition in Switzerland.

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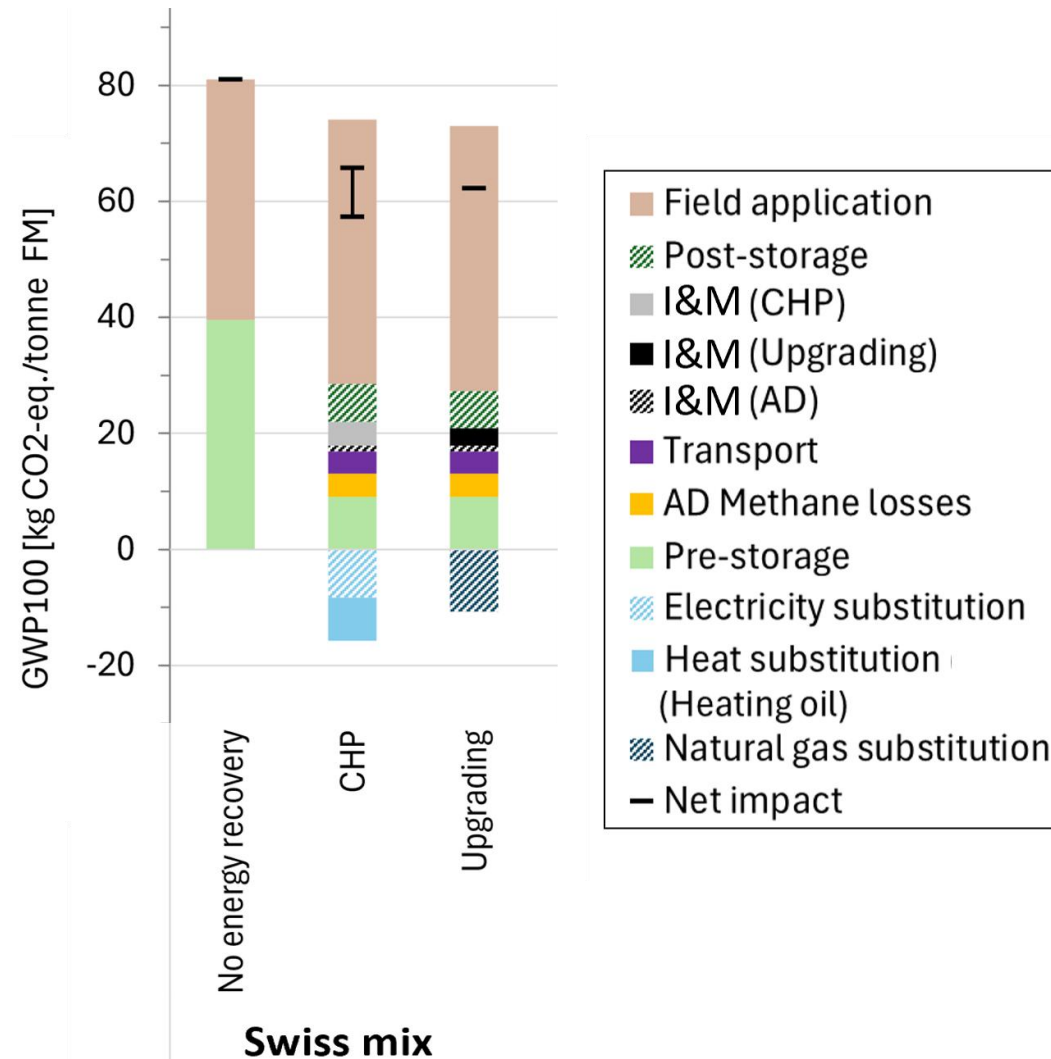
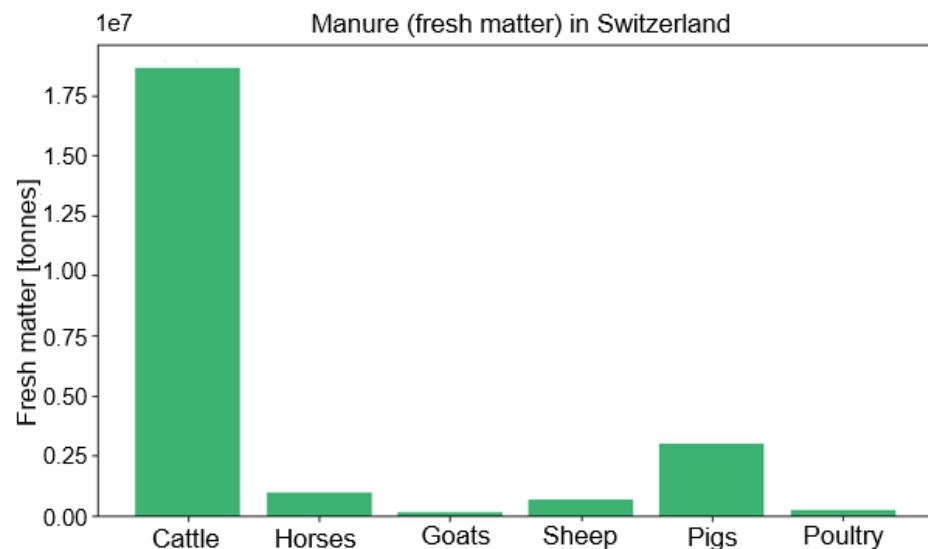
Manure-to-Energy Cuts Climate Impact by 26–36%

- Poultry manure has the highest impact (>340 kg CO₂-eq./t); horse manure the lowest.
- Baseline: storage & field application dominate.
- Energy pathways cut impact mainly via shorter storage and substitution credits → CHP with heating-oil substitution wins on climate benefit; upgrading is close behind.



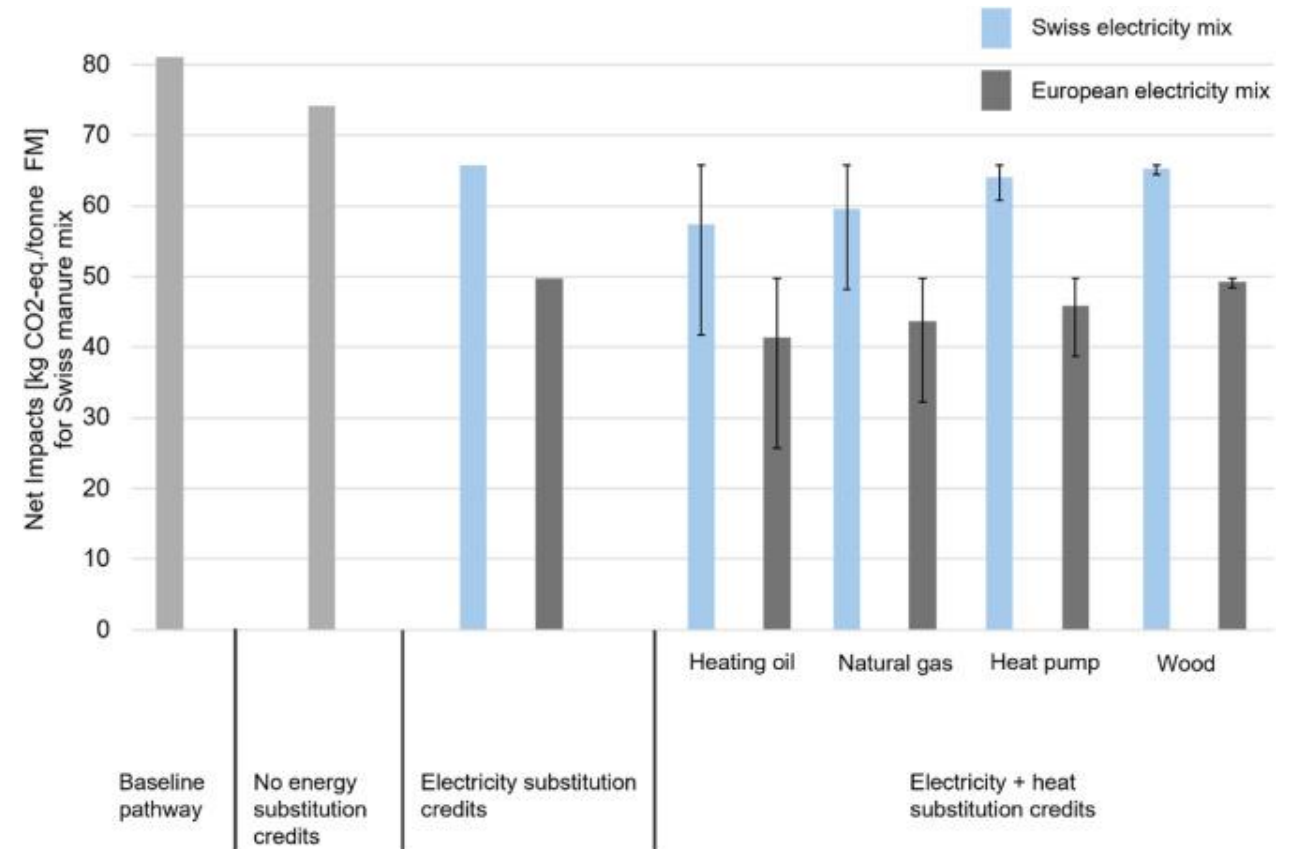
Manure-to-Energy Cuts Climate Impact by 26–36%

- For the Swiss manure mix: 80 kg CO₂-eq./t FM (baseline) → 57–66 kg (CHP) → 62 kg (upgrading).



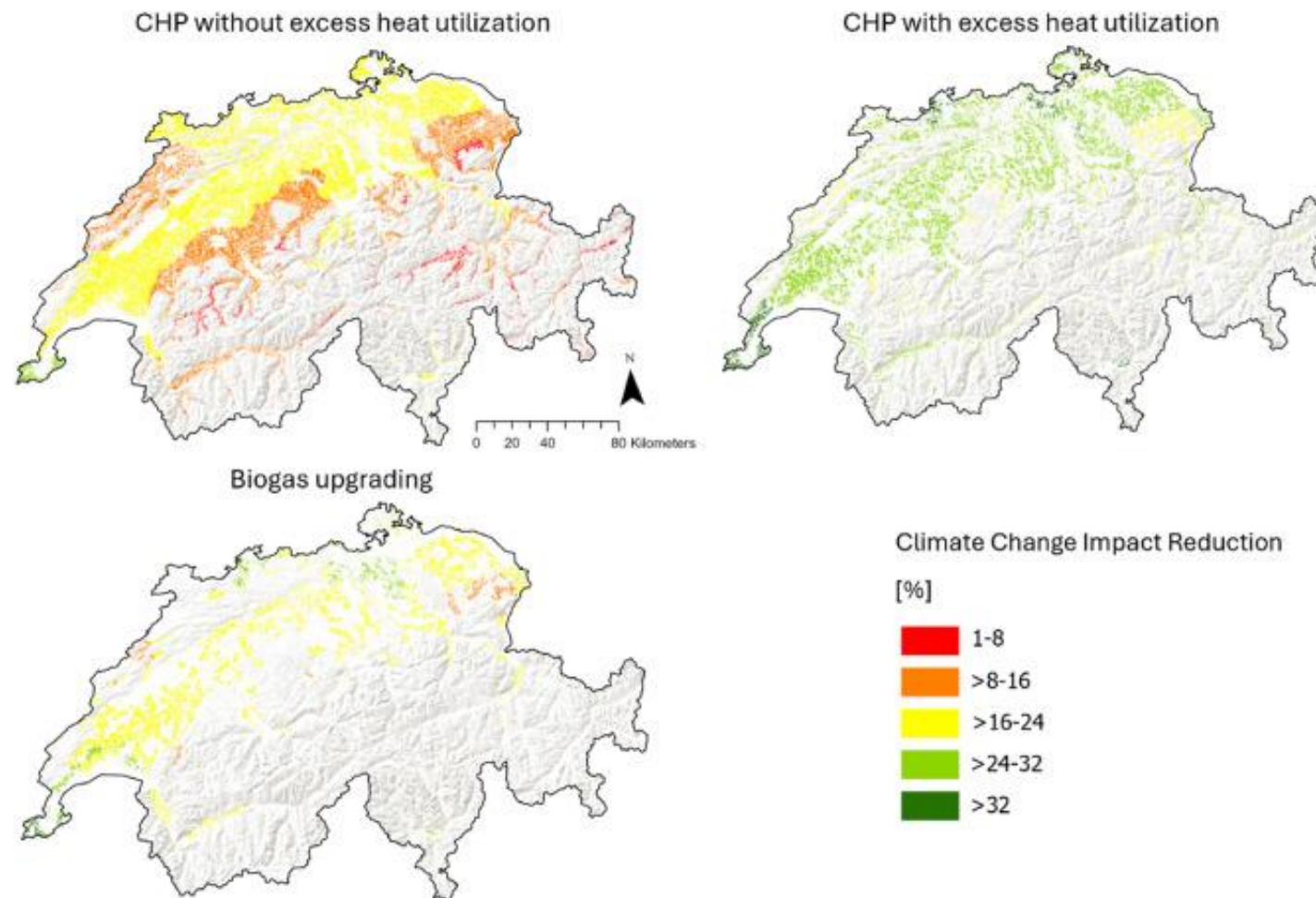
What the Net Benefit Depends On

- For energy pathways, the substituted energy carrier matters.
- Four heat substitution credits and two electricity mixes



National spatial assessment

- **CHP + excess heat use: mean 27.7% reduction; highest of all pathways.**
- Biogas upgrading: mean 21.5% reduction, concentrated on the Central Plateau.
- CHP without excess heat use: mean 15.7% reduction.
- Alpine regions (e.g. Grisons) consistently show the lowest mitigation potential → colder climate.
- Practical implication: technology choice should follow local heat demand and available gas grid infrastructure, not a one-size-fits-all rule.



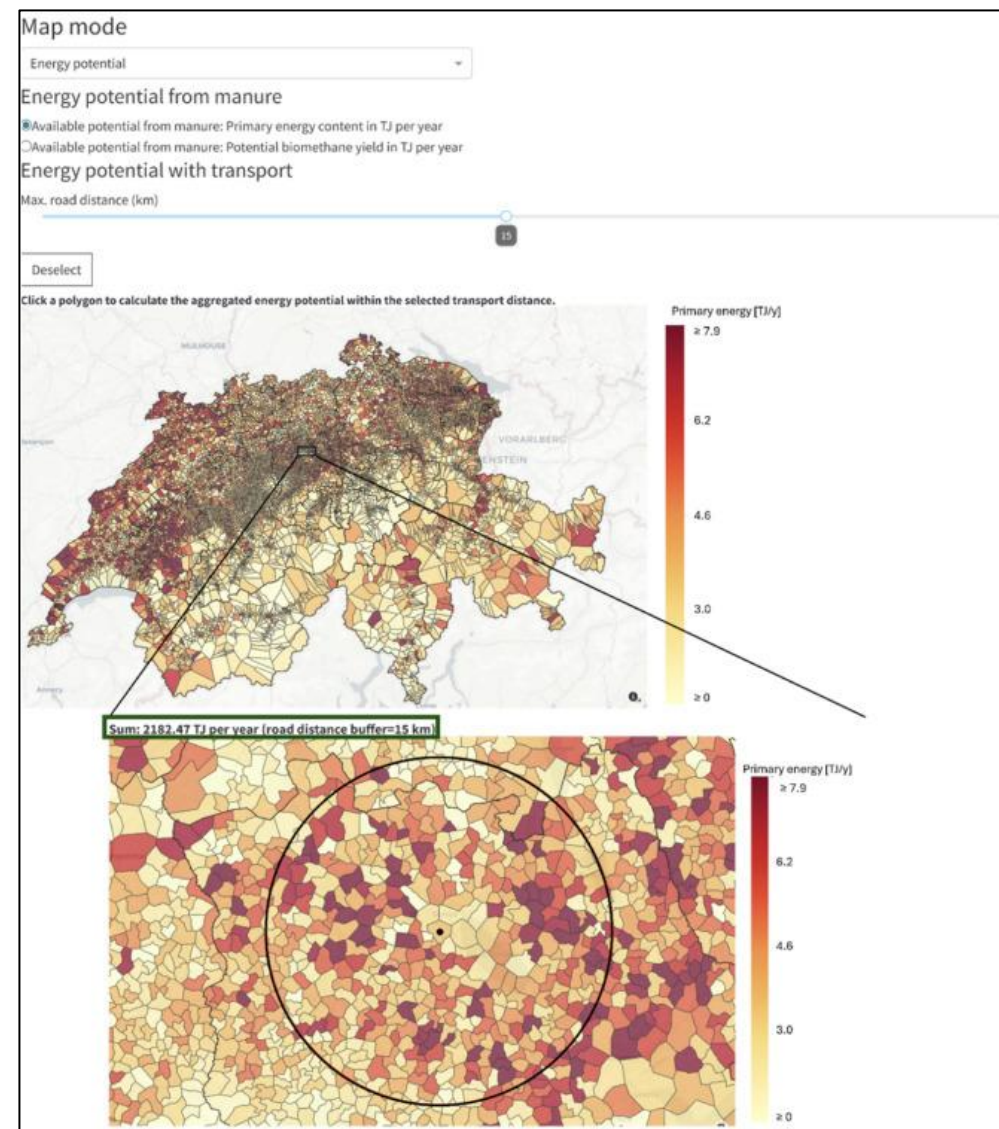
A Decision-Support Tool for Farmers & Policymakers

Web-based GIS platform providing spatial information on:

- Manure-based energy potential
- Regulatory framework for plant siting
- Technical restrictions
- Climate change impacts (GWP100)

Enabling stakeholders to:

- Interactively assess and compare manure-to-energy pathways
- Work across multiple spatial scales
- Evaluate potential at multiple levels (technical, legal, environmental)



Limitations and Outlook

Limitations

- Storage or field application mitigation options not modelled.
- No CO₂-capture, could reduce emissions of the upgrading pathway.
- Literature-based average efficiencies, no economy of scale.

Outlook

- Additional manure-to-energy pathways (methanol synthesis, hydrothermal liquefaction)
- Additional impact categories (eutrophication)
- Social acceptance and adoption of pathways

Take-Home Messages

26–36% lower climate impact

Manure-to-energy pathways cut climate impact by 26–36% compared to direct field application.

Leverage points for mitigation

Through anaerobic digestion, pre-storage emissions can be substantially reduced, while optimized storage, field application, and nutrient management could further reduce emissions.

No universal winner

No single pathway (CHP vs. upgrading) is universally best, the optimal choice depends on local conditions.

GIS + LCA → real decisions

Spatially explicit, GIS-integrated LCA is essential to turn a national strategy into locally implementable decisions.

Thank You for Your Attention



Read the full paper →

Werner, S. et al. (2027). Unlocking manure's biogas potential from local to national scale: A case study of Switzerland. Biomass and Bioenergy, 217.

Try the decision-support tool

biogasplantstool.azurewebsites.net

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reFuel.ch - Renewable Fuels and Chemicals for Switzerland

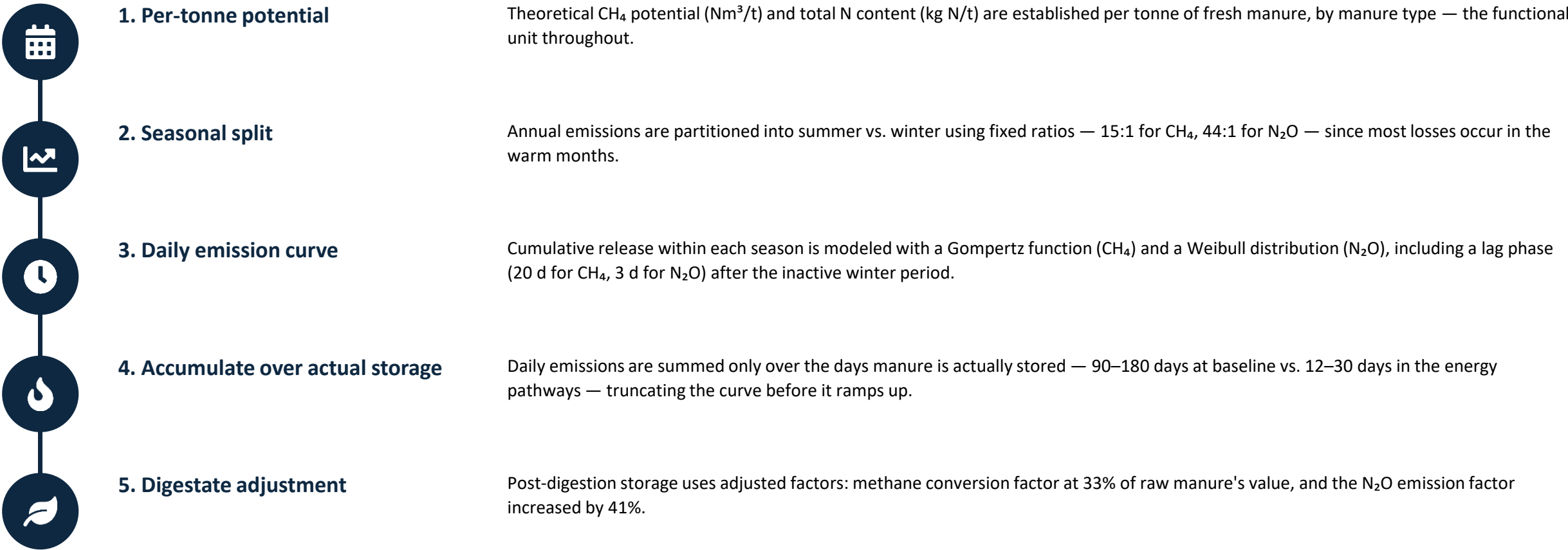
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The authors bear sole responsibility for the conclusions and the results presented.

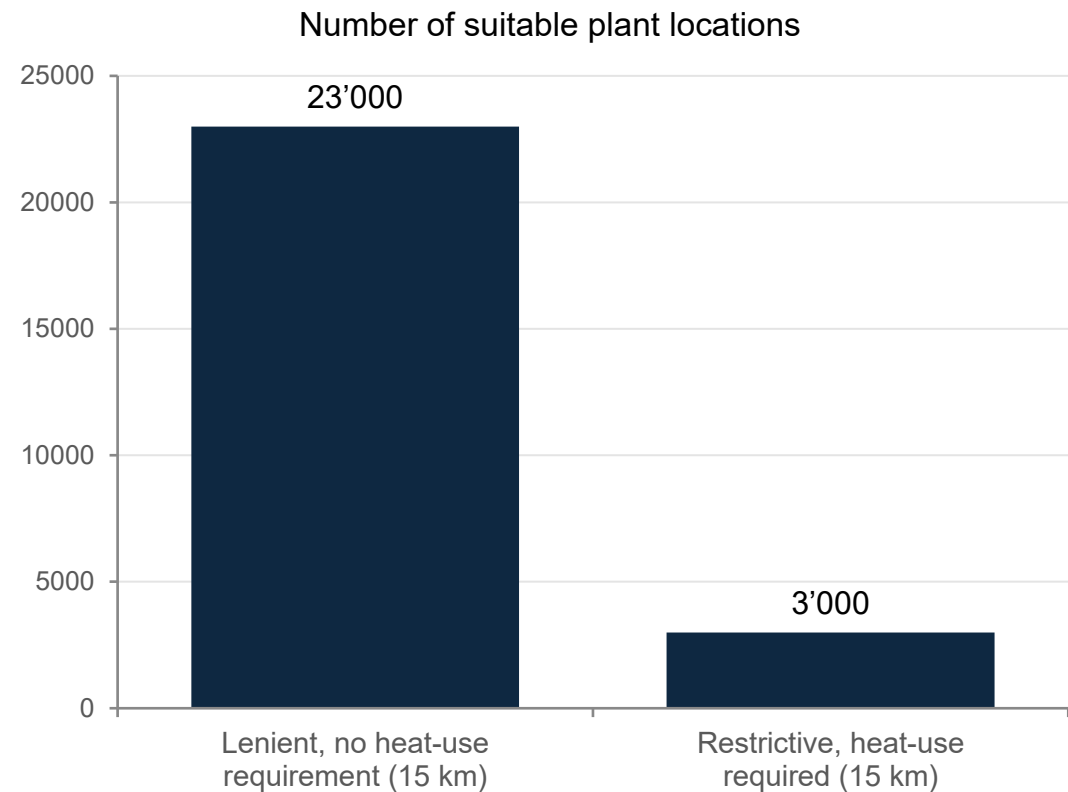


Modeling Storage Emissions: Daily Disaggregation

How annual, per-tonne emission potentials become day-by-day CH₄ / N₂O releases, truncated at each pathway's actual storage duration.



Legal Limits Cut Feasible Sites Far More Than Potential



-87%
fewer feasible plant locations under the most restrictive legal + technical scenario

<2%
difference in total national biomethane potential between the most lenient and most restrictive scenarios