Biogas Research Center
- för utveckling av resurseffektiva biogaslösningar -

Learnings and reflections from system studies during phase 2

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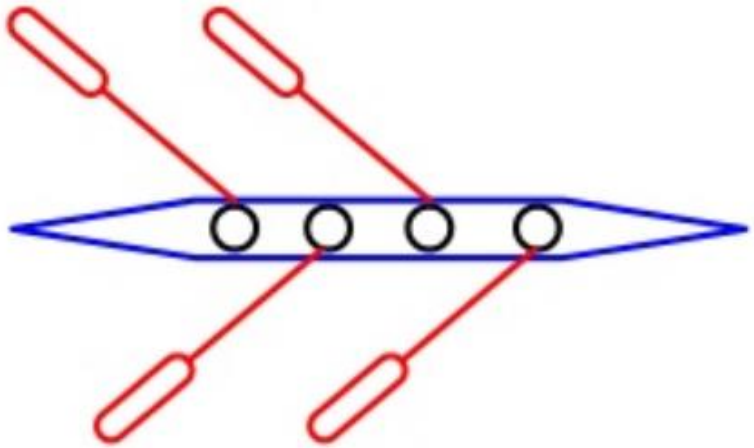
System thinking: Seeing the bigger picture, for good!

Coordination, Alignment, Inter-relations

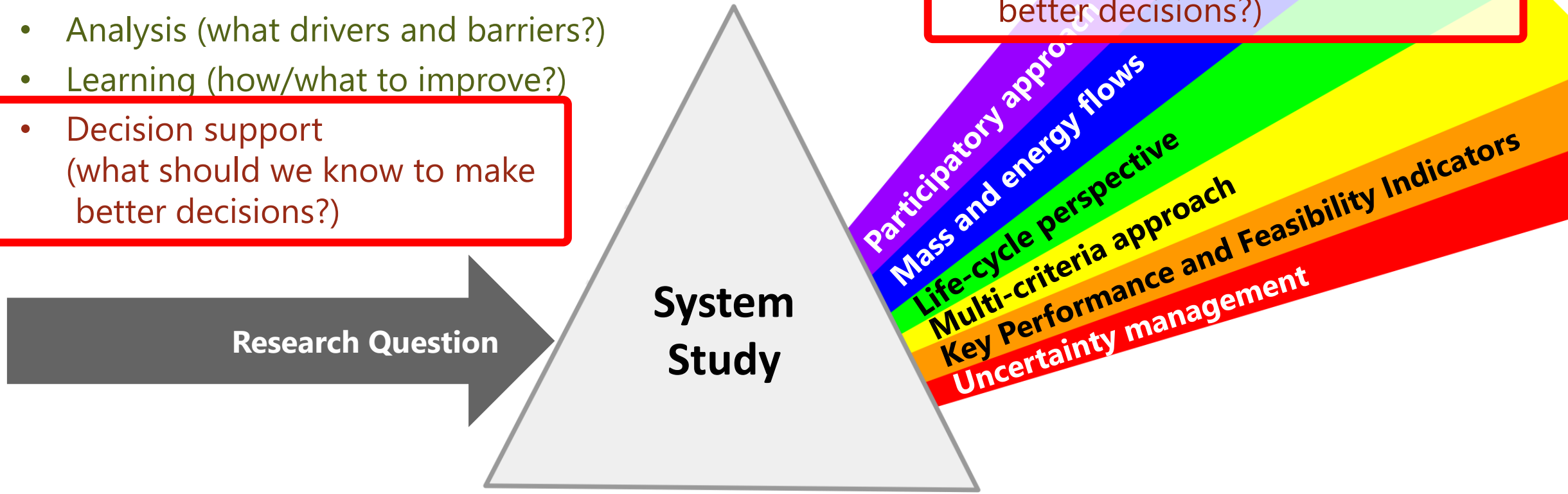
Broad perspectives

Complementary perspectives



Our approaches to systems study

- Potentials (how much?)
- Performance (how sustainable? how efficient?)
- Feasibility (how easy to implement?)
- Comparison (which option?)
- Analysis (what drivers and barriers?)
- Learning (how/what to improve?)
- Decision support
  (what should we know to make better decisions?)



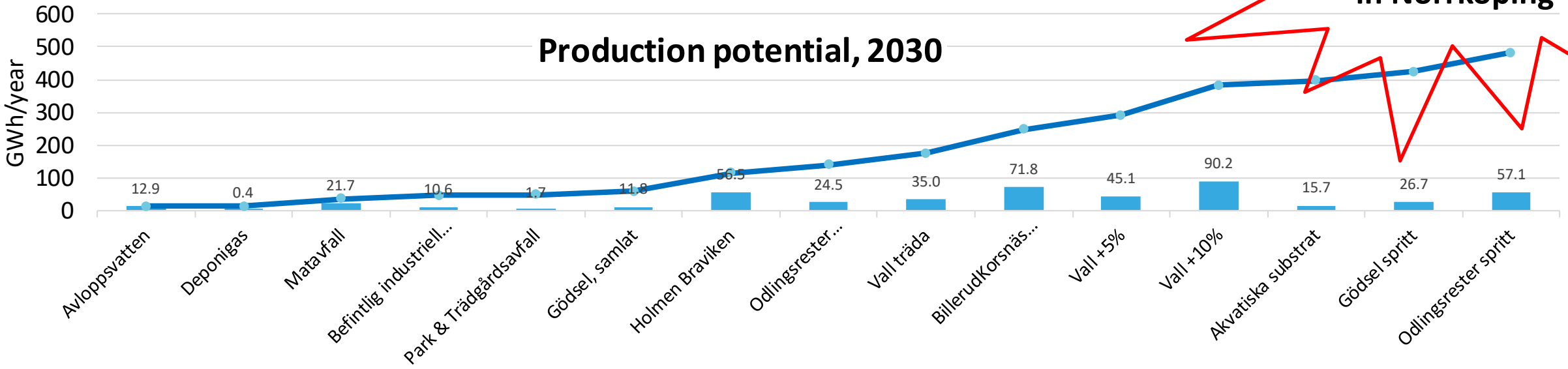
- Decision support
  (what should we know to make better decisions?)

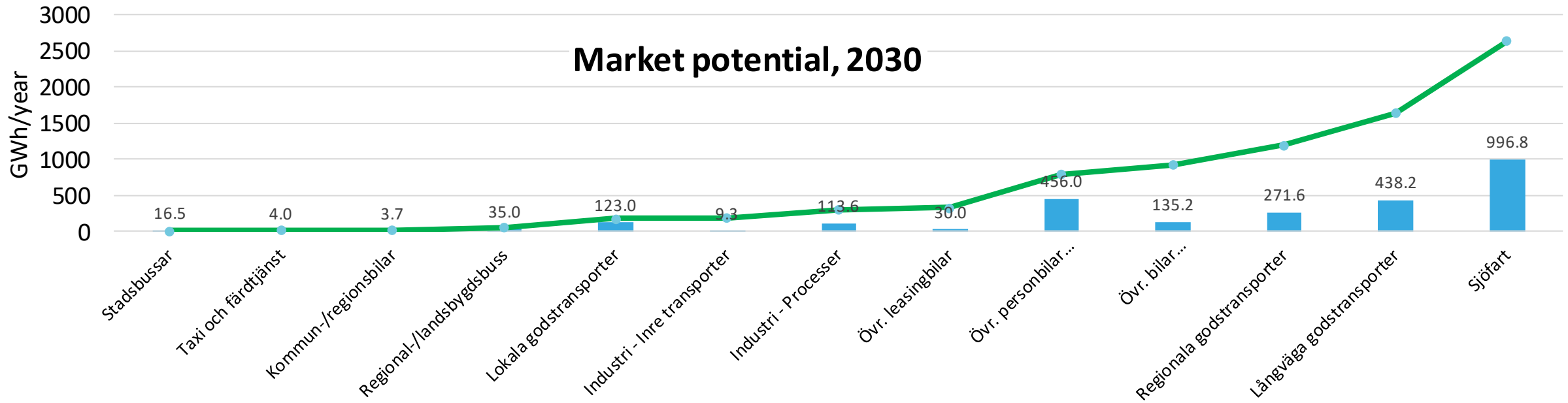
Overview of a few of our system studies

	Participatory	Mass/energy analysis (quantitative)	Life-Cycle Assessment (quantitative)	Multi-Criteria Analysis (qualitative & quantitative)	Key Performance / Feasibility Indicators	Uncertainty management	Other (ex. Potential study)
Systematic assessment of feedstock for biogas production	✓	✓		✓	✓	✓	✓
Biogas in sea-food processing cluster (Rena Hav)	✓	✓		✓	✓	✓	
Land-based salmon farming and biogas production (Smögen Lax)	✓	✓		✓	✓	✓	
Biogas role in biorefinery development (Skogn/SBF)	✓	✓	✓				
Indicators for well-to-wheel assessment of public transportation	✓	✓	✓		✓		✓
System study of biogas production from food waste (4 cases)	✓	✓	✓		✓	✓	✓
Biogas role in biorefinery development (Lantmännen Reppe)	✓	✓	✓	✓	✓	✓	
Biogas production and market potential in Norrköping municipality	✓	✓					✓

Biogas potential in Norrköping

Ex1: Biogas potential in Norrköping





Marcus Gustafsson, Axel Lindfors, Stefan Anderberg, Jonas Ammenberg, Mats Eklund (2018). Biogaslösningar i Norrköping — Potential för produktion och marknad

Ex1: Biogas potential in Norrköping

Biogas potential in Norrköping

- Potential feedstock exist mainly in:
  - agricultural sector (although divided among many actors/farms)
  - industries (mainly papermills – Braviken and Skärblacka).

- Potential demand exists mainly in:
  - the transport sector, particularly heavy transports (trucks) and cars

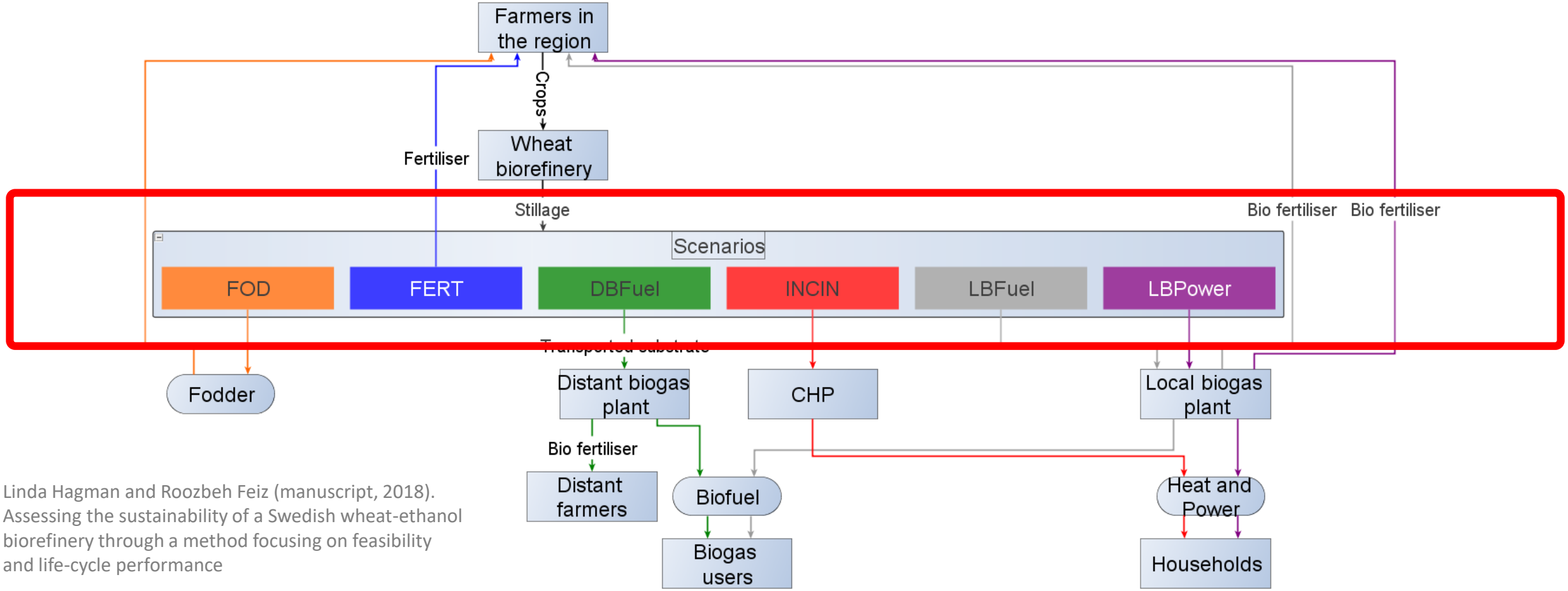
- Potential demand is far higher than the potential production
  - But, not all of the demand is expected to be covered by biogas

Marcus Gustafsson, Axel Lindfors, Stefan Anderberg, Jonas Ammenberg, Mats Eklund (2018). Biogaslösningar i Norrköping — Potential för produktion och marknad

Biogas role in biorefinery development

Ex2: Lidköping wheat-ethanol biorefinery

- Lantmännen Reppe wheat-ethanol biorefinery in Lidköping; produces ethanol, gluten, starch and syrup from wheat
- What are the most suitable ways of treating the byproduct, stillage?
  (produce fodder, directly use as biofertilizer, or anaerobically digest and produce biogas and biofertilizer?)
- Comparison of the scenarios using multi-criteria analysis



Linda Hagman and Roozbeh Feiz (manuscript, 2018). Assessing the sustainability of a Swedish wheat-ethanol biorefinery through a method focusing on feasibility and life-cycle performance

Biogas role in biorefinery development

Ex2: Lidköping wheat-ethanol biorefinery

Key area	Indicator	FOD	FERT	INCIN	LB Fuel	LB Power	DB Fuel
Profitability or cost efficiency (performance)	Profitability or cost efficiency	Good ***	Poor ***	Very Poor ***	Good ***	Fair ***	Good ***
	Transportation efficiency	Fair ***	Very Good ***	Very Good ***	Very Good ***	Very Good ***	Very Poor ***
						Good *	Very Good ***
Energy and environmental performance, r and resource e (performance)						od *	Very Good ***
						od *	Very Good ***
		Fair ***	Poor ***	Very Poor ***	Good ***	Good ***	Very Good ***

- From almost all the studied aspects, the scenarios involving biogas production from stillage showed good performance and feasibility
- Biogas has helped the growth of the studied biorefinery

Linda Hagman and Roozbeh Feiz (manuscript, 2018). Assessing the sustainability of a Swedish wheat-ethanol biorefinery through a method focusing on feasibility and life-cycle performance

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Biogas role in biorefinery development

Ex2: Lidköping wheat-ethanol biorefinery

Key area	Indicator	FOD	FERT	INCIN	LB Fuel	LB Power	DB Fuel
Technical feasibility (feasibility)	Technological readiness	Good ***	Good ***	Very Poor ***	Good ***	Very Good ***	Good ***
	Infrastructural readiness	Very Good ***	Very Good ***	(Fair) Poor **	Good ***	Very Good ***	Good ***
Organisational feasibility (feasibility, low risk)	Actor's readiness	Very Good ***	Good ***	Good ***	Very Good ***	Very Good ***	(Fair) Good **
Public acceptanc institutional feasi (feasibility, low ri							Fair **
							Good **
	business			***	***	***	Very Good ***

- From almost all the studied aspects, the scenarios involving biogas production from stillage showed good performance and feasibility
- Biogas has helped the growth of the studied biorefinery

Ex3: Biogas from food waste

System analysis of biogas from food waste

- Considering four co-digestion plants that use food waste for producing biogas
  - More biogas (Kalmar), Tekniska verken (Linköping), Scandinavian biogas (Södertörn), VMAB (Mörrum)

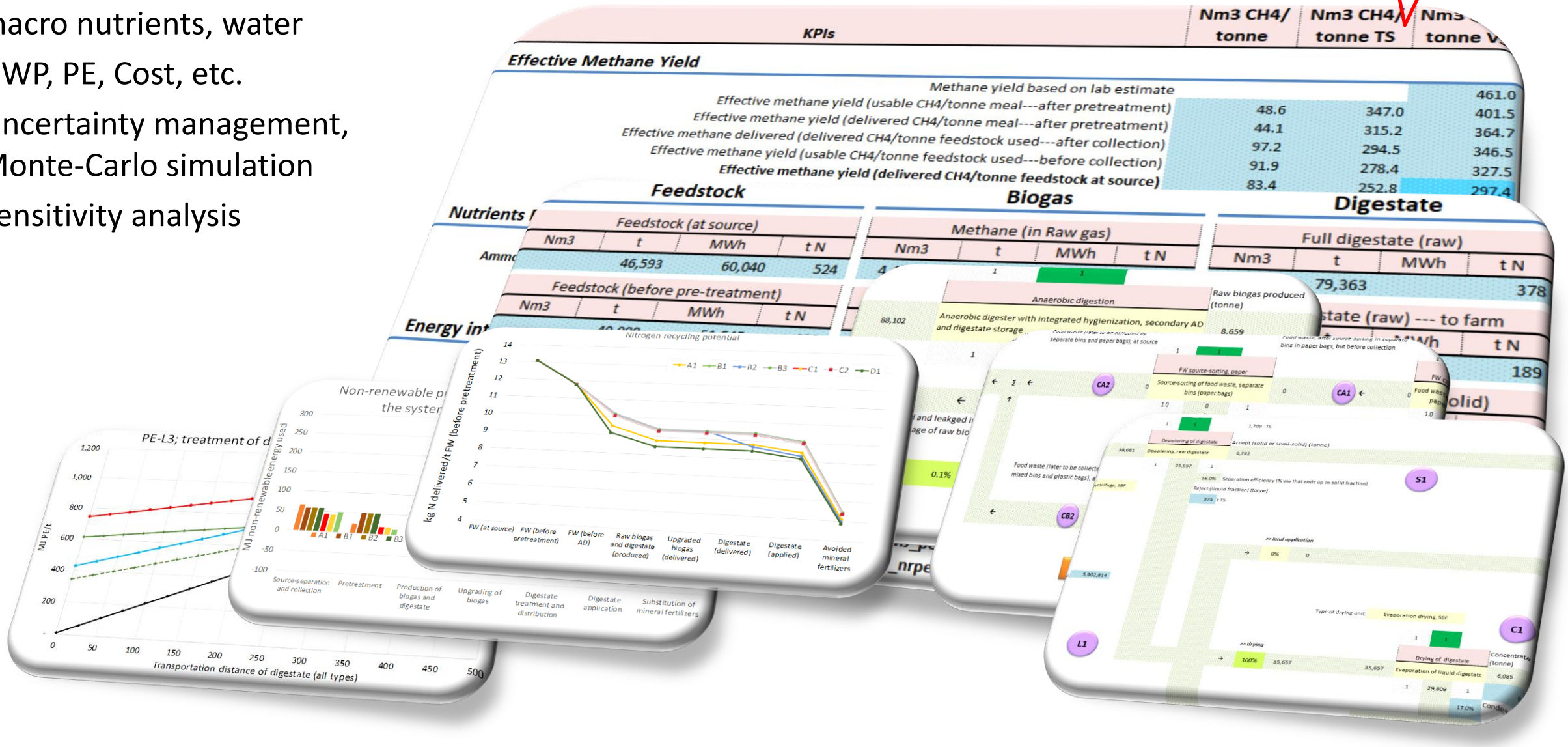
- Assess the life-cycle environmental and economic performance of biogas production from food waste
  - systems analysis, energy analysis
  - key performance indicators
  - uncertainty analysis

System analysis of biogas from food waste

Ex3: Biogas from food waste

SysBiogas v.1: an Excel-based model for life-cycle analysis of biogas solutions

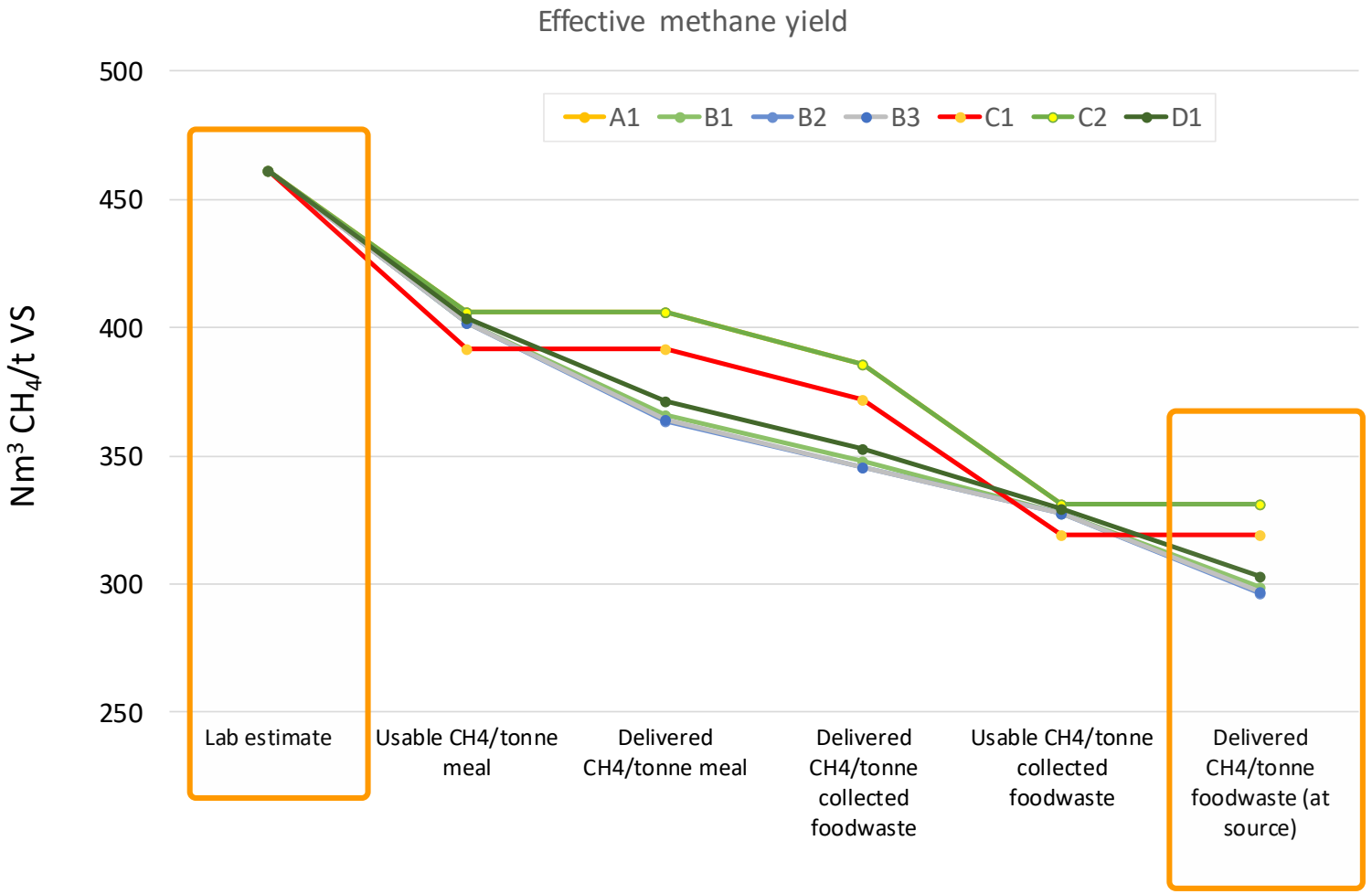
- Flows: mass (wet, dry), energy, macro nutrients, water
- GWP, PE, Cost, etc.
- Uncertainty management, Monte-Carlo simulation
- Sensitivity analysis



Ex3: Biogas from food waste

System analysis of biogas from food waste

- A few Key Performance Indicators are suggested to capture the performance of biogas production from food waste
- Example: effective methane yield

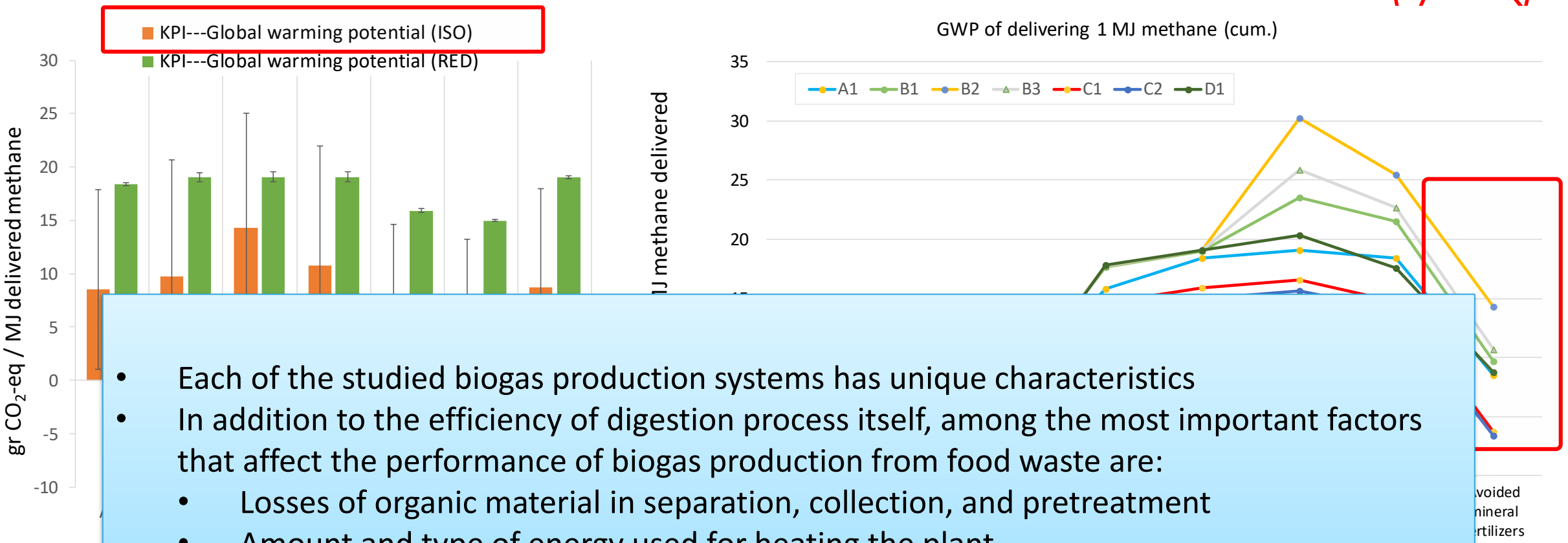


Key Performance Indicators for biogas production—Integrated assessment of producing biogas from food waste (manuscript, 2018). Roozbeh Feiz, Maria Johansson, Emma Lindkvist, Jan Moestedt, Sören Nilsson Påledal, Niclas Svensson

Environmental and economic systems analysis of biogas production from household food waste—multiple cases from Sweden (manuscript, 2018). Roozbeh Feiz, Maria Johansson, Emma Lindkvist, Niclas Svensson

KPIs: cumulative performance curves

Ex3: Biogas from food waste



- Each of the studied biogas production systems has unique characteristics
- In addition to the efficiency of digestion process itself, among the most important factors that affect the performance of biogas production from food waste are:
  - Losses of organic material in separation, collection, and pretreatment
  - Amount and type of energy used for heating the plant
  - The need for additional digestate treatment due to excessive distance to farm areas

Key Perfor
Lindkvist,

Environme
Johansson, Emma Lindkvist, Niclas Svensson

What have we learned?

- Versatile and complex
- Great potential for growth
- Values are much more than the biogas itself
- Role in biorefineries and biobased industrial development
  - "enablers of growth"
- Technology, often not the main barrier
- Uncertain policies can act as barrier

- Developed and tested approaches, methods, frameworks, models, and tools
  - Can be used for many different types of studies in future
- Learnings among the researchers, and hopefully all other colleagues and participants

Our main learnings are with our people!

- Jonas Ammenberg
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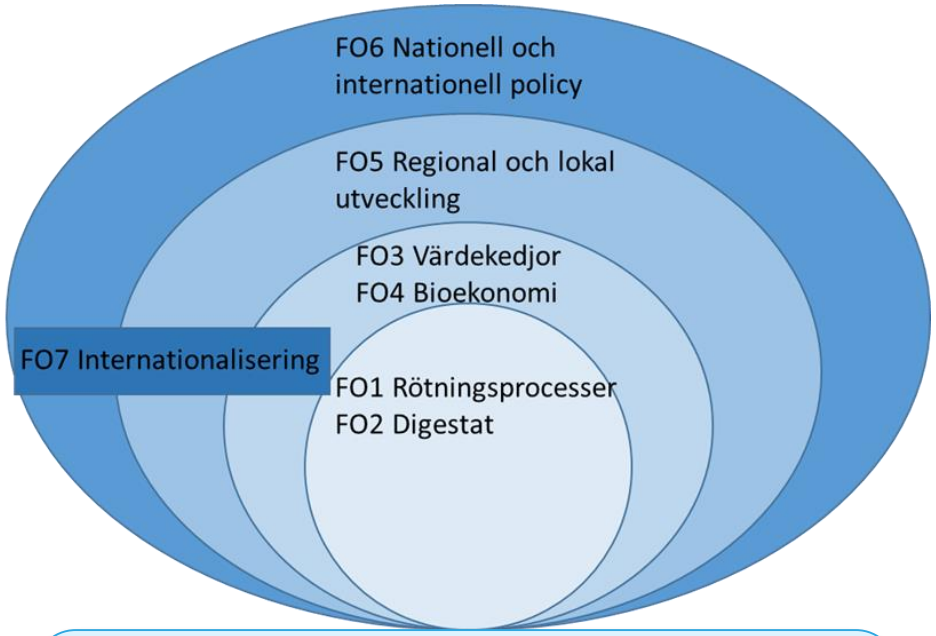
Reflections on the way forward

- Life-cycle performance of various biogas production pathways; and their competing alternatives
- Effect of scale, location, feedstock, and technology on the life-cycle performance of biogas systems
- Life-cycle performance of different products and services, before and after using biogas/biofertilizer in their system

- Effect of LBG on the expansion of the biogas market in the heavy transport; potential, performance and feasibility
- Feasibility and performance of biogas solutions in international contexts with Swedish relevance
- Potential role of biogas solutions for better nutrient recirculation in the regions, considering real-world constraints

- How to better capture the diverse values of biogas solutions in communicable terms?

- …



Lets use tomorrow's workshop for more discussion about this!

Sure, models are always a bit different than reality, …

… but I now know a bit more about biogas solutions and the strengths and weaknesses of systems analysis! Perhaps, this can only work by dialogue, sharing, flexibility and openness; and a curious but forgiving mind supported by a little bit of playfulness and endurance, and hopefully immune from arrogance!

Thank you for your attention!
Roozbeh