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SUSMILK

Life Cycle Assessment of improvement options in dairies

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SUSMILK Final Conference

Santiago de Compostela, Spain, 22-23.9.2016

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration

Content of presentation

- Methodology and key questions
- Results of the Life Cycle Assessment
  - Conducted analyses
  - Explanation of the weighting and normalizing approaches (value choices)
  - Results and recommendations for heat, cooling and electricity
  - Results for optimization

GENERAL INFORMATION ON WP7

Content of the WP 7

- Objective:
  - Environmental, economic and social impacts caused by the new components and concepts
  - Exergy-based analysis (Richtvert)
  - Economical/Social analysis (Fraunhofer Umsicht)
- Based on LCA standards and new (EU) developments
- Scenarios and sensitivity analysis are conducted
- Weaknesses and improvement potentials are identified

Deliverables WP7

Deliverable Number	Deliverable Title	Nature	Dissemination level	Month
D7.1	Goal and scope definition for the life cycle assessment	O	CO	12
D7.2	Life cycle inventory data in electronic format	O	CO	19
D7.3	Report on life cycle assessment, economic assessment, potential employment effects and exergy-based analysis	R	PU	31
D7.4	Recommendations for the dairy industry	R	PU	36

Tasks within the WP

7.1: Method description for LCA and literature review

7.2: Goal and scope definition

7.3: Modelling of life cycle inventories

7.4: Life cycle impact assessment

7.5: Exergy-based analysis

7.6: Result interpretation, sensitivity analysis

7.7: Cost analysis and employment effects

7.8: Recommendations

Input or interactions with other partners

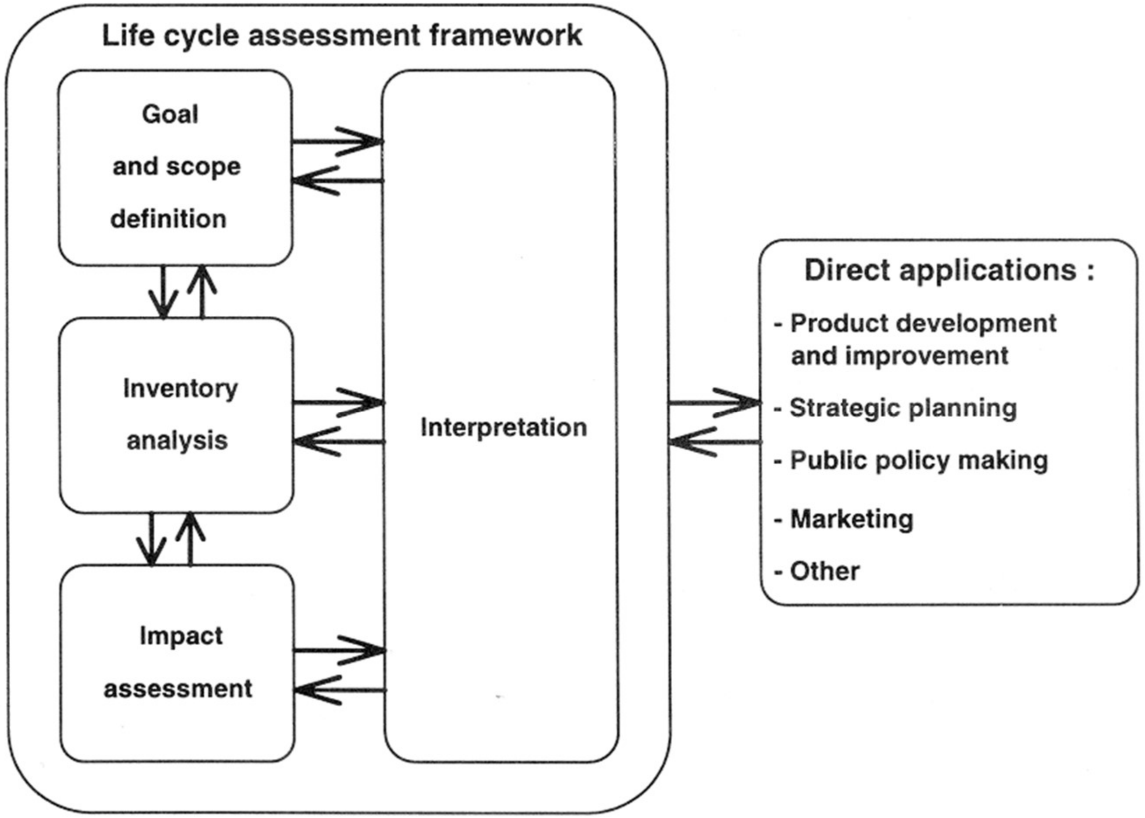
- Within WP7:
  - Expert input of Richtvert for exergy-input analysis
  - Expert input of Fraunhofer for cost analysis, employment effects and recommendations
  - Data from project partners developing components
- Inputs from other WPs:
  - WP1: Input for goal & scope definitions and data for the inventories and analysis
  - WP5: Key data and assumptions for improvement scenarios
- Inputs to other WPs:
  - WP9: Input for the communication and dissemination

LIFE CYCLE ASSESSMENT

Life Cycle Assessment methodology

- ISO 14040/44
- Balance of all in- and outputs
- Life cycle from cradle to gate
- Assessment of different environmental impacts (e.g. climate change, water depletion, resource depletion)

ISO standard 14040: LCA



Goal and scope definition:

- Goals of the LCA
- Key questions to be answered
- Object of investigation
- System boundaries
- Functional unit

GOAL AND SCOPE

Goal of the LCA

- Analyze a baseline model of an European dairy plant
- Simplified model with regard to product portfolio and inclusion of waste management
- Analyze and evaluate improvement scenarios for technologies delivering heat, electricity and chilling
- Some SUSMILK improvement options concerning e.g. concentration of raw milk or treatment of effluents could not be modelled in the LCA due to lack of data at the time of finalizing the data collection.

Key questions to be answered with the LCA

The following key questions are answered in this LCA study:

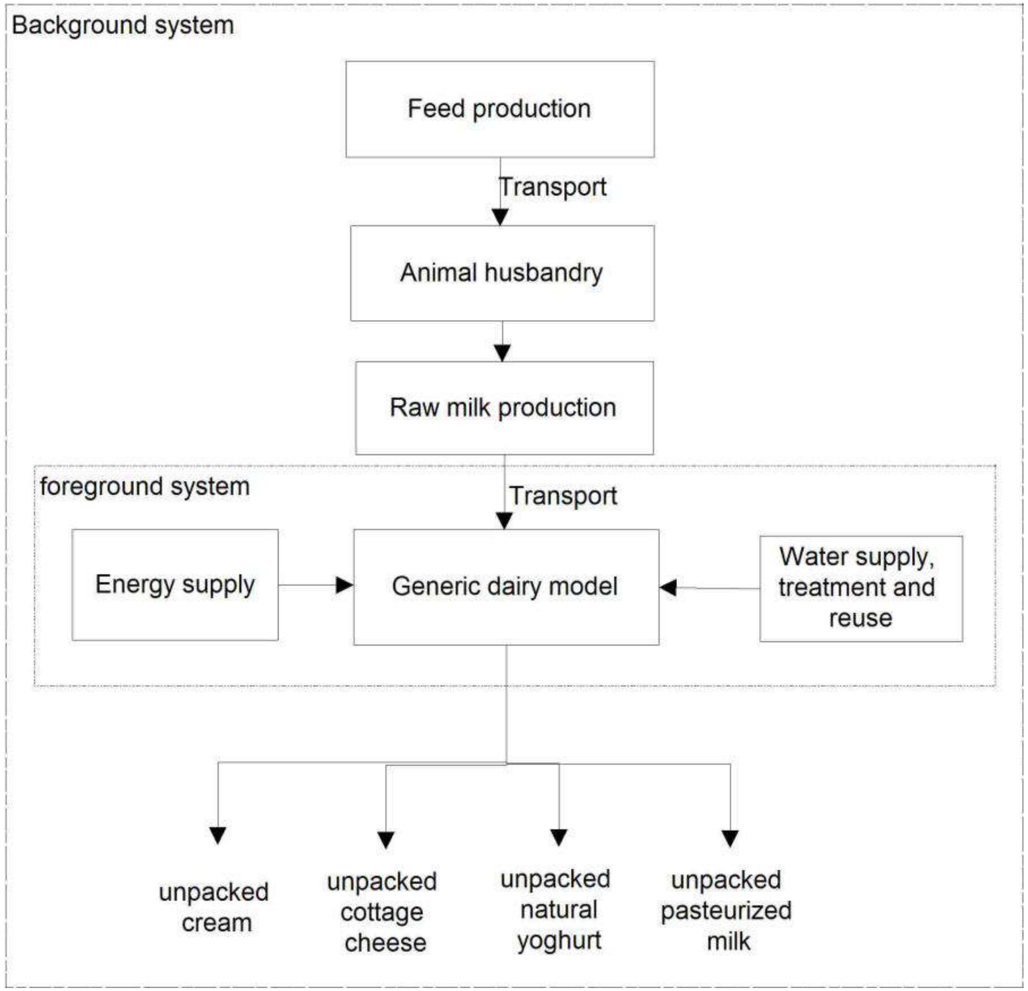
- How relevant are the energy and water uses in different process stages in the dairy from an environmental point of view?
- Which influence on the environmental impacts can be expected by replacing conventional technologies by other state-of-the-art or new (SUSMILK) technologies?

Object of investigation: dairies

Dairy plant	Raw milk input (l/year)	Distance farm-plant (km)	Milk	Cheese	Yoghurt	Cream	Butter	Other dairy products	Energy use
Feiraco	106'003'117	30 (1-150)	X		X	X		Milk shake, Laban	Natural gas
Karwendel (Exquisa)				X					
Mlekara			X			X			
Queizuar	6'644'890	200		X		X		Cheese whey	Diesel
Wiegert			X	X	X		X		

- 5 dairies across Europe
  - Specific size
  - Specific portfolio: multi-product milk processing chain
  - Only Exquisa has a single product processing chain

System boundaries: cradle-to-gate



- Foreground system:
  - Milk processing
  - Energy & Water, but no packaging material
  - ➢ Data from partners
- Background system:
  - Feed cultivation
  - Raw milk production
  - ➢ Data from ESU database (CH, RO)
  - ➢ Data from ecoinvent database

Functional unit for the LCA

- Selected **functional unit:**
  Raw milk input in liter
  → Focus of the project is milk processing
  → Investigation of single dairy products is not foreseen
- The **reference flow** for the modelling:
  Raw milk input per day (600 000 l)
  of operation for the generic dairy model
- The reference year is 2013

Task 7.3 resp. Deliverable D 7.2: Data Collection

LIFE CYCLE INVENTORY ANALYSIS (LCI)

Life cycle inventory analysis (LCI)

- LCI is the basis for the LCA (Life Cycle Assessment)
- LCI includes all material and energy flows of each modelled process:
  - Inputs and outputs (e.g. energy, water, chemicals, ..)
  - Emissions to air, water and soil
  - Resource uses (energy, water, land)
- LCI (Del. 7.2) has been delivered in Month 25

Example inventory data

defined process ↓

	F	G	J	K	L
3	Name	Location	Infrastructure-Process	Unit	round wood, Scandinavian softwood, under bark, u=70% at forest road
4	Location				NORDEL
5	rastructureProcess				
6	Unit				
7	ammonium sulphate, as N, at regional storehouse	RER	0	kg	1.3E+0
8	lubricating oil, at plant	RER	0	kg	4.3E-2
9	gravel, crushed, at mine	CH	0	kg	3.2E+2
10	diesel, burned in building machine	GLO	0	MJ	8.0E+1
11	power sawing, without catalytic converter	RER	0	h	7.1E-2
12	transport, lorry 16t	RER	0	tkm	1.6E+1
13	softwood, Scandinavian, standing, under bark, in forest	NORDEL	0	m3	1.0E+0

Inputs for the new process ↓

Location ↓

↓ Unit

↓ values

→ Imported to LCA software

Example data documentation

Reference function	round wood, Scandinavian softwood, under bark, u=70% at forest road, NORDEL, [m3]
name	round wood, Scandinavian softwood, under bark, u=70% at forest road
localName	Nadelrundholz, Skandinavien, Festkubikmeter, u=70%, ab Waldstrasse
infrastructureProcess	no
unit	m3
category	wooden materials
subCategory	extraction
localCategory	Holzbaustoffe
localSubCategory	Gewinnung
amount	1
includedProcesses	This module includes material and energy amounts for stand establishment, tending, site development, thinnings and final cutting of scandinavian round softwood (logs for sawmill), its transport to the nearest forest road as well as the land and materials use for the forest roads
generalComment	The volume does not include the bark. CO2 assimilation is based on 49.4% carbon in the wood. Biomass energy equals gross calorific value including bark.
infrastructureIncluded	yes
datasetRelatesToProduct	yes
Geography	round wood, Scandinavian softwood, under bark, u=70% at forest road, NORDEL, [m3]
location	NORDEL
text	Typical data for the forest industry in Scandinavia from a finnish LCA database
Technology	round wood, Scandinavian softwood, under bark, u=70% at forest road, NORDEL, [m3]
text	Modern average technology used in Scandinavia
Time period	round wood, Scandinavian softwood, under bark, u=70% at forest road, NORDEL, [m3]

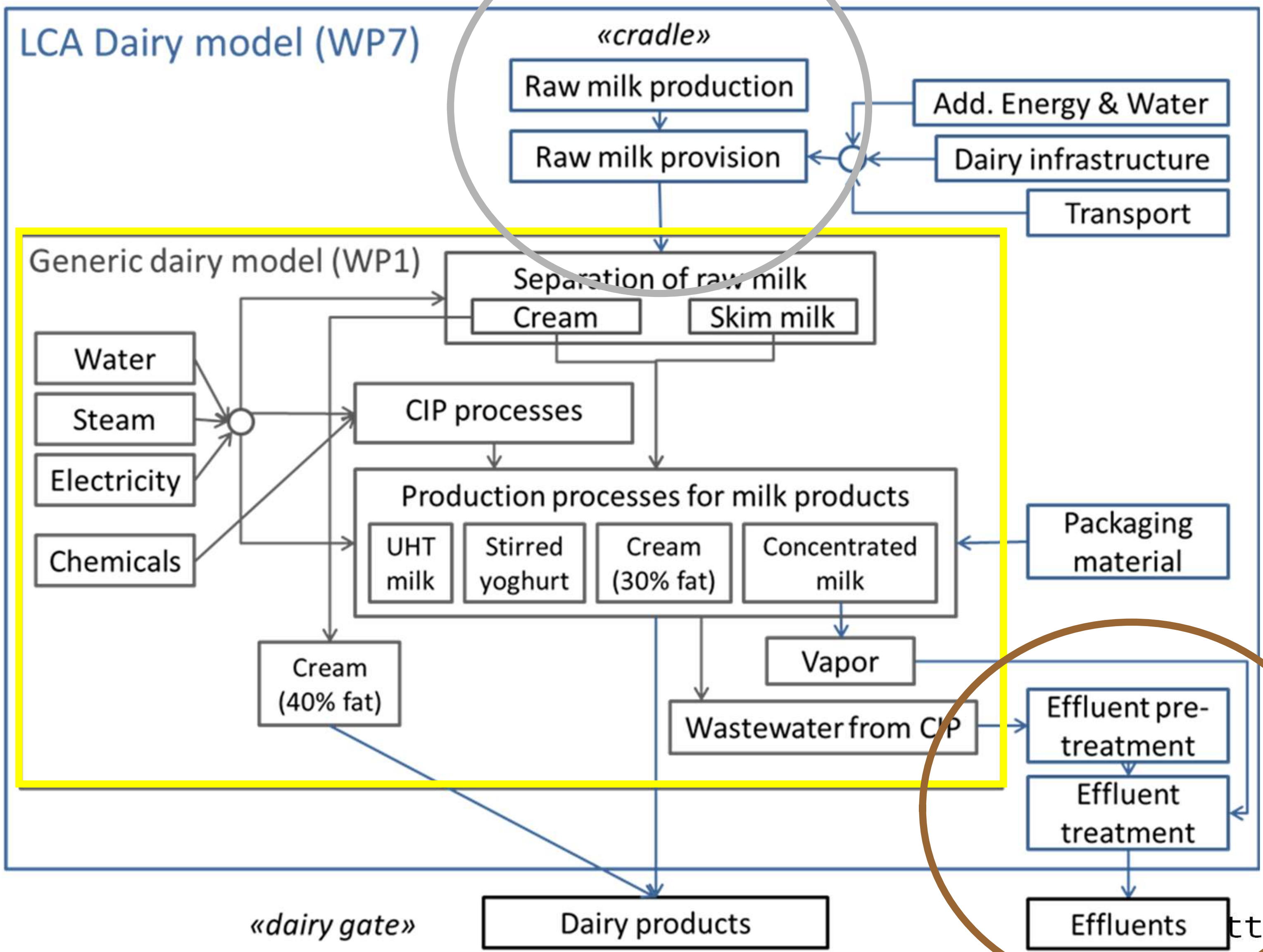
Object of investigation

- LCA dairy model
  - Based on generic dairy model (WP1 data)
  - Plus additional inputs (e.g. infrastructure)
- LCA improvement options
  - Based on information from WP1, WP5 and data from questionnaires answered by project partners about their technical components

Additional inputs - background processes

- For the LCA we need more data than provided by the generic dairy model
- Further data collection for background processes
  - Literature data for full list of Input/Output flows in dairies
  - Delivery of materials and milk to the dairy
  - Effluent pre-treatment in dairies and final treatment in wastewater treatment plants

Schematic depiction of models



Grouping of inputs into process stages for analysis of LCA dairy model

Process stage	Model
Raw milk input	LCA dairy model
Purchased ingredients, dairy plant, additions	LCA dairy model
Transport of milk	LCA dairy model
Wastewater	LCA dairy model
Consumer packaging	LCA dairy model
Electricity, surplus	LCA dairy model
Electricity	Generic dairy model
Steam for production	Generic dairy model
Steam for CIP	Generic dairy model
Chemicals (HNO_3, NaOH)	Generic dairy model
Water use	Generic dairy model

LIFE CYCLE IMPACT ASSESSMENT

What was analyzed?

- LCA dairy model (operation of dairy for one day)
- Provision of heat
- Provision of cooling
- Provision of electricity
- Sensitivity analyses
- Optimized dairy

Life cycle impact assessment categories

according to the ILDC recommendations

Impact category	Indicator unit
Climate change	kg CO_2 eq
Ozone depletion	kg CFC-11 eq
Freshwater ecotoxicity	CTUe = Comparative Toxic Unit for ecosystems
Human toxicity, cancer effects Human toxicity, non-cancer effects	CTUh = Comparative Toxic unit for humans
Particulate matter	kg $PM_{2.5}$ eq
Ionizing radiation (Human health effects)	kg U^{235} eq (to air)
Photochemical ozone formation	kg NMVOC eq
Acidification	mol H+ eq
Terrestrial eutrophication	mol N eq
Aquatic eutrophication	Freshwater: kg P eq Marine: kg N eq
Abiotic resource depletion	kg antimony (Sb) eq
Water depletion	m^3 water use related to local scarcity of water
Land use	kg C deficit
Cumulative Exergy Demand (CExD)	MJ-eq

Life Cycle Impact Assessment

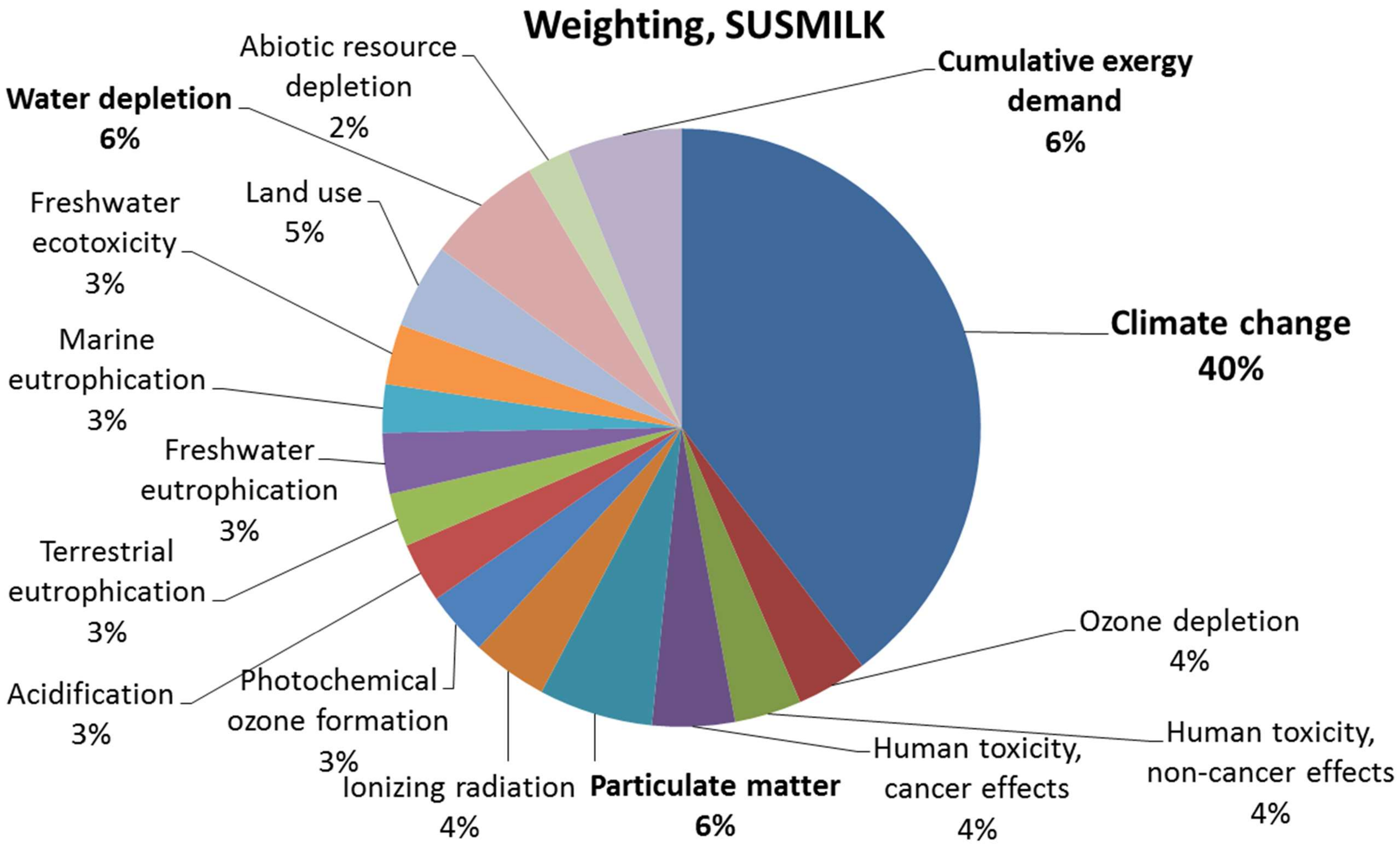
Cumulative LCI results	CO_2, CH_4: Greenhouse gasses,
↓ Classification	Global warming potential (GWP)
↓ Characterization	CO_2=1; CH_4=23kg CO_2-equivalent
↓ Normalization	GHG-emission Europe: 6.5 Mia. t CO_2-eq.
↓ Grouping	Sorting and ranking
↓ Weighting	Aggregation based on weighting principles
↓ **Environmental indicator**	

Calculation of the unweighted results

- ILCD & Exergy
  - Midpoint, no weighting of environmental impacts
  - 15 categories of ILCD + exergy (according to ISO)
  - E.g. climate change, water use etc.
- Detailed discussion in public Del. 7.3 https://www.esu-services.ch/projects/lcafood/susmilk/
- Too complicated for this presentation

Calculation of the weighted single score results: SUSMILK-points

- «SUSMILK-points»: value choices of project partners
  - Normalization (“Reference”): Total European emissions
  - Weighting: average of chosen percentages by partners


Weighting, SUSMILK
Abiotic resource depletion 2%
Cumulative exergy demand 6%
Water depletion 6%
Land use 5%
Freshwater ecotoxicity 3%
Marine eutrophication 3%
Freshwater eutrophication 3%
Terrestrial eutrophication 3%
Acidification 3%
Photochemical ozone formation 3%
Ionizing radiation 4%
Particulate matter 6%
Human toxicity, cancer effects 4%
Human toxicity, non-cancer effects 4%
Ozone depletion 4%
Climate change 40%

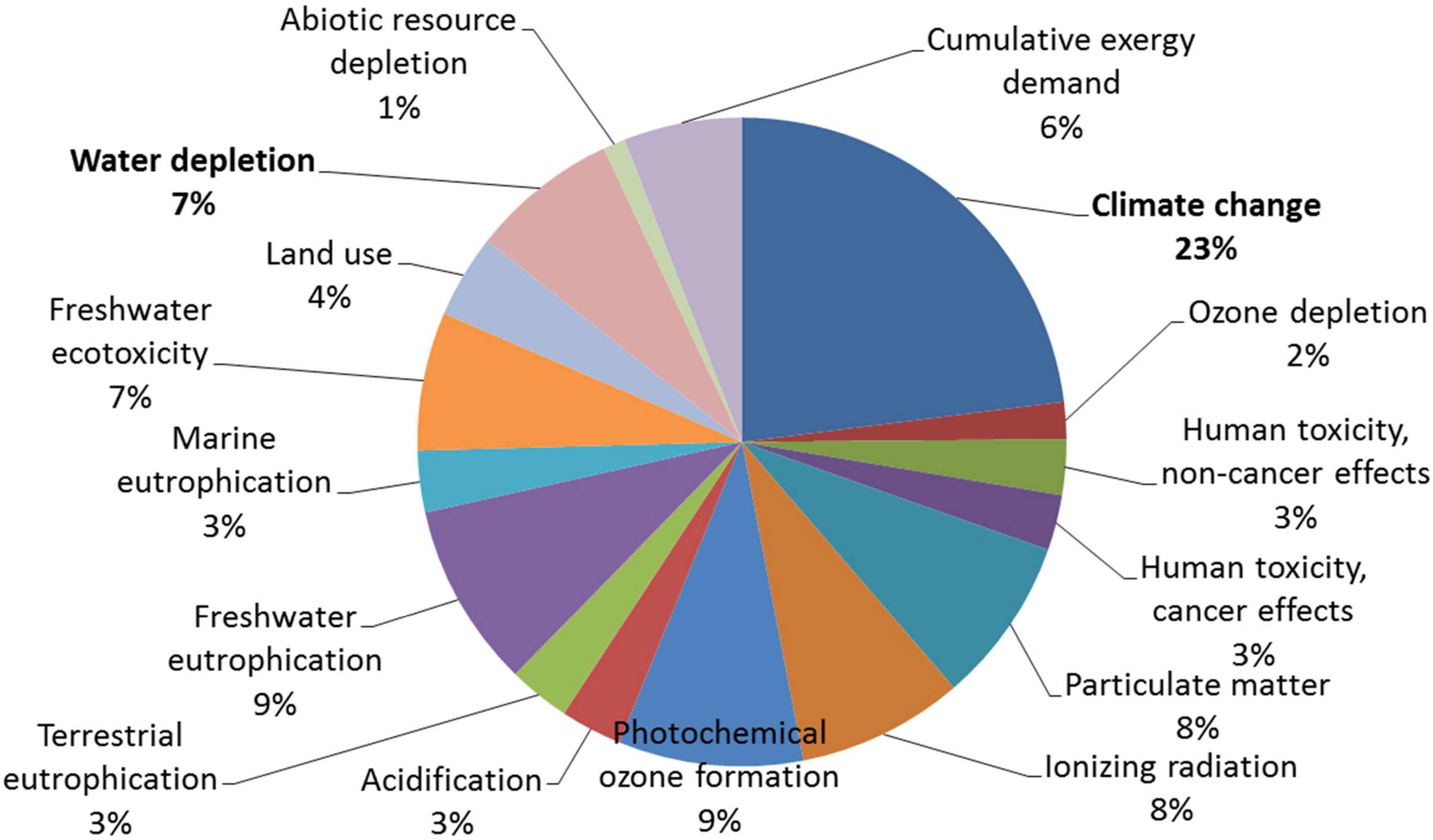
Calculation of the weighted single score results: ESU-points

- «ESU-points»: value choices of LCA experts
  - Normalization, three approaches:
    - Global emissions / resource uses per person and day
    - Impact of LCA dairy operation, including milk
    - Impact of LCA dairy operation, excluding milk
- Weighting according to reliability of data (back- & foreground), reliability of method, overlap and the focus of the SUSMILK- project

ESU-points: Criteria of weighting

		Robustness European normalization	Reliability, LCI, background	Reliability, LCI, foreground	Reliability, LCIA	Overlap, LCI	Focus SUSMILK	Overall score	**Weighting, ESU**
Climate change	kg CO2 eq	100%	100%	100%	100%	100%	100%	100.0%	**23.0%**
Ozone depletion	kg CFC-11 eq	60%	20%	80%	100%	100%	50%	8.0%	**1.8%**
Human toxicity, non-cancer effects	CTUh	20%	50%	80%	60%	100%	50%	12.0%	**2.8%**
Human toxicity, cancer effects	CTUh	20%	50%	80%	60%	100%	50%	12.0%	**2.8%**
Particulate matter	kg PM2.5 eq	100%	90%	80%	100%	100%	50%	36.0%	**8.3%**
Ionizing radiation	kBq U235 eq	60%	90%	100%	80%	100%	50%	36.0%	**8.3%**
Photochemical ozone formation	kg NMVOC eq	60%	100%	100%	80%	100%	50%	40.0%	**9.2%**
Acidification	molc H+ eq	80%	100%	100%	80%	33%	50%	13.3%	**3.1%**
Terrestrial eutrophication	molc N eq	60%	100%	100%	80%	33%	50%	13.3%	**3.1%**
Freshwater eutrophication	kg P eq	40%	100%	100%	80%	100%	50%	40.0%	**9.2%**
Marine eutrophication	kg N eq	40%	100%	100%	80%	33%	50%	13.3%	**3.1%**
Freshwater ecotoxicity	CTUe	20%	100%	100%	60%	100%	50%	30.0%	**6.9%**
Land use	kg C deficit	60%	90%	100%	40%	100%	50%	18.0%	**4.1%**
Water depletion	m3 water eq	40%	80%	100%	40%	100%	100%	32.0%	**7.4%**
Abiotic resource depletion	kg Sb eq	20%	30%	80%	80%	50%	50%	4.8%	**1.1%**
Cumulative exergy demand	MJ-eq	100%	80%	80%	80%	50%	100%	25.6%	**5.9%**

Weighting, ESU



LCA dairy model

- Analysis of process stages with and without the milk input
- Analysis of products
- Allocation: Comparison of the split of inputs in the LCA dairy model to the suggested split of the inputs by Feitz et al. (2007)

Grouping for analysis of LCA dairy model

Name of the group	Description
Raw milk input	Input of raw milk for processing; purchased products not included
Purchased products, dairy plant, additions	Purchased ingredients, infrastructure of dairy plant, production of raw milk and additional impacts of processing considered with literature data (not including transport to dairy, milk itself or additional electricity)
Transport of milk	Refrigerated transport of raw milk to the dairy
Wastewater	Treatment of wastewater inside and outside the dairy, but not including electricity for pre-treatment
Consumer packaging	Product packaging (Production and disposal)
Electricity, surplus	Additional energy use according to the LCA dairy model
Electricity	Electricity use according to generic dairy model
Steam for production	Heat use delivered by steam
Steam for CIP	Steam used for cleaning the machinery internal
Chemicals	Chemicals used for CIP
Water use	All inputs needed for water use, including cooling water and infrastructure, but without the electricity use

Indicators shown in the analysis

- Climate change:

  Global warming potential, time horizon of 100 years (IPPC)

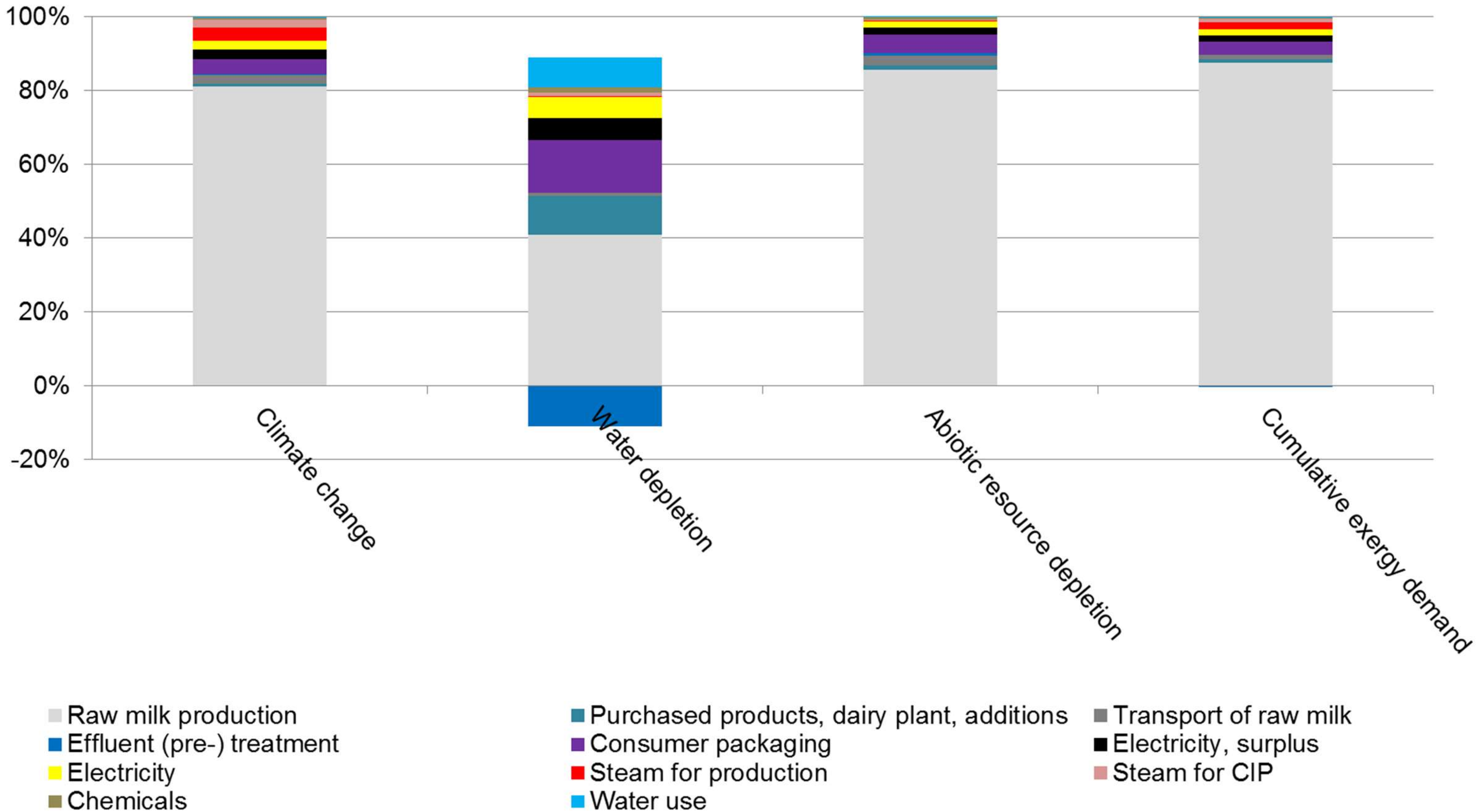
- Water resource depletion:

  Scarcity adjusted amount of water used (depending of source of water & country)

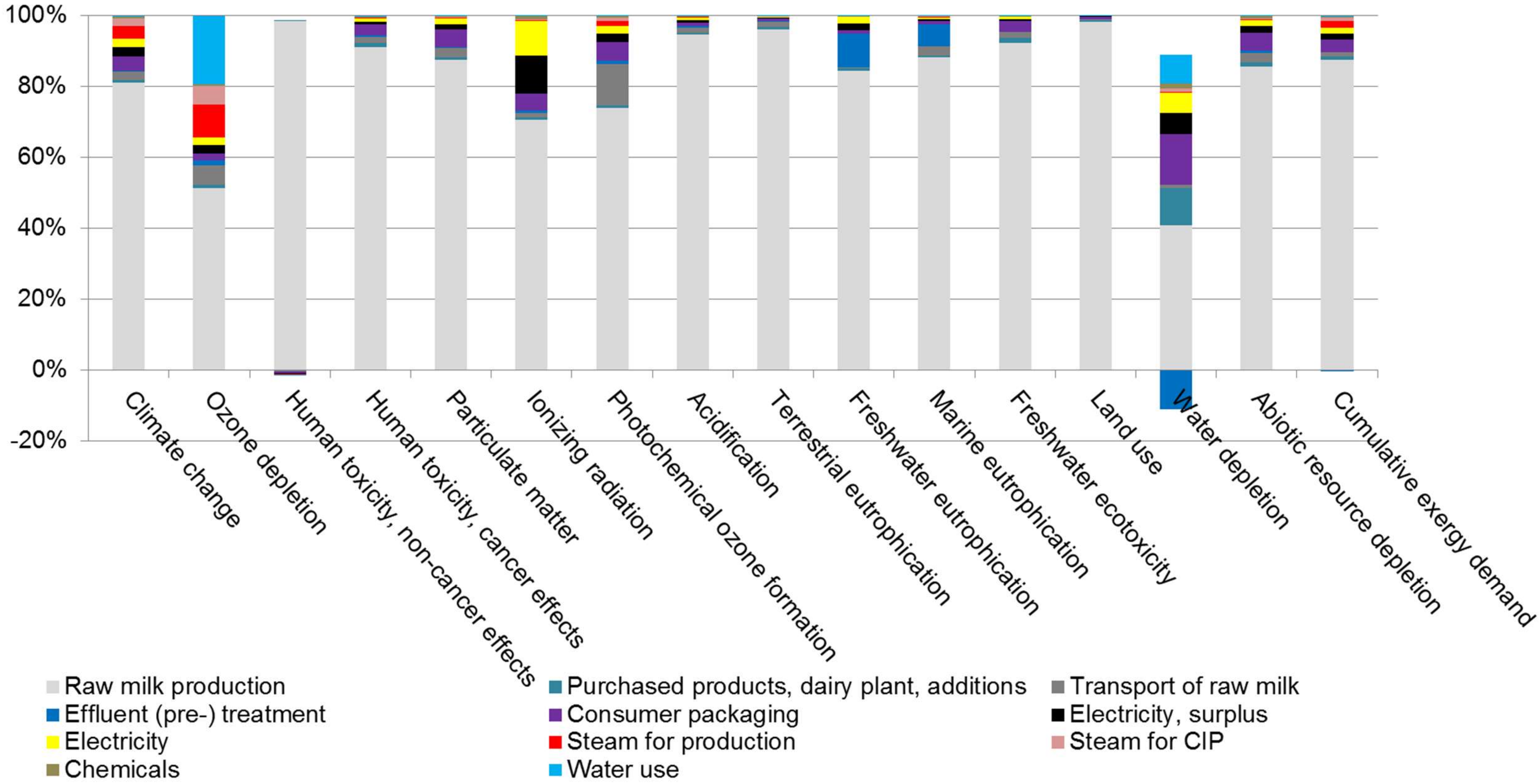
- Mineral, fossil & renewable resource depletion:

  Scarcity of mineral resource, «reserve base», i.e. identified resources that meets criteria related to current mining practice.

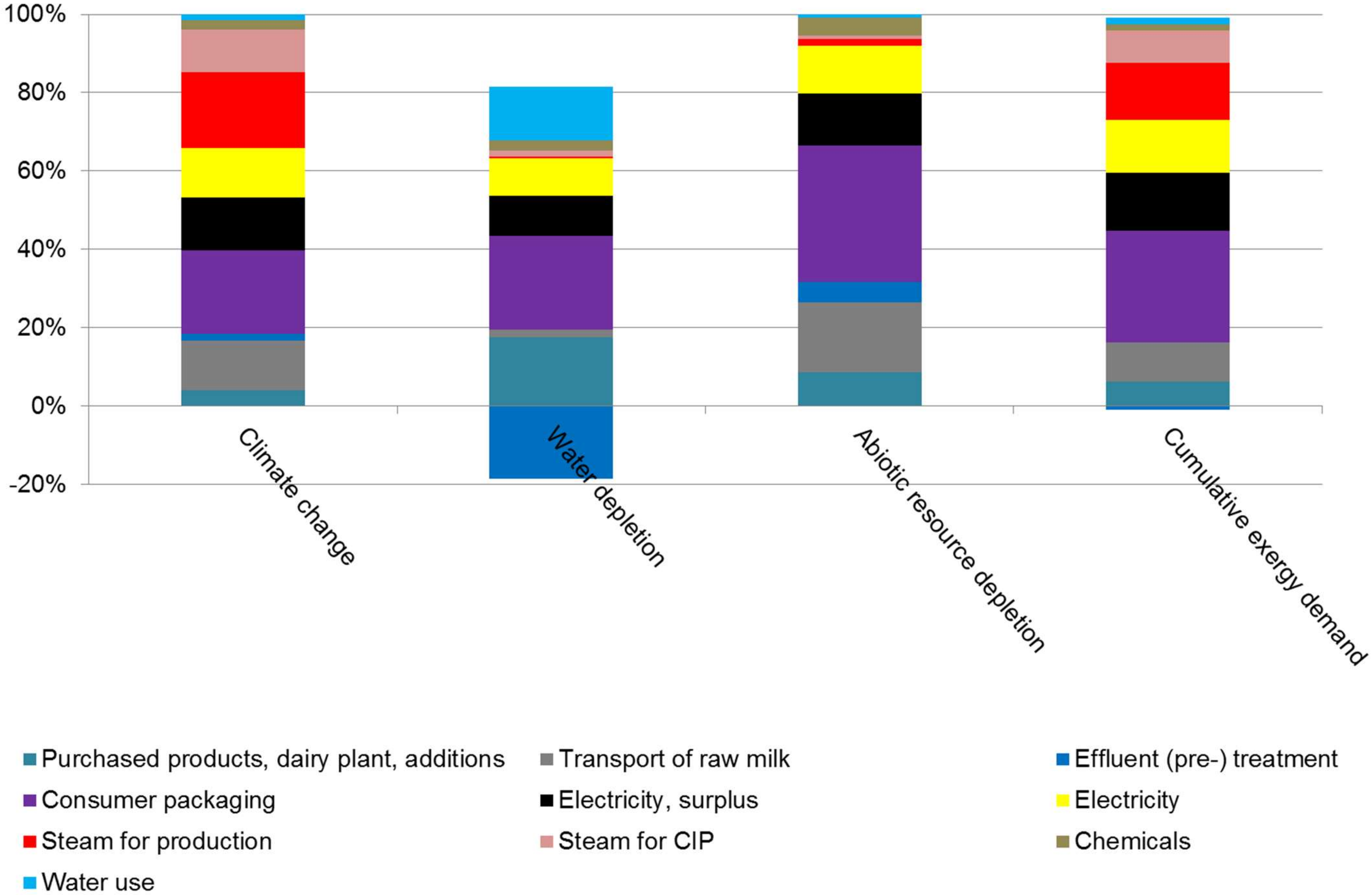
LCA dairy model: With raw milk production



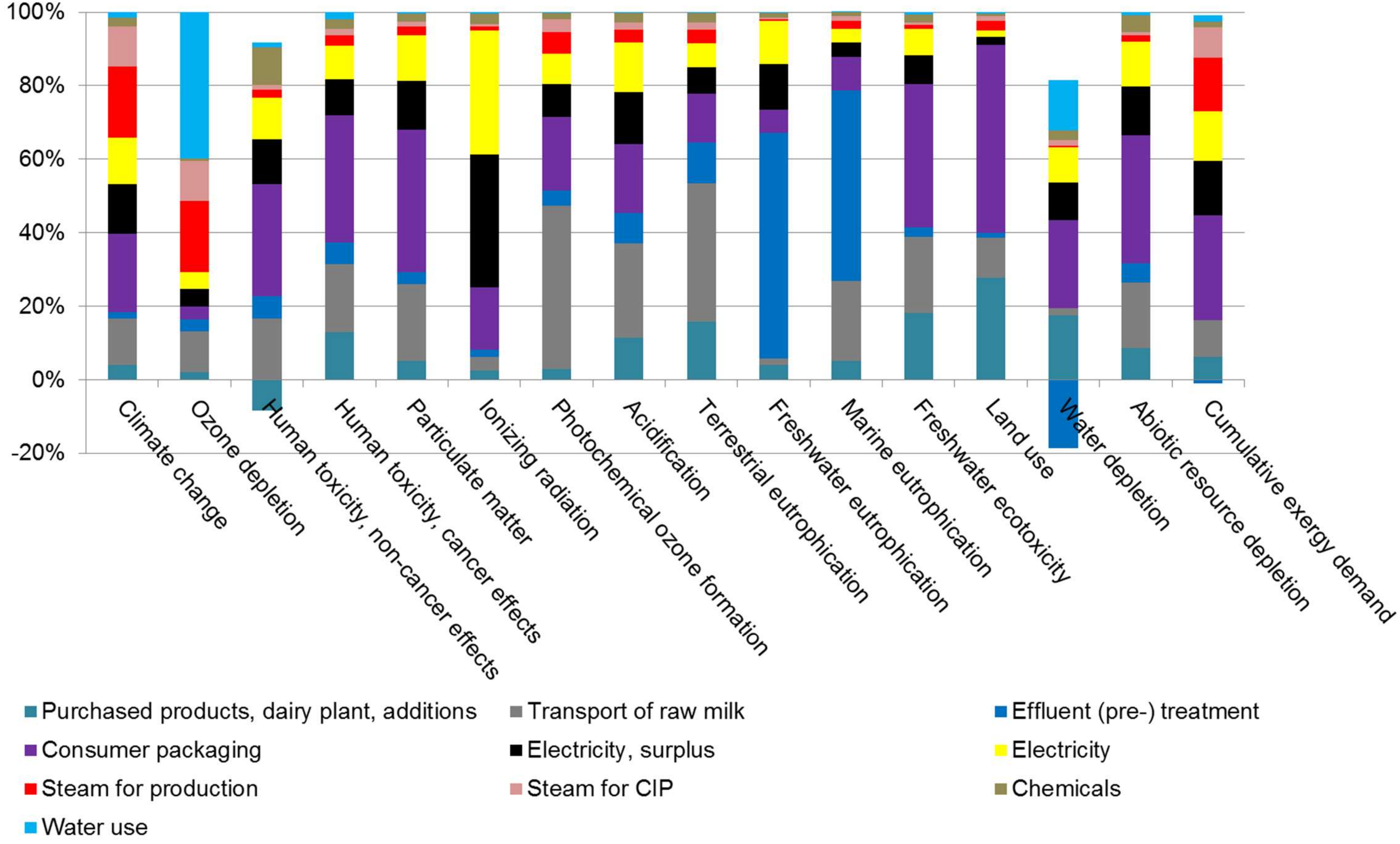
LCA dairy model: With raw milk production



LCA dairy model: Without raw milk input



LCA dairy model: Without raw milk input



LCA dairy model: conclusions

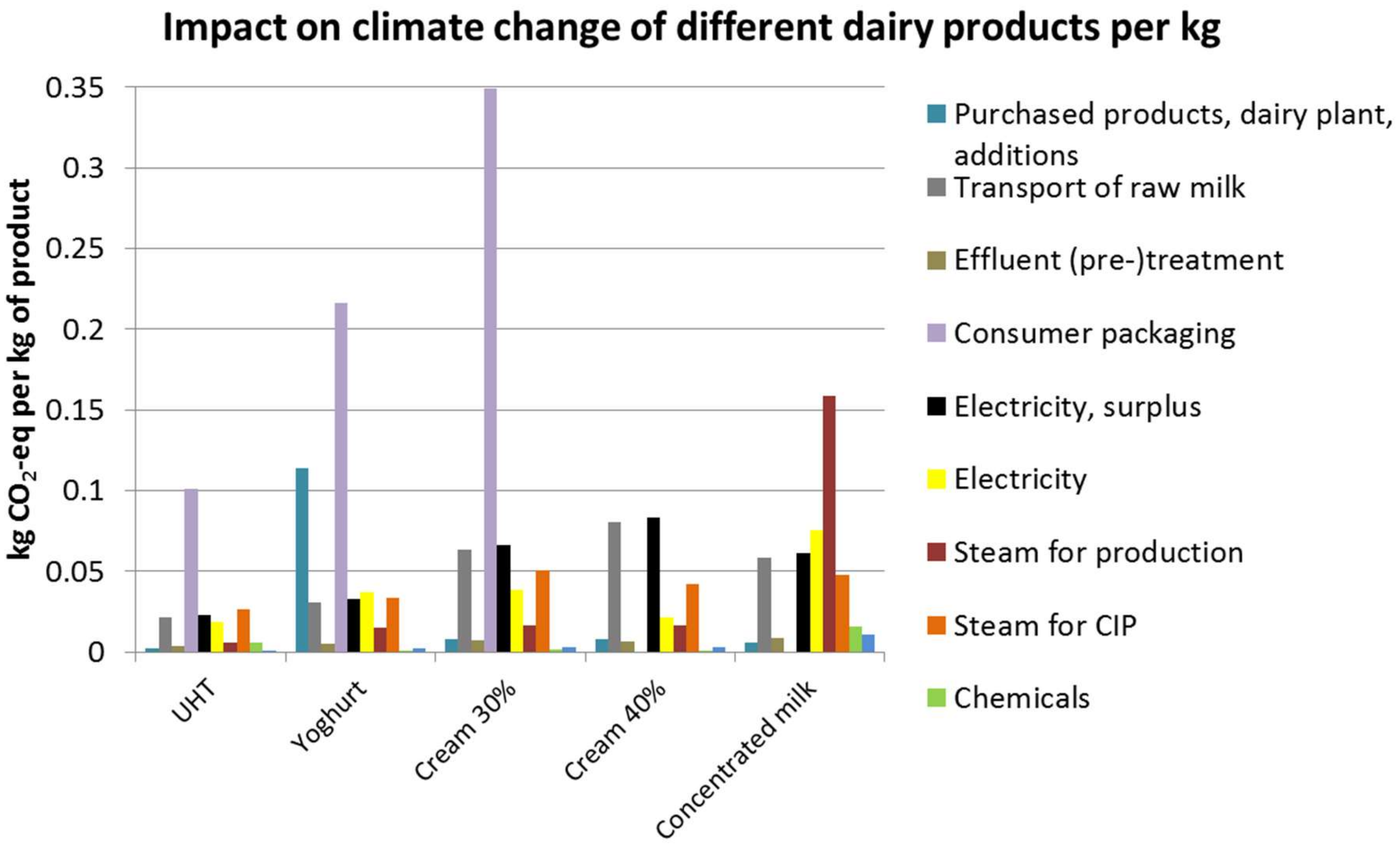
- Milk input main impact in most categories
- Without milk
  - Transport, packaging, waste water treatment: main, depending on impact category
  - Chemicals: Little impact
  - Packaging, steam: climate change

Analysis of products: Allocation method used

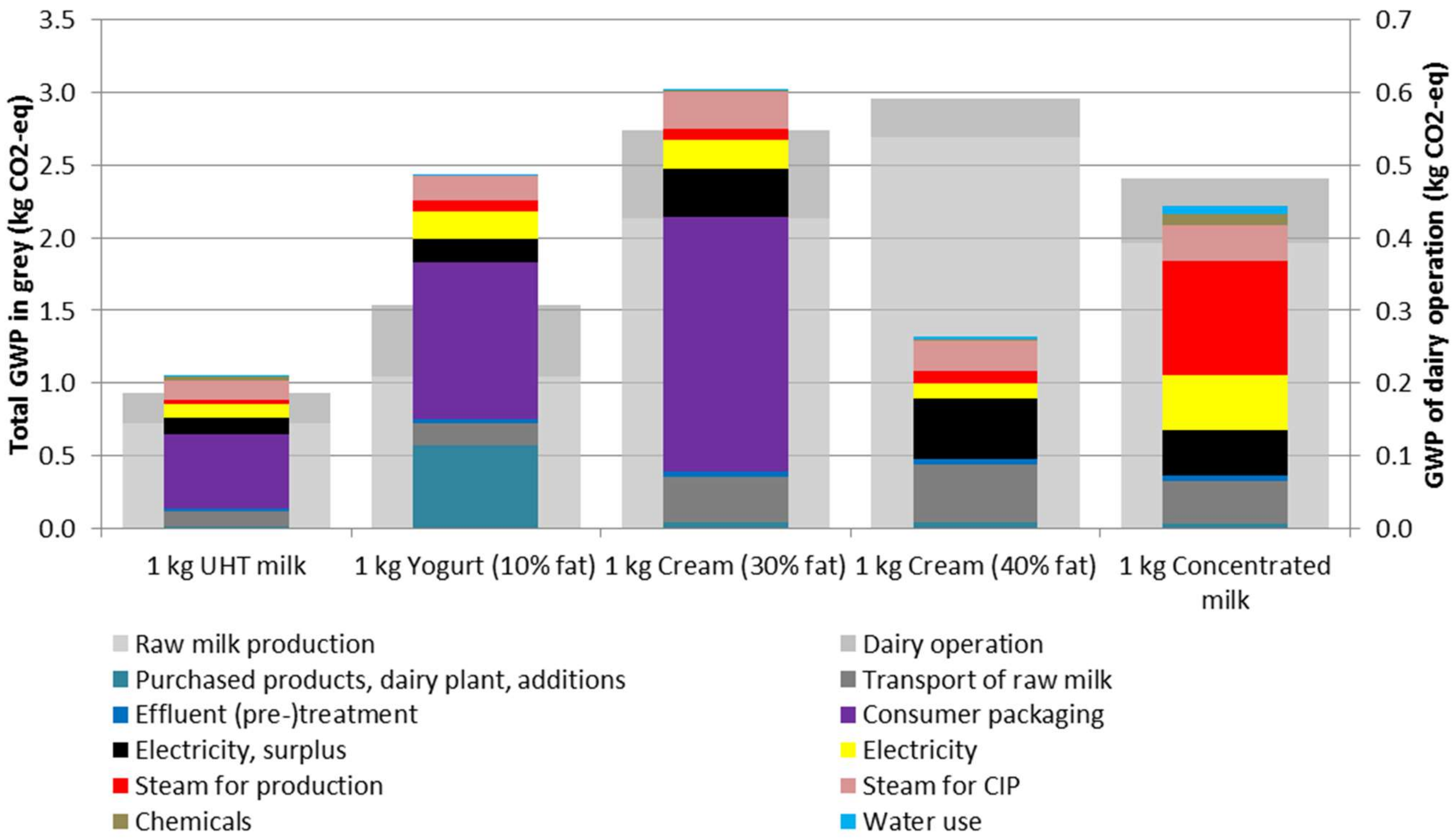
- Allocation = how are inputs & outputs e.g. of a process distributed to the useful products
- Mostly avoided by sub-processes
- Additional inputs (i.e. dairy plant):
  Added to the raw milk; allocation to products depending on raw milk (cream & skim milk) input
- Separation of raw milk into cream and skim milk:
  At the moment allocation based on dry matter

Carbon footprint of processing & transport

Without raw milk input, per kg of product



Analysis of products



Columns in the back: total GWP (left axis). Raw milk production: light grey, dairy operation: dark grey). The colored columns show the subdivision of the dairy operation in process stages (right axis).

Conclusion: Preliminary analysis of products

Main impacts

- Packaging

  -> No packaging: cream 40% & concentrated milk

- Purchased ingredients -> milk powder for yogurt
- Steam for production -> for concentrated milk
- Transport and electricity

Provision of heat: Considered options

- Natural gas
  - Boiler (reference, ecoinvent)
  - Cogeneration with motor and turbine (ecoinvent)
  - Gas-engine driven heat pump (Simaka; heat: waste & cogen. natural gas)
- Light fuel oil boiler (ecoinvent), diesel boiler (Queizuar)
- Wood
  - Cogeneration (ecoinvent)
  - Pellet boiler (Queizuar/Solarfocus)
- Solar collectors
  - Small system on roof (Queizuar/Solarfocus)
  - Large system on field & on roof (Solarfocus) + location specific sensitivity analysis

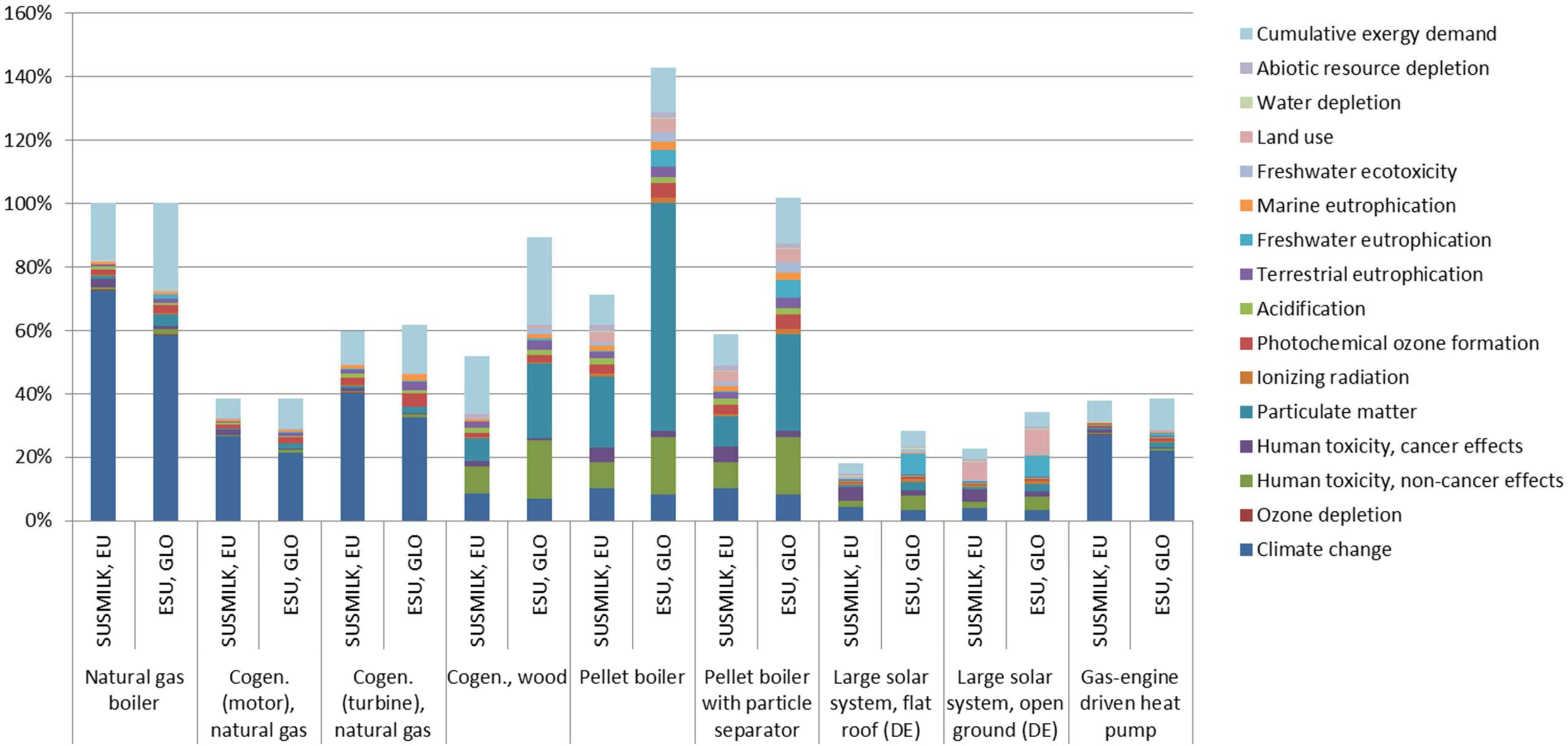
Provision of heat: Results ILCD

Referenced to natural gas (100%)

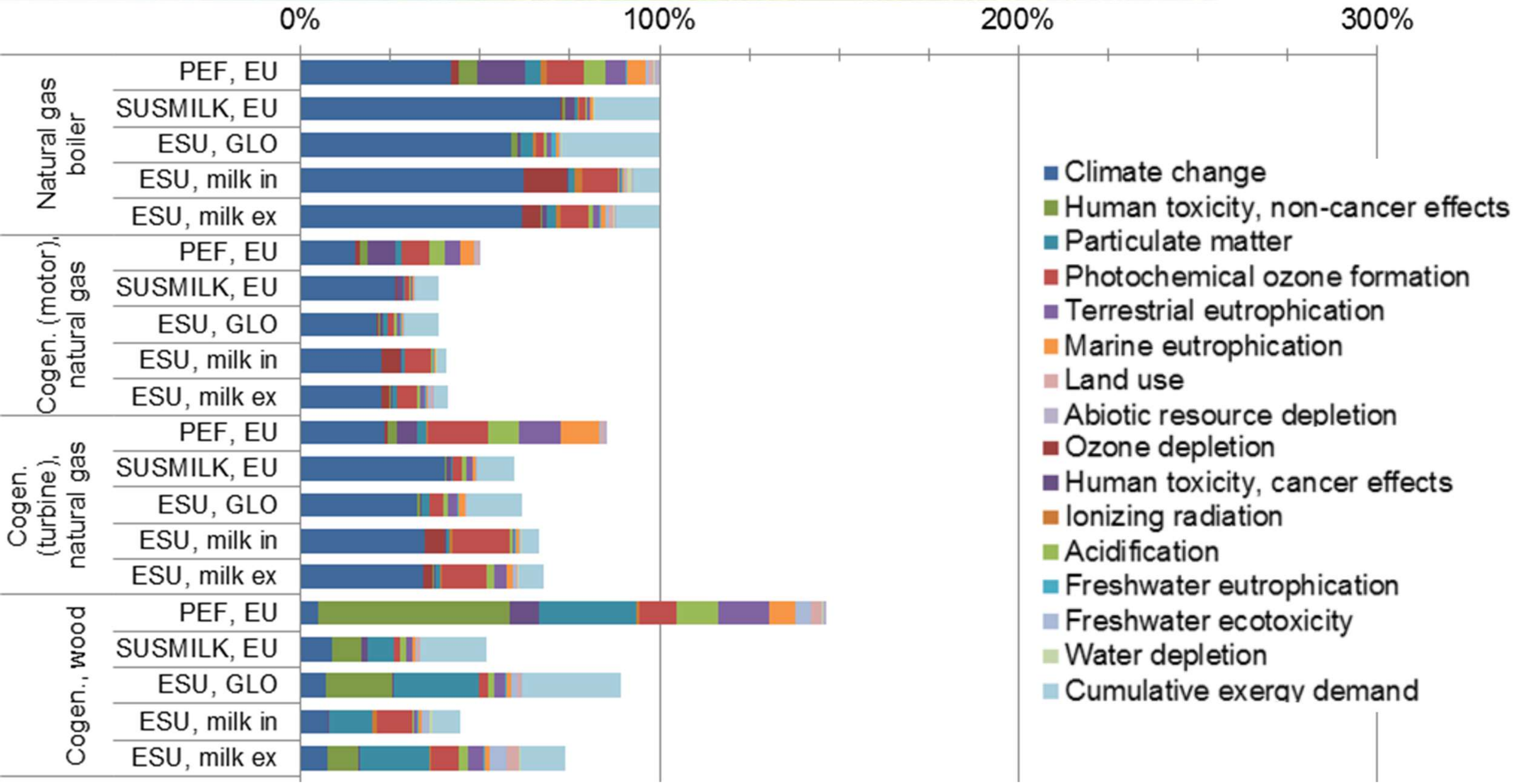
Impact category	Light fuel oil boiler	Diesel boiler	Cogen. (motor), natural gas	Cogen. (turbine), natural gas	Cogen., wood	Pellet boiler	Pellet boiler with particle separator	Small solar system (ES)	Large solar system, flat roof (DE)	Large solar system, open ground (DE)	Solar-pellet-system (ES)	Gas-engine driven heat pump
Climate change	127%	129%	37%	55%	12%	14%	14%	8%	6%	6%	13%	37%
Ozone depletion	9%	9%	41%	49%	1%	9%	9%	3%	2%	2%	9%	36%
Human toxicity, non-cancer effects	2592%	385%	44%	48%	1072%	1064%	1064%	492%	260%	252%	1002%	45%
Human toxicity, cancer effects	180%	159%	58%	43%	62%	183%	184%	414%	159%	145%	208%	45%
Particulate matter	559%	600%	43%	57%	682%	2082%	889%	140%	78%	74%	1871%	39%
Ionizing radiation	131%	130%	13%	32%	55%	269%	270%	195%	186%	181%	261%	65%
Photochemical ozone formation	220%	360%	73%	159%	97%	189%	189%	29%	18%	17%	171%	39%
Acidification	514%	485%	67%	145%	189%	236%	236%	85%	50%	48%	220%	39%
Terrestrial eutrophication	232%	333%	80%	214%	266%	285%	285%	37%	23%	23%	258%	37%
Freshwater eutrophication	155%	150%	22%	36%	55%	431%	432%	1443%	548%	529%	542%	78%
Marine eutrophication	231%	326%	80%	214%	145%	287%	287%	34%	21%	21%	259%	37%
Freshwater ecotoxicity	2750%	729%	55%	44%	487%	878%	880%	592%	273%	258%	848%	53%
Land use	695%	702%	41%	57%	243%	1235%	1235%	35%	18%	2072%	1105%	37%
Water depletion	424%	424%	22%	35%	57%	171%	171%	246%	203%	197%	179%	62%
Abiotic resource depletion	153%	150%	39%	47%	55%	1638%	1640%	1499%	627%	610%	1632%	104%

Provision of heat: SUSMILK and ESU-points

Referenced to natural gas (100%)



Provision of heat: Single Score



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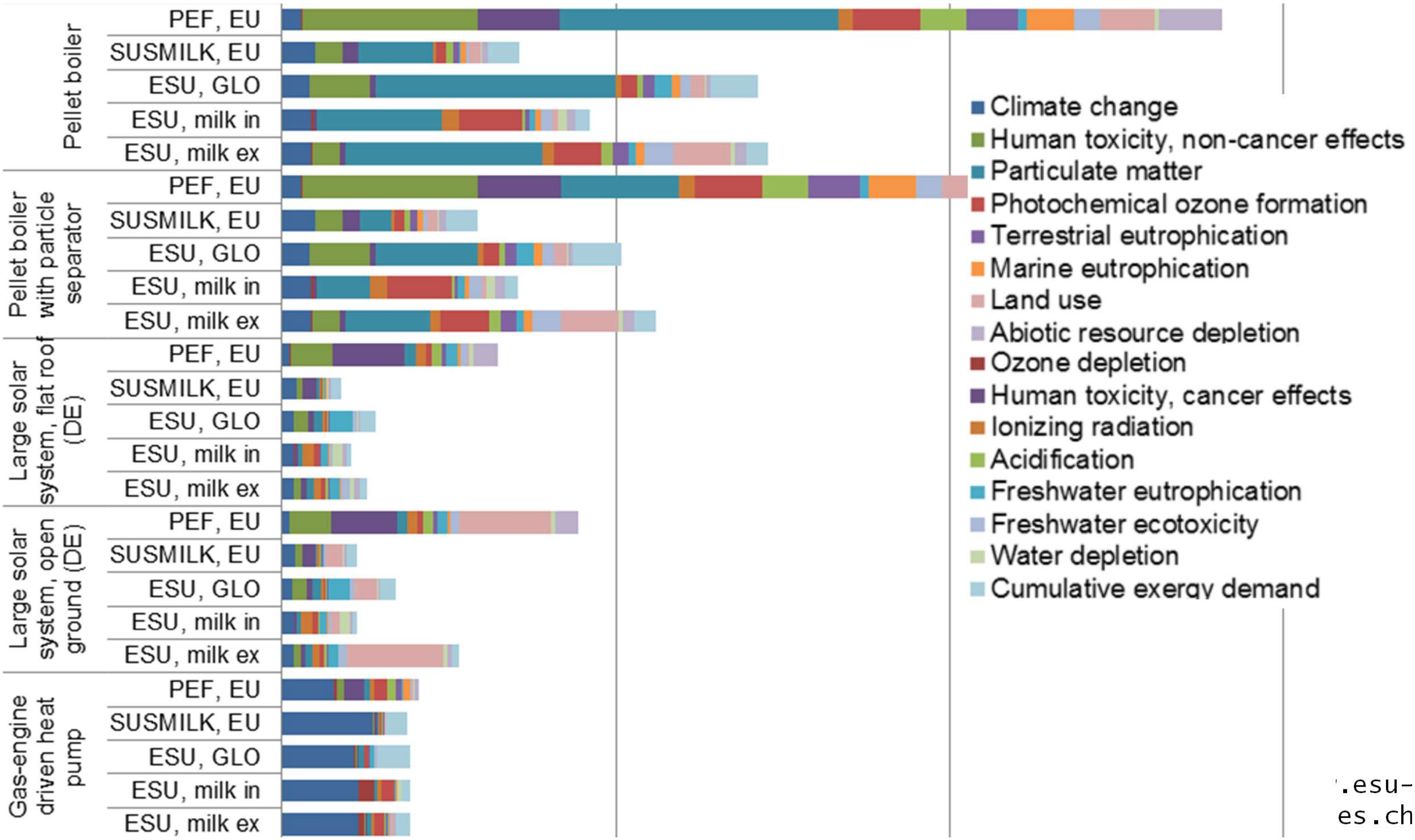
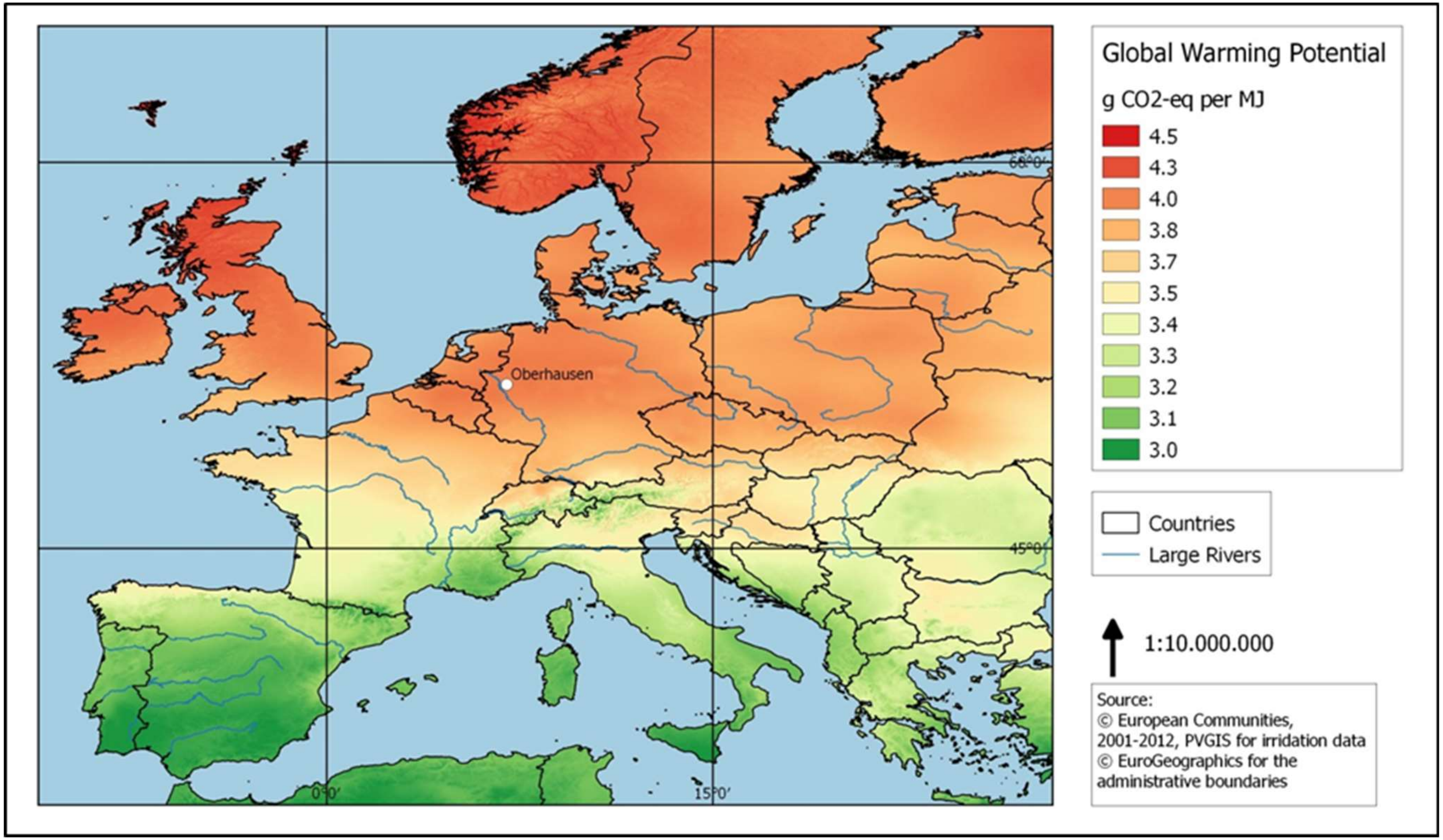
Provision of heat: Single Score



Crucial impacts for heat

- Large solar collector fields: Land use; tin & copper use for abiotic resource depletion
- Pellet boiler: emissions from combustion, especially for particulate matter
- Options with natural gas: CO_2-emissions for climate change
- Heat pump: Combustion of natural gas (NO_x, CO_2) for different categories

Sensitivity Analysis: heat at solar collectors on flat roof



Global warming potential, depending on irradiation

Recommendations heat provision

- Recommended (best overall results)
  - Heat pump using waste heat
  - Cogeneration (motor) with natural gas
- Ambiguous
  - Solar collector: Depending on location and on value choice, installation on roof recommended
  - Cogeneration (turbine)
  - Pellet boiler, cogeneration with wood: Reduction for climate change, increase for particle emissions
- Not recommended:
  - Light fuel oil boiler, diesel boiler

Provision of cooling: Considered options

- Electrical chiller (reference, own model)
- Groundwater cooling (own model)
  - At Oberhausen + location specific sensitivity analysis
- Absorption chiller
  - Driven by waste heat (Parker)
  - Driven by heat from cogeneration (Parker, generic data)

Provision of cooling: ILCD

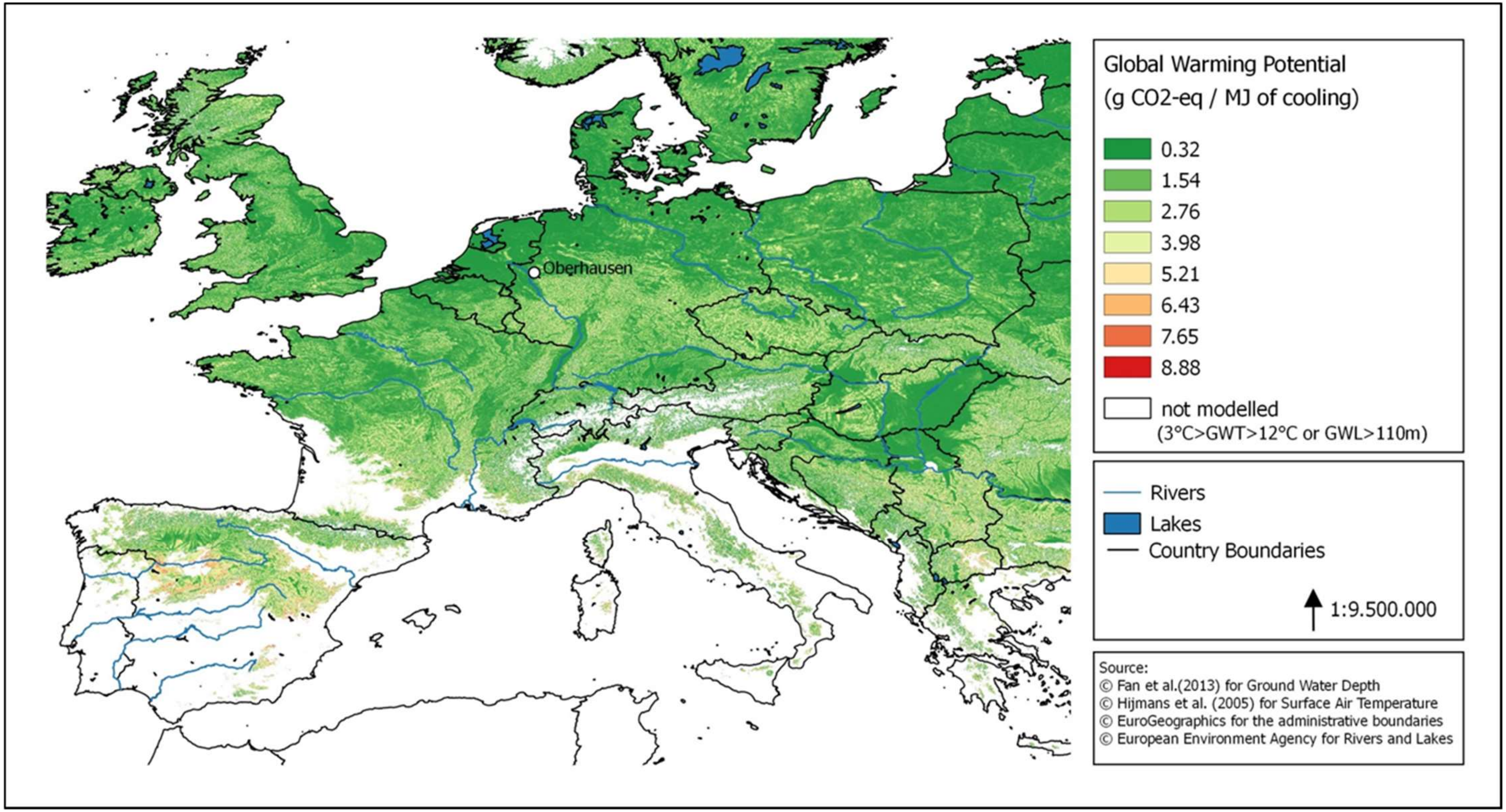
Referenced to ice water at electric chiller (100%)

Impact Category	Cold water, 6°C, at absorption chiller 100 kW (heat from cogen)	Cold water, 7°C, at absorption chiller 50 kW (waste heat)	Cold water, 7°C, at absorption chiller 50 kW (heat from cogen)	Cold water, 12°C, at electric chiller	Cold water, 12°C, at groundwater pump
Climate change	113%	**4%**	80%	100%	**3%**
Ozone depletion	**21%**	**0%**	**13%**	100%	**0%**
Human toxicity, non-cancer effect	127%	**9%**	**21%**	97%	**6%**
Human toxicity, cancer effects	191%	28%	49%	97%	**9%**
Particulate matter	53%	**6%**	**19%**	100%	**4%**
Ionizing radiation	**25%**	**5%**	**6%**	100%	**3%**
Photochemical ozone formation	82%	**5%**	105%	100%	**4%**
Acidification	57%	**5%**	36%	100%	**4%**
Terrestrial eutrophication	72%	**6%**	102%	100%	**4%**
Freshwater eutrophication	66%	**5%**	**7%**	99%	**4%**
Marine eutrophication	67%	**5%**	103%	100%	**4%**
Freshwater ecotoxicity	141%	**14%**	**25%**	98%	**6%**
Land use	149%	**7%**	74%	100%	52%
Water depletion	127%	**5%**	**7%**	99%	**3%**
Abiotic resource depletion	**234%**	**17%**	**23%**	97%	**5%**

Provision of cooling: Crucial impacts

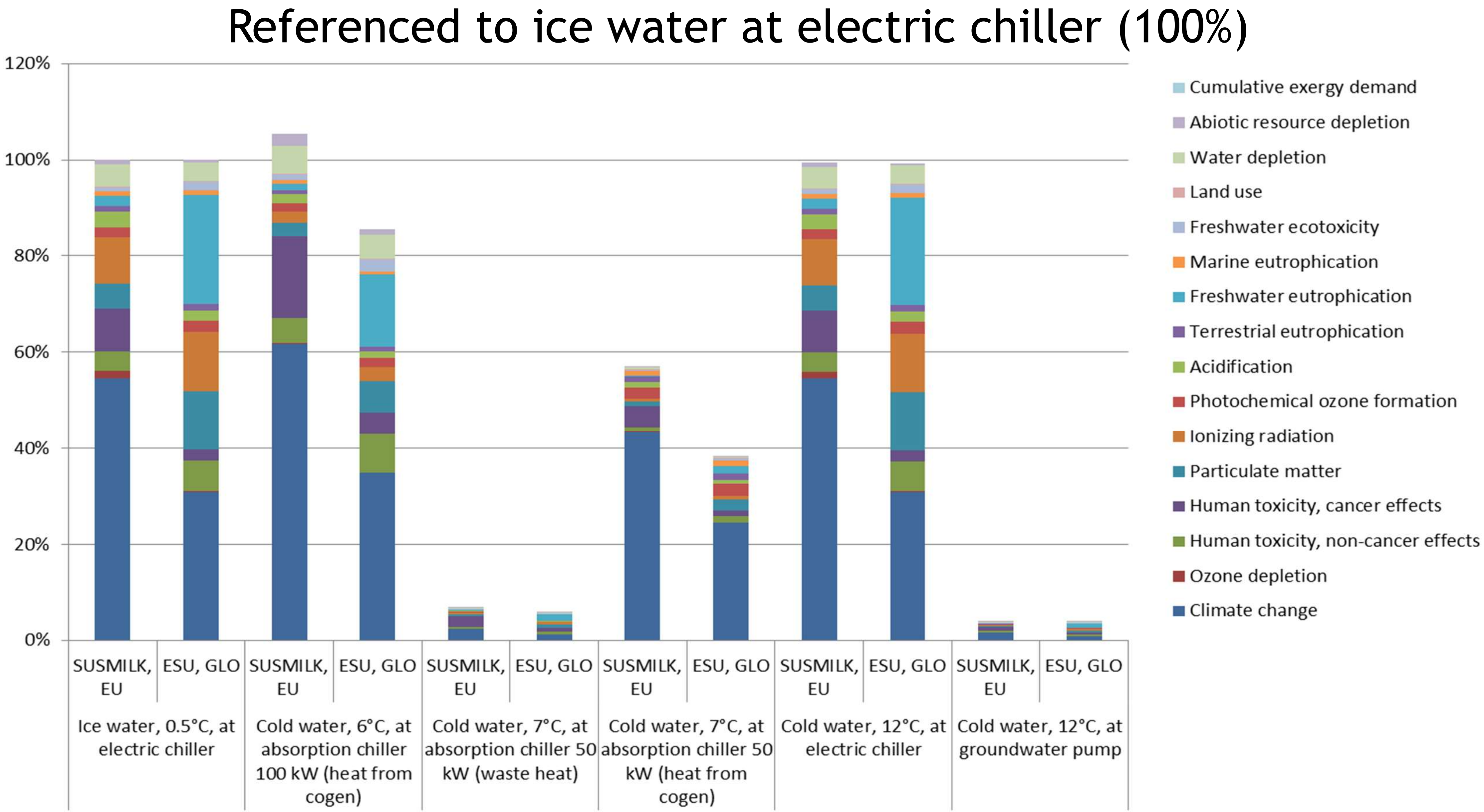
- For most categories, ground water & absorption chiller (waste heat):
  -> Electricity demand
- Categories human toxicity, resource depletion:
  -> Steel input for absorption chiller
  -> Steel, iron, copper input for groundwater pump

Sensitivity Analysis of ground water cooling



Global warming potential, depending on ground water depth and temperature

Provision of cooling: SUSMILK- and ESU-Points



Recommendations cooling compared to electric cooling

- Recommended
  - Groundwater cooling
    -> if no water scarcity and if local laws allow it
  - Absorption chiller with waste heat
    -> if waste heat available
- Ambiguous
  - Absorption chiller with heat from cogeneration
    -> Less reduction potential

Electricity: Considered options

- From grid (ecoinvent, reference)
- From cogeneration (ecoinvent)
  - With natural gas: Motor, turbine
  - With wood

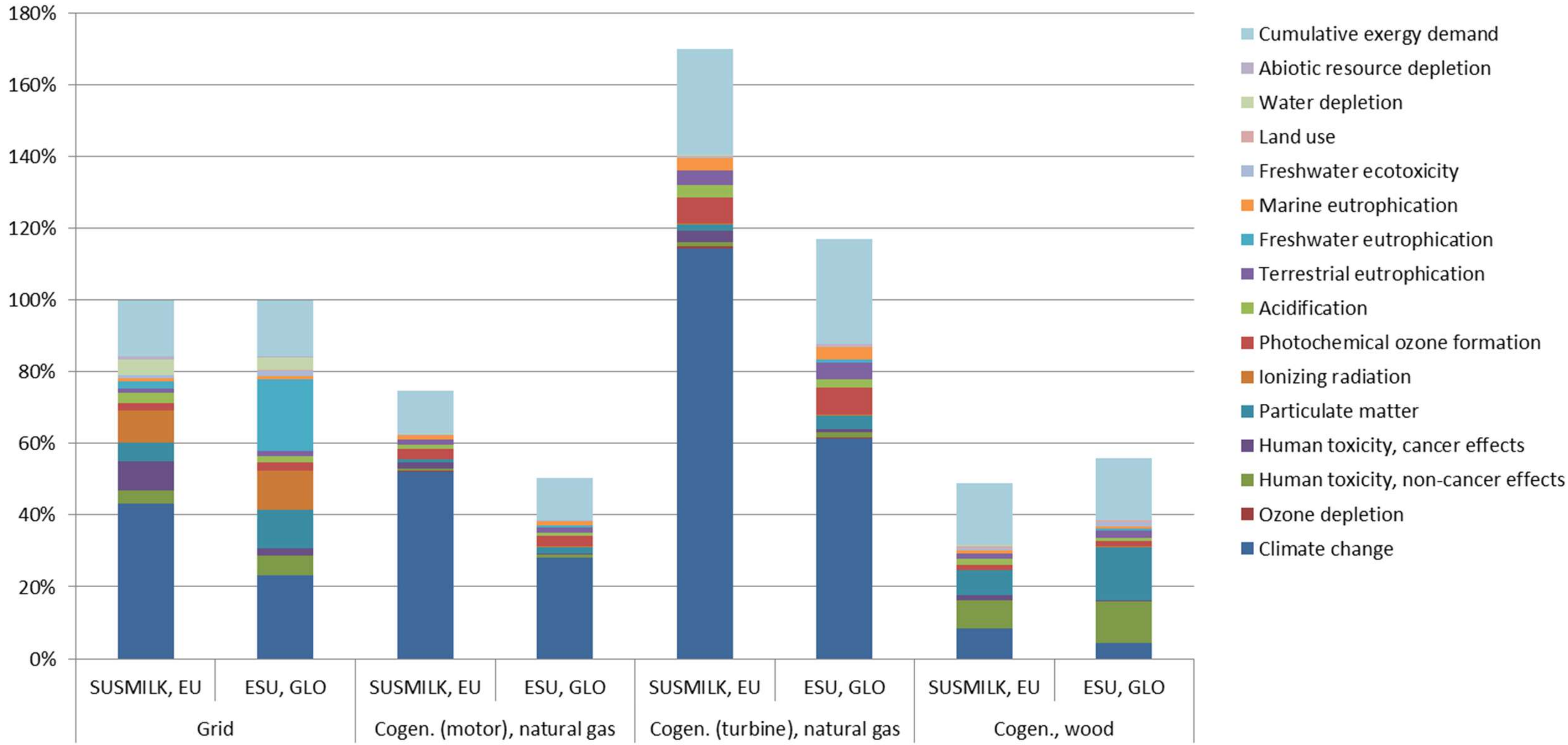
Provision of electricity: Results ILCD

Referenced to electricity from European grid (100%)

	Cogen. (motor), natural gas	Cogen. (turbine), natural gas	Cogen., wood
Climate change	121%	**265%**	**19%**
Ozone depletion	**300%**	**636%**	**4%**
Human toxicity, non-cancer effects	**14%**	28%	**211%**
Human toxicity, cancer effects	**22%**	40%	**20%**
Particulate matter	**16%**	35%	135%
Ionizing radiation	**1%**	**3%**	**2%**
Photochemical ozone formation	134%	**349%**	70%
Acidification	42%	116%	50%
Terrestrial eutrophication	130%	**374%**	153%
Freshwater eutrophication	**2%**	**4%**	**3%**
Marine eutrophication	132%	**379%**	84%
Freshwater ecotoxicity	**11%**	**20%**	75%
Land use	91%	**219%**	**309%**
Water depletion	**2%**	**4%**	**2%**
Abiotic resource depletion	**10%**	**19%**	**11%**
Cumulative exergy demand	75%	187%	110%

Electricity: SUSMILK- and ESU-points

Referenced to electricity from European grid (100%)



Recommendations electricity

- Recommended
  - Cogeneration (motor) with natural gas
  - Cogeneration with wood (less good results) -> particulate matter and human toxicity
- Ambiguous
  - Cogeneration (turbine)

→ In line with recommendations for heat

Results daily dairy operation

- Raw milk production is the main impact
- Without milk
  - Transport, packaging, waste water treatment: main inputs, depending on impact category
  - Chemicals: little impact
  - Steam, packaging: relevant for climate change

Scenarios for technology improvements

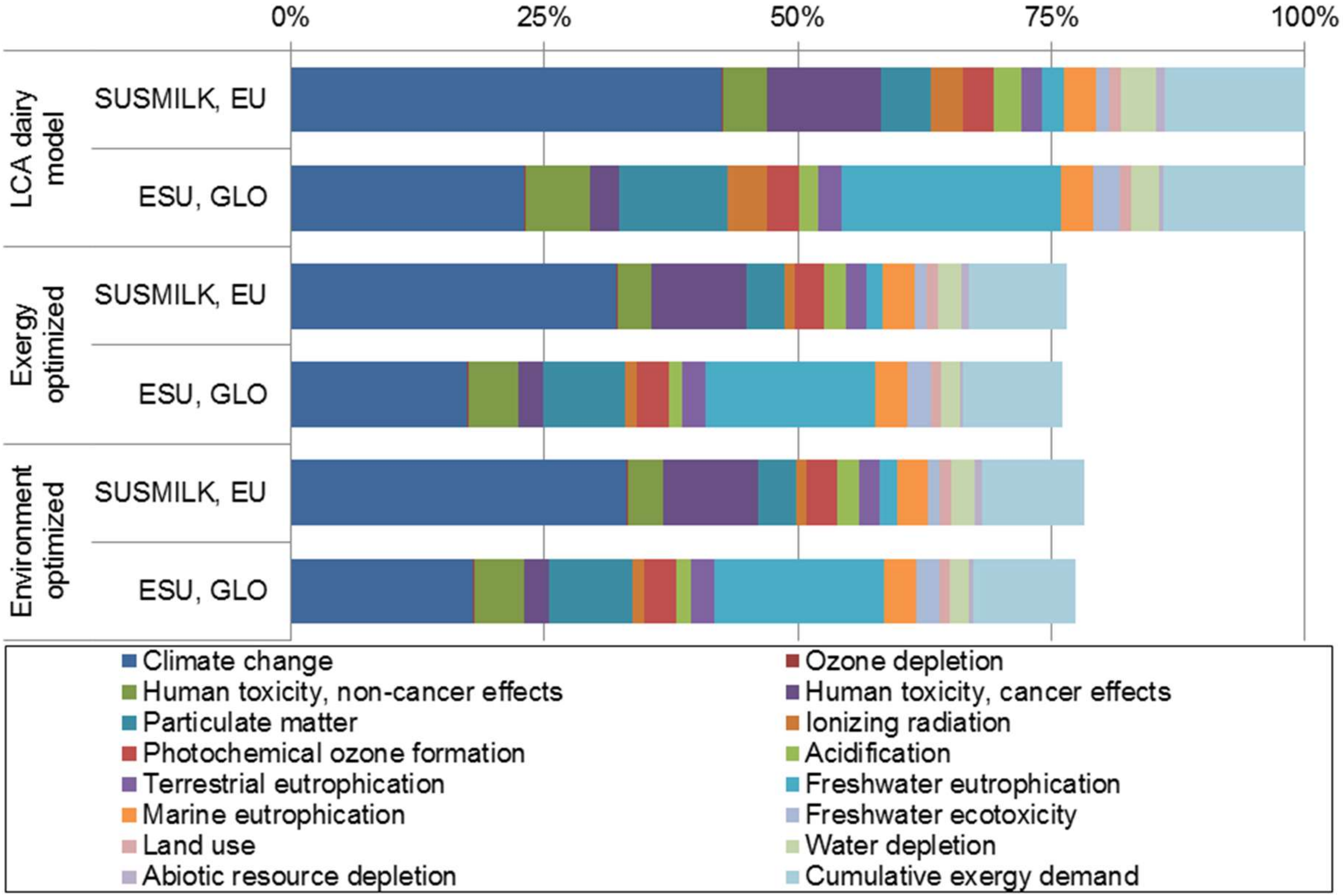
Scenario	Partner	Role in technology development	Energy source	Energy supply	Dairies involved in testing	Work package
1	Simaka	Development of a new heat pump and use of water as steam carrier		Heat (hot water)	Karwendel	WP2
3	Solarfocus	Development of high temperature solar panels and weather-based control system		Heat (hot water)	Queizuar	WP2
2	Parker	Development and in-house testing of absorption chiller prototype	Solar heat Waste heat	Cooling energy	Feiraco	WP2
4	Acram	Development and demonstration of membrane filtration for milk pre-concentration at farm			Wiegert	WP3
5	Fraunhofer	Band belt drying of milk concentrate	Waste heat		Wiegert	WP3
6	FINS	Development of membrane filtration to reuse CIP solutions			Mlekara	WP4
7	LNEG KTU	Development of technologies for biogas and bioethanol production	Wastewater whey	Biogas (CHP) Bioethanol	No demonstration	WP4

Improvement scenarios: Modelled options

- LCA dairy model, based on generic dairy model
  - Reference value
- Exergy optimized
  - Reduction of heat and electricity use by heat exchangers, CHP
- Environment optimized
  - Groundwater cooling, CHP for heat and electricity, roof top solar collectors with 4000 m2

Improvement scenarios

Referenced to the generic dairy model (100%)



Interpretation and Conclusion

- Reduction of about 25% compared to average dairy operation is possible
- The ideal energy solution depends on the specific situation
  - Location (irradiation, groundwater level, temperature)
  - Heat (temperature) and cooling demands
  - Waste heat availability
- A major share of environmental impacts is not influenced by the improvement options (e.g. delivery of raw milk)

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Milk Processing

Life cycle assessment of a detailed dairy model & recommendations for the allocation to single products

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ESU-services Ltd, Schaffhausen
https://www.esu-services.ch

LCA food 2016

Dublin, Ireland, 19.-21. October 2016

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration

ALLOCATION

Content of presentation

- LCA dairy model
  - Assumptions, build-up
- Two topics
  - A: Dairy operation
    - Analyses of process stages
  - B: Allocation of environmental impacts to dairy products
    - Global warming potential per kg of dairy product
    - Comparison with allocation of Feitz et al.
  - For each topic, goal, scope, methods, results and interpretation is shown

LCA dairy model

- Model assumptions
  - 600’000l raw milk processed per day
  - Products: UHT milk, yogurt, cream, concentrated milk
- Detailed model build-up
  - More than 40 sub-processes in the dairy modelled
  - Based on literature and values from experts
  - Complemented with additional inputs to include all inputs of the dairy operation from cradle to gate
  - Allocation of raw milk separation with milk solids

Goal A

A) Which process stages of dairy operation are important from an environmental point of view?

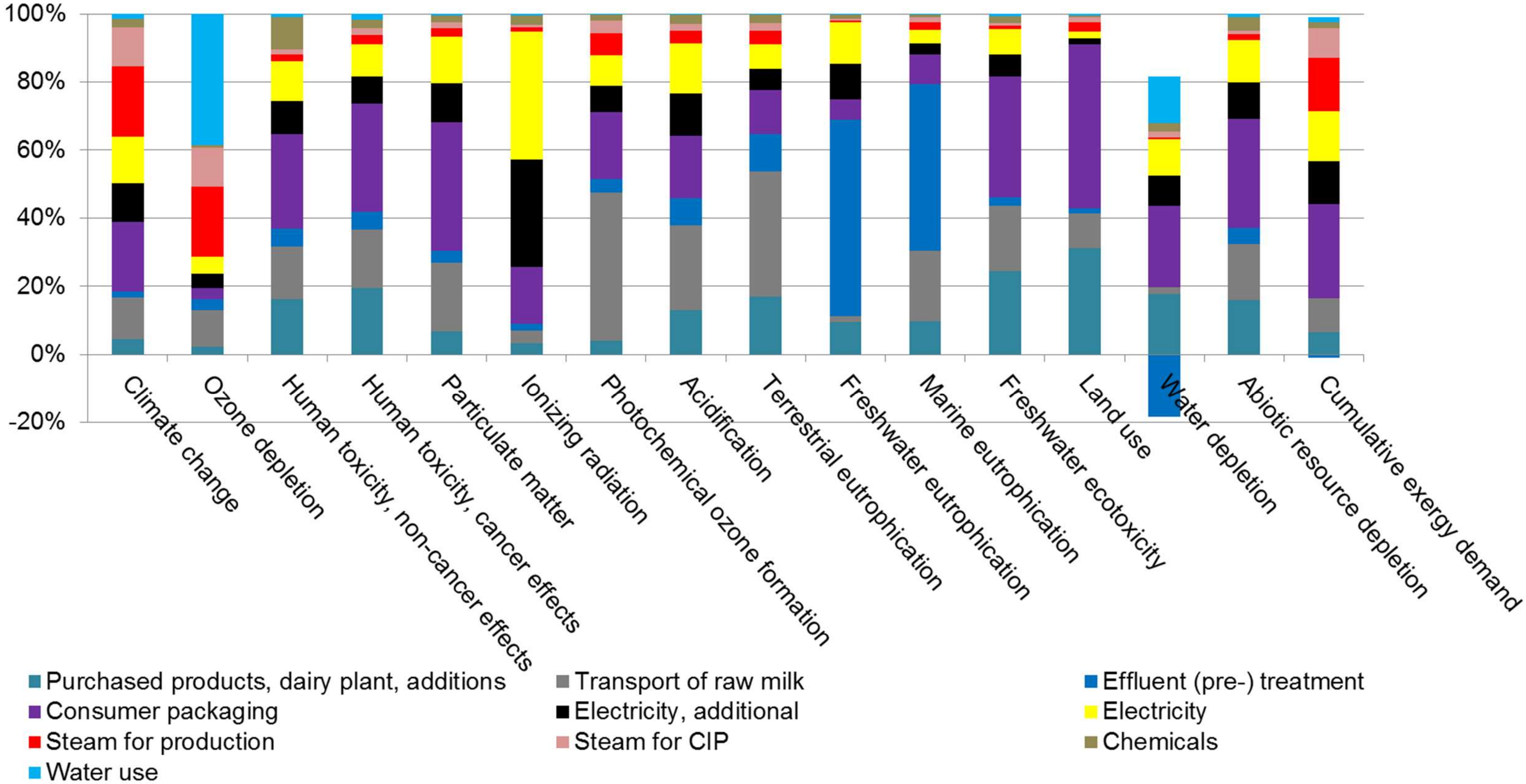
Scope A

- Impact Assessment Methods
  - 15 ILCD midpoint categories
  - Cumulative exergy demand
- Functional unit
  - A) one day of operation
- Scope: From cradle to dairy gate, incl. disposal of packaging
  - A) But **excluding** raw milk input

Methods A: Inputs groups for analysis

- Raw milk production
- Purchased products; dairy plant; additions
- Transport of raw milk
- Effluent (pre-)treatment
- Consumer packaging (production and disposal)
- Electricity
- Steam for production /CIP
- Chemicals used for CIP
- Water use and cooling (excl. electricity use)

Results A: Dairy operation



Interpretation A: Dairy operation

- High share in many categories
  - Transport of raw milk
  - Packaging (incl. disposal)
- High share for climate change and exergy
  - Heat, provided by natural gas boiler
- Low share
  - Chemicals for cleaning in place

Goal B

B) How can energy, water and chemical use of a dairy be allocated to the dairy products?

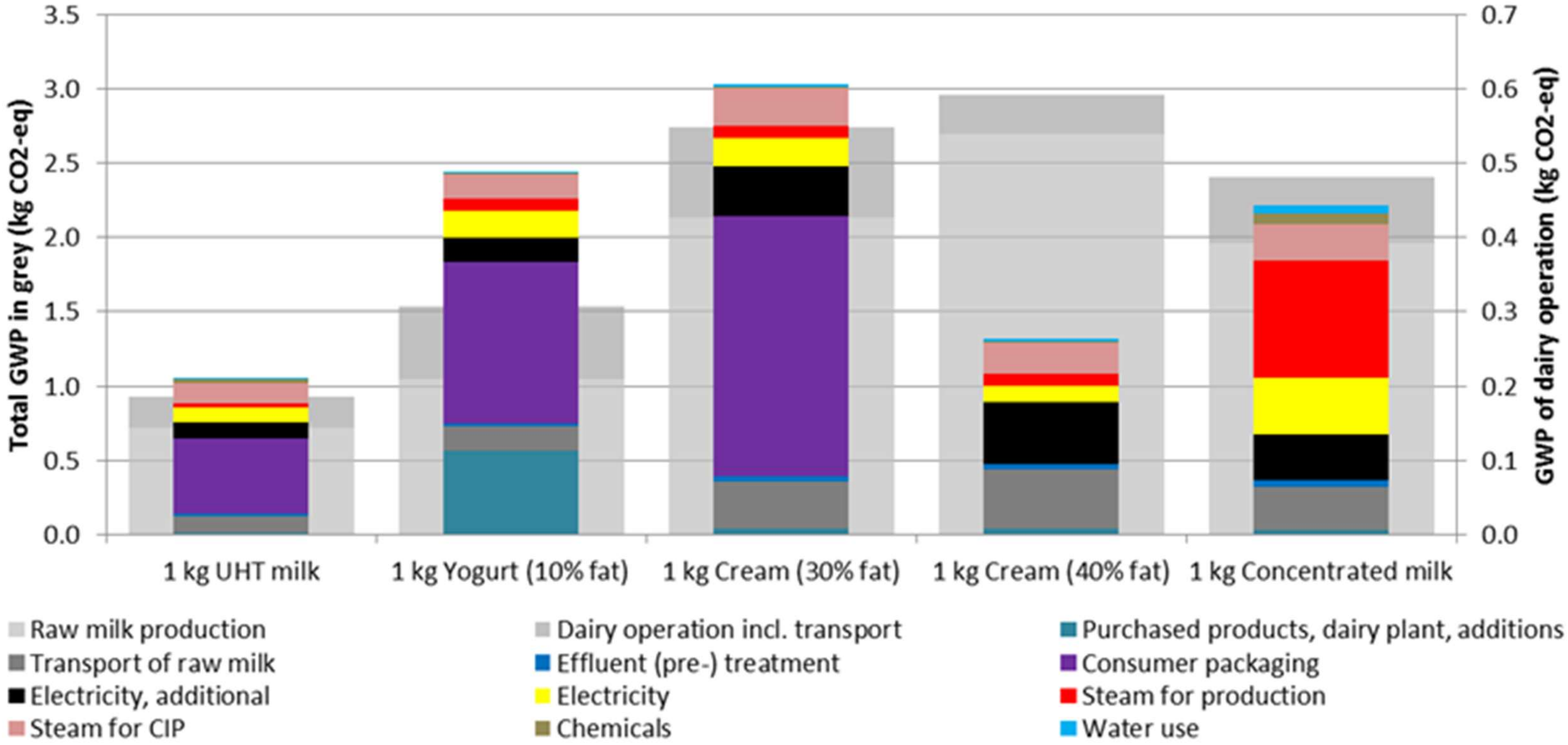
Scope B

- Impact Assessment Methods
  - Climate Change
  - Selected single inputs per kg of product
- Functional unit
  - B) 1kg of dairy product
- Scope: from cradle to dairy gate, incl. disposal of packaging
  - B) **Including** raw milk input

Methods B

- Climate Change
  - Same input groups as for A
  - Showing the impact of raw milk plus transport separately from the other inputs
- Selected single inputs per kg of product
  - For products yogurt, cream (40%) and UHT milk
  - Inputs according to the detailed LCA dairy model
  - Allocation of sum of inputs (3 products) of the LCA dairy model according to the method suggested by Feitz et al.

Results B: Dairy products RK46



Folie 82

RK46 Weglassen?, ist irgenwie zu viel
Regula Keller; 20.07.2016

Interpretation B: Dairy products

- All products
  - Raw milk input and transport have the highest share
- Yogurt, cream (30%), UHT milk
  - Packaging has a high share (other products are unpacked)
- Concentrated milk
  - heat input has highest share

Results B: Allocation

b) Allocation of the LCA dairy model inputs (based on 3 products) according to Feitz et al. (2007)							
	Raw milk kg	*Water use* kg	*Elec-tricity* MJ	*Themal energy* MJ	*Alkaline cleaners* g	*Acid cleaners* g	*Waste water* l
Yogurt (0.2/3.4% fat)	1.2	2.5	1.0	0.9	4.5	0.745	2.535
Cream (40% fat)	3.6	1.3	0.2	0.3	4.5	0.745	1.358
UHT milk (3.7% fat)	1.1	1.3	0.4	0.5	4.5	0.745	1.358

c) Inputs according to the LCA dairy model							
	Raw milk	*Water use*	*Elec-tricity*	*Steam use*	*NaOH 50 %*	*HNO3 70 %*	*Waste water*
Yogurt (10% fat)	1.4	1.8	0.5	0.6	1.325	0.096	1.776
Cream (40% fat)	3.6	2.4	0.8	0.8	1.709	0.124	2.364
UHT milk (3.5% fat)	1.0	1.2	0.3	0.4	6.070	1.086	1.261

Interpretation B:

- Water, electricity and heat
  - More allocated to cream based on the LCA dairy model compared to suggestion of Feitz et al.
- Amount of chemicals
  - No differentiation given in Feitz et al.
  - LCA dairy model: highest for UHT milk, lower for cream, lowest for yogurt, based on detailed CIP model

SUMMARY & OUTLOOK

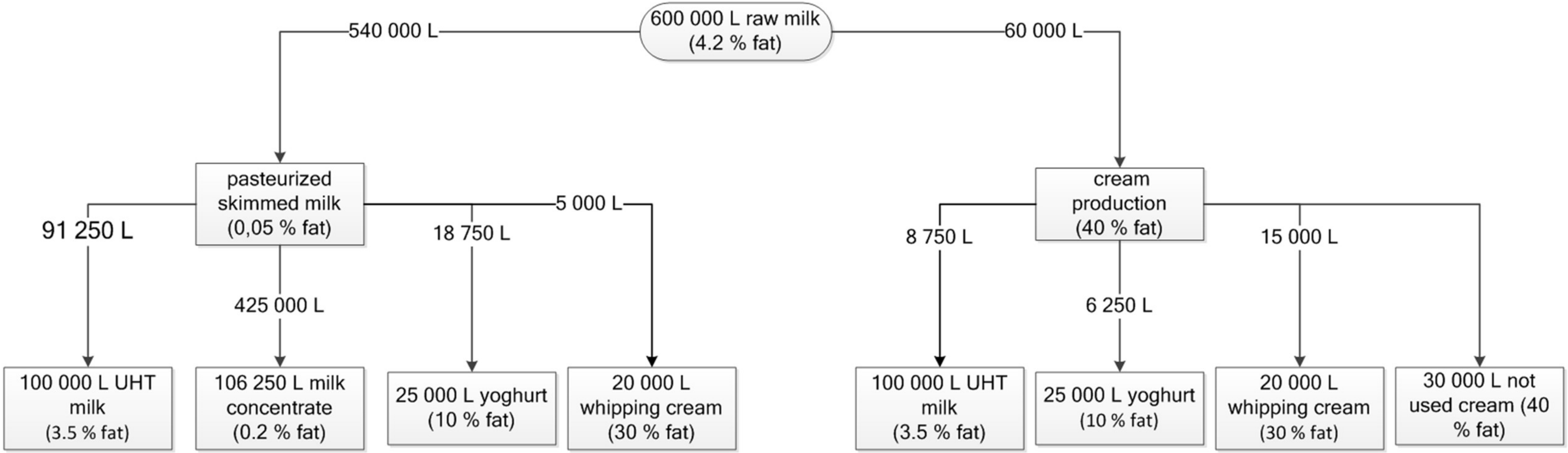
Questions?

https://www.esu-services.ch/projects/lcafood/susmilk/

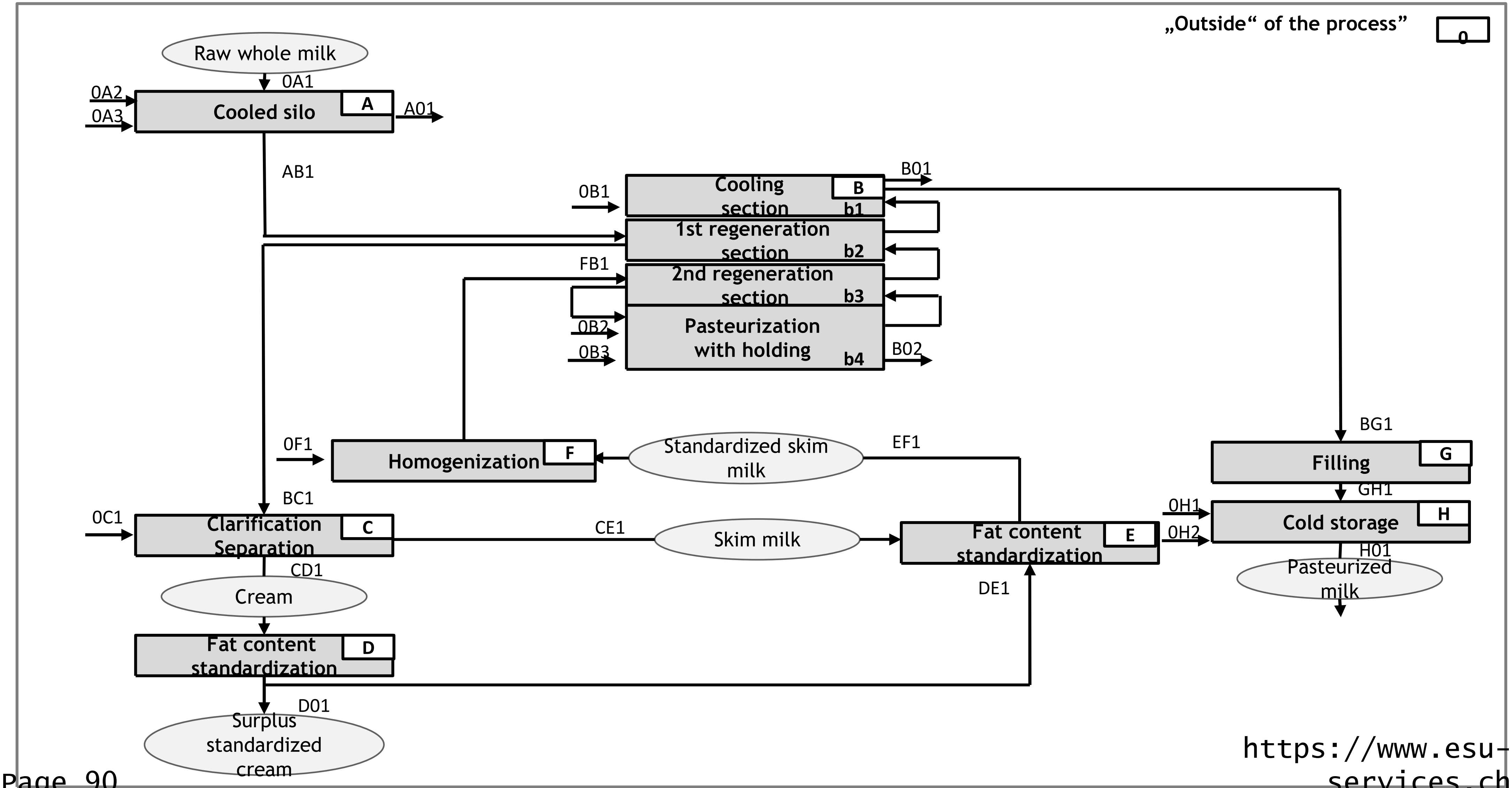
Jungbluth N., Keller R., Doublet G., König A. and Eggenberger S. (2016) Report on life cycle assessment, economic assessment, potential employment effects and exergy-based analysis: Part I - LCA. Deliverable 7.3. SUSMILK - Re-design of the dairy industry for sustainable milk processing. Seventh Framework Programme: Project no. 613589. Funded by EC. Deliverable D7.3.

WEITERE FOLIEN

Generic Dairy model



Generic dairy model pasteurized milk



Preliminary data for generic dairy per liter milk input

Input		Generic dairy model
	Country	DE
Raw milk	l raw milk	**1**
Electricity	kWh	**0.102**
Natural gas for heat	kWh	**0.232**
Total water	m^3	**0.0028**
Refrigerants	kg	**7.19E-6**
Detergents	kg	**0.0038**
Lubricant	kg	**4.96E-5**
Products	kg	**Milk, milk concentrate, yoghurt, whipping cream**
Transport per liter milk	**km/l**	**0.006**

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