LCA calculations in (LT)DH systems

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LowTEMP training package - OVERVIEW

Introduction

- Intro Climate Protection Policy and Goals
- Intro Energy Supply Systems and LTDH
- Energy Supply Systems in Baltic Sea Region

Energy Strategies and Pilot Projects

- Methodology of Development of Energy Strategies
- Pilot Energy Strategies – Aims and Conditions
- Pilot Energy Strategy – Examples
- Pilot Testing Measures
- CO_2 emission calculation
- LCA calculation

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- Life cycle costs of LTDH projects
- Economic efficiency and funding gaps
- Contracting and payment models
- Business models and innovative funding structures

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- Pipe Systems
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- Thermal, Solar Ice and PCM Storages
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1. Life Cycle Thinking
2. What is and why Life Cycle Assessment?
3. LCA methodology according to ISO14040-44
4. (LT)DH systems and LCA
5. Case study for (LT)DH using LCA

1. Life Cycle Thinking

Life Cycle Thinking: meaning

Systems thinking

- Standard Industrial model (linear)
- Life Cycle thinking (closed loop)

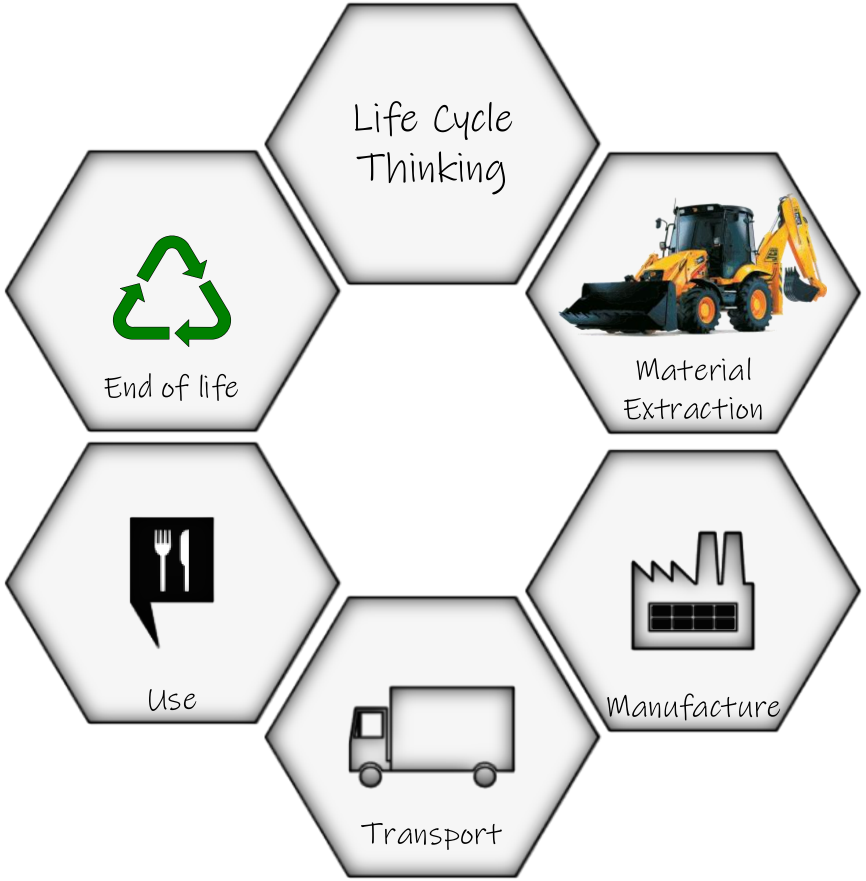

Figure 1: Product Life Cycle's General Scheme, author: Riga Technical University, Institute of Energy Systems and Environment

LC Thinking Benefits

- Aid Policy makers for better choice making
- Burden allocation on several actors
- Identification of cleaner production process
- Guide consumers towards sustainable development

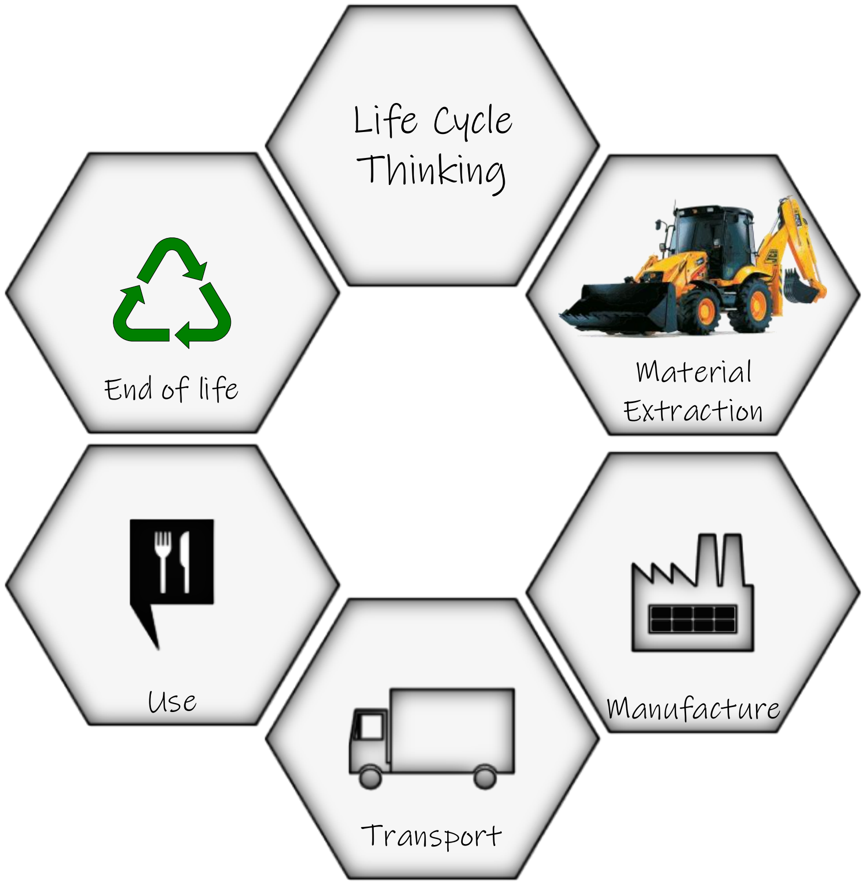

Figure 1: Product Life Cycle's General Scheme, author: Riga Technical University, Institute of Energy Systems and Environment

2. What is and why Life Cycle Assessment?

Life Cycle Assessment

- Scientific Approach: based on measurable and predictable attributes
- Focused on Impact: What is the net result to the environment?
- Throughout the Life Cycle: A "cradle-to-grave"… or "cradle-to-cradle" approach

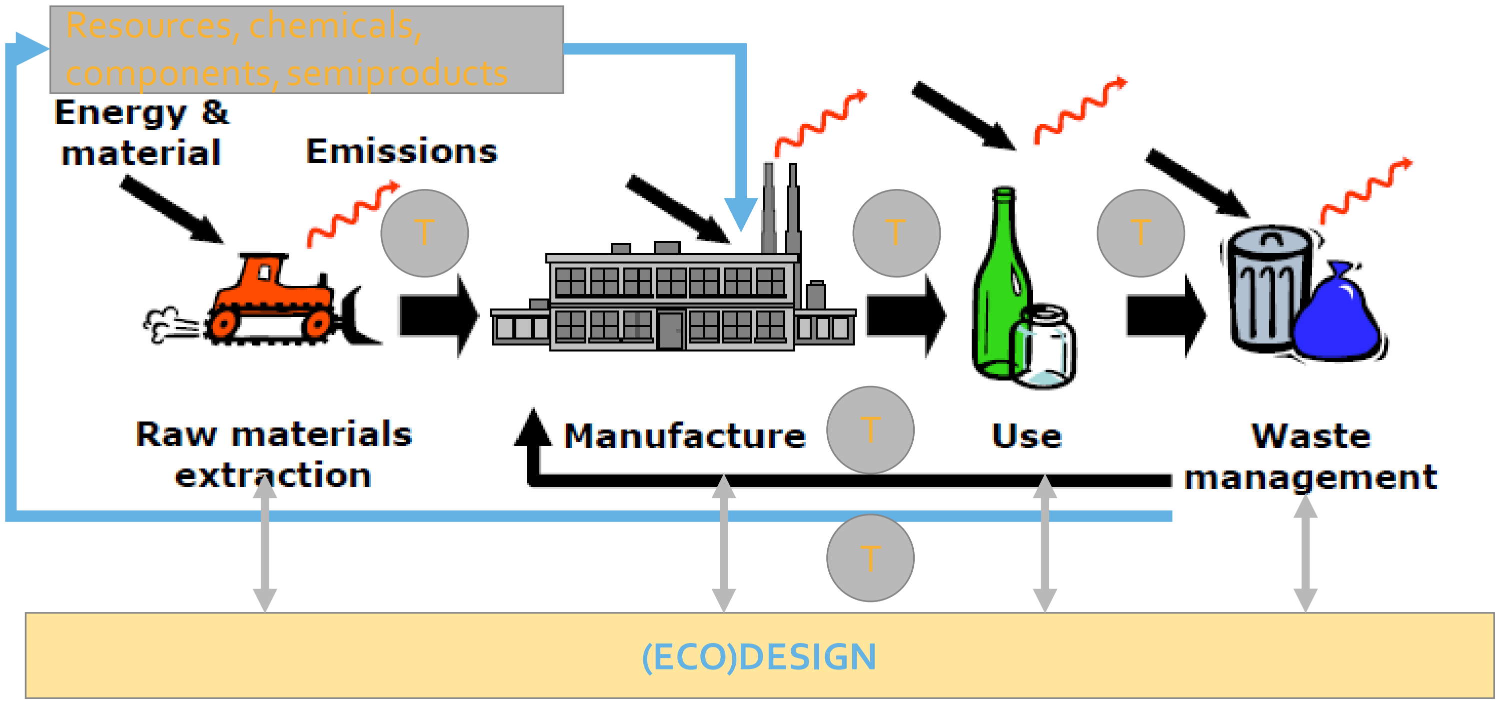

Figure 2: cradle-to-grave approach within the Ecodesign context, author: Riga Technical University, Institute of Energy Systems and Environment

Life Cycle Assessment: Objective

- Definition of the in- and out-flows of materials and energy involved in a product system
- Further identification of the environmental critical points in terms of impact – i.e. «hot-spots»

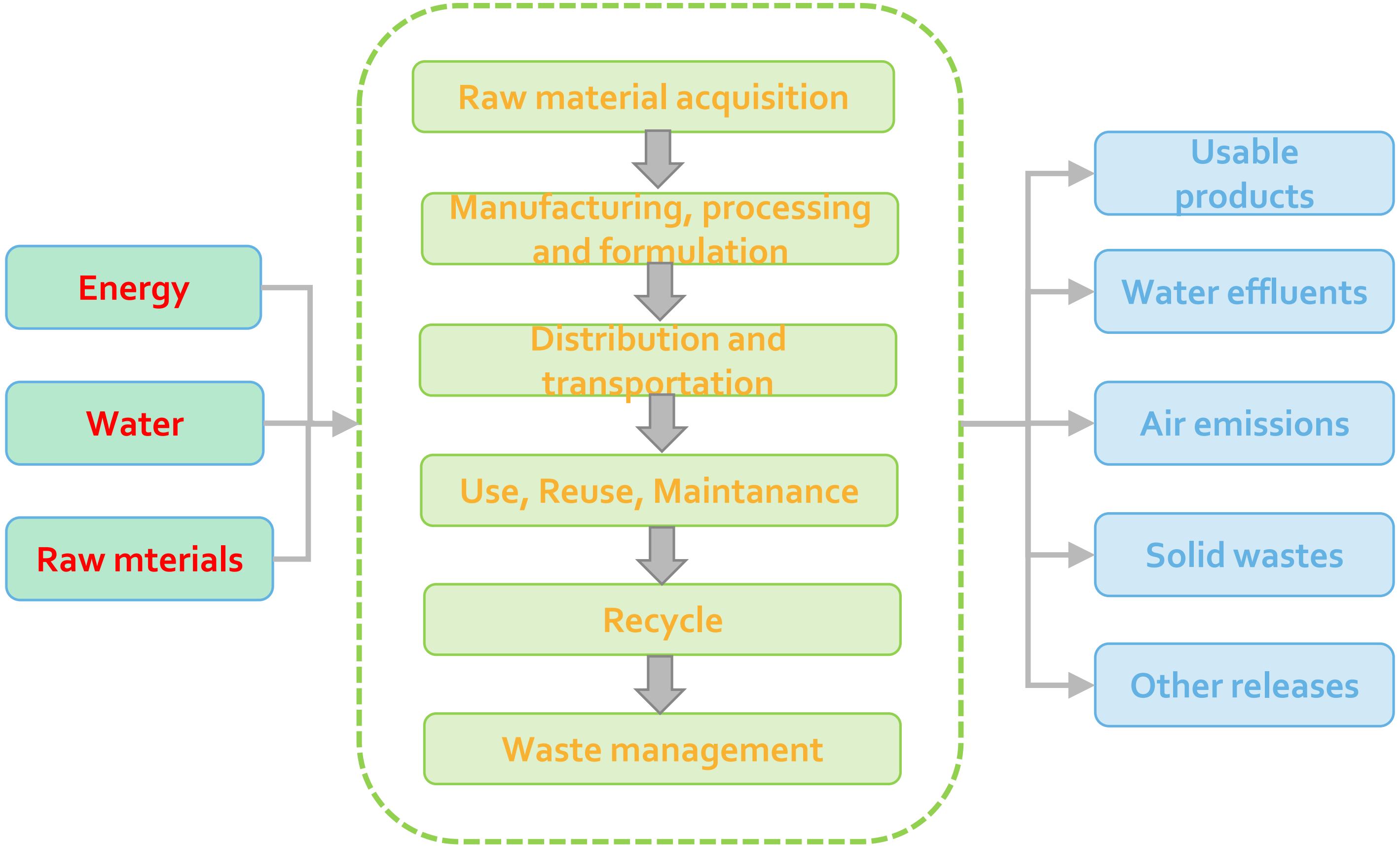

Figure 3: in- and out-flows of materials and energy involved in a product system, , readapted from https://www.slideshare.net/majidaliakbarian/lca-of-the-persian-carpet-by-majid-aliakbarian [1]

Why Life Cycle Assessment?

- Comparative tool for sustainability and environmental peformances assessment
- Holistic approach avoiding burden shifting
- Allows Consideration of Trade-Offs
- Promotes Situation-Based Decisions
- Ranking methods

Characteristics of LCA

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LCA system boundaries

- Cradle-to-Grave
- Resources use & emissions
- Foreground & background

Types of LCA

- Standalone vs comparative
- Attributional vs consequential

LCA is a way of structuring/organizing the relevant parts of the life cycle.

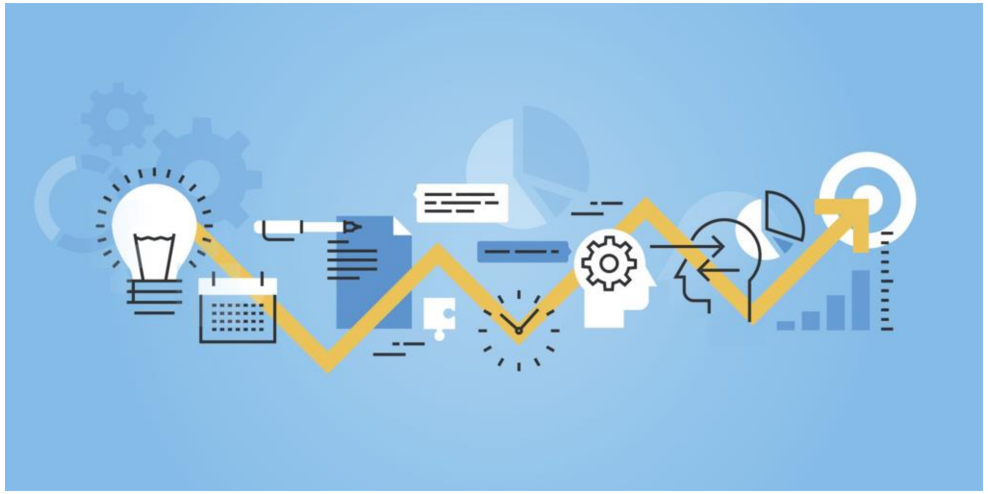
It is a tool to track performance.

It is a model of a complex reality reflecting:

- ✓ Lice cycle of a product,
- ✓ Their impacts, consequences on our health, the health of ecosystems, the availability of resources etc...

Each model is a simplification of reality.

3. LCA methodology according to ISO14040-44


Source: picture from MS Powerpoint database image's stock [3].

LCA methodology

ISO Standards

ISO 14040

- Released in 1997
- Principles and framework
- Product system definition.

ISO 14044

- Came later in 2006
- Requirements and guidelines
- LCA Methodology is described

ISO 14047, 14048, 14049

- Impact assessment
- Data documentation format
- Goal and scope definition and inventory analysis

LCA Methodology

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ISO 14044:2006

LCA Steps	Goal & Scope
	Inventory analysis
	Impact assessment
	Interpretation

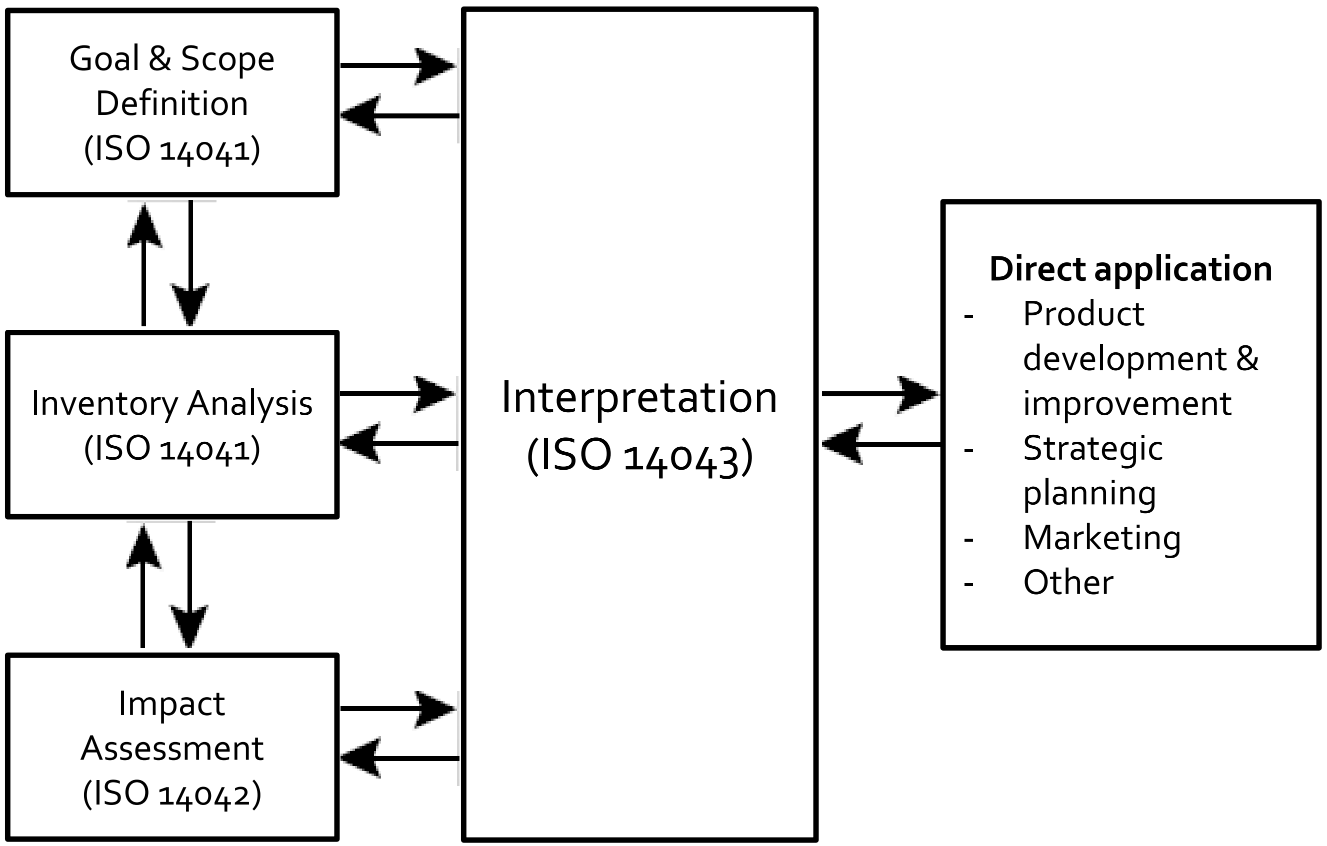
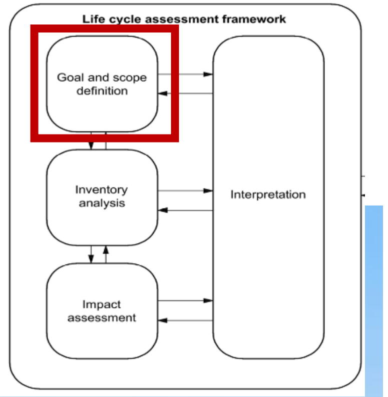


Figure 4: ISO-Standards 14044:2006 scheme, Source: readapted from EN ISO 14044-2006 [4]

Goal and Scope

Goal:

- Purpose/Reasons to be carried out
- Intended application/decision to support
- Intended audience
- Whether the results will be used in comparative assertions released publicly

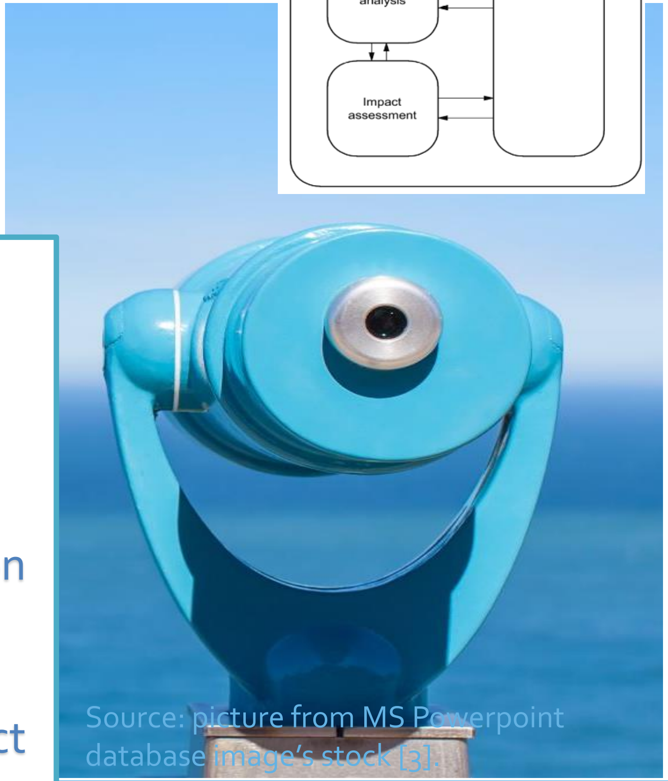


Scope:

- Definition of: studied product, the FU, system boundaries, impacts and assessment criteria, data requirements and allocation procedures.
- For DH systems the scope should evaluate the environmental performance within a pre-defined boundary including the energy source, the distribution network and the final demand.

Functional unit (FU):

- Provides a reference to which the inputs and outputs are related to ensure comparability of LCA results on a common basis.
- It is the quantified performance of a product system



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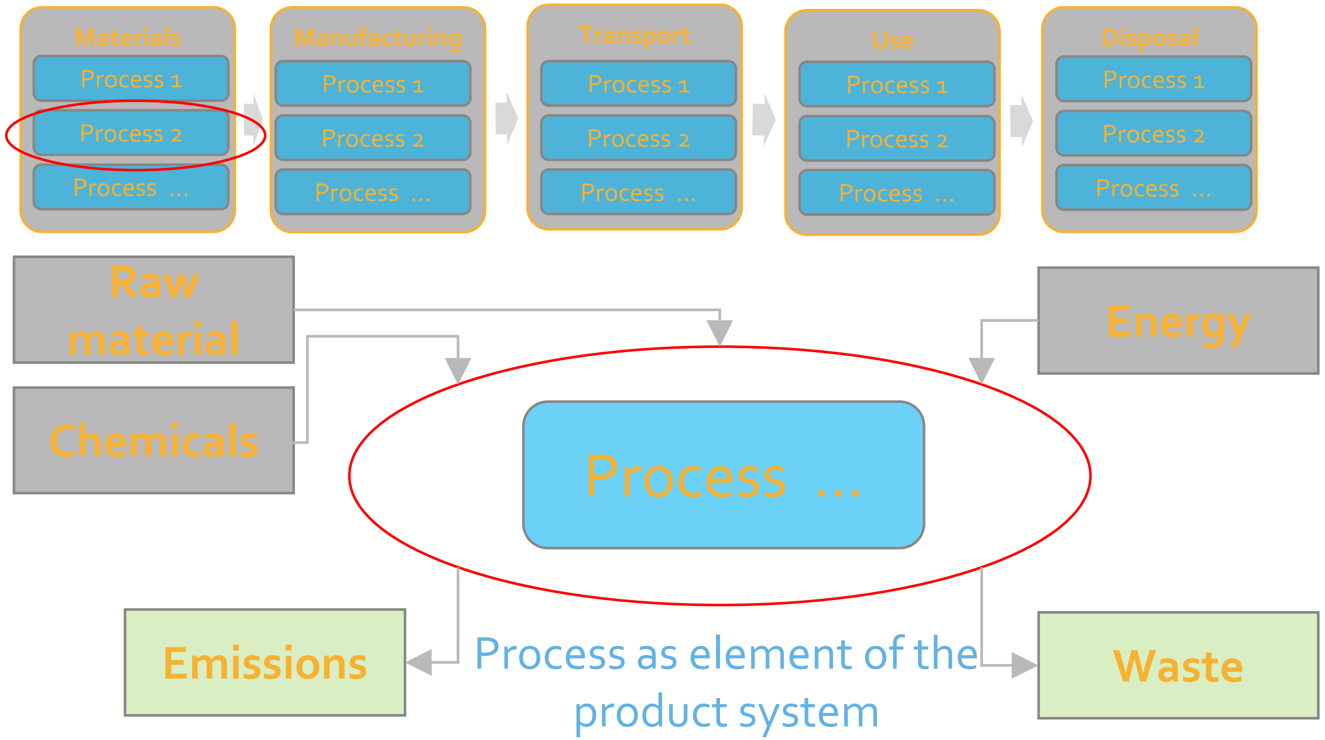
Life Cycle Inventory (LCI)



Identify and quantify energy, water and materials usage and environmental releases (e.g., air emissions, solid waste disposal, waste water discharges).

Source: pictures from MS Powerpoint database image's stock [3].

1. Draw a flow chart and data collection

2. Model for Product system

3. Evaluate and report results

Life Cycle Impact Assessment

Modelling impacts of inventory results on the areas of protection through a number of environmental impact pathways

- Evaluates the significance of potential environmental impacts using from the Life Cycle Inventory
- Inventory data and emissions calculations are sorted in specific environmental impact categories
- The effect on the environment in each impact category is quantified through category indicators

Human Health
Natural Environment
Natural resources

Life Cycle Impact Assessment

Mandatory elements

Selection of impact categories, category indicators and characterization model

↓

Classification: assignment of life cycle inventory results

↓

Characterization: calculation of category indicator results

↓

Results: indicators, LCIA

↓

Optional elements

Normalization: calculation of category indicators to reference information

Grouping

Weighting

Figure 5: Life Cycle Impact Assessment according to ISO-Standards 14044:2006 scheme, Source: readapted from EN ISO 14044-2006 [4].

LCI results		Climate change		Acidification		Particulate matter	
1000 g	CO_2	x 1	= 1000				
10 g	SO_2			x 1.31	= 13.1	x 0.061	= 0.61
5 g	N_2O	x 298	= 1490	x 0.74	= 3.7	x 0.0072	= 0.036
4 g	$PM_{2.5}$					x 1	= 4
			+		+		+
Characterized results		2.49	kg CO_2-eq.	0.0168	mol H^+-eq.	0.0046	kg $PM_{2.5}$-eq.
Normalized results		0.000366	person*year	0.00034	person*year	0.00169	person*year
Weighting factor			x 23		x 4.2		x 6.6
							+
Weighted results							0.021 pt

Figure 6: normalized results in Life Cycle Impact Assessment, Source: Ecodesign and LCA course, Riga Technical University, Institute of Energy Systems and Environment from "Advanced modelling in SimaPro- course material, Pre-consultants, May 2013" [5].

Life Cycle Impact Assessment

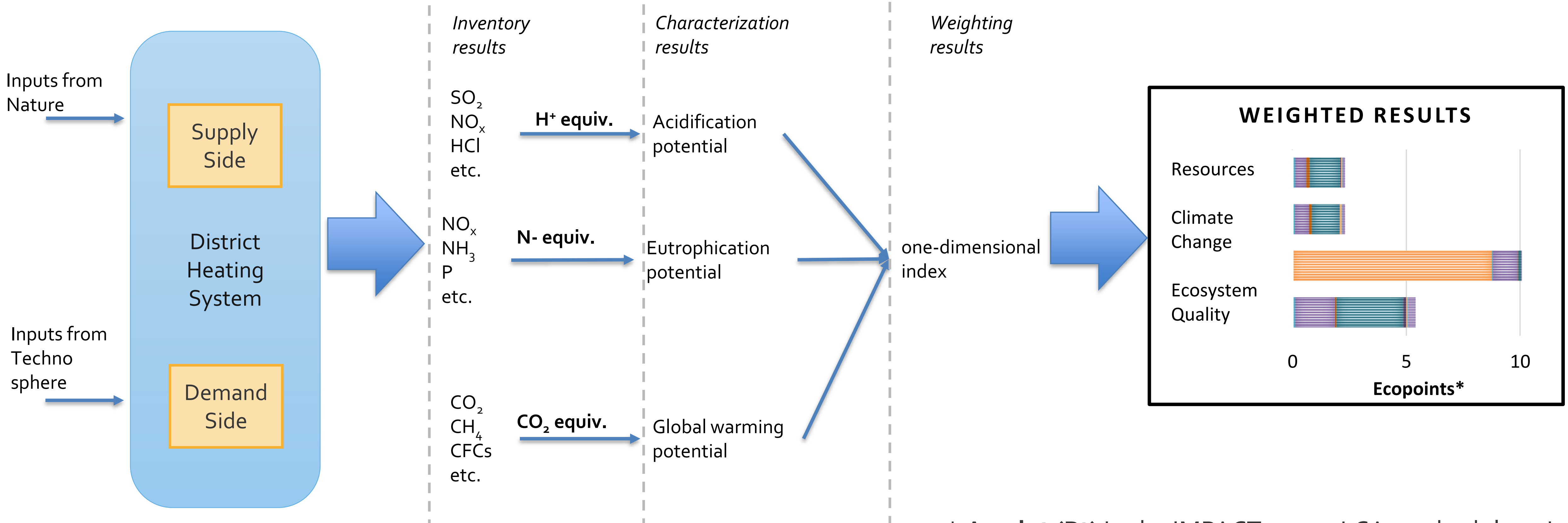


Figure 7: single score in the Life Cycle Impact Assessment, Source: Ecodesign and LCA course, Riga Technical University, Institute of Energy Systems and Environment readapted from Henrikke Baumann, Anne-Marie Tillman. The Hitch Hiker's Guide to LCA : an orientation in life cycle assessment methodology and application, 2004 [6]

* **A point (Pt)** in the IMPACT 2002+ LCA methodology is the average impact caused by or on a person in a specific category during one year in Europe.

Life Cycle Interpretation (LCI)

Several elements are considered: identification of significant issues based on results, evaluation of consistency and sensitivity checks, and discussion of conclusions, limitations and recommendations.

Source: pictures from MS Powerpoint database image's stock [3].

- Goal& Scope definition
- Inventory analysis
- Impact assessment

Identification of significant issues, selection of environmental impact or method

Reliability of results by completeness check, sensitivity check, consistency check, etc.

Conclusions, limitations, recommendat ions

Application

4. (LT)DH systems and LCA

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Benefits of LCA on DH systems

- **Define an updated data inventory of all DH subsystems** to be used as further benchmarks
- Clarify **which subsystems** and parts of a district heating system **are affecting the overall environmental performance** of the infrastructure
- **Provide alternatives based on eco-design perspectives** implementable **in Municipality Energy strategies** including SECAP
- Comparison with the **business-as-usual DH scenarios** (e.g. distribution network using natural gas)

- The LCA results may be of interest for:
  - energy planner and energy companies
  - engineers
  - DH operators
  - public officials and
  - decision makers
  - Researchers/LCA practitioners

Current state-of-art of LCA on DH

Author, year of study	Methodology	Subject of study	Software
Oliver-Sola, 2009	LCA ISO 14044	DH infrastructure with street section of 100 m, 10 blocks of 24 dwellings each	Gabi 4
Nitkiewicz, 2014	LCA ISO 14044	Low-temperature heating plant with electric heat pump, absorption heat pump and gas-fired boiler	SimaPro 7.3.2
Parajuli, 2014	LCA	District heat production in a straw fired CHP plant	SimaPro 7.3.3
Ivner, 2015	LCA ISO 14044	Industrial excess heat in DH system	SimaPro software and ENPAC tool
Sandvall, 2017	TIMES	Small-town, medium-sized and a large DH system with specific characteristics in terms of DH supply technologies and fuel use	TIMES_UH model
Bartolozzi, 2017	LCA ISO 14040 and 14044	Heating and cooling in residential neighborhood of 1000 inhabitants (equivalent to 250 apartments), located in Tuscany, Italy	SimaPro 8.02
Havukainen, 2018	LCA ISO 14040 and 14044	Small-scale CHP plant fired by forest biomass, located in the Saimaanharju, Taipalsaari, Finland	GaBi 6.0
Pericault, 2018	LCA and LCC	System processes of five alternatives for water supply, sanitation and heating in a residential area in Gallivare, Sweden	Open LCA

How to build an LCA for DH system

Large scale solar

Biomass

Industry surplus heat

CHP
- Biomass
- Waste

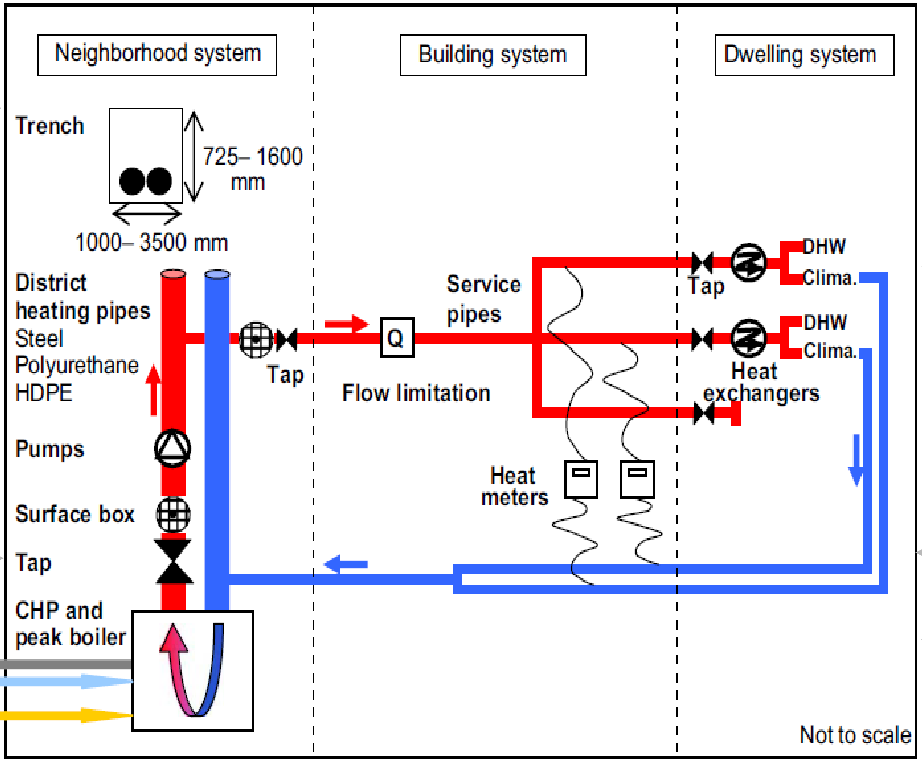


Figure 8: comparative LCA scenario for (LT)DH systems, source: readapted from Oliver-Solà et.al (2009) [8].

Geothermal

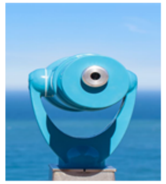
Future energy sources

Surplus electricity
- PV
- Wind
- Wave
- …

Transformation scenario identification

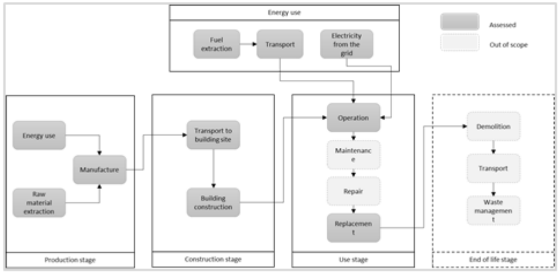
- B-as-U
- Scenario 1
- Scenario 2
- Scenario 3
- …
- Scenario n

How to build an LCA for (LT)DH system



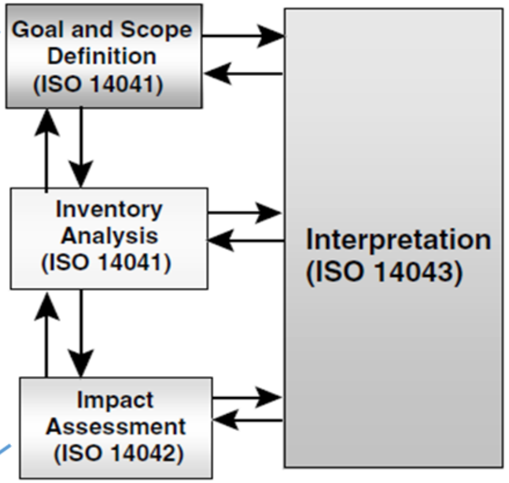
To assess the total environmental performance of a DH systems over a lifespan of 25 years, including operation and maintenance activities.

Source: pictures from MS Powerpoint database image's stock [3].

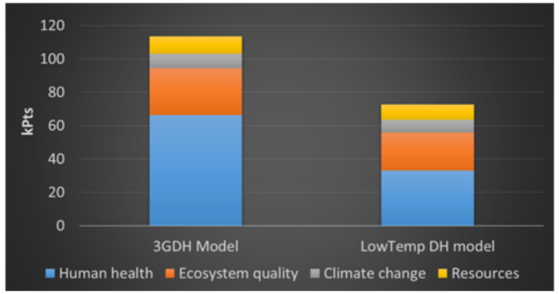


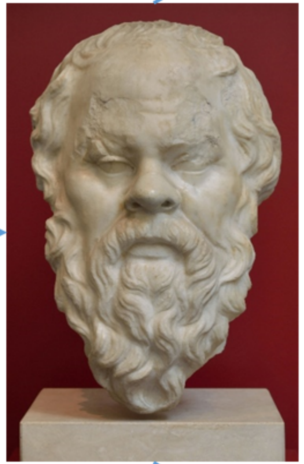
Material/Assemblies	Amount	Unit
Solar Plant	18.2	p
Old District heating Pipelines	10.6	p
New District heating Pipelines	1.39	p
Old Boilerhouse - No furnace	1	p
DH nodes	10.6	p
Boiler's pumps, taps, heat m., exch. & flow device	2	p
Node's pumps and taps	10.6	p
Pipeline's pumps, taps, heat meters, exch., flow d	10.6	p
Op. Phase	25	p
Processes	Amount	Unit
Furnace, wood chips, average storage area, 1000kW	4.5	p
Furnace, wood chips, with silo, 5000kW	1	p
Hot water tank, 600l	4.16	p

Source: LowTEMP project, http://www.lowtemp.eu/wp-content/uploads/2020/12/LCA-report-pilot-measure-Belava.pdf [8].



Source: ISO-Standards 14044:2006 scheme, Source: readapted from EN ISO 14044-2006 [4]





Source: pictures from MS Powerpoint database image's stock [3].

Eco-Design Solution

SECAP DH strategy to implement

5. Case study for (LT)DH using LCA

Examples from:
- Beļava Parish in Gulbene Municipality
- Pilot Energy Strategy (Galgauska Parish in Gulbene)

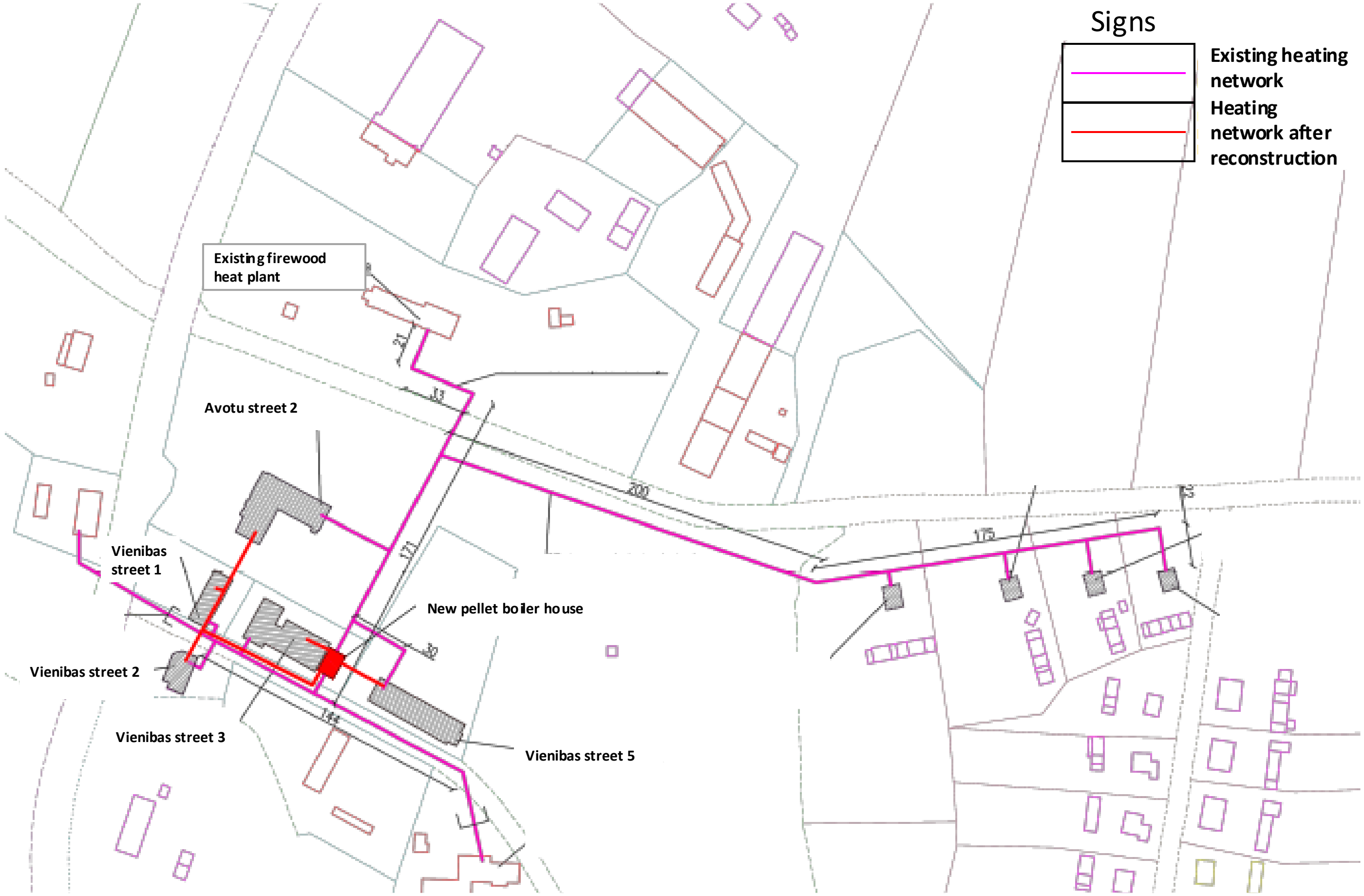
GoA 4.2 –LCA scheme for Gulbene, Beļava parish

PILOT MEAURE GULBENE

- Full reconversion of a former 3rd generation type DH distribution network to a novel Low Temperature DH system

- **Old system**: boiler house operating with wood logs fired boiler and distribution network not renovated
- **New system**: LTDH with a 0.2 MW new pellet boiler house, new distribution grid and the remote data monitoring system

Figure 9: the Beļava parish LTDH network, Source: M. Feofilovs et al. ,2019 [9].



GoA 4.2 –LCA scheme for Gulbene, Beļava parish

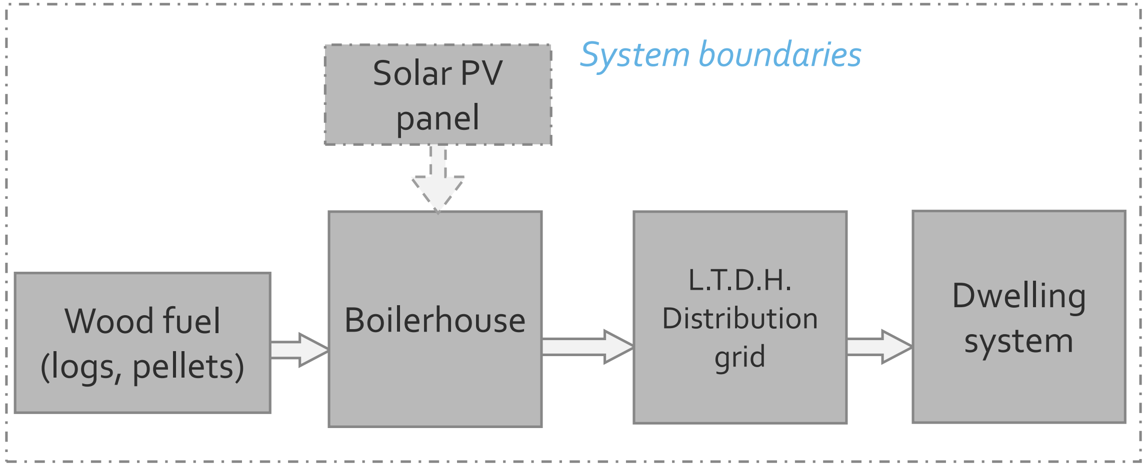


Figure 10: LCA's system boundaries for the Beļava parish LTDH network.

Scenario	Characteristics
1	New DH system 90/60
2	New LTDH system 60/35 with solar PV panels
3	New LTDH system 60/35
4	Old DH system 90/60

FUNCTIONAL UNIT

Thermal energy supply to the heated area over a certain assumed lifetime of DH

Life Lice Inventory

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Part of DH	Materials / Assemblies / Processes	Amount	Unit
New boiler house	Steel, low-alloyed	113.3	kg
	Steel, chromium steel 18/8	390.1	kg
	Concrete, sole plate and foundation	4.2	m3
	Sand	14	kg
	Polyureth		
	Cast iron		
	Brass		
	Stone wo		
	Flat glass,		
	Alkyd pai		
	Polyethyl		
	Exhaust a		
	Ventilatio		
	Room-co		
	Exhaust a		
	Ventilatio		
	Ventilatio		
	Insulation		
	Intermodi		
	Furnace,		
	Metal wo		
	Metal wo		
	Metal wo		
	Extrusion,		

New DH pipeline network	Chromium steel pipe	10639.4	kg
	Polyurethane, rigid foam	816.8	kg
	Polyethylene, low density, granulate	2038.7	kg
	Concrete block	2901	kg
	Sand	323.5	kg
	Cast iron	283	kg
	Copper	15	kg
	Pitch	10	kg
	Alkyd paint, white, without solvent, in 60 % solution state	7.2	kg
	Gravel, crushed		
	Mastic asphalt		
	Cable, three-c		
	Concrete, sole		
	Metal working,		
	Extrusion, plas		
	Metal working,		
	Metal working,		
	Welding, arc, s		
	Excavation, hy		

DH nodes	Steel, low-alloyed	256.8	kg
	Stone wool	1.2	kg
	Cast iron	132	kg
	Copper	9	kg
	Brass	61.6	kg
	Stone wool	1805.1	kg
	Alkyd paint, white, without water, in 60 % solution state	4.8	kg
	Cable, ribbon cable, 20-pin, with plugs	15	kg
	Metal working, average for steel product manufacturing	256.8	kg
	Metal working, average for metal product manufacturing	132	kg

Source: M. Feofilovs et al. ,2019 [9].

Environmental damage assessment

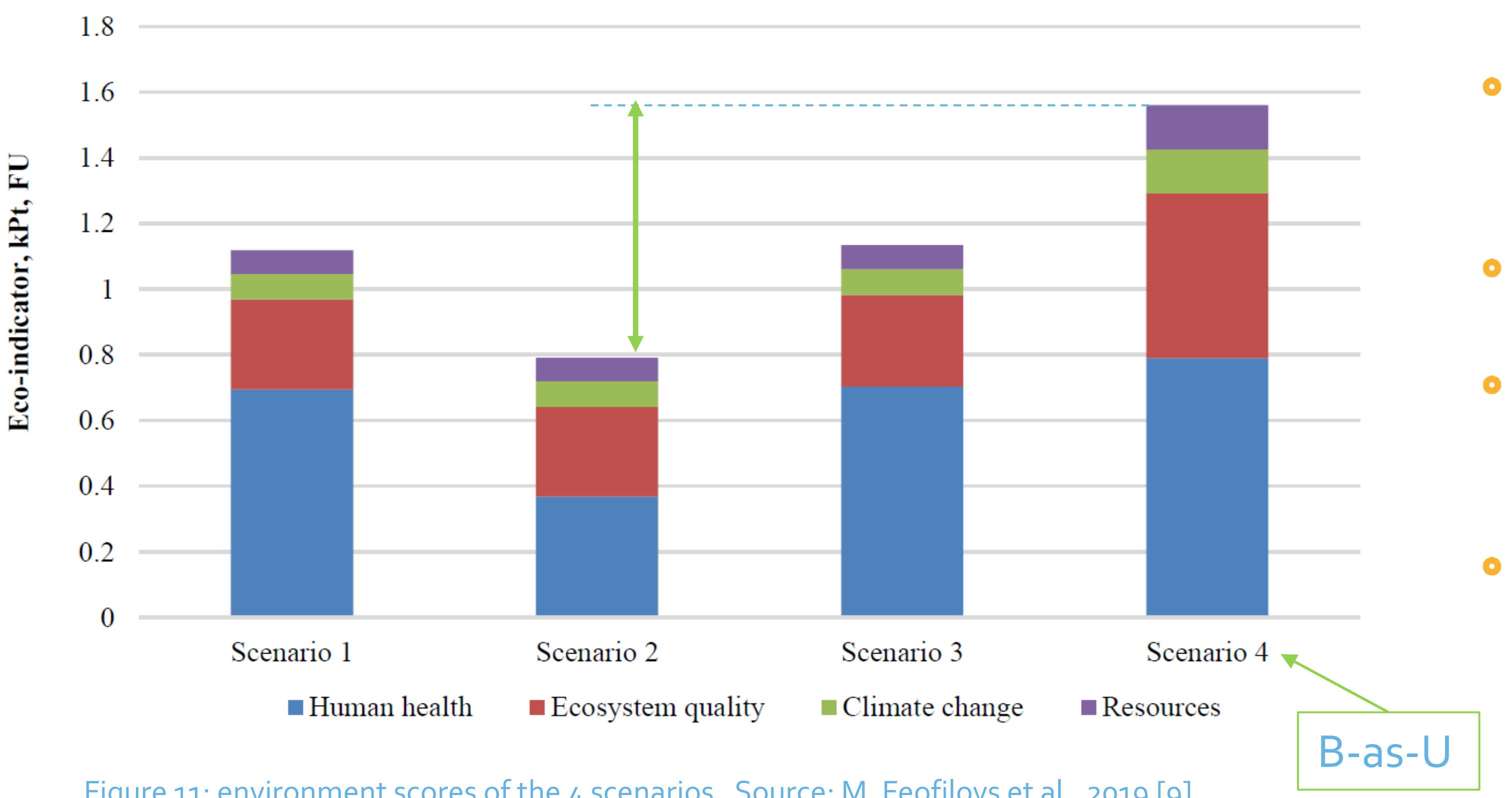


Figure 11: environment scores of the 4 scenarios, Source: M. Feofilovs et al. ,2019 [9].

- Environmental improvements: decrease, of approximately 50%
- Highest contribution: operational phase
- The impact of the construction and maintenance phase is marginal
- Important decrease on:
  - Global warming potential (62%)
  - Ecosystem (54%)

Galgauska Parish

Figure 12a: Belava (Gulbene Municipality) pilot testing measure, http://www.lowtemp.eu/map/, [10]

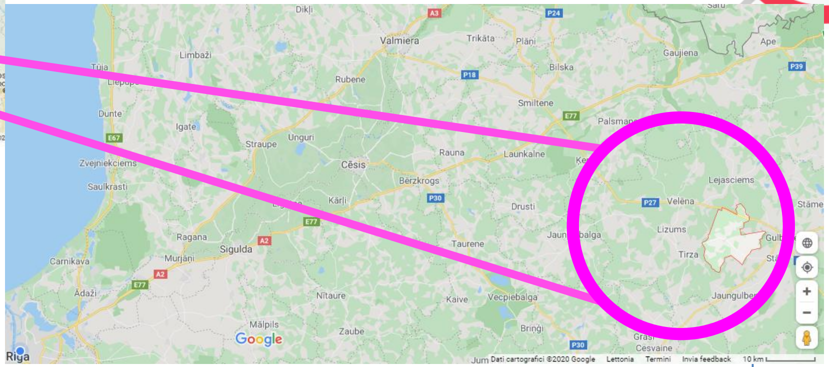


Figure 12b: Belava (Gulbene Municipality) pilot testing measure, Source: https://www.google.lv/maps [11]

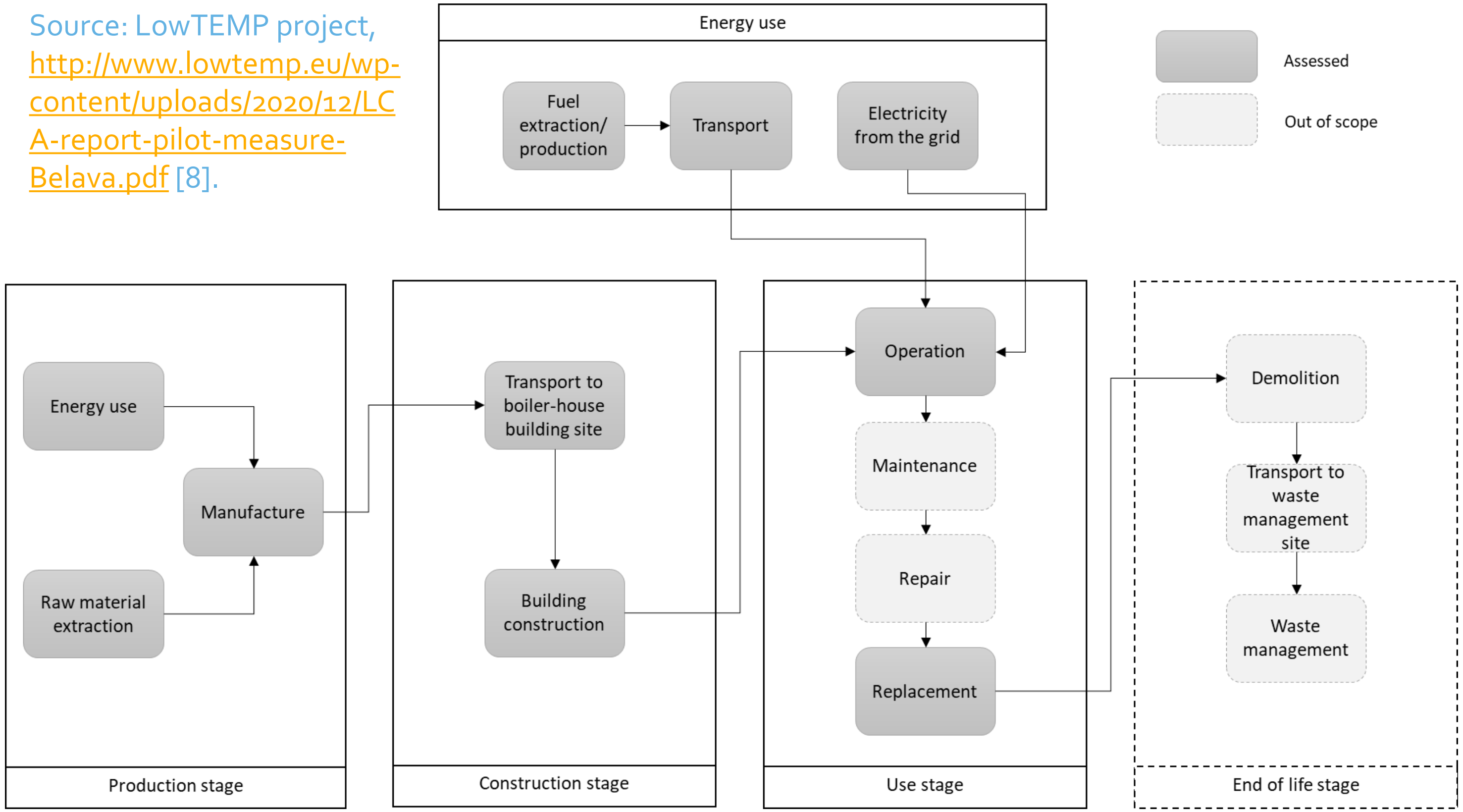
Currently, 3rd generation DH system is running in Gulbene municipality and its parishes. But, a more energy efficient performance by the development of a Low Temperature District heating network is intended.

Goal & Scope

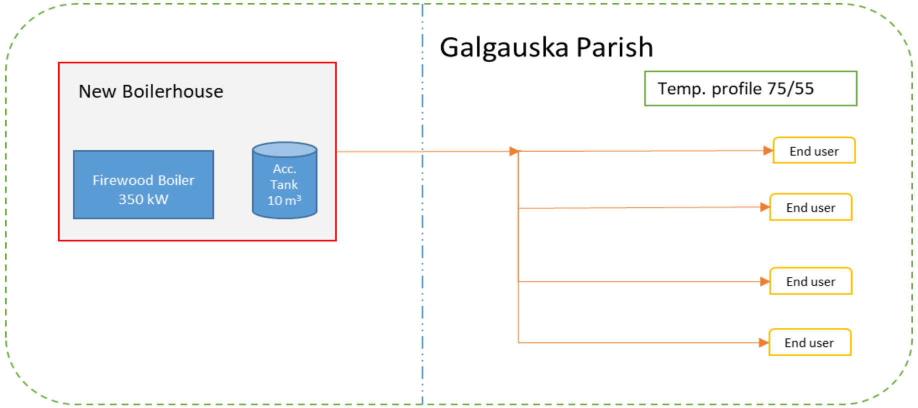
- Assess the environmental impact of current DH system in Galgauska parish
- Assess the environmental impact of potential LowTemp DH system.
- Functional Unit: the construction, operation and maintenance of DH system over an assumed time horizon to deliver the required heat demand .
- Analysis of results at midpoint categories using IMPACT 2002+ method and endpoint categories.

Gulbene City – System boundaries

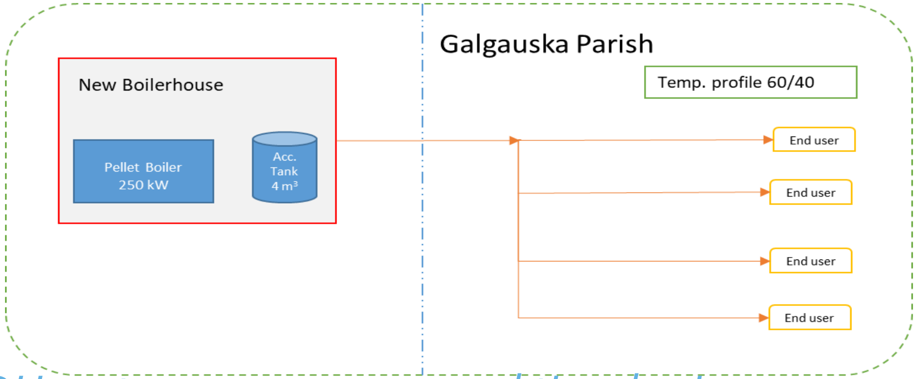
Source: LowTEMP project, http://www.lowtemp.eu/wp-content/uploads/2020/12/LCA-report-pilot-measure-Belava.pdf [8].



Scenario 1



Scenario 2



***FUNCTIONAL UNIT**: functional unit is the operation and maintenance of DH system over an assumed time horizon for delivering the required heat demand of different Gulbene's parishes and municipality*

Gulbene City – Life Cycle Inventory

LowTEMP

Source: LowTEMP project, http://www.lowtemp.eu/wp-content/uploads/2020/12/LCA-report-pilot-measure-Belava.pdf [8].

NEW BOILER HOUSE		
Material/Assemblies in SimaPro	**Amount**	**Unit**
Steel, low-alloyed {GLO}| market for | APOS, U	*113,3*	*kg*
Steel, chromium steel 18/8 {GLO}| market for | APOS, U		
Concrete, sole plate and foundation {CH}| market for | APOS, U		
Sand {GLO}| market for | APOS, U		
Polyurethane, rigid foam {GLO}| market for | APOS, U		
Cast iron {GLO}| market for | APOS, U		
Brass {CH}| market for brass | APOS, U		
Stone wool {GLO}| market for stone wool | APOS, U		
Flat glass,		
Alkyd pai		
Polyethyle		
Exhaust a		
Ventilatio		
Room-co		
Ventilatio		
Ventilatio		
Insulation		
Processes		
Metal wo		
Metal wo		
Metal wo		
Polymer f		
Extrusion,		

New DH Pipelines		
Material/Assemblies in SimaPro	**Amount**	**Unit**
Steel, low-alloyed {GLO}| market for | APOS, U	*10639,4*	*kg*
Polyurethane, rigid foam {RoW}| market for polyurethane, rigid foam | APOS, U	*816,8*	*kg*
Polyethylene, low density, granulate {GLO}| market for | APOS, U	*2038,7*	*kg*
Concrete block {GLO}| market for | APOS, U	*2901*	*kg*

Building renovation
Polystyrene, extruded {GLO}| market for | APOS, U
Adhesive mortar {GLO}| market for | APOS, U
Gypsum plasterboard {GLO}| market for | APOS, U
Glazing, double, U<1.1 W/m2K, laminated safety glass {GLO
Alkyd paint, white, without solvent, in 60% solution state {R
Stone wool {GLO}| market for stone wool | APOS, U
Epoxy resin, liquid {RER}| market for epoxy resin, liq
Glass fibre {GLO}| market for | APOS, U
Glued laminated timber, for indoor use {RER}| produ
Orthophthalic acid based unsaturated polyester resi
Steel, chromium steel 18/8 {RER}| steel production, c
Soil for construction
Sand {GLO}| market for | APOS, U
Polystyrene foam slab for perimeter insulation {GLO}
Concrete, normal {RoW}| market for | APOS, U
Acrylic filler {RER}| market for acrylic filler | APOS, U
Ceramic tile {GLO}| market for | APOS, U

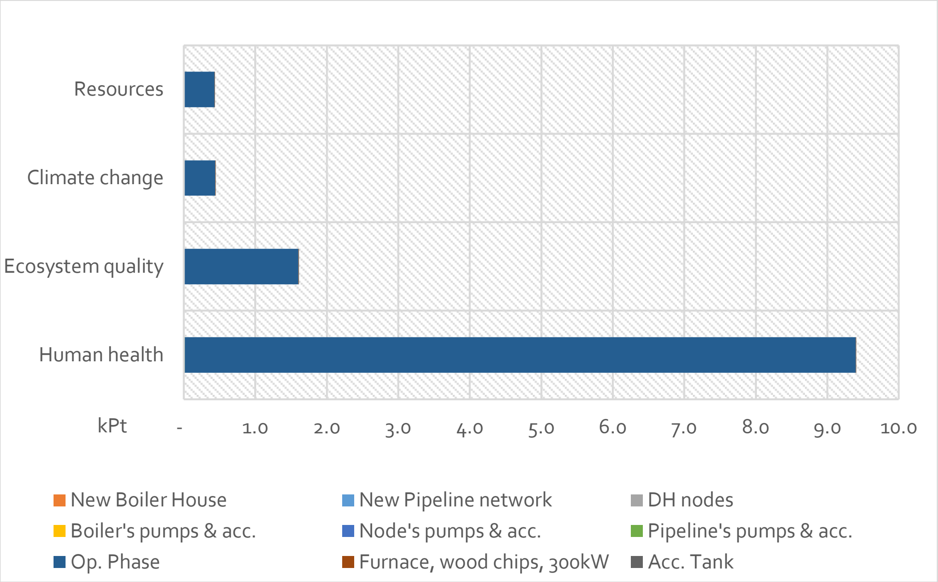
OPERATIONAL PHASE - Galgauska Scenario 1		
Material/Assemblies in SimaPro	**Amount**	**Unit**
Roundwood, from sustainable forest management, under bark {GLO}| market for | APOS, U	*950*	*m3*
Processes	**Amount**	**Unit**
Heat, district or industrial, other than natural gas {RoW}| heat production, hardwood chips from forest, at furnace 300kW |	*926*	*MWh*
Electricity, medium voltage {LV}| market for | APOS, U	*13,9*	*MWh*

OPERATIONAL PHASE - Galgauska Greenest Scenario		
Material/Assemblies in SimaPro	**Amount**	**Unit**
Wood pellet, measured as dry mass {RER}| market for wood pellet | APOS, U	*188*	*ton*
Processes	**Amount**	**Unit**
Heat, district or industrial, other than natural gas {RoW}| heat production, softwood chips from forest, at furnace 300kW | A	*728*	*MWh*
Electricity, medium voltage {LV}| market for | APOS, U	*10,9*	*MWh*

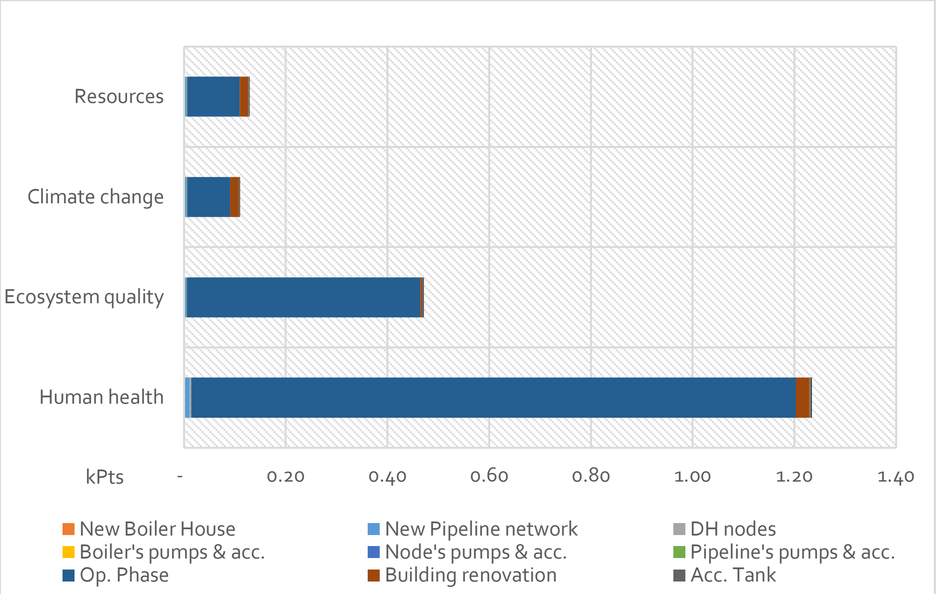
Gulbene City – Life Cycle Impact Assessment

Life Cycle Impact Assessment

Scenario 1



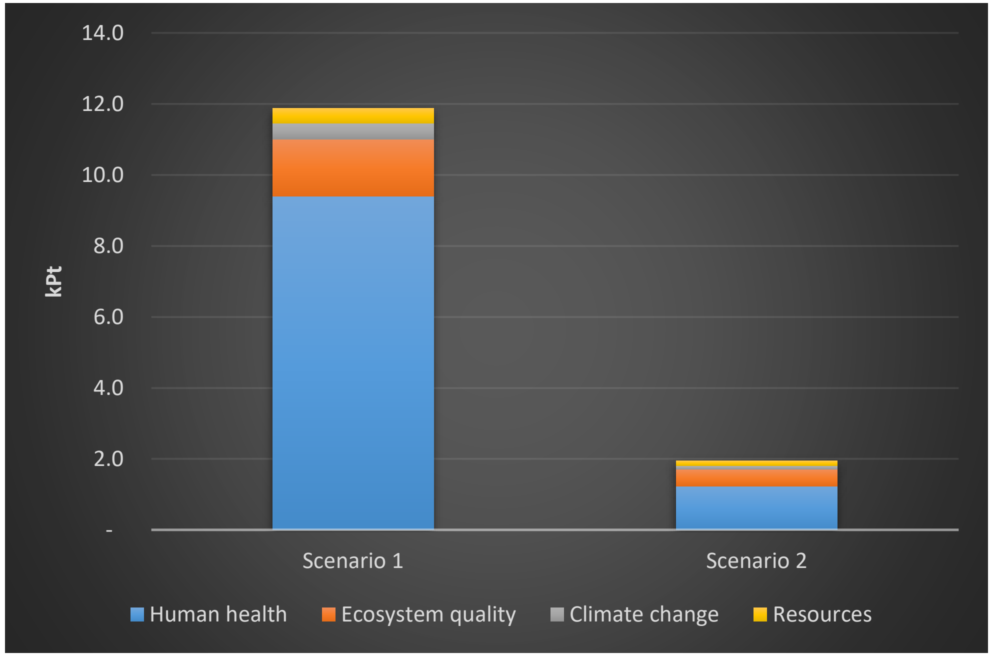
Scenario 2



Source: LowTEMP project, http://www.lowtemp.eu/wp-content/uploads/2020/12/LCA-report-pilot-measure-Belava.pdf [8].

Gulbene City – Life Cycle Impact Assessment

Life Cycle Interpretation



- A remarkable environmental impact reduction in all end point categories is achieved when moving from a 3GDH to a LTDH system
- Environmental burden is taken down in all impact categories for the lifespan of the project
- The Human health area is the one where most of the environmental benefit is received, with a total reduction of 86 %

Source: LowTEMP project, http://www.lowtemp.eu/wp-content/uploads/2020/12/LCA-report-pilot-measure-Belava.pdf [8].

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