Environmental Impacts through Geothermal Power Generation in Germany

A study for the Federal Environment Agency of Germany

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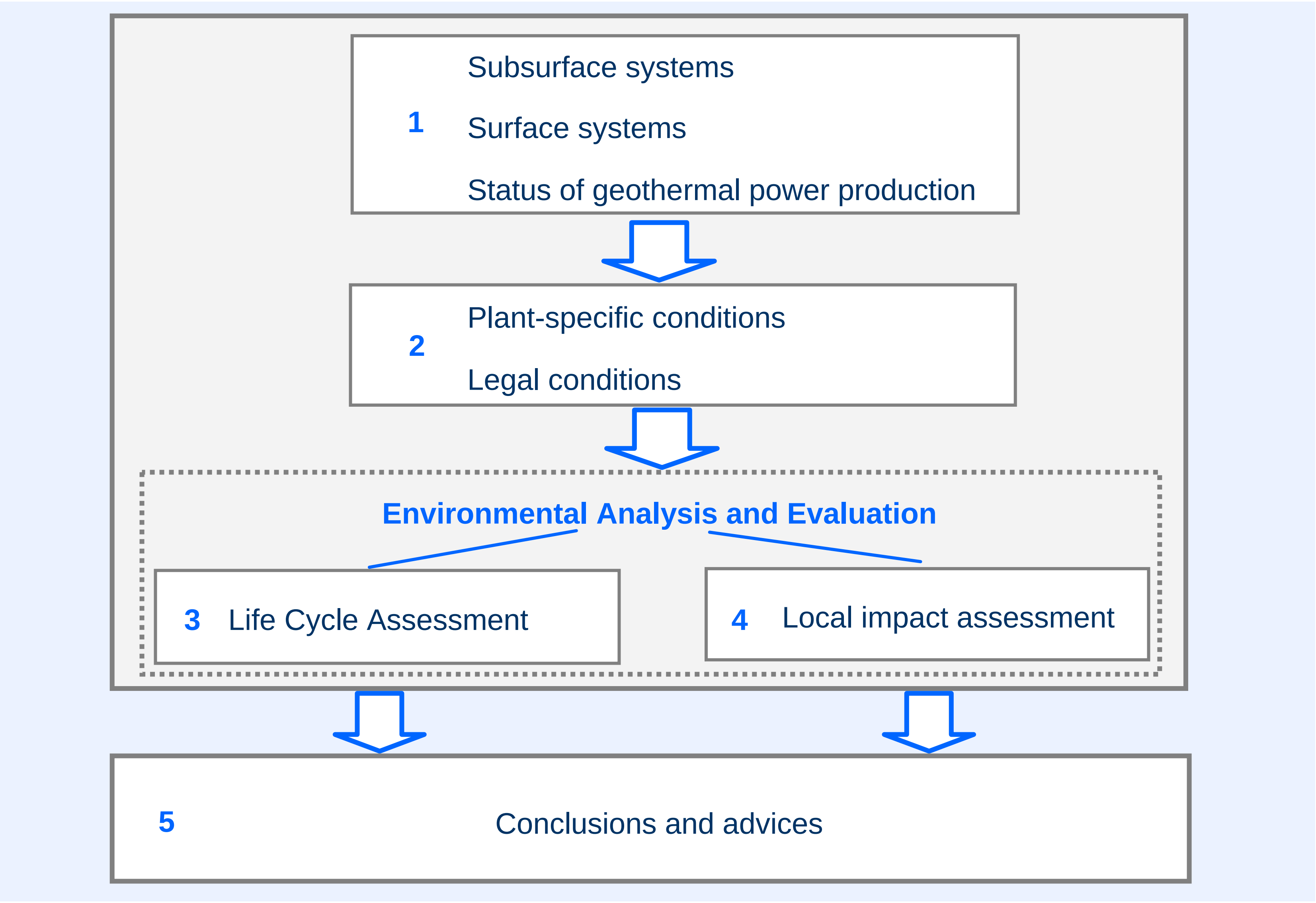
Federal Environment Agency of Germany (UBA)

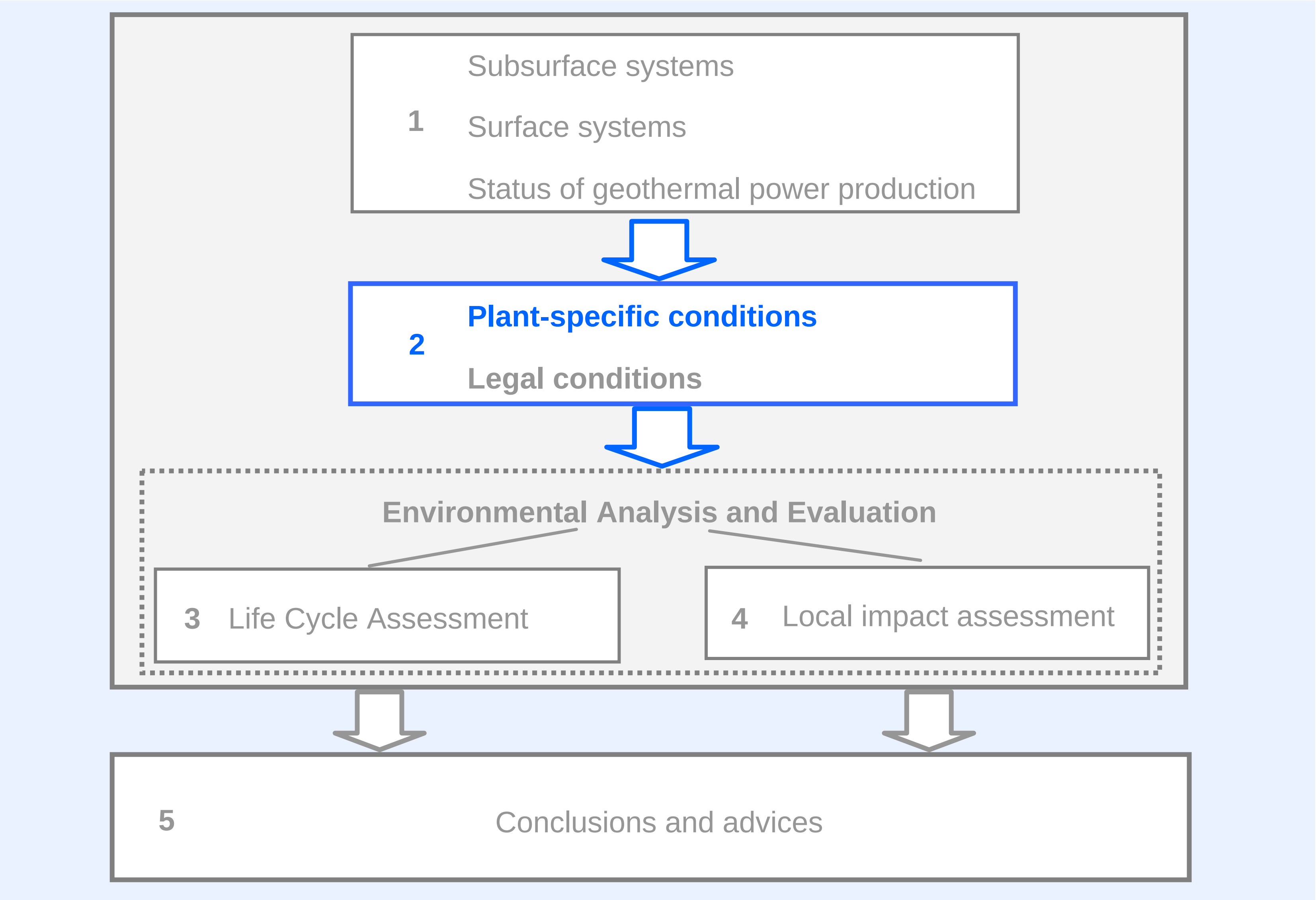
Introduction

- Geothermal energy has experienced a rising interest in Germany
- A wider use needs to result in general benefits for the environment compared to the existing alternatives
- The environmental impacts need to be analysed at the beginning of the market introduction

→ The Federal Environment Agency of Germany (UBA) has commissioned a study

Approach of the study

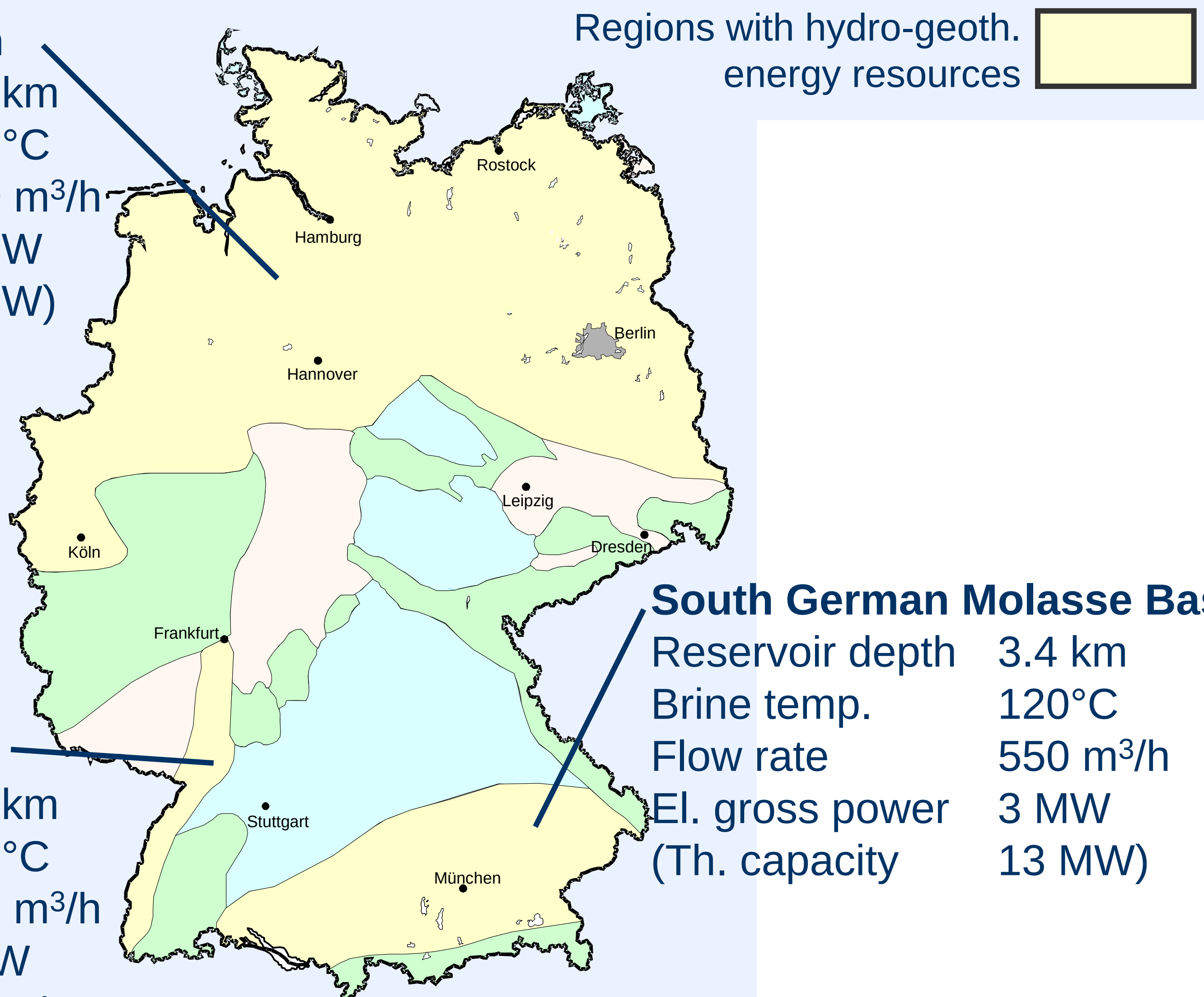



Subsurface systems
1
Surface systems
Status of geothermal power production
Plant-specific conditions
2
Legal conditions
Environmental Analysis and Evaluation
3 Life Cycle Assessment
4 Local impact assessment
5
Conclusions and advices

Geothermal reference systems
Aquifer-Doublets for power (& heat)

North German Basin

Reservoir depth	4.4 km
Brine temp.	150°C
Flow rate	100 m^3/h
El. capacity	1 MW
(Th. capacity	2 MW)



Upper Rhine Valley

Reservoir depth	3.0 km
Brine temp.	150°C
Flow rate	150 m^3/h
El. capacity	3MW
(Th. capacity	7 MW)

South German Molasse Basin

Reservoir depth	3.4 km
Brine temp.	120°C
Flow rate	550 m^3/h
El. gross power	3 MW
(Th. capacity	13 MW)

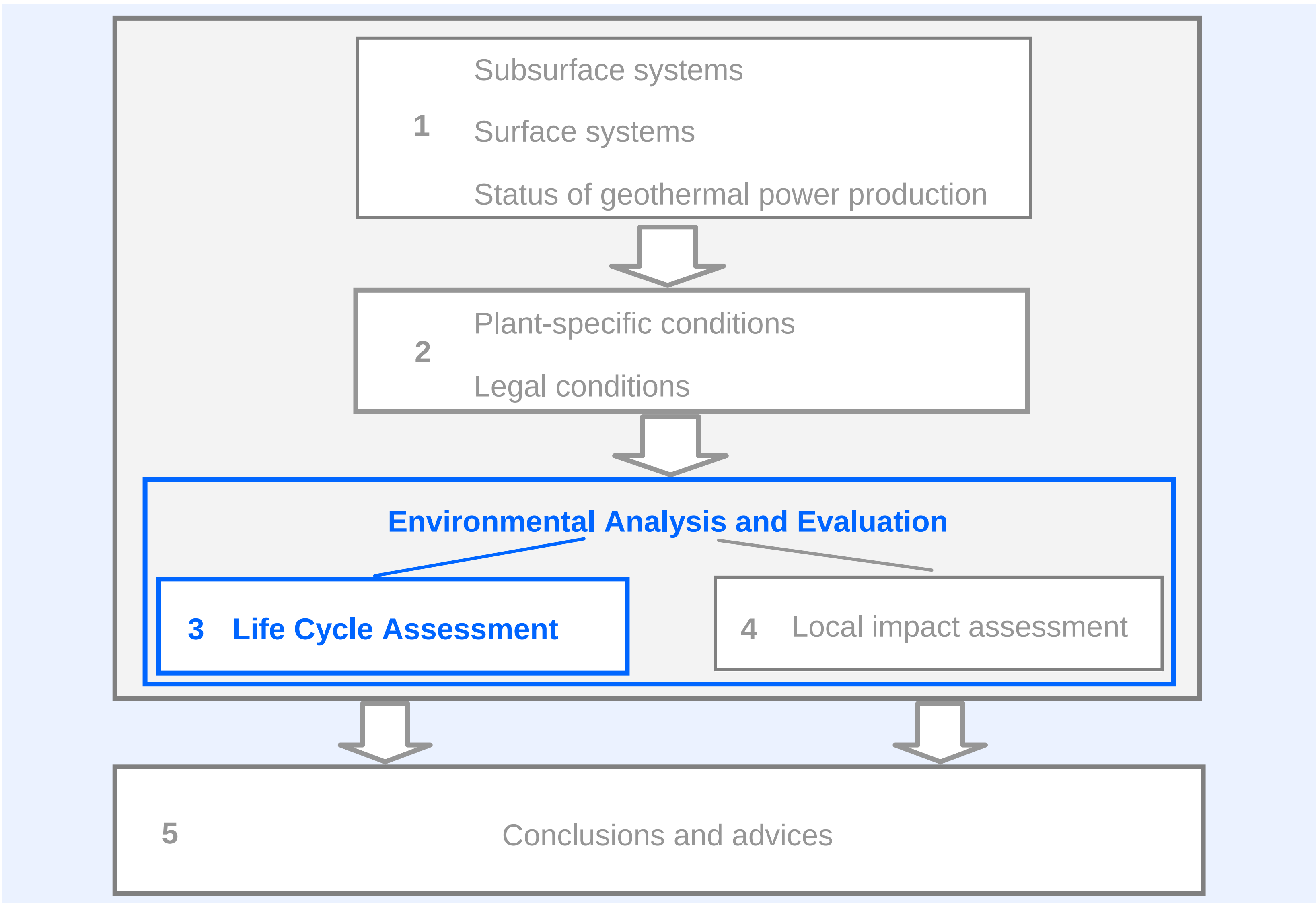
Non-geothermal reference systems for power (& heat)

Renewable energies

- Solid Biomass
- Biogas
- Photovoltaik
- Wind
- Hydropower

Fossil energies

- Lignite
- Hard coal
- Natural gas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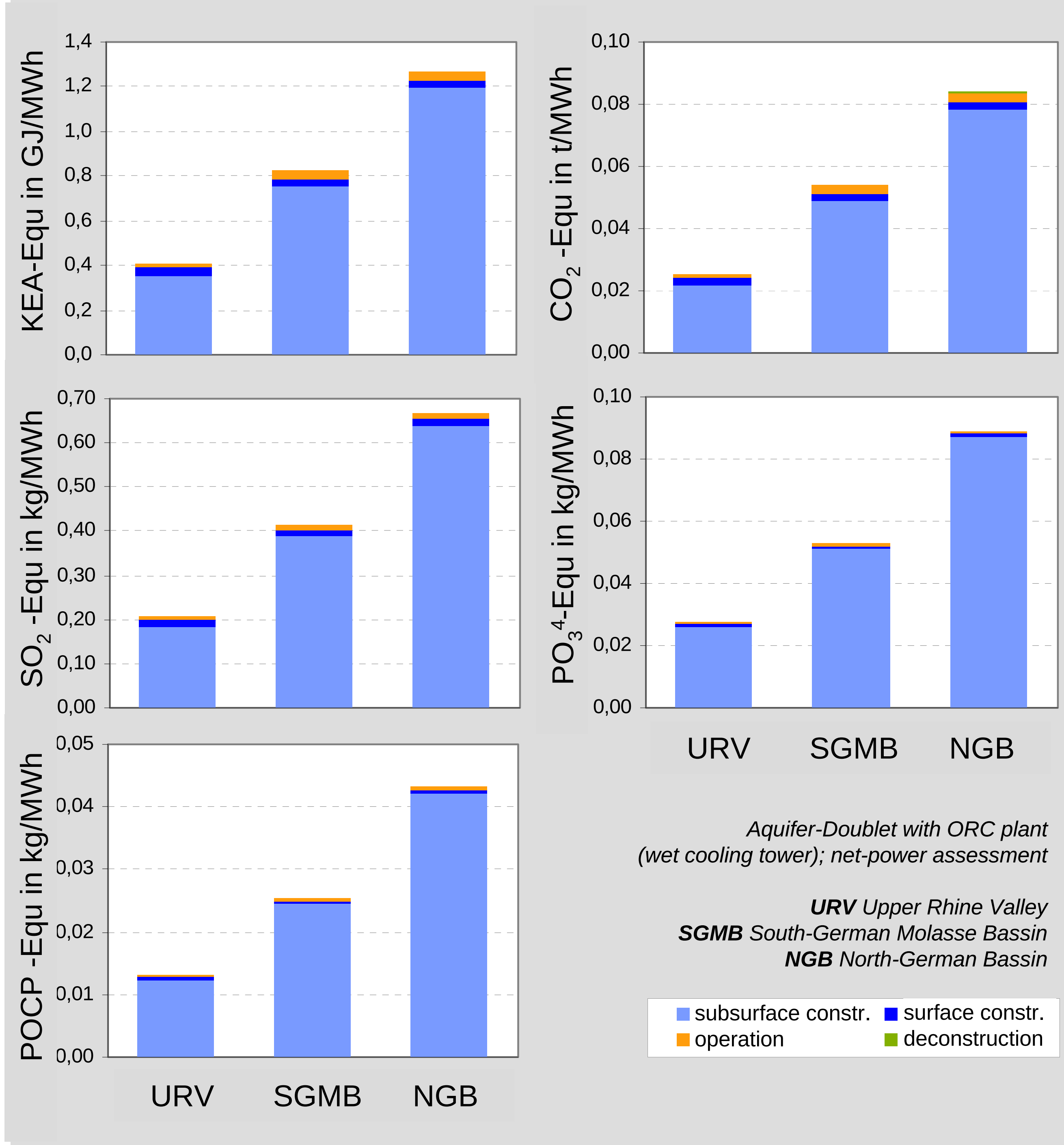
Life Cycle Assessment
- Methodology -

- Consumption of finite energy carrier (KEA-Equivalent)
- Anthropogenic greenhouse effect (CO_2-Equivalent)
- Acidification of natural eco-systems (SO_2-Equivalent)
- Emissions with eutrophication potential (PO_3^{4}- Equivalent)
- Potential of ground-level ozone synthesis (POCP-Equivalent)
- …

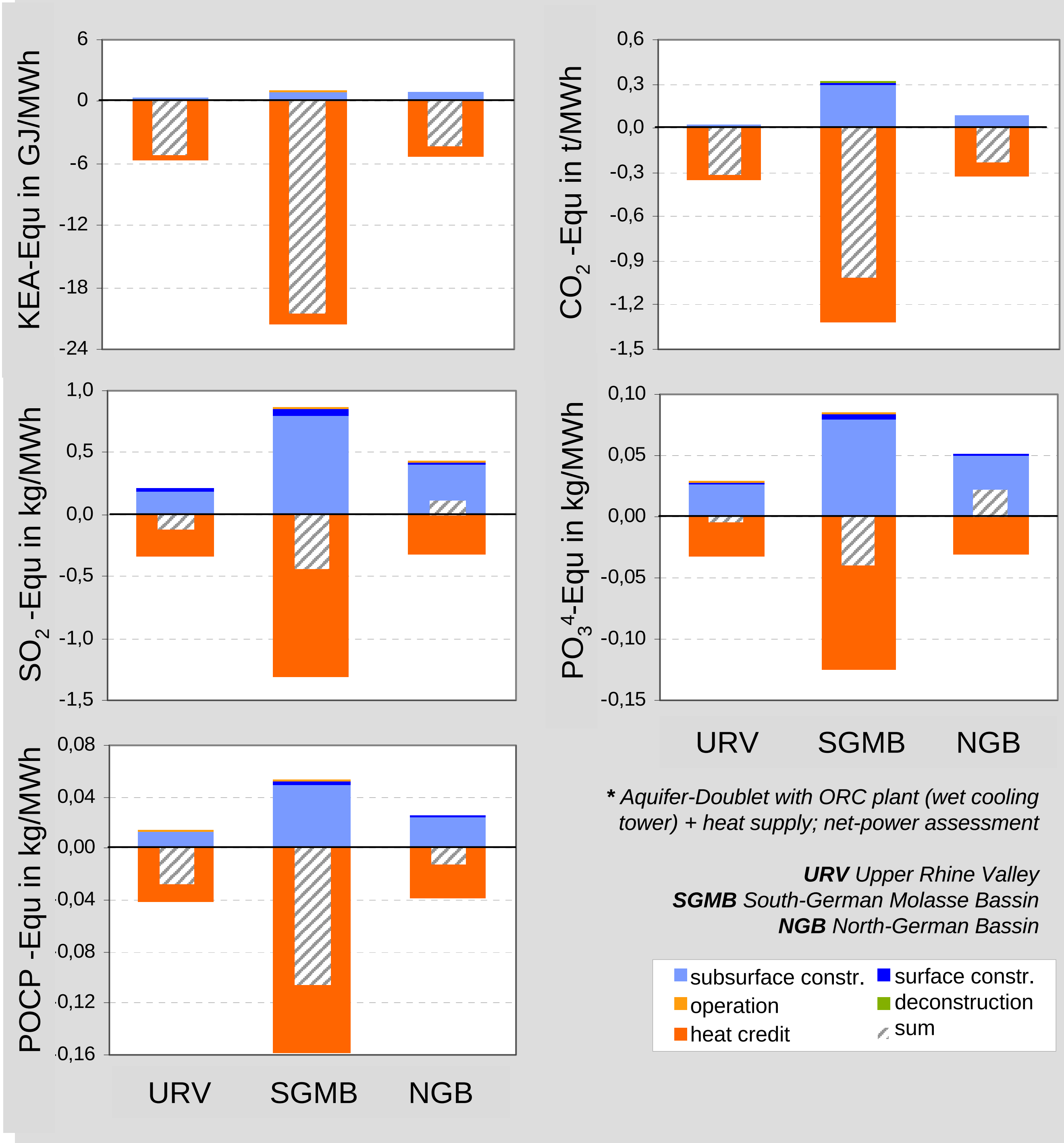
Life Cycle Assessment
- Approach -

- LCA geothermal reference systems
- Sensitivity analysis ➡ influence of:
  - Plant size (stimulation, borehole concept, flow rate)
  - Power plant cycle (ORC, Kalina)
  - Cooling cycle (wet cooling tower, dry condensation)
  - Drilling rig input (diesel driven, electricity driven)
  - Technical lifetime
  - System boarder (net-electr. and gross-electr. balancing)
- LCA non-geothermal systems

Life Cycle Assessment
- Exemplary results (power) -



Life Cycle Assessment
- Exemplary results (power&heat) -

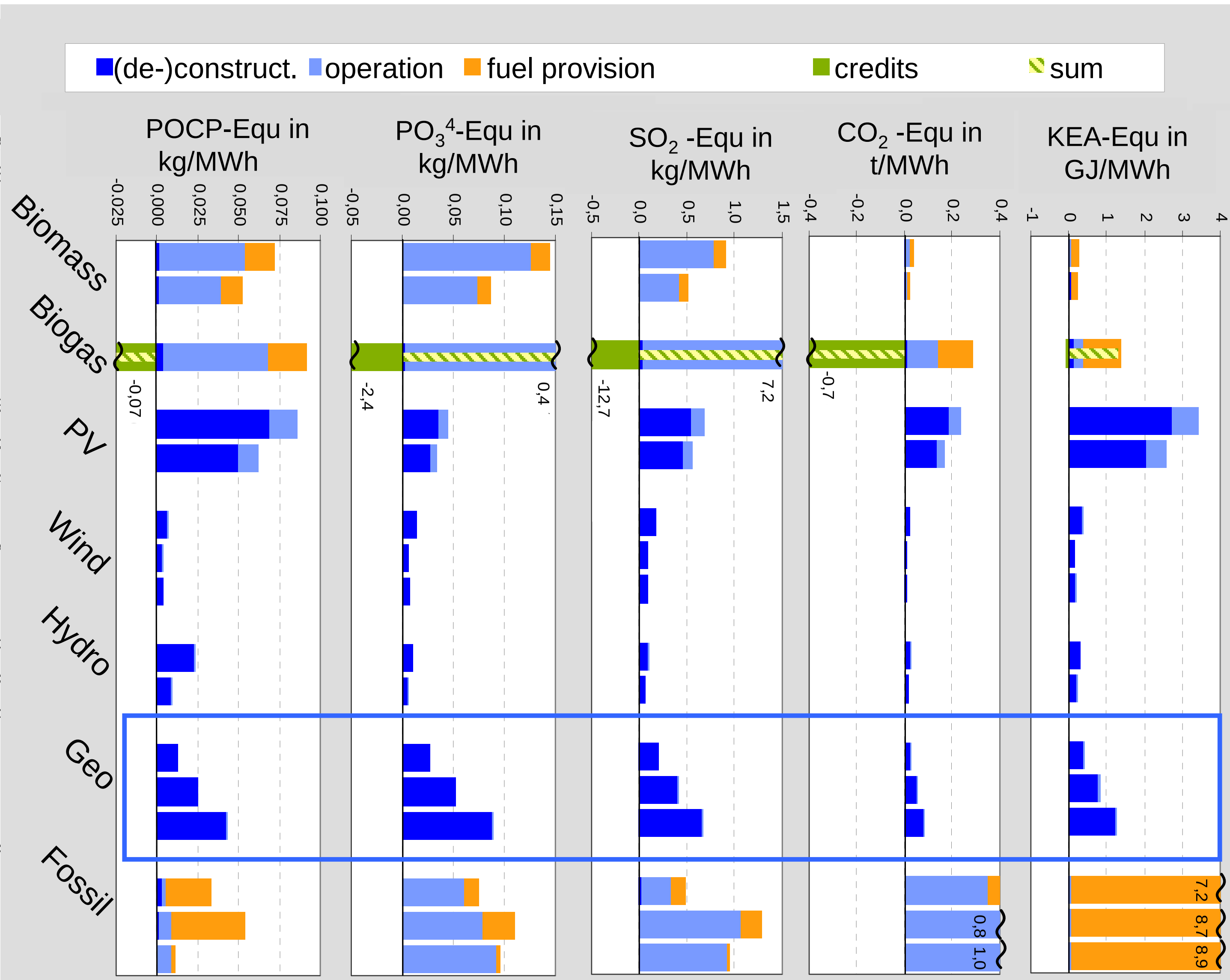


** Aquifer-Doublet with ORC plant (wet cooling tower) + heat supply; net-power assessment*

***URV** Upper Rhine Valley*
***SGMB** South-German Molasse Bassin*
***NGB** North-German Bassin*

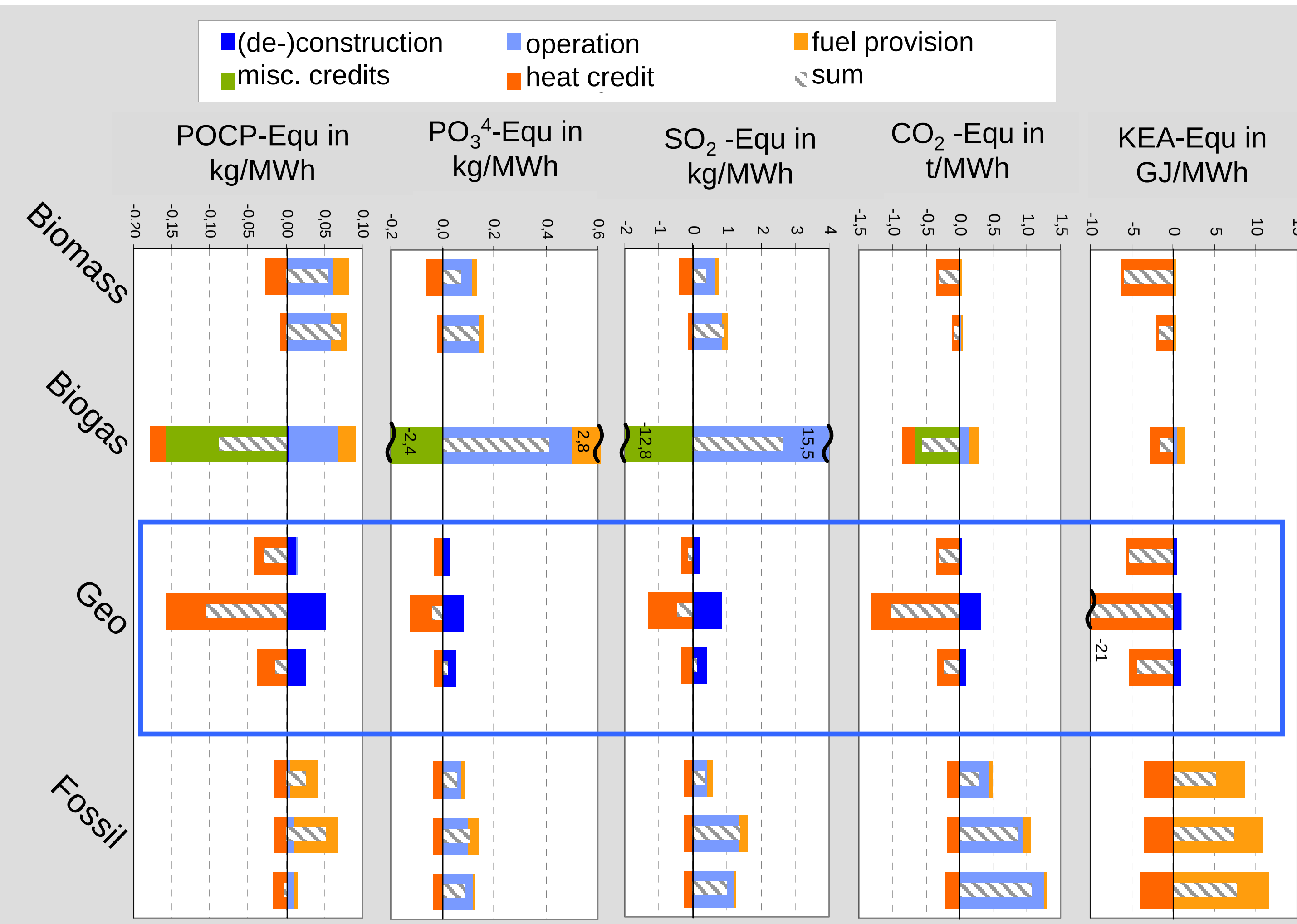
Life Cycle Assessment

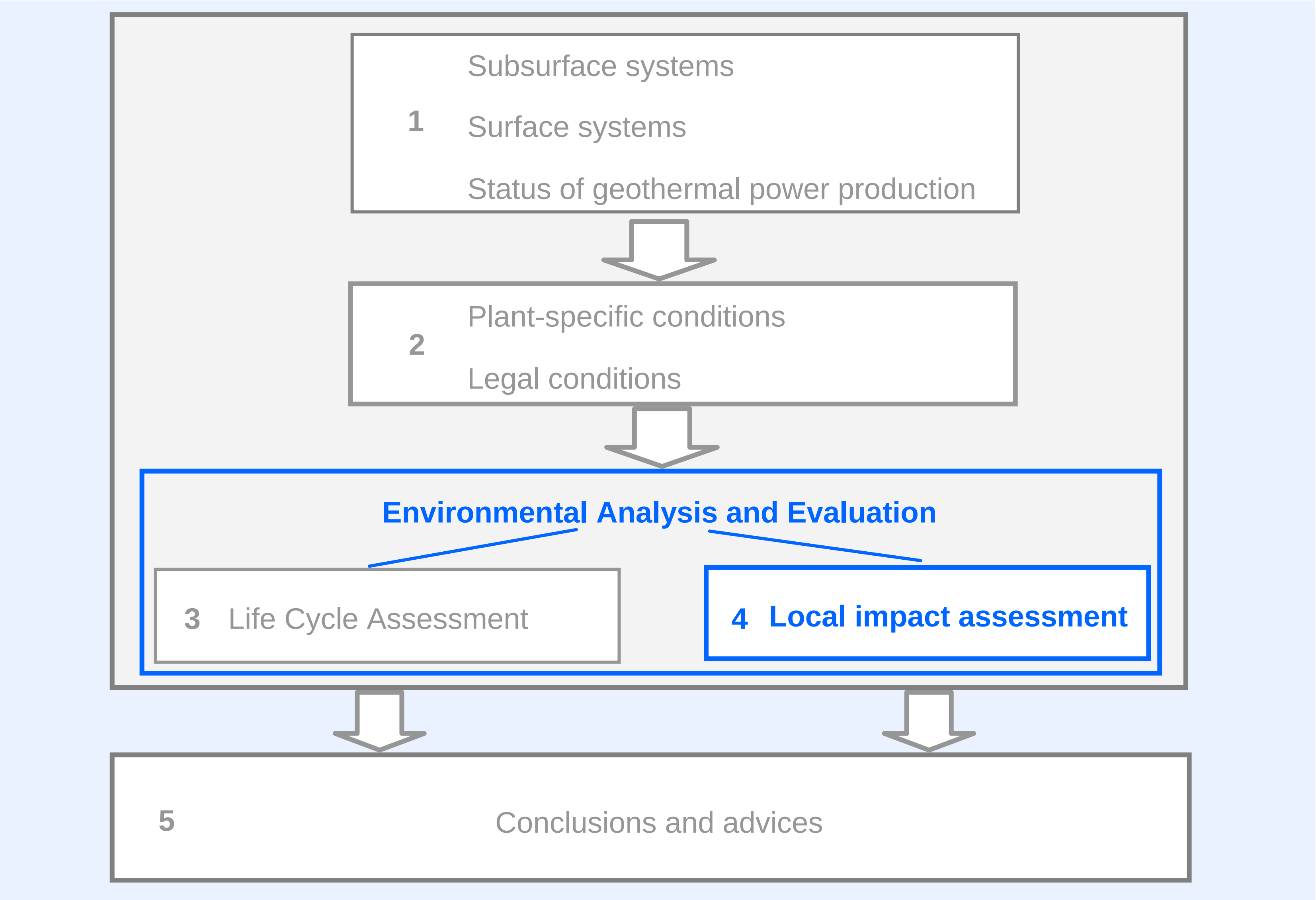
- Exemplary results (power) -



Life Cycle Assessment

- Exemplary results (heat&power) -

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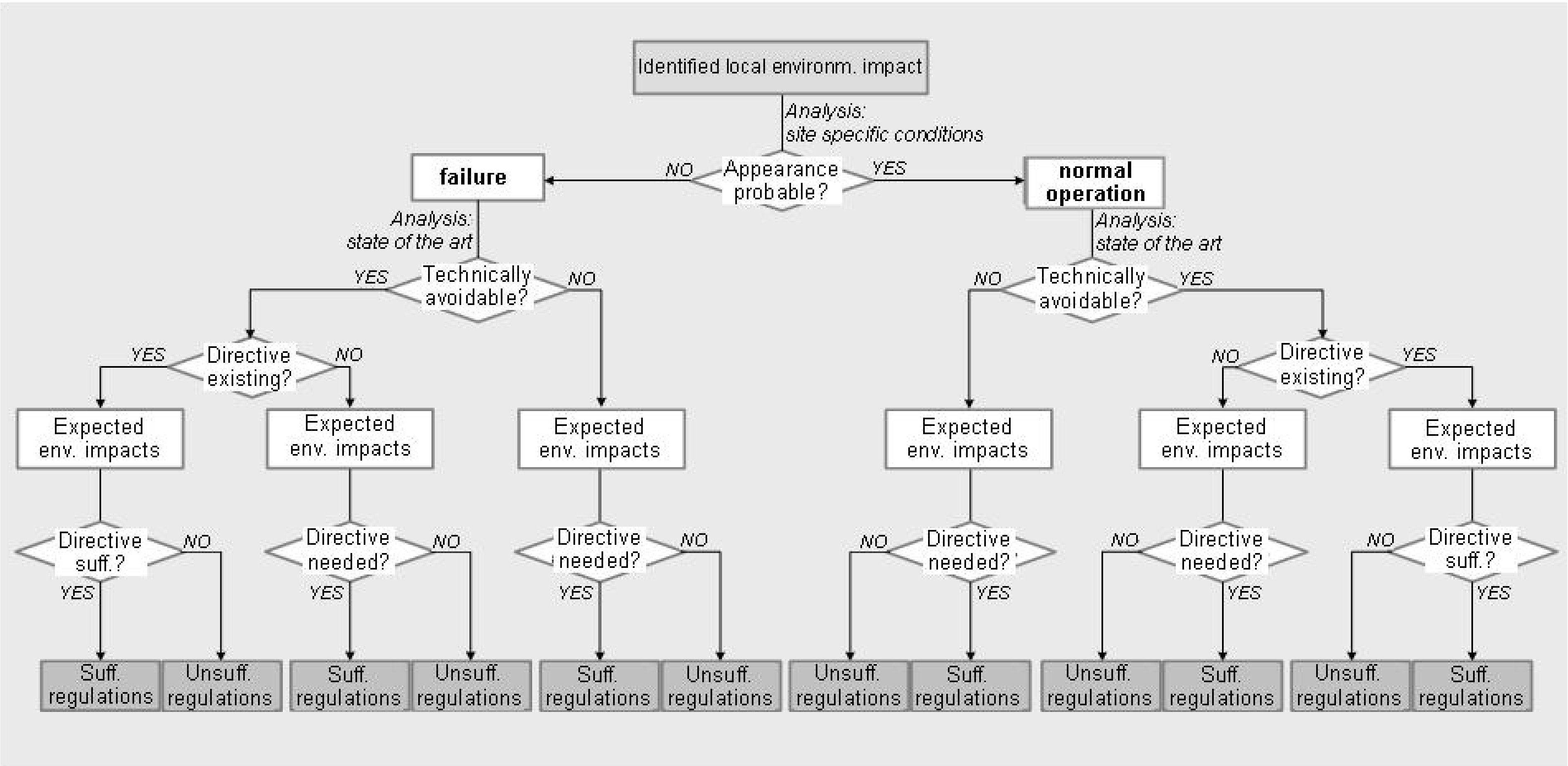
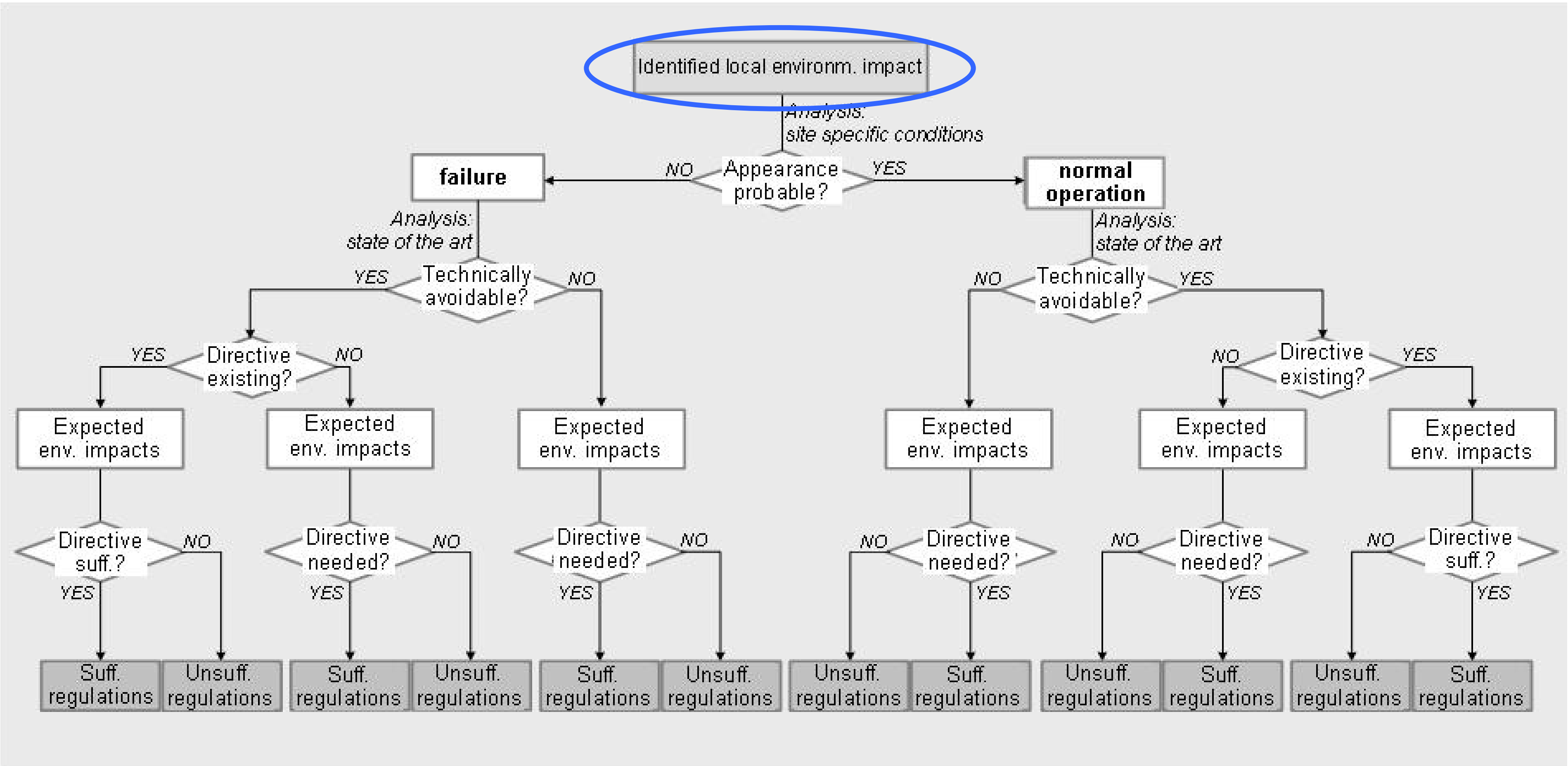
Local Environmental Impact Analysis
- Methodology -

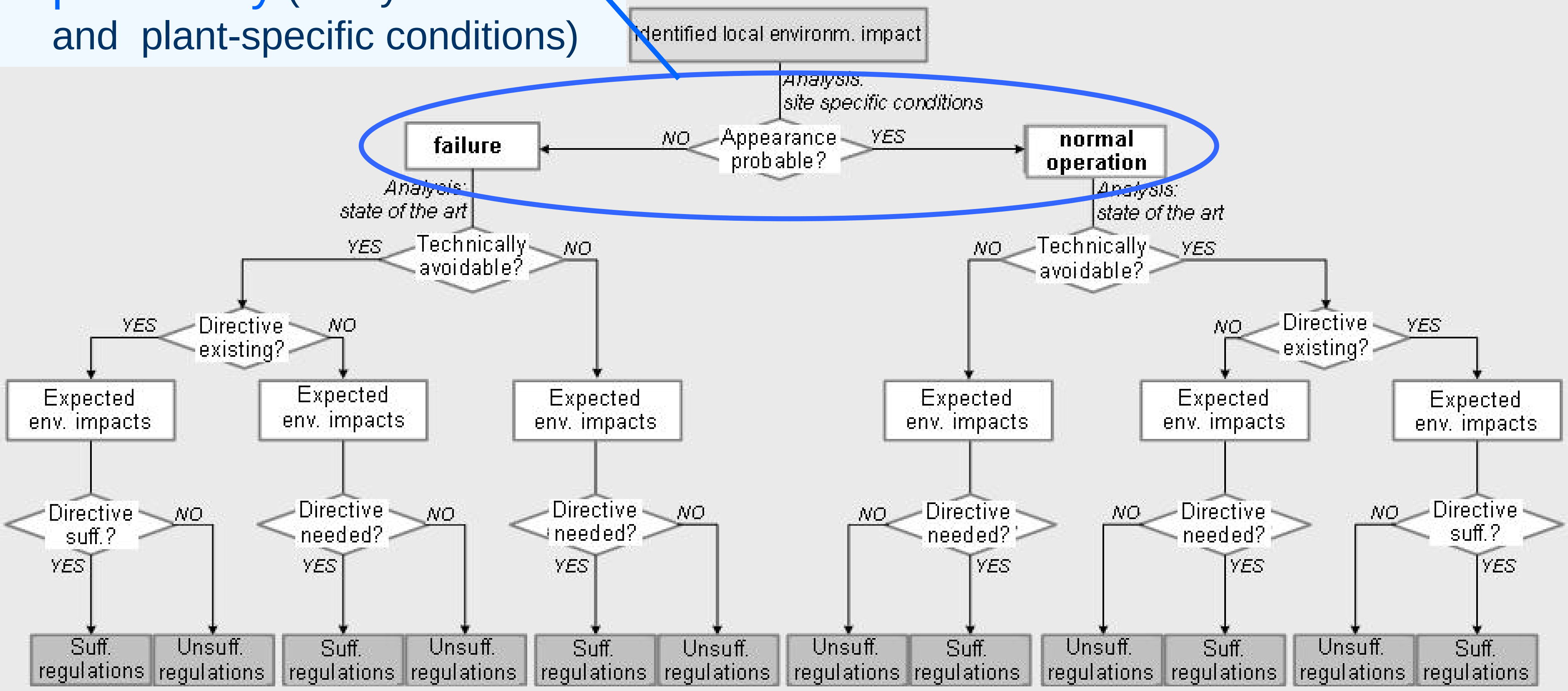


Local Environmental Impact Analysis
- Methodology -



Local Environmental Impact Analysis
- Methodology -

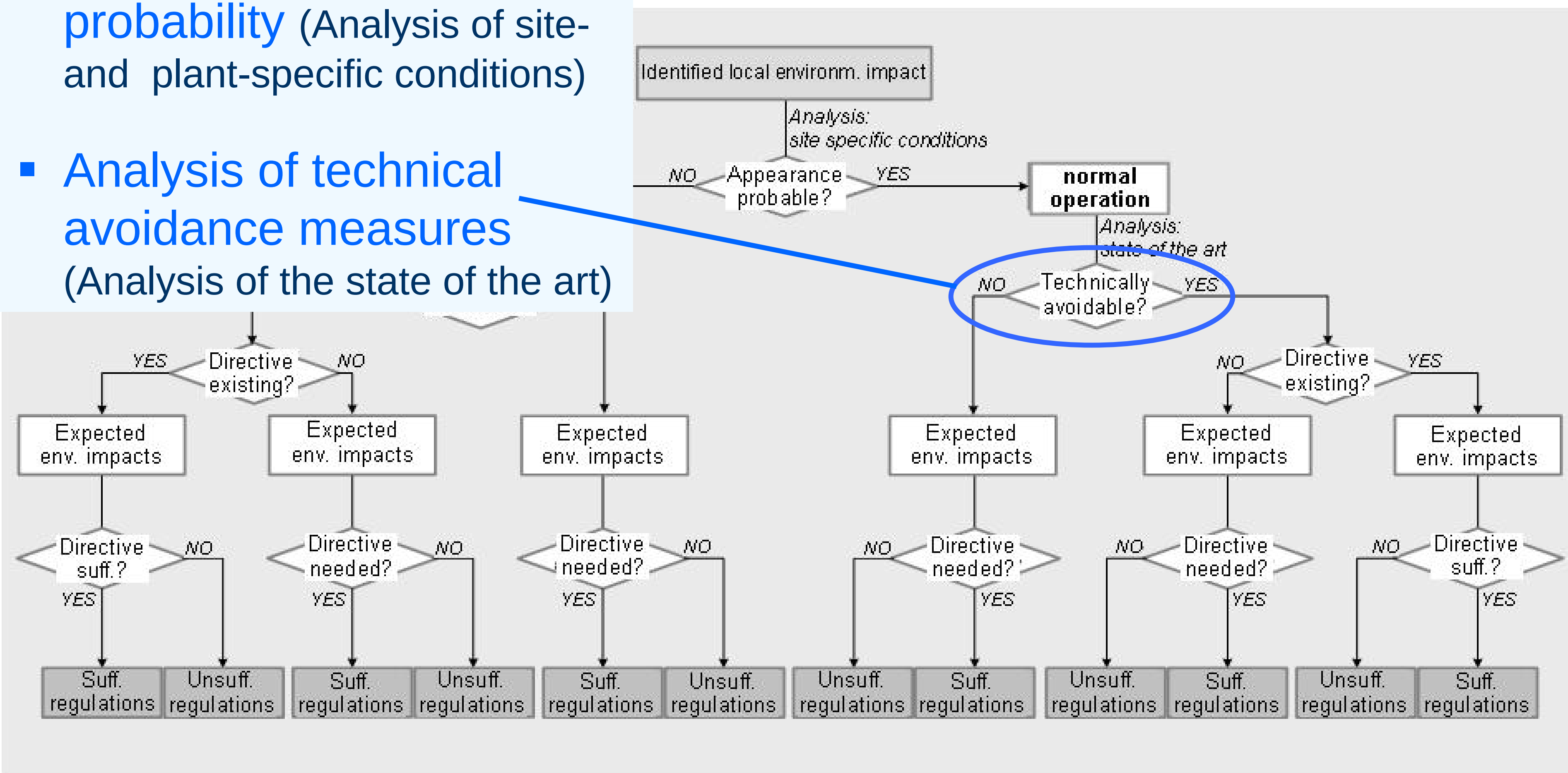
- Analysis of appearance probability (Analysis of site- and plant-specific conditions)



Local Environmental Impact Analysis
- Methodology -

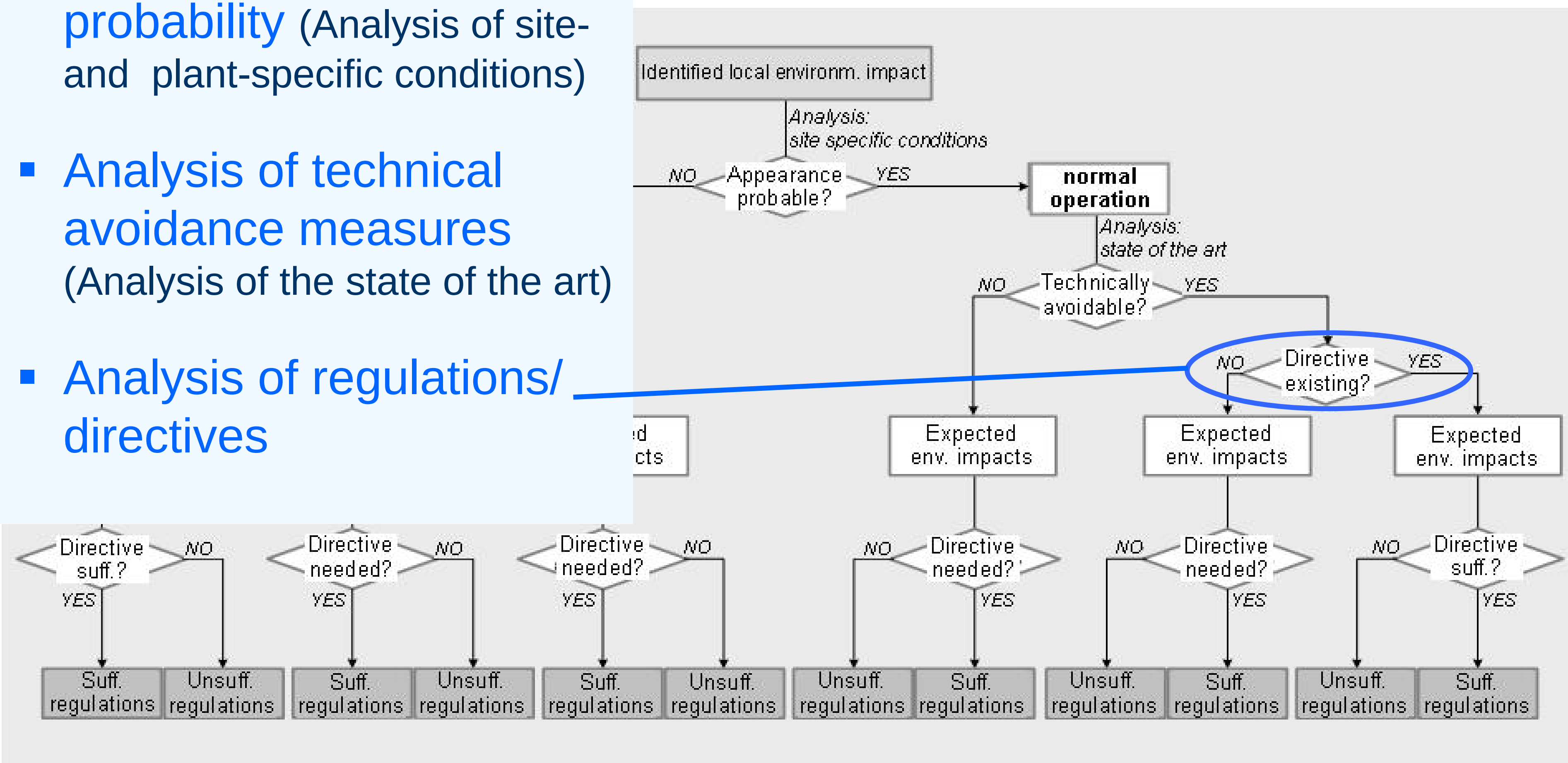
- Analysis of appearance probability (Analysis of site- and plant-specific conditions)

- Analysis of technical avoidance measures (Analysis of the state of the art)



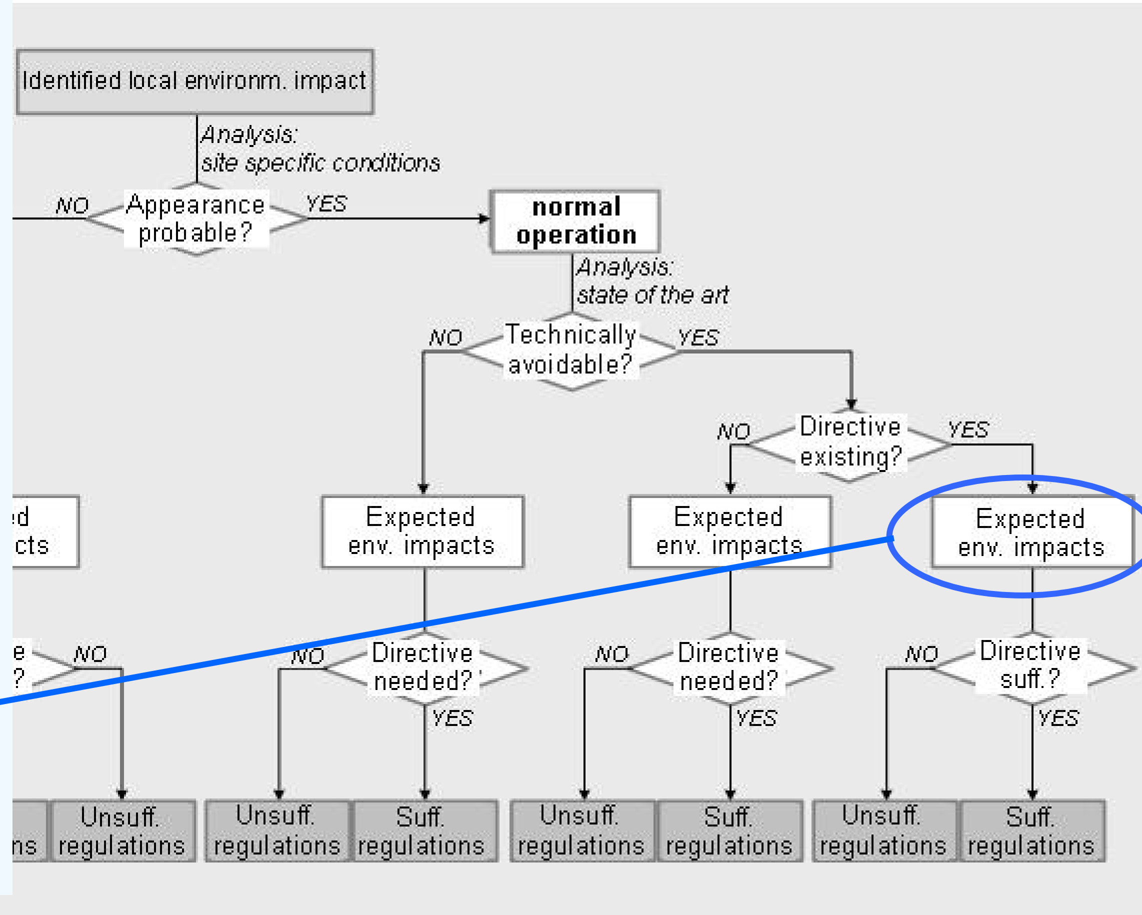
Local Environmental Impact Analysis
- Methodology -

- Analysis of appearance probability (Analysis of site- and plant-specific conditions)
- Analysis of technical avoidance measures (Analysis of the state of the art)
- Analysis of regulations/ directives



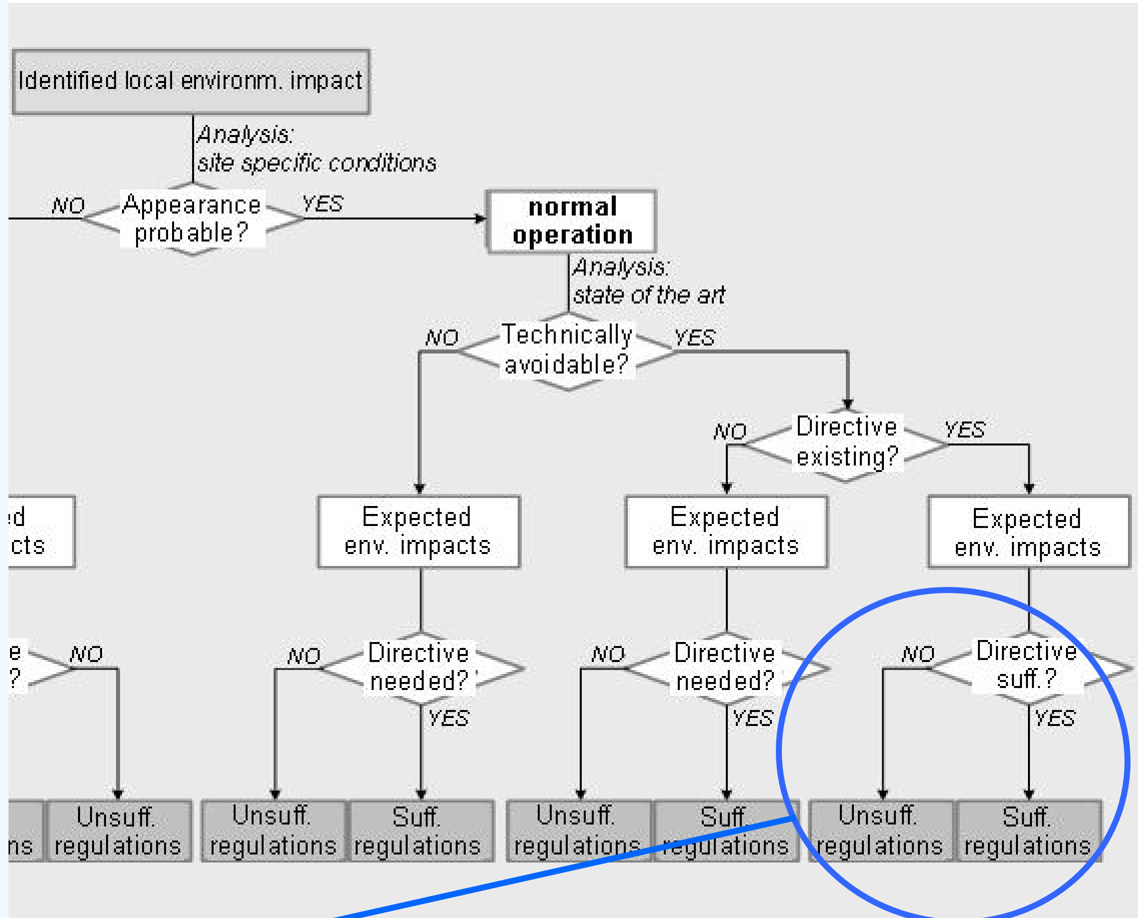
Local Environmental Impact Analysis
- Methodology -

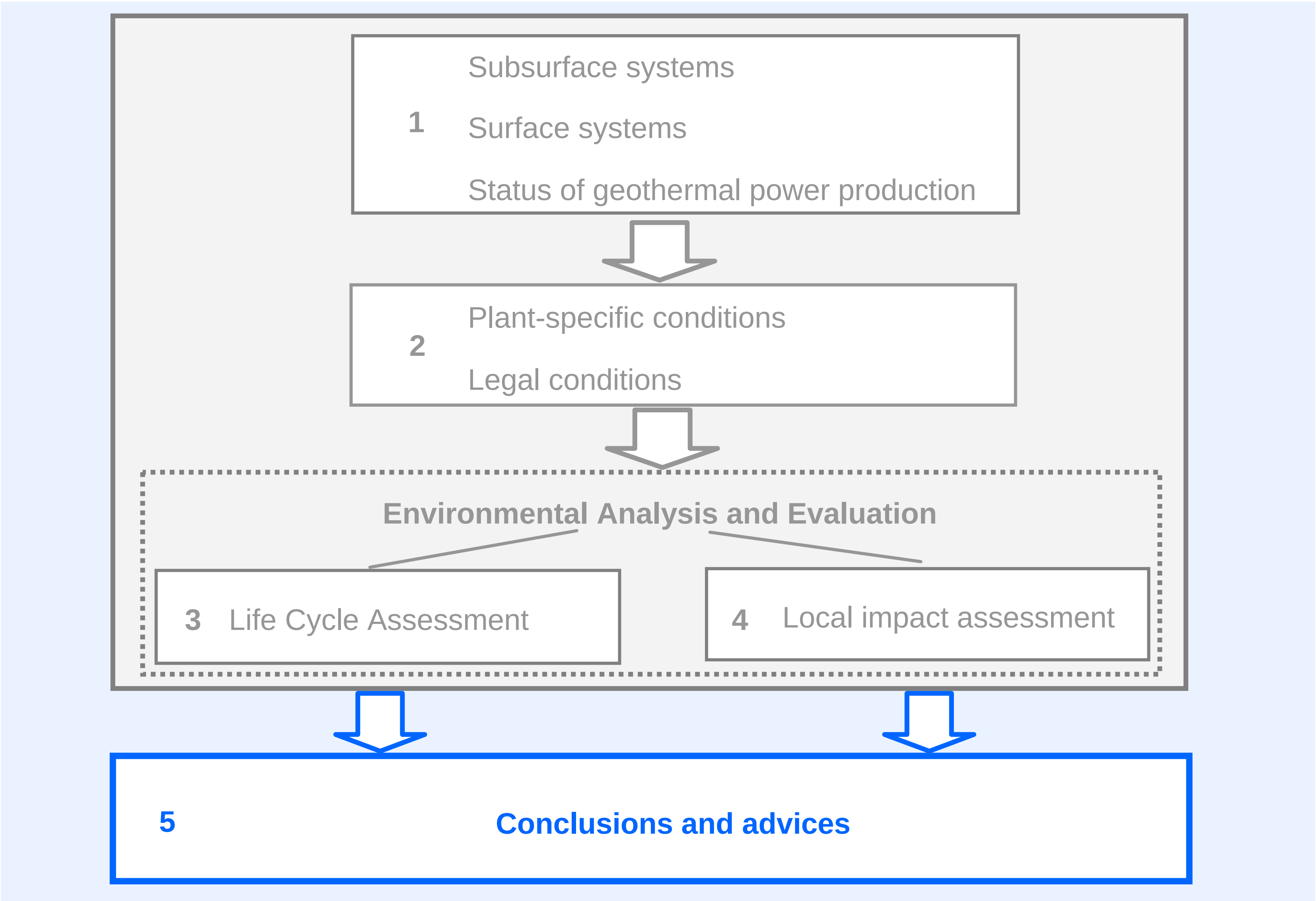
- Analysis of appearance probability (Analysis of site- and plant-specific conditions)
- Analysis of technical avoidance measures (Analysis of the state of the art)
- Analysis of regulations/ directives
- Analysis and evaluation of expected environm. impacts (impact, duration, mitigation measures, …)



Local Environmental Impact Analysis
- Methodology -

- Analysis of appearance probability (Analysis of site- and plant-specific conditions)
- Analysis of technical avoidance measures (Analysis of the state of the art)
- Analysis of regulations/ directives
- Analysis and evaluation of expected environm. impacts (impact, duration, mitigation measures, …)
- Analysis and Evaluation of the existing regulations





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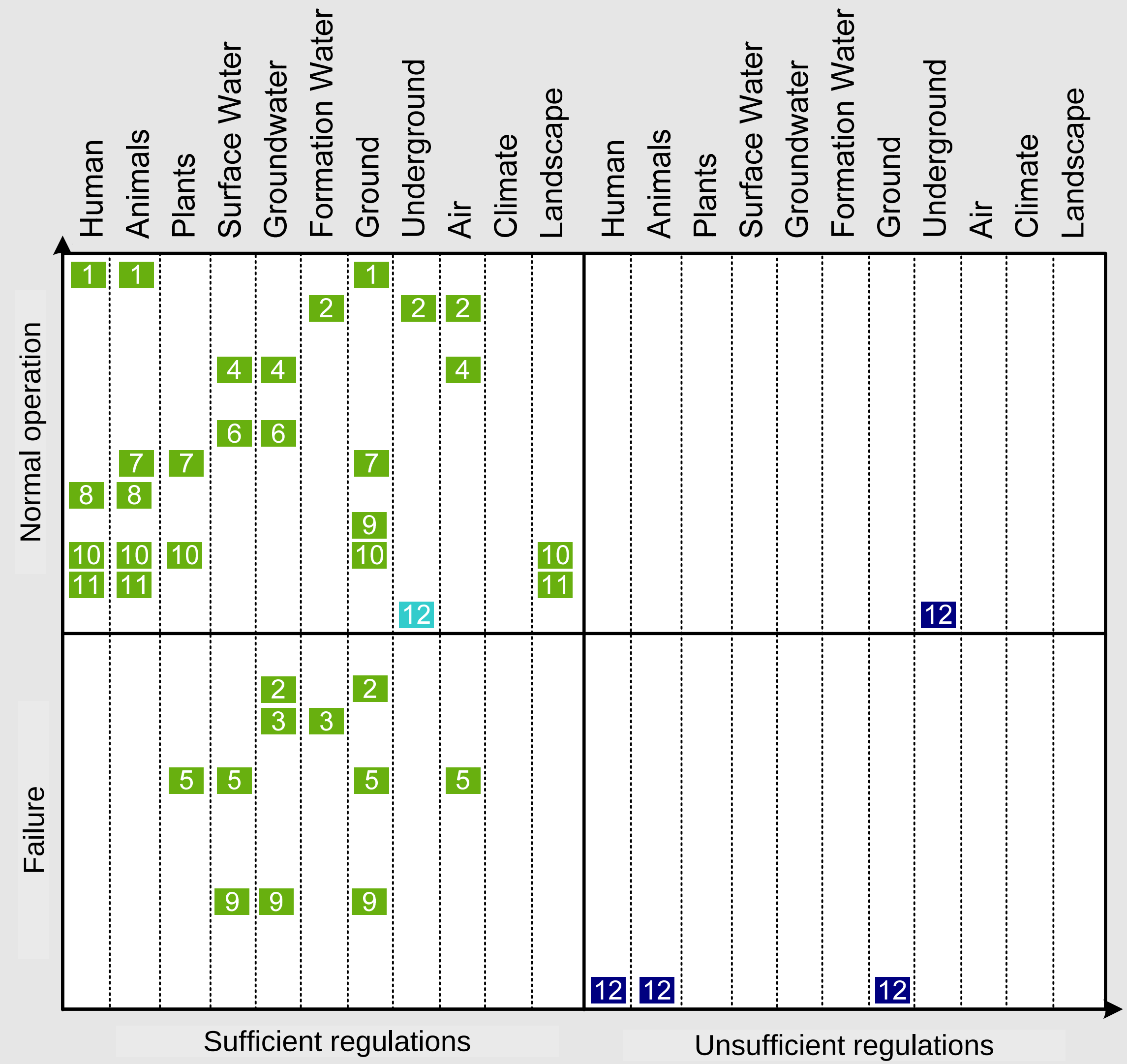
Local Environmental Impact Analysis

- Exemplary results -

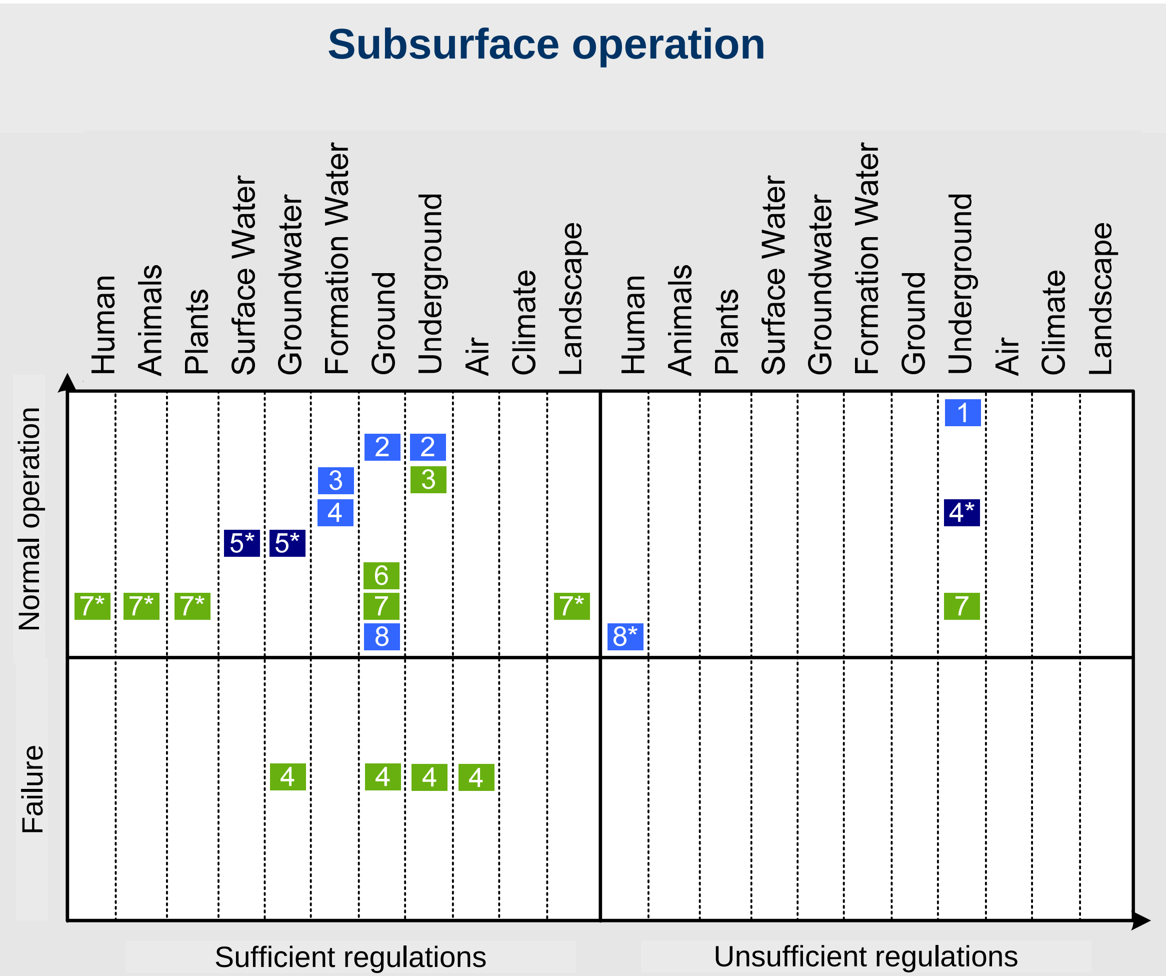
Subsurface construction



1 Ground motion
2 Material emissions
3 Hydraulic short-circuit
4 Thermal emissions
5 Borehole blow-out
6 Water demand
7 Soil excavation/ Soil compaction
8 Noise emissions
9 Waste accumulation/disposal
10 Land use
11 Visual impact
12 Induced microseismicitiy

- all systems
- subsurface closed systems
- subsurface open systems
- Aquifer-systems
- HDR-systems

Local Environmental Impact Analysis
- Exemplary results -



1 Hydraulic alternations
2 Soil subsidence
3 Cooling
4 Material emissions
5 Water demand
6 Thermal emissions
7 Land use
8 Waste accumulation/disposal

* Site-specific environmental impact

- all systems
- subsurface closed systems
- subsurface open systems
- Aquifer-systems
- HDR-systems

Conclusions & advices

- Hydro-geothermal **power** generation has a **good** Life Cycle performance compared to the analysed alternatives
- A hydro-geothermal **power and heat** supply has a **better** Life Cycle performance than the analysed alternatives
- The local environmental impacts through hydro-geothermal power generation are sufficiently regulated
- Geothermal power generation can contribute to a sustainable energy provision in Germany…

Conclusions & advices

- … but following advices for the policy can be derived :
  - Scientific monitoring
  - Promotion of further R&D
  - Adjustment of regulations to geothermal particularities
  - Strengthened promotion of heating networks
  - Public information

➔ Not ONE geothermal conept is the environmental optimum it is the site-specif over-all concept

Thank you very much for your attention!

Dieses Vorhaben wurde im Auftrag des Umweltbundesamtes im Rahmen des Umwelt-forschungsplanes – Förderkennzeichen 205 42 110 erstellt und mit Bundesmitteln finanziert.

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Basic conditions

- geothermal reference systems -

	Upper Rhine Valley	South-German Molasse Bassin	North-German Basin
Reservoir parameters			
Borehole concept	Aquifer-Doublet [a]	Aquifer-Doublet [a]	Aquifer-Doublet [a]
Borehole depth in km	3,0	3,4	4,4
Brine temperature in °C	150	120	150
Total brine flow in m^3/h	300 [b]	550 [c]	100 [b]
PI [i] bzw. II [i] in $m^3/(h\ MPa)$	60 [b]	200 [c]	20 [b]
Technical lifetime in a	30 [d]	30 [d]	30 [d]
Power plant			
Electrical power in MW_{el}	3 [e]	3 [e]	1 [e]
Efficiency [f] in %	12 [f]	10 [f]	12 [f]
El. full load hours in h/a	7.500 [g]; 7.300 [h]	7.500 [g]; 7.200 [h]	7.500 [g]; 7.300 [h]
Heat provision			
Feed / return temperature in °C	70 / 50	70 / 50	70 / 50
Thermal power in MW_{th}	7	13	2
Th. full load hours in h/a	1.800	1.800	1.800

a vertical borehole in the Upper Rhine Valley with a distance of 1.000 m; **b** hydraulically stimulated, source: /GGA 2006/; **c** chemically stimulated, source: /GGA 2006/, /GTN 2005/; **d** feed pump 4 a, power plant, heat exchanger 15 a; **e** ORC-plant with forced air-cooled wet cooling tower; **f** design-point efficiency, source: own calculation, /Köhler 2005/; **g** only power provision; **h** power and heat provision; **i** productivity- resp. injectivity-index

Basic conditions

- non-geothermal reference systems -

	El. power in MW_{el}	El. full load hours in h/a	El. efficiency / th. rate of utilisation in %	Technical lifetime in a
Solid biomass				
Biomass gasification [a] (GuD [b])	20	7.500	42	15
Biomass gasification [a] (GuD [a]-CHP [c])	0,5	7.500	27 / 38	15
Fluidized bed combustion [d] (D [e])	20	7.500	30	15
Grate firing [d] (D [e]-CHP [c])	5	7.500	7 / 12	15
Biogas				
Biogas block power plant [f]	0,5	7.500	36	15
Biogas block heat and power plant [f]	0,5	7.500	36 / 47	15
Photovoltaics				
Roof-top system [g]	0,005	800		20
Open space system [g]	1	1.000		20
Windenergy				
Onshore wind energy plant	2,5	1.400		20
Onshore wind energy plant	5	2.000		20
Offshore wind energy plant	5	4.500		15

[a] 100 % forestry wood; [b] Gas and steam plant; [c] Combined heat and power; [d] 50 % waste wood, 50 % forestry wood; [e] Steam process; [f] wet fermentation of 70% cattle and swine liquid manure and 30 % renewable primary products; [g] polycristalline modules

Basic conditions

- non-geothermal reference systems -

	El. power in MW_{el}	El. full load hours in h/a	El. efficiency / th. rate of utilisation in %	Technical lifetime in a
Hydroenergy				
„small“ hydroelectric power plant	0,3	4.300		45
„large“ hydroelectric power plant	30	4.500		45
Fossil fuels				
Natural gas (GuD [a])	800	5.000	58	25
Natural gas (GuD [a]-CHP [b])	500	5.000	48 / 40	25
Hard coal dust firing (D [c])	800	7.000	45	30
Hard coal dust firing (D [c]-CHP [b])	800	4.000	36 / 30	30
Lignite dust firing (D [c])	800	8.000	42	30
Lignite dust firing (D [c]-CHP [b])	800	4.000	32 / 30	30

[a] gas and steam plant; [b] combined heat and power; [c] Steam process;