A Constructive Technology Assessment of Stationary Energy Storage Systems
- A prospective Sustainability Analysis with the focus on electrochemical storage systems –

Manuel Baumann

3rd Winter School on Technology Assessment, 10th of December 2012, Lisbon FCT




1. Introduction

- Bachelors degree “European energy economics”
- Masters degree in "Energy and ecologic management"
- since 2012 Research associate at ITAS

Field of work:

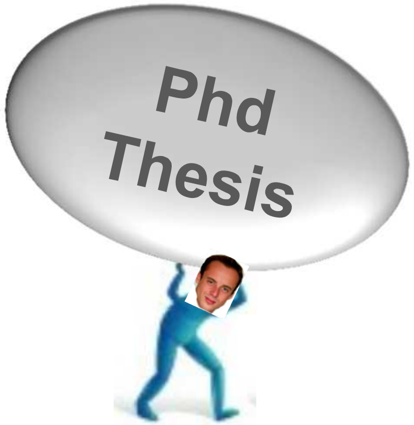
- Mobile and stationary electro chemical storage systems
- Description of real condition requirements during operation phase
- Creation of technical and economical scenarios for energy storage systems

1. Introduction: Supervisors

- **Principle supervisor: Dr.- Ing. Marcel Weil**

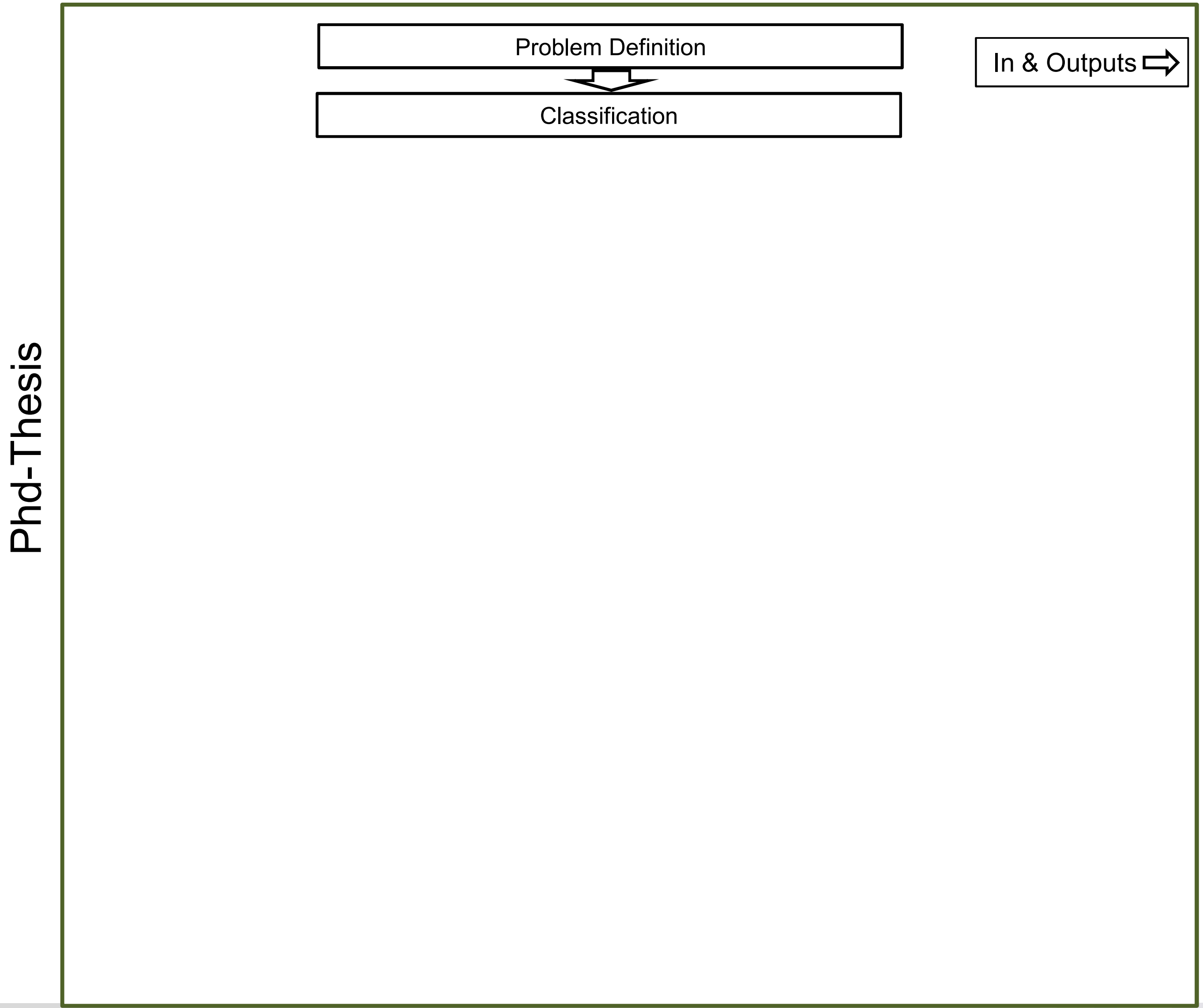
- **Second supervisor: Prof. Dr. Antonio Moniz**

- **Me**



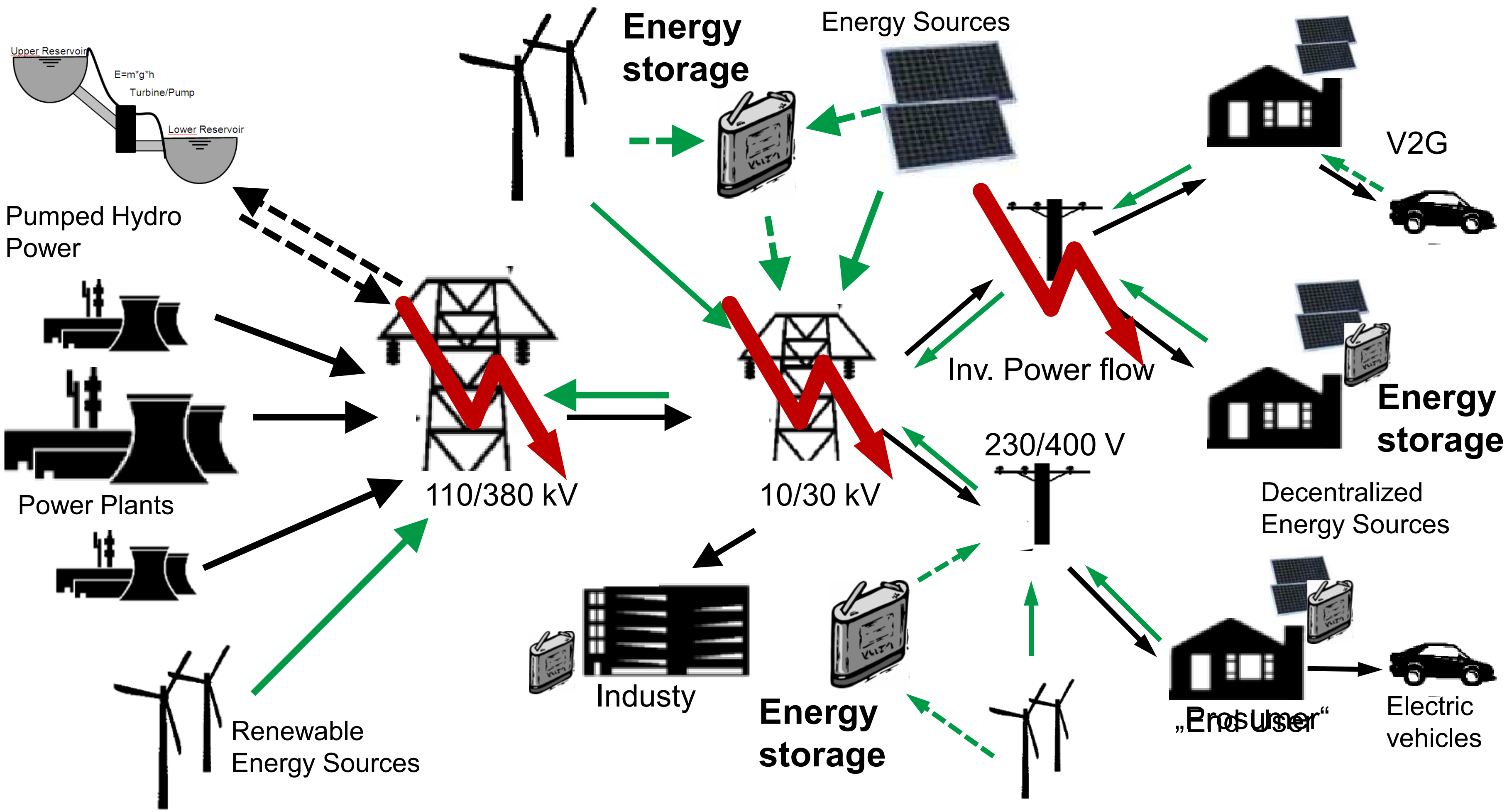
1. Introduction: Formal frame

- Organisational Structure:
  - Helmholtz project „stationary and mobile electrochemical Energy Storage“
  - Related Institutions wihtin the project: KIT, RWTH Aachen, DLR…..
  - Related Institutions wihtin the Thesis: UNL – FCT, KIT-ITAS


Phd-Thesis
Problem Definition
Classification
In & Outputs

Problem Definition

Classification

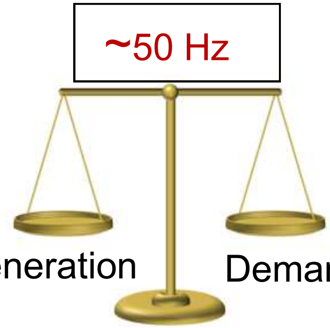


Source: Own figure inspired by Tomic et. al 2005

Problem Definition

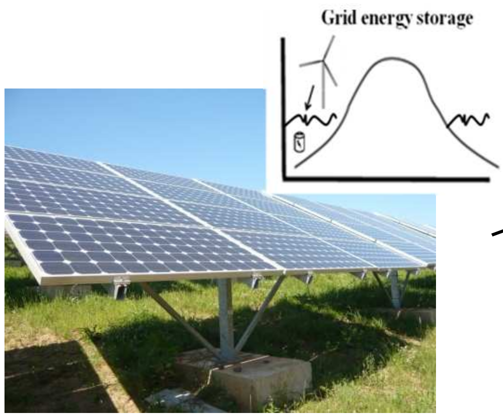
Classification

Transmissions & Distribution deferal

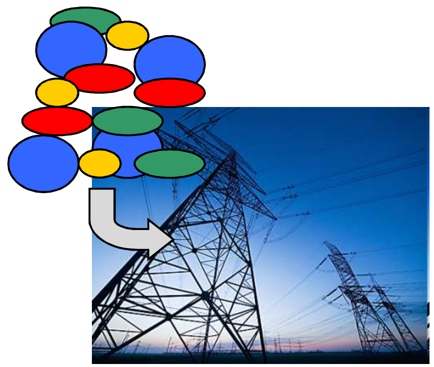


Ancillary services provision

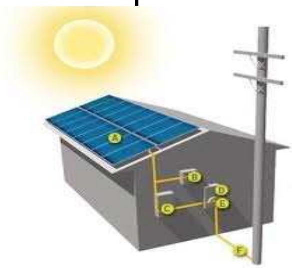
Energy Storage



Fluctuating Energy Sources Integration



Decentralized energy generation storage



End user storage

Dipl. Ing. Manuel Baumann.

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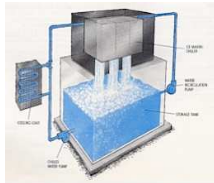
Different possibilities of Energy Storage:



- Mechanical (pumped hydro storage, CAES ……)
- Electrochemical (batteries…)
- Chemical (hydrogen, wind gas…..)
- Thermal (molten salt, ice storage…..)
- Electro static (capacitors, SMES….)

Focus: electrochemical Energy Storage

- Don´t require specific geologic and orographic conditions less landscape concerns
- Especially interesting for low to middle voltage areas
- ……

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Problem Definition

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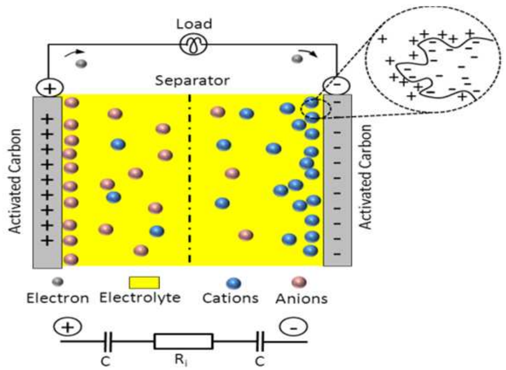
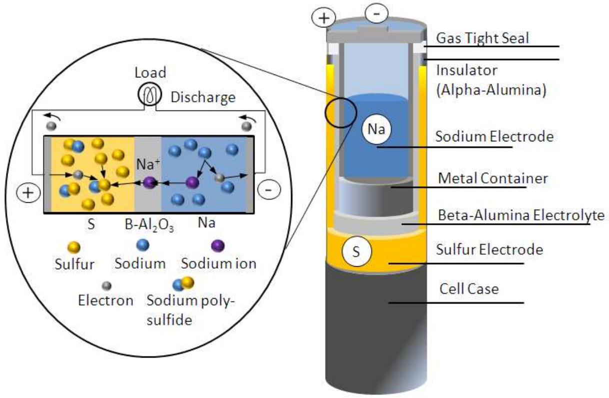
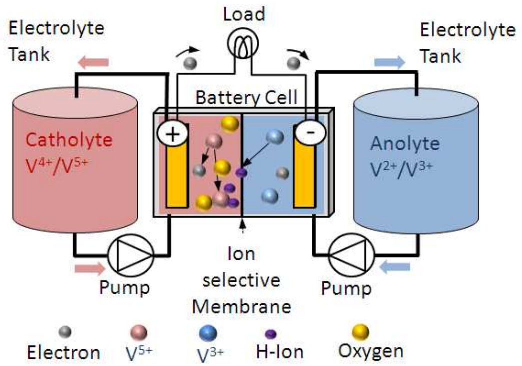
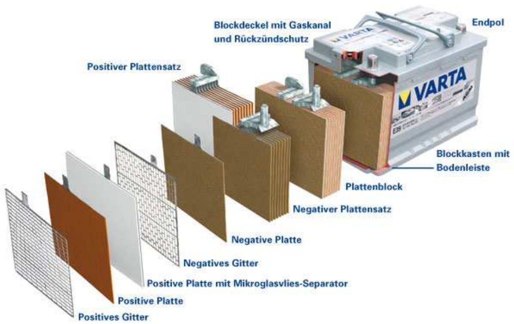
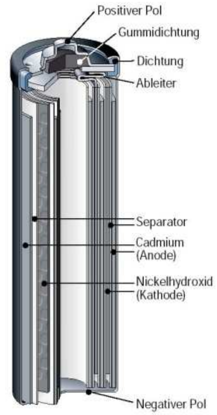




Electrochemical Energy Storage Technologies

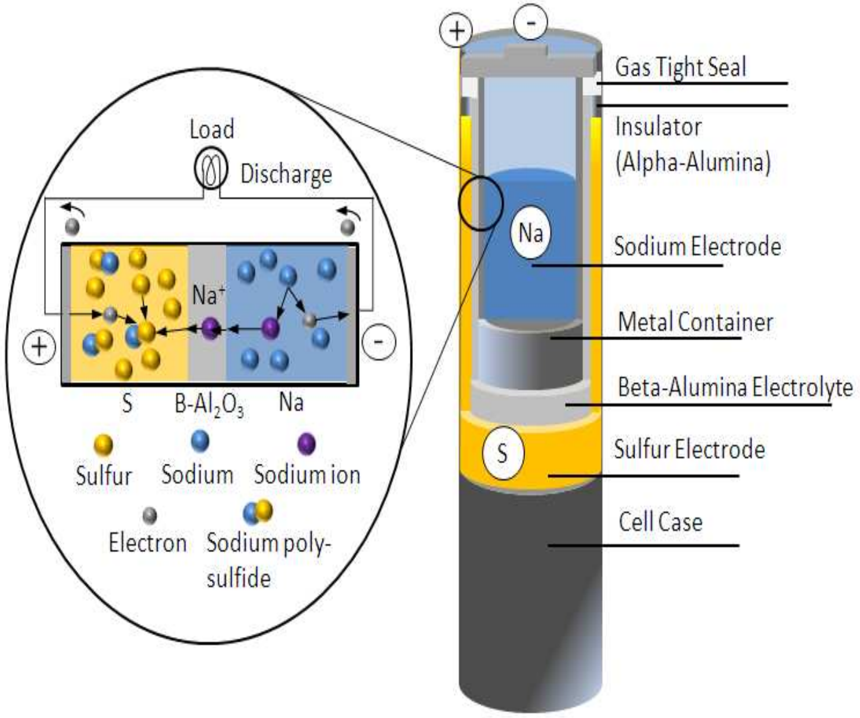


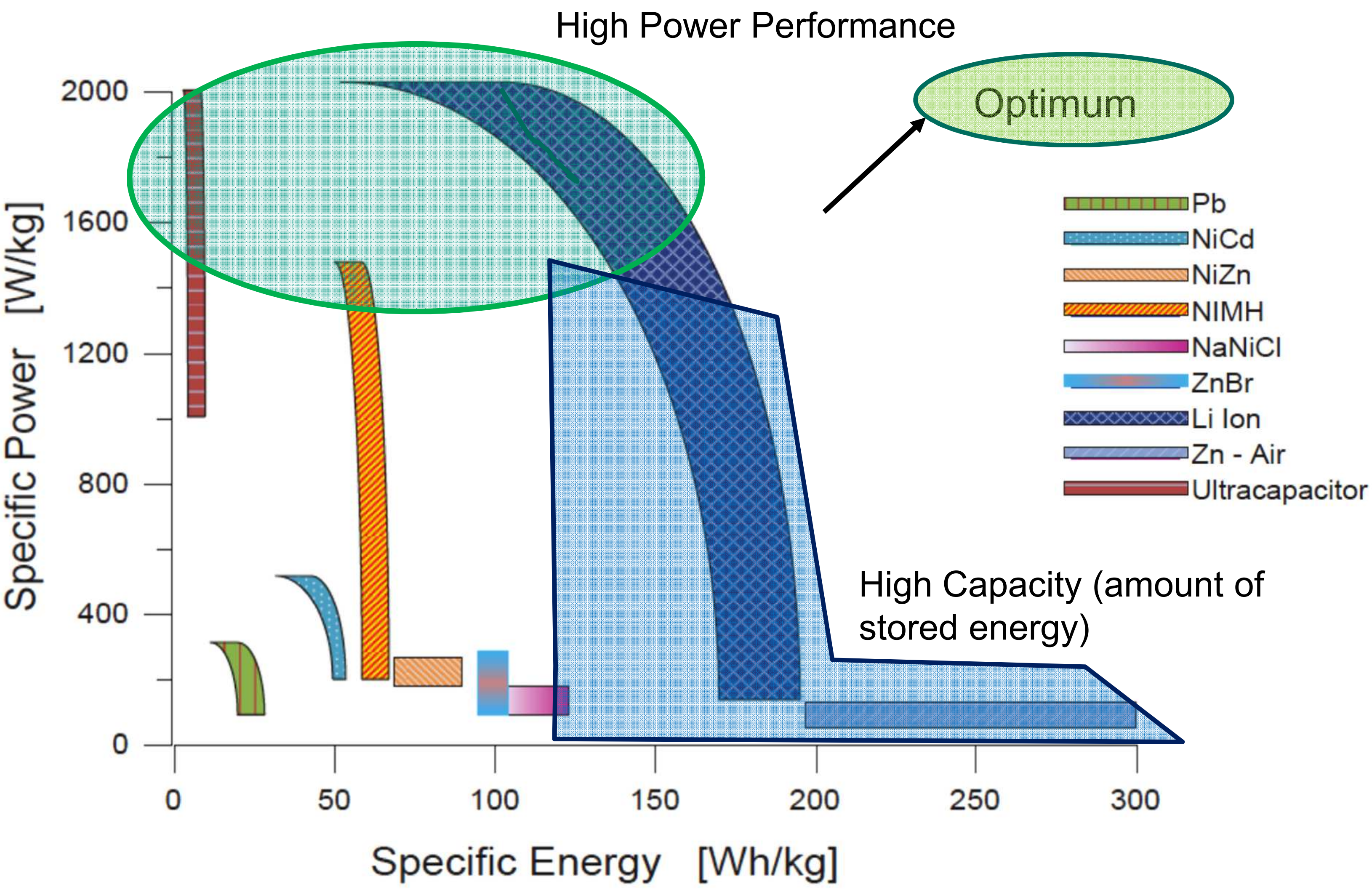




- Example A: Sodium Sulfur Battery
- Already commercially used for Grid applications

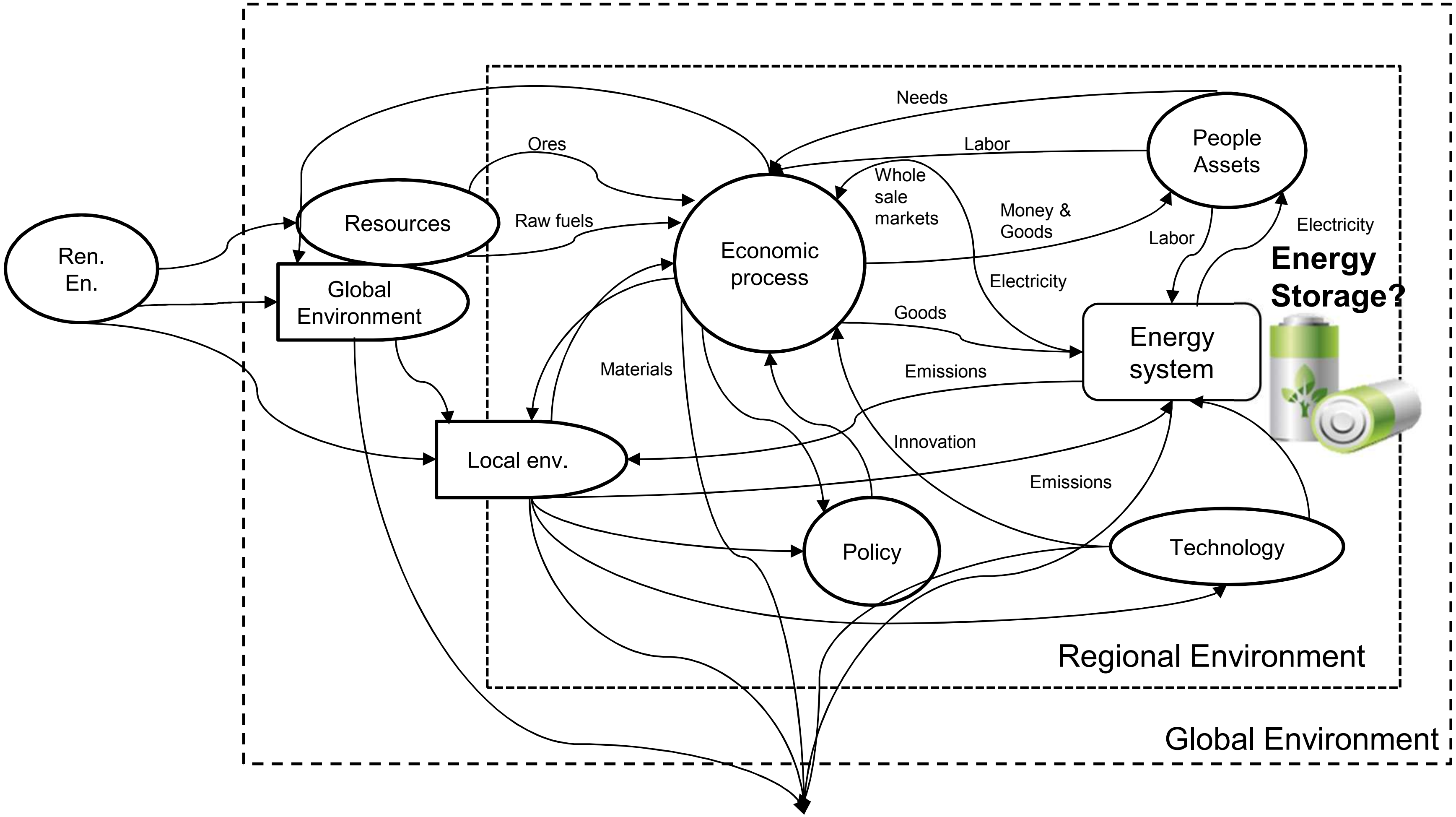
+	High energy density
+	Acceptable Efficiency grades (~ 80 %)
+	High cycle stability
+	Calendaric life time
+	Good cost performance
-	High self discharge grades
-	Poor power density
-	Thermal management system + insulation
..	……..




High Power Performance
Optimum
2000
1600
1200
800
400
0
Specific Power [W/kg]
0
50
100
150
200
250
300
Specific Energy [Wh/kg]
Pb
NiCd
NiZn
NIMH
NaNiCl
ZnBr
Li Ion
Zn - Air
Ultracapacitor
High Capacity (amount of stored energy)

Problem Definition

Classification



Decision making & Technology development

Own figure inspired by Wang et al. 2009

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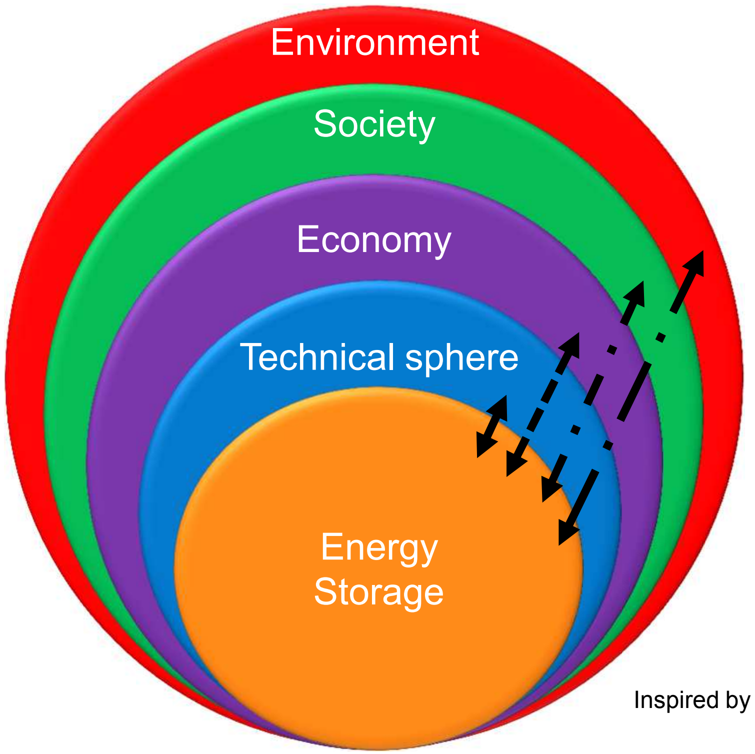
- It is insufficient to exclusively look at the operation phase to assess a complex technology (Grunwald et al. 2002)
- Can lead to misleading interpretations which can disregard social or ecological impact factors over the whole life cycle of a technology

Integrated Concept for decision making and technology development

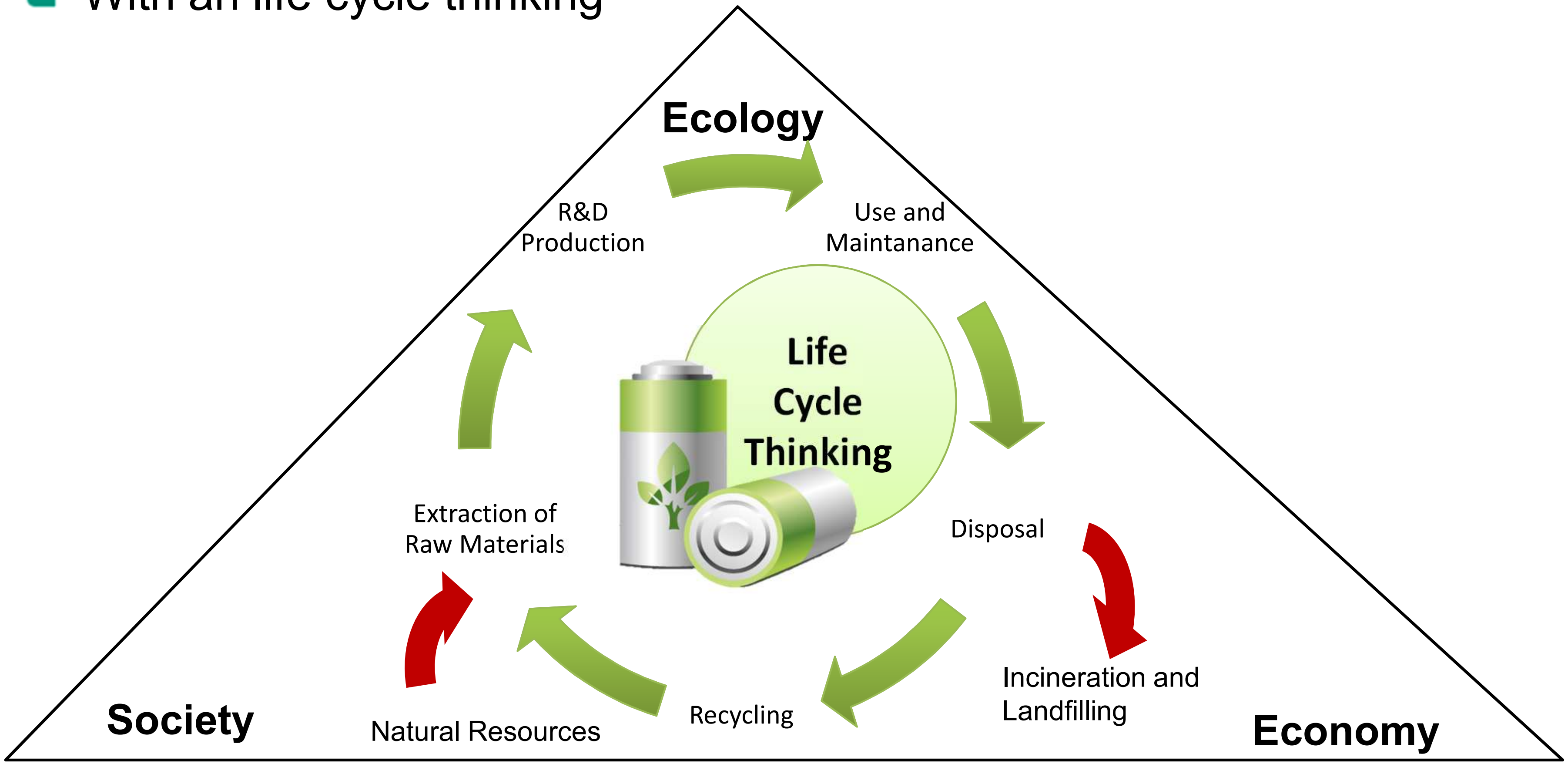


Inspired by Musango & Brent 2012

Problem Definition

Classification

- With an life cycle thinking



- Sustainability: a balance of social and economic activities as well as the environment (Wang et al. 2009)

Classification and aim

Is this a Technology Assessment (TA) Problem?

- TA : *„scientific and communicative contribution to solve technological related societal problems“* (Grunwald, A. 2002)
- Develop aggregated reports for decision makers about the actual level of knowledge and abilities regarding potential impacts (Grunwald, A. et al. 1999)

Problem Definition

Classification

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Constructive TA*:

- “Constructive” TA is based on a seamless web of related highly heterogenic factors which also underlie dynamic new switch stands (Grunwald, A. et. al 99)
- Expectation of minimizing mismatches, wrong investments, possible social conflicts, and environmental impacts of a new technology in an early development stage (Shot & Rip, 1997)
- Assist rational decision making as well as development in energy system options, planning, management and economy for a sustainable development (Wang et. al, 2009)

*Final classification of the work has to be worked out

The academic question is……..

How to evaluate different energy storage technologies in a prospective manner with a full integrated sustainability approach to form a base for decision making?

Source: kommunikationsabc.de

Problem Definition

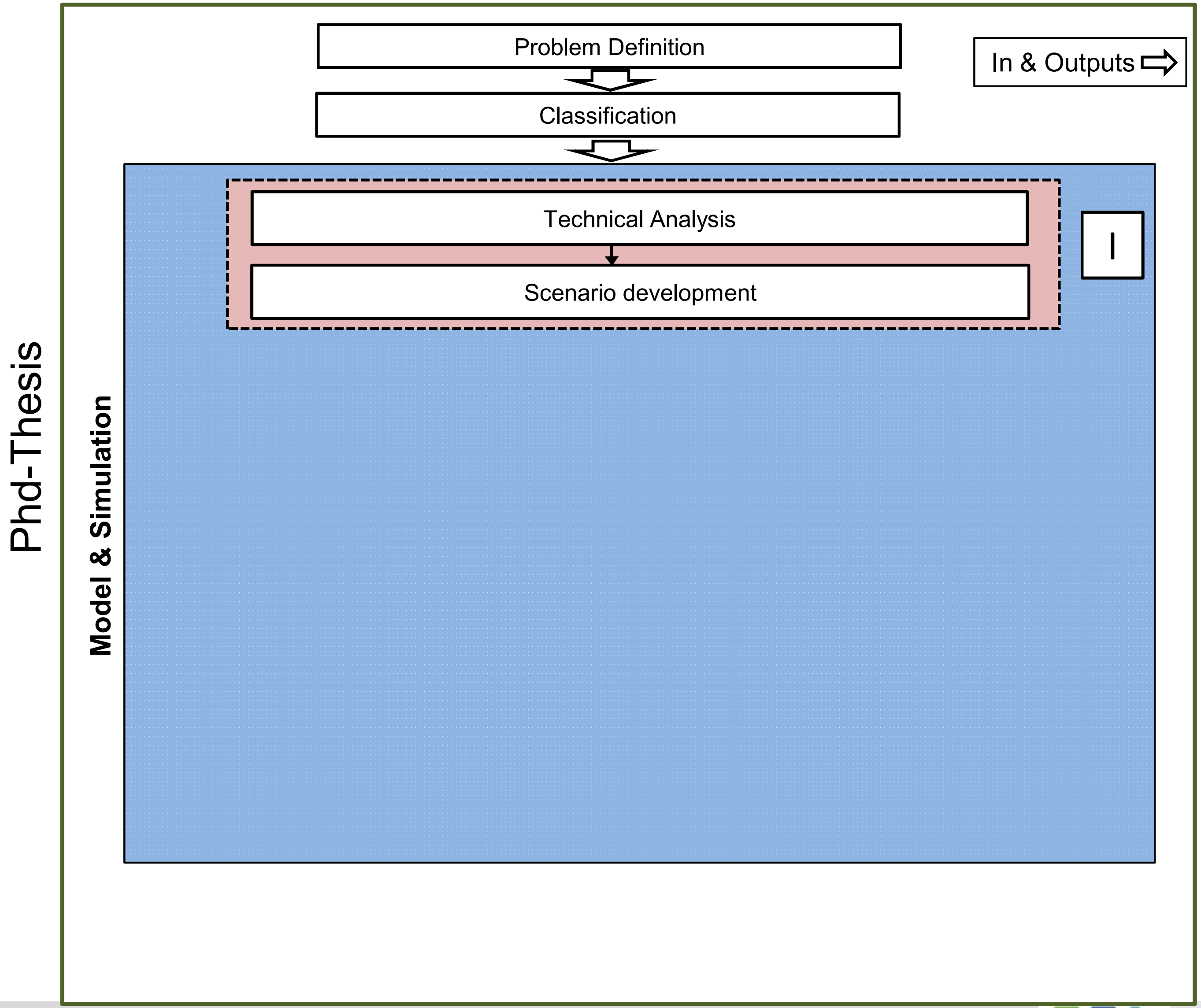
Classification

The **potential** Solution…………

- Economic, tecnological and ecological comparison of (electrochemical) Energy storage technologies based on a life cycle sustainability Analysis (LCSA) and multi criteria Analysis (or evaluation) (MCA)

- Develop a new **LCSA-MCA** model through new combined highly interdisciplinary approach

Source: de.colourbox.com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Model & Simulation
Technical Analysis
I
Scenario development

1. Definition of the field of technology

2. Investigate actual state of development and further development requirements

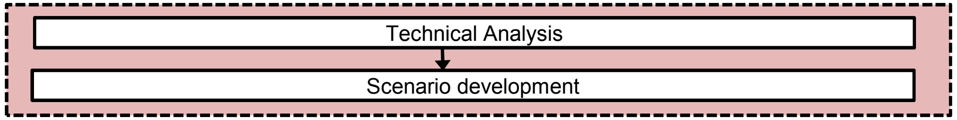
3. Indentify possible bottlenecks

4. Investigate future trends

5. Identify application fields & market potential

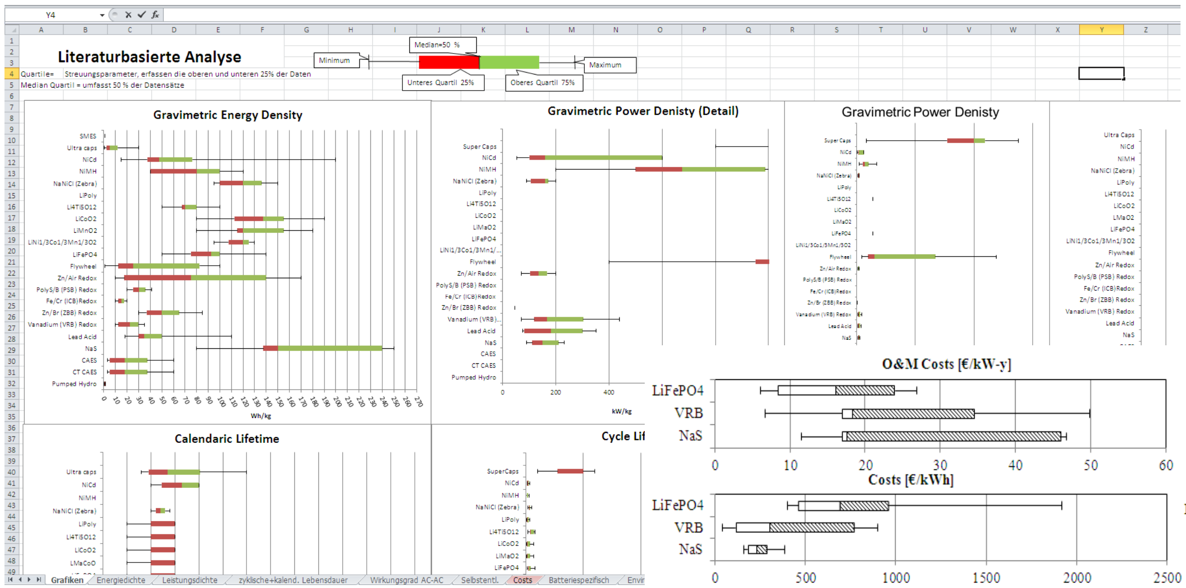
6. …..

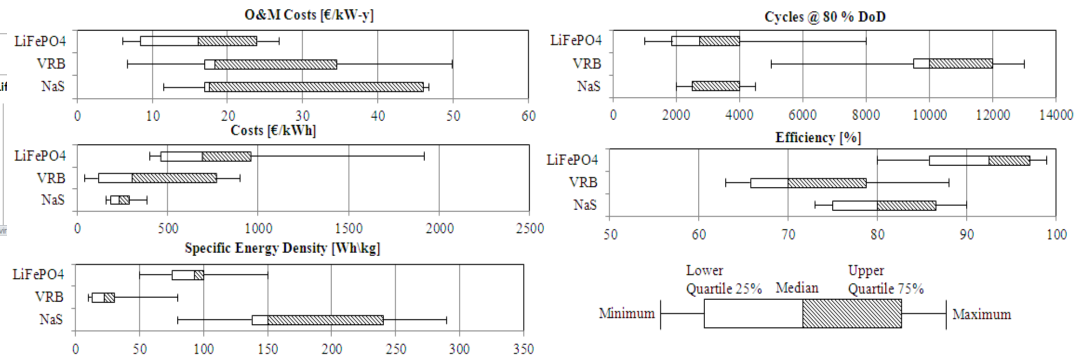
Source: mugler.de



I

- Develope an Energy Storage Technology data base
- Relevant values based on literature and manufactures
- Sources: Scopus, Science Direct, IEEEXplore, Interviews etc.





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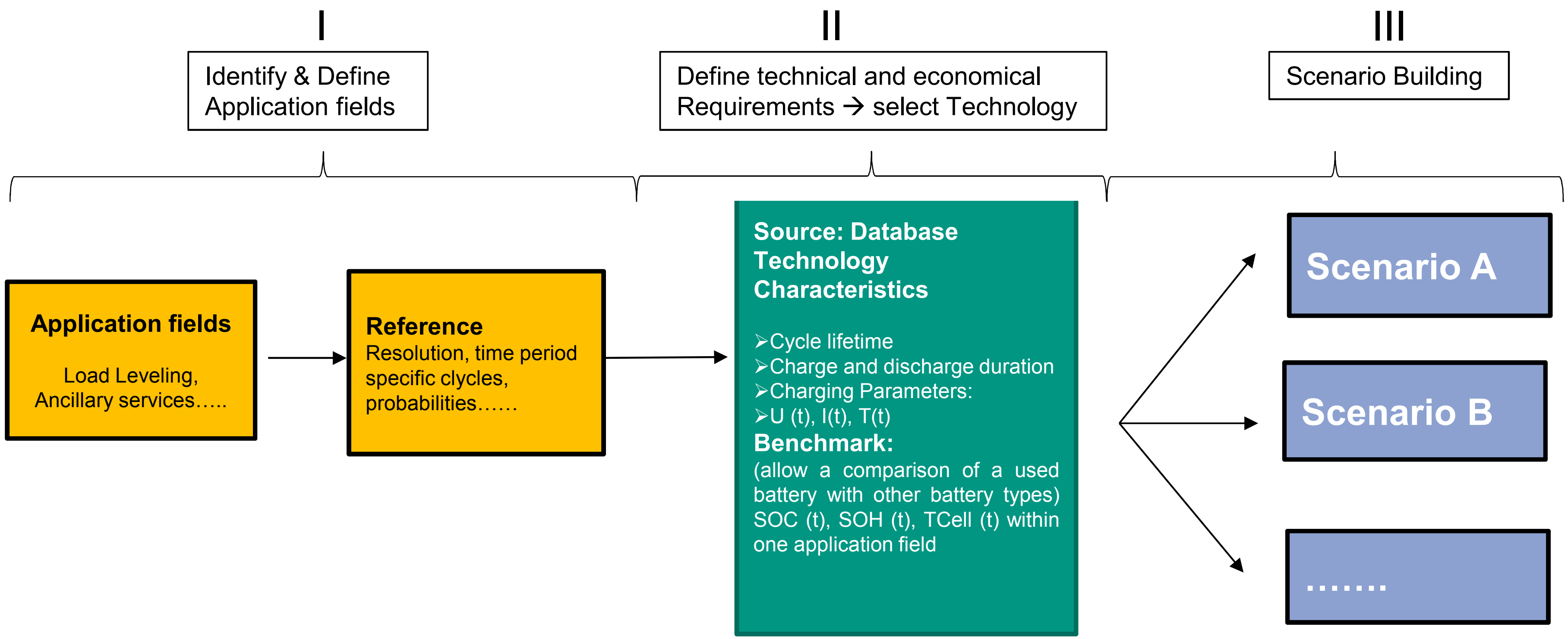
- Definition of different application fields / system integration scenarios
- Identify application fields of different Energy Storage technologies



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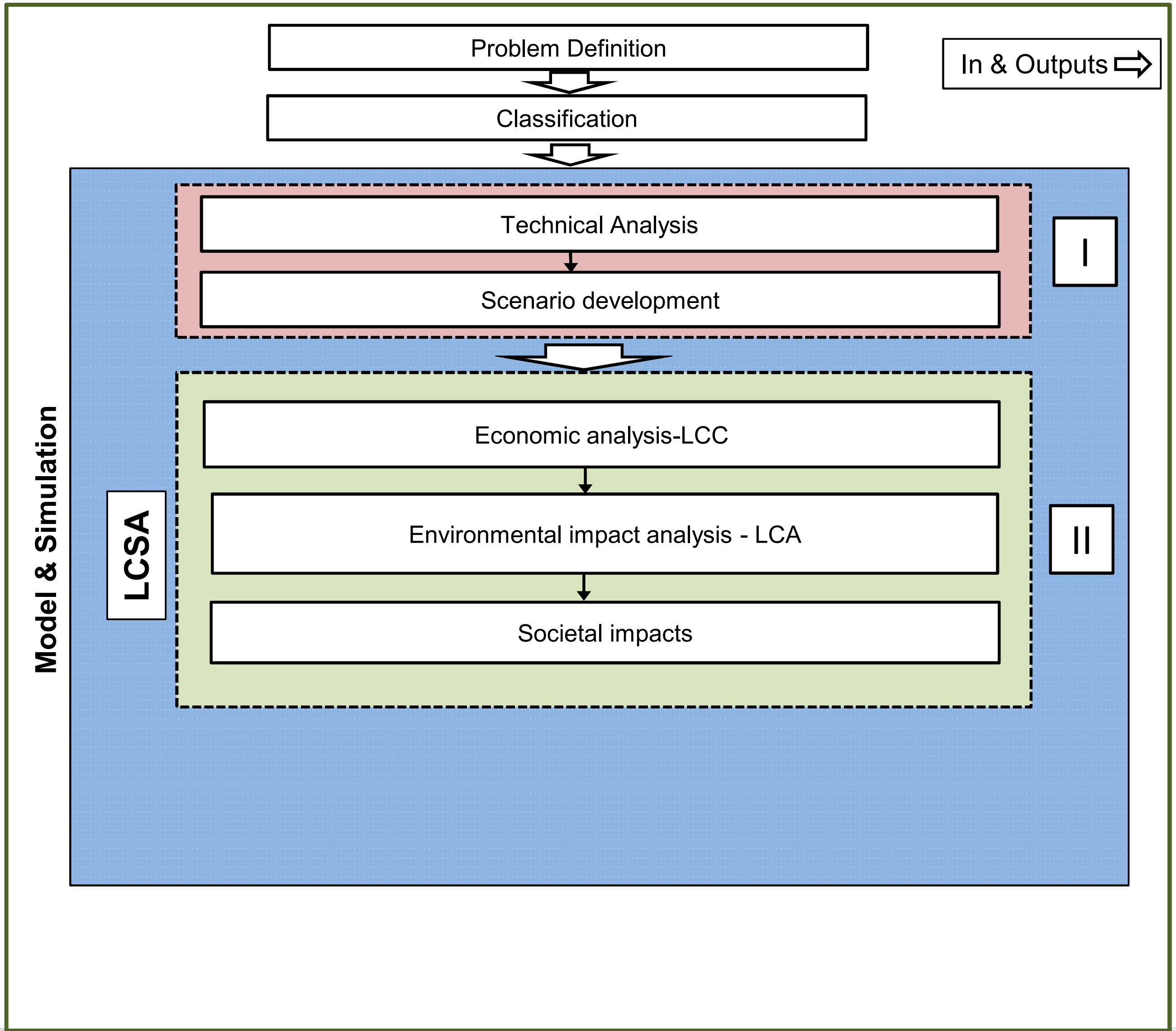
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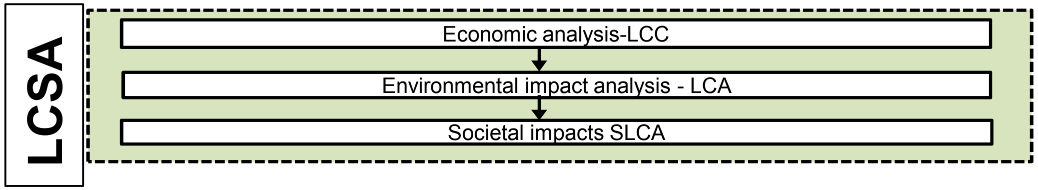
Scenario development
I
Economic analysis-LCC
Environmental impact analysis - LCA
Societal impacts
II
LCSA
Model & Simulation



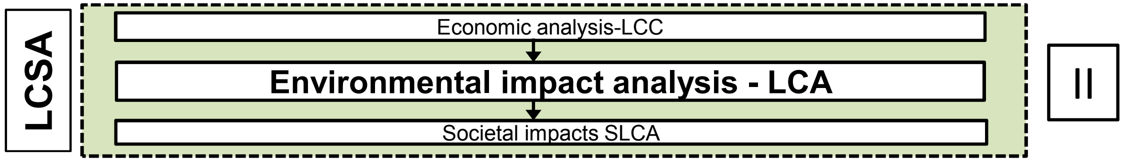
- Based on comprehensive literature research (developed data base)
- Life Cycle Sustainability Assessment (LCSA)

LCSA = LCA + LCC + SLCA

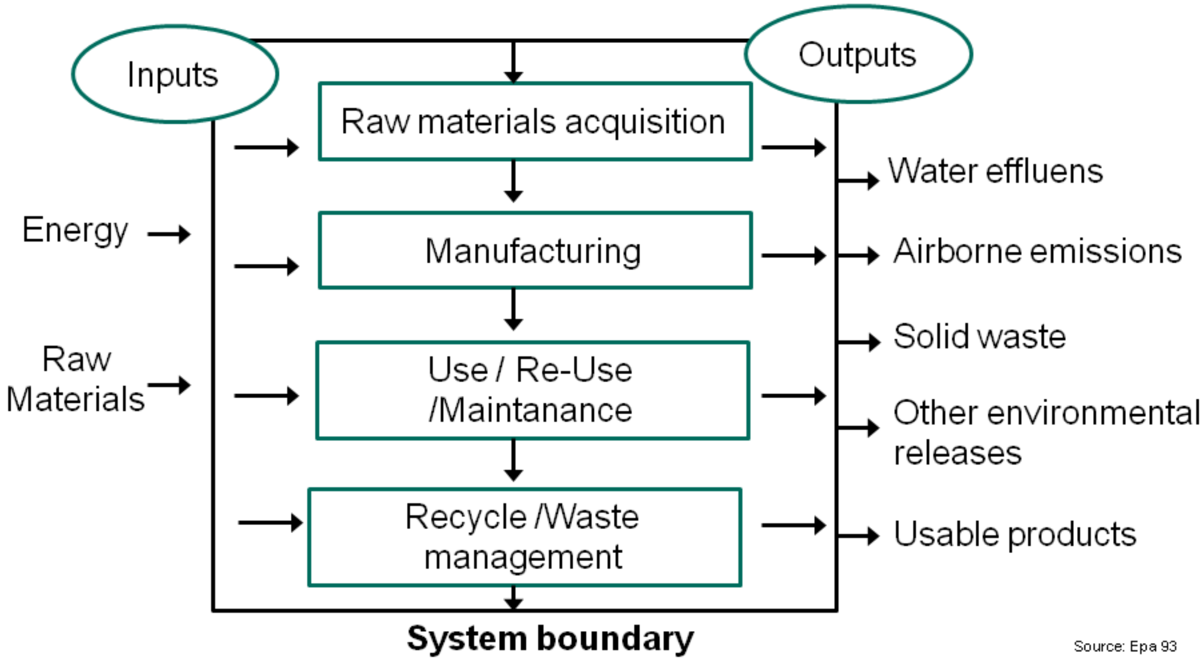
LCSA	Life Cycle Sustainability Assessment
LCA	Environmental Life Cycle Assessment
LCC	LCA-type Life Cycle Costing
SLCA	Social Life Cycle Assessment

Life Cycle Assessment – LCA
Life Cycle Costing – LCC

Source: superinvest.de & adpic.de

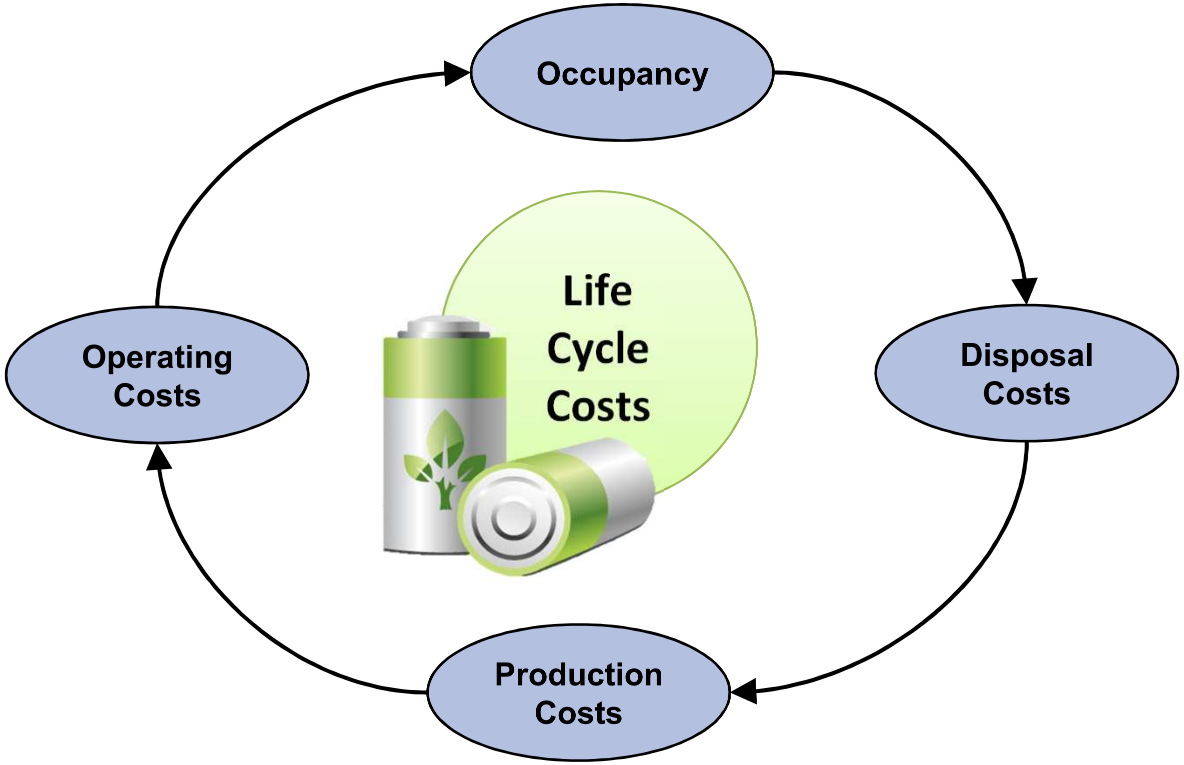


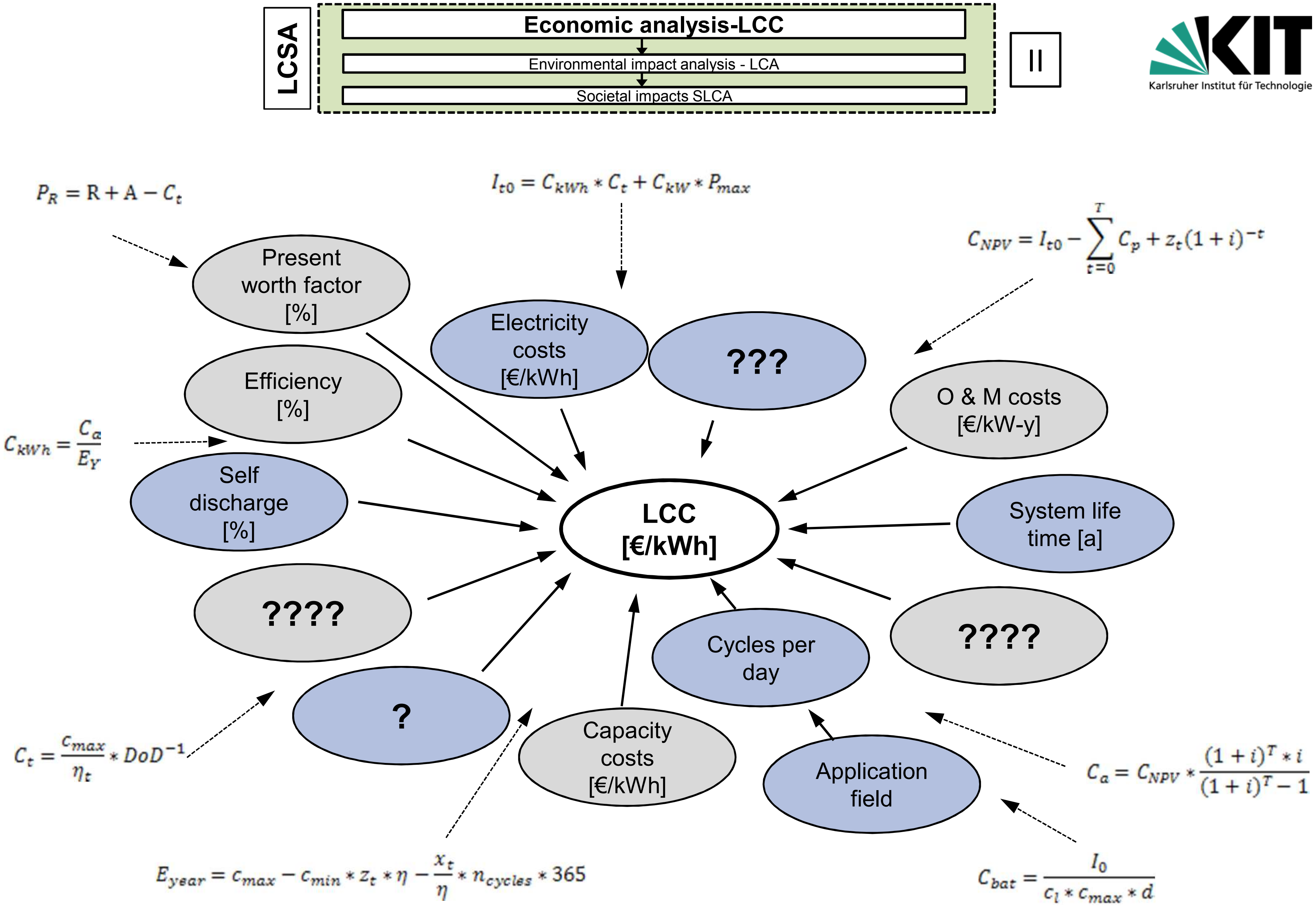
- Ecologic perspective to assess environmental aspects and potential impacts associated with a product regarding their complete life cycle (cradle-to-grave)
- Choice of right components or entire technologies
- Standardized methodology (ISO 14040)



Source: Epa 93

- Techno-economic perspective to evaluate costs
- Similarity to LCA
- Dynamic investment calculations (Net Present Value method (NPV) Annuity….)





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LCSA

Economic analysis-LCC

Environmental impact analysis - LCA

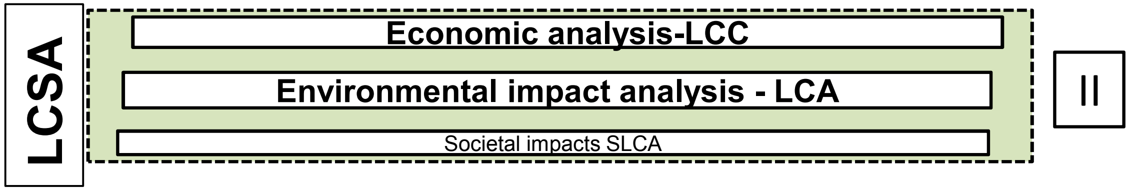
Societal impacts SLCA

II

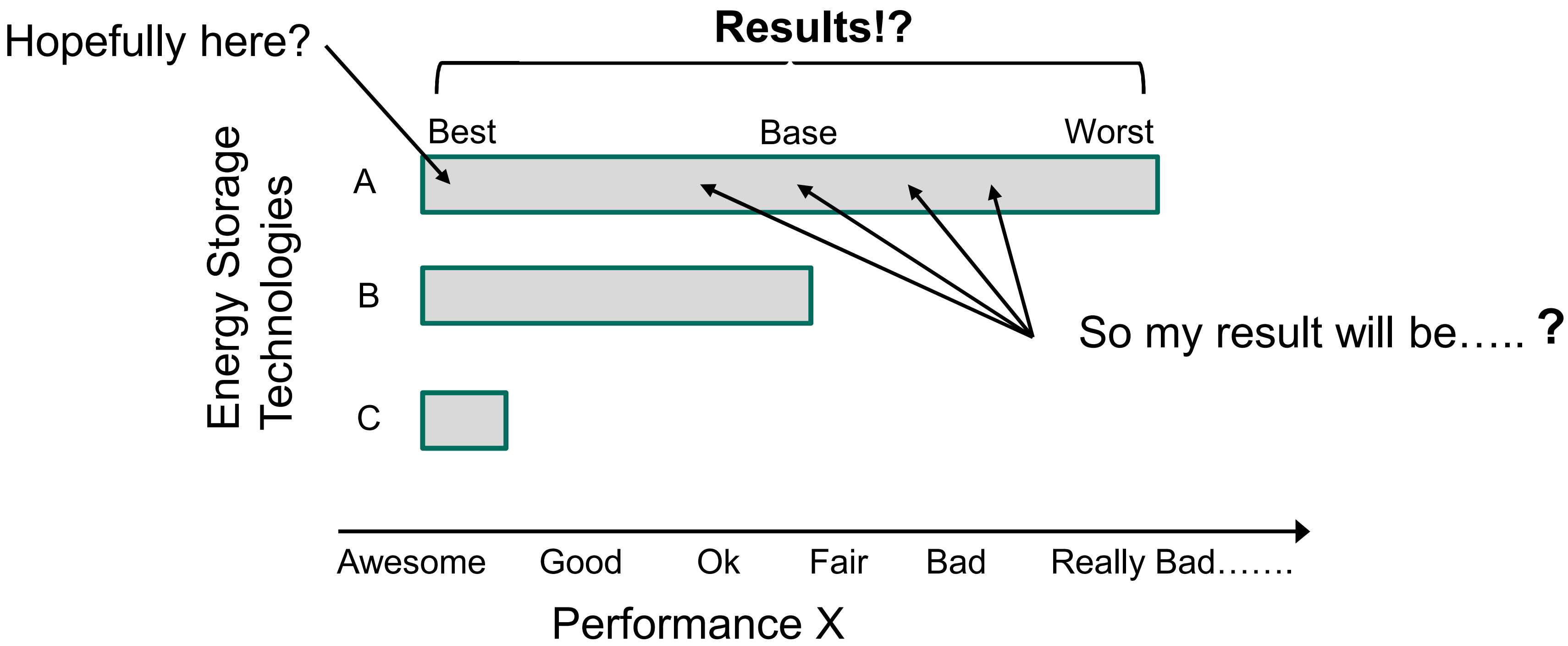
- Can be very detailed, potentially expensive and time consuming
- Huge amount of Data required (equal production process etc.)
- How reliable is my database and is there even data available?
- ……..

High amount of uncertainties & many assumptions!

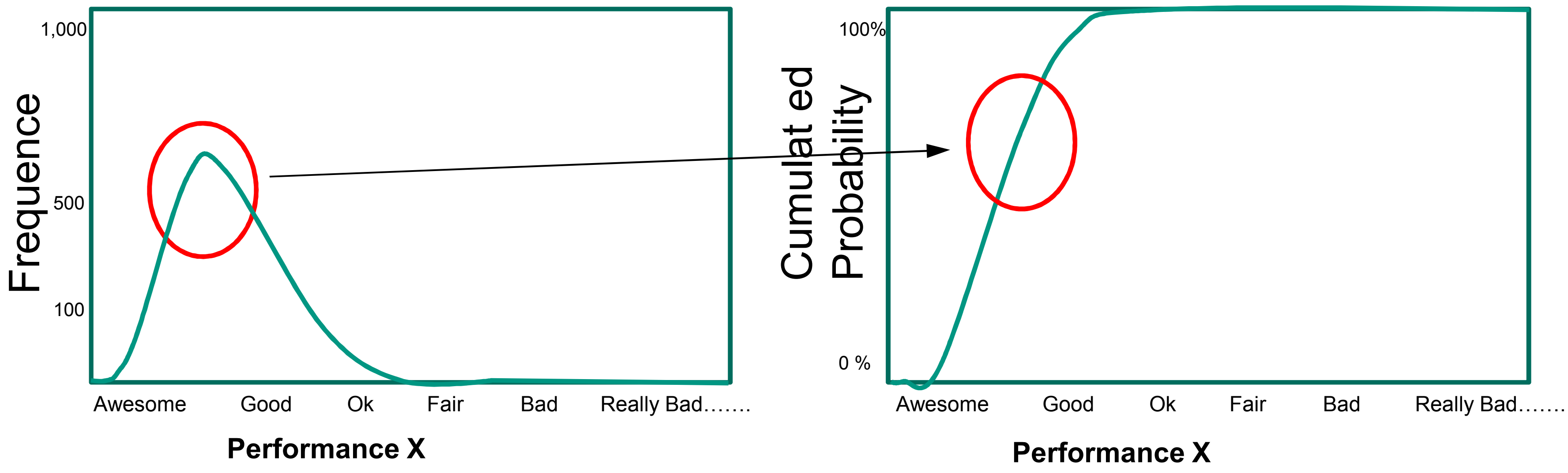
Source: freeenterprise.com



- Deterministic methods (LCA+LCC)
  - Different scenarios equal best, worst and base case
  - To show possible spreads of an performance/result and future developments.



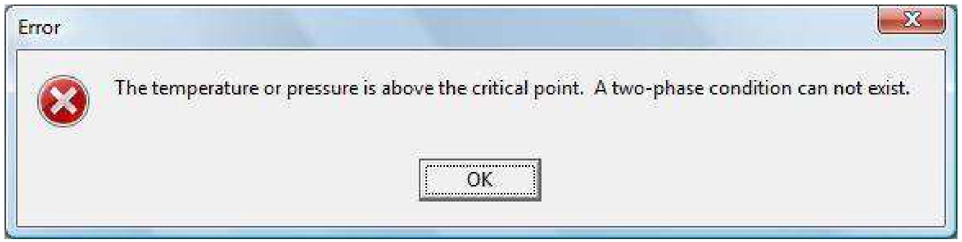
- Probalistic methods to ashure determenistic approach
- Monte Carlo Simulation (numerical solution of mathematical problems)
- Create adequate number of simulations



There will be probability Y that the technology *C* will be „awesome“ to „good“ regarding performance X (e.g. Results will be mean, median, percentiles …)

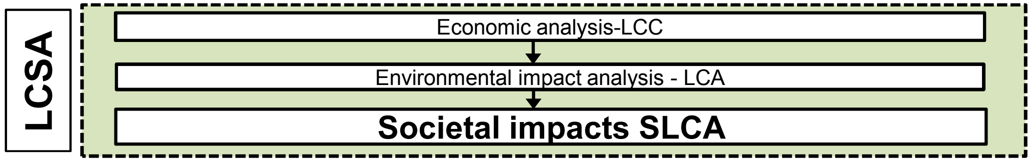
- Again: Adequate amount of data is required
- When there is not enough data, adequate assumptions have to be done
- Command variables, input values and related distribution functions as well as connecting functions have to be known

Rubbish in, rubbish out……



Social Life Cycle Assessment - SLCA

Source: carookee.net

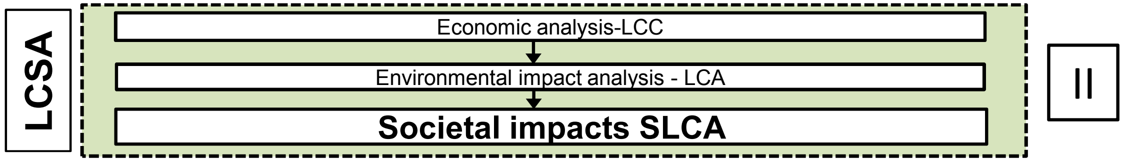


- The societal perspective for e.g. reaction of residents, local added value or contribution to regional development etc. (Zschieschang, 2012)

- Important criteria for peoples acceptance of energy systems (Wang et al, 2009)
  - Base for political, legislative and administrative framework
  - Tendency of institutional actors, policy of public information

- High similarity to LCA (yet some differences)

- Mainly qualitative and only partially quantitative approach possible



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- There is no really standard to make a SLCA
- SLCA is/was rarelly used for the energy sector
  - Only a few studies (e.g. Gallego et al. 2009 & 2010, Oberschmidt 2010)
- Which impact categories to include in the assessment and how to measure these?
  - Interviews with decision makers and stakeholders?
- How to weight a social criteria?
  - Subjective, objective or combined?
- Perception of social impacts is very variable
  - Equal vaqueness of human feelings and recognitions (Wang et al. 2009)

LCSA

Economic analysis-LCC

Environmental impact analysis - LCA

Societal impacts SLCA

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- Difficult approach
- No possibility to cope with uncertainties
- Methodolgy/approach not clear yet
- Develop a complex equation to solve problem:

Engineer + SLCA =

Source: philosophiesofmen.blogspot.com

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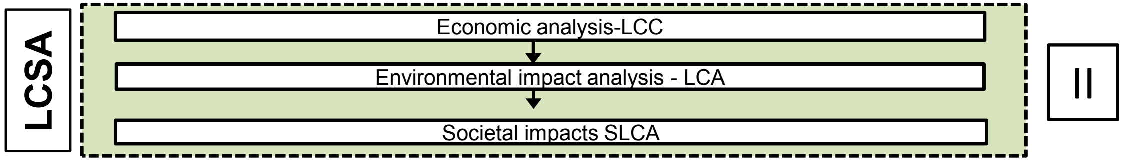
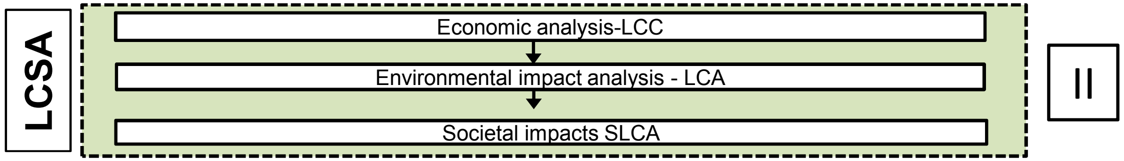
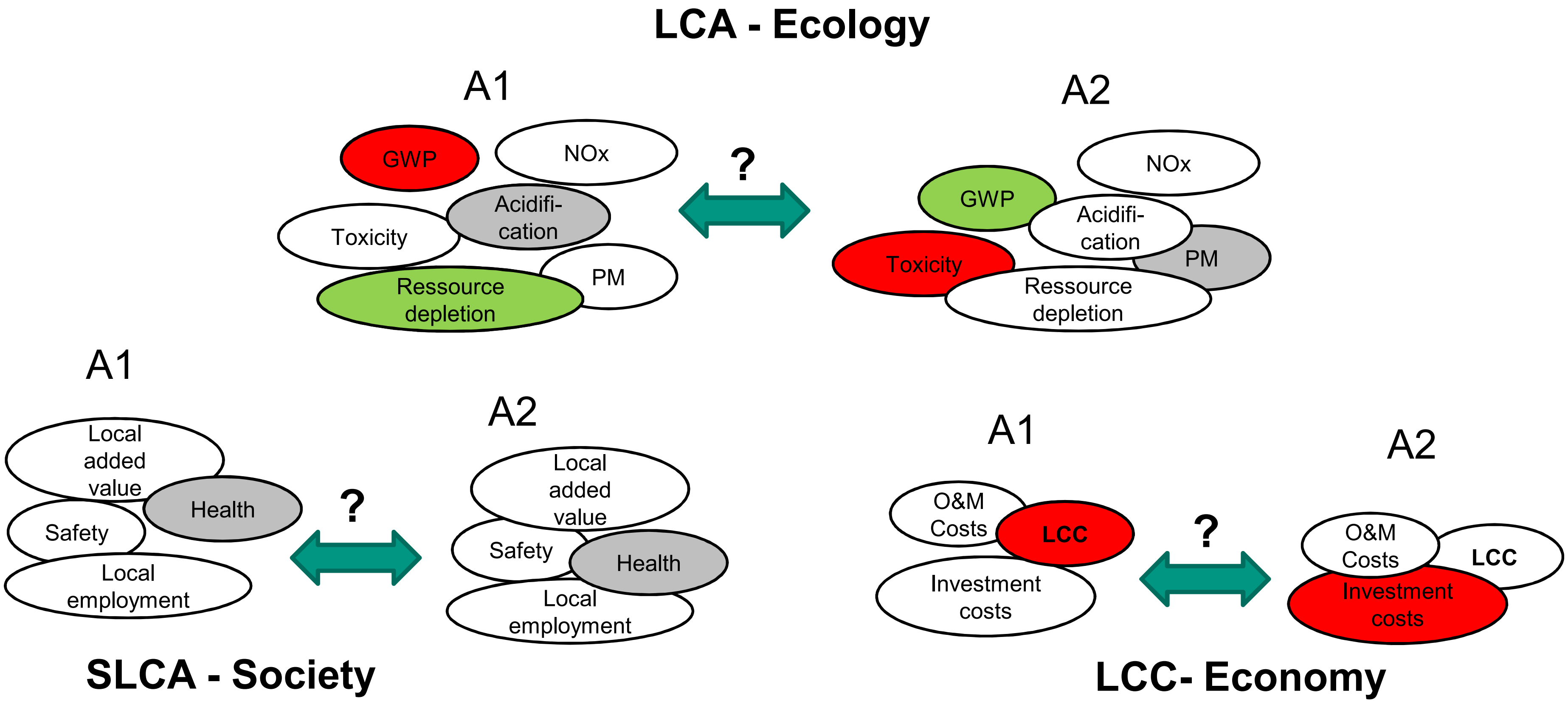


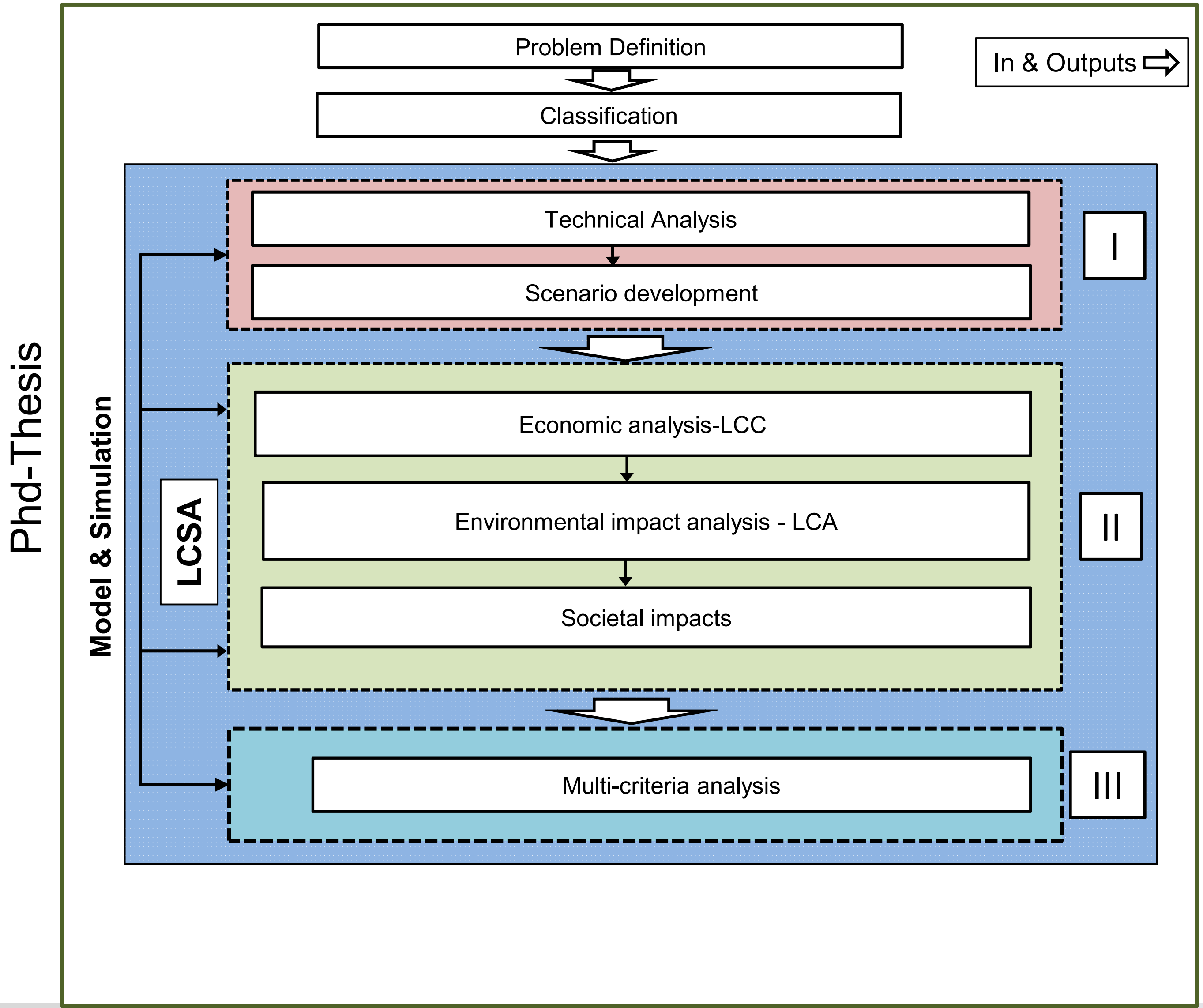
LCSA – Results?



- Results Technology A1 vs. Technology A2 within application X



⇨ **How compare the alternatives?**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Multi-criteria analysis
III

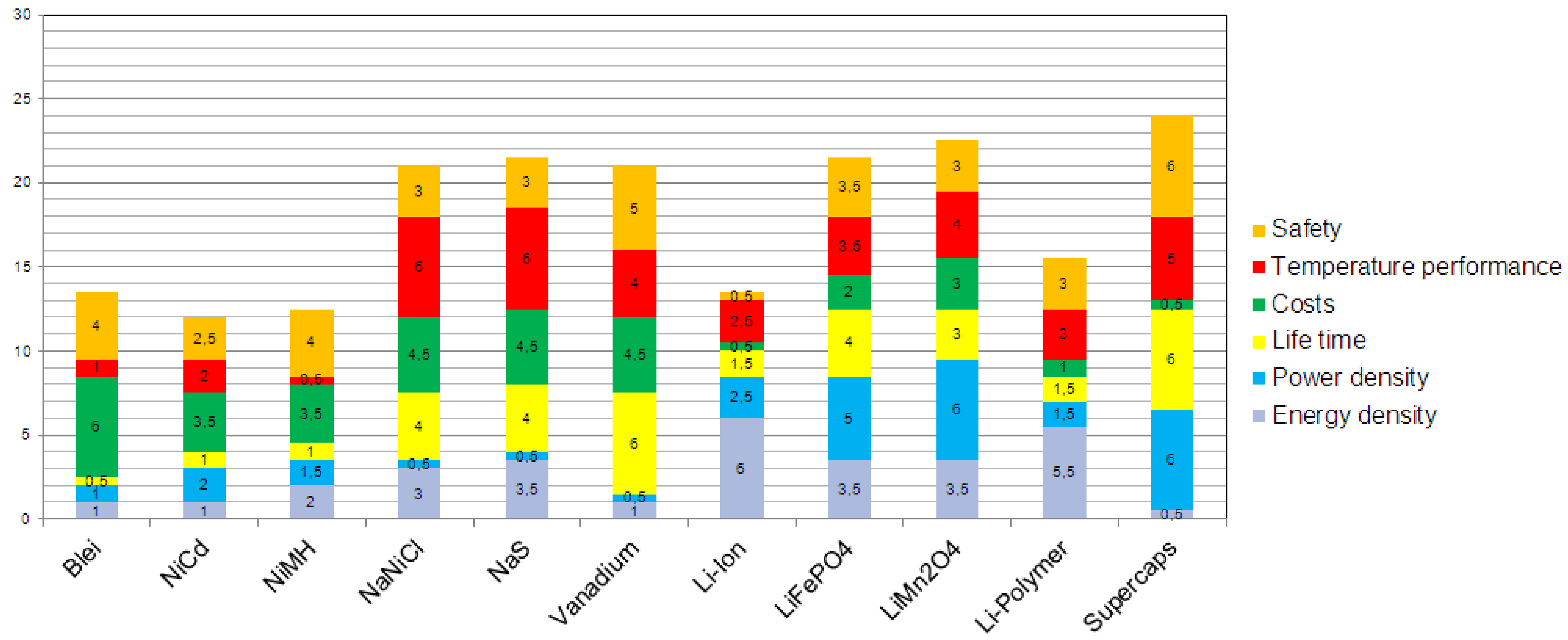
- multi-criteria evaluation or analysis (MCA) to consolidate different category dimensions for one evaluation scale
- Suitable to adress complex problems with high uncertainty

- Identify adequate weighting methods
- Identify proper multi-criteria decision analysis or evaluation methods
- What criteria are even relevant from a stakeholders view?
- How aggregate them?

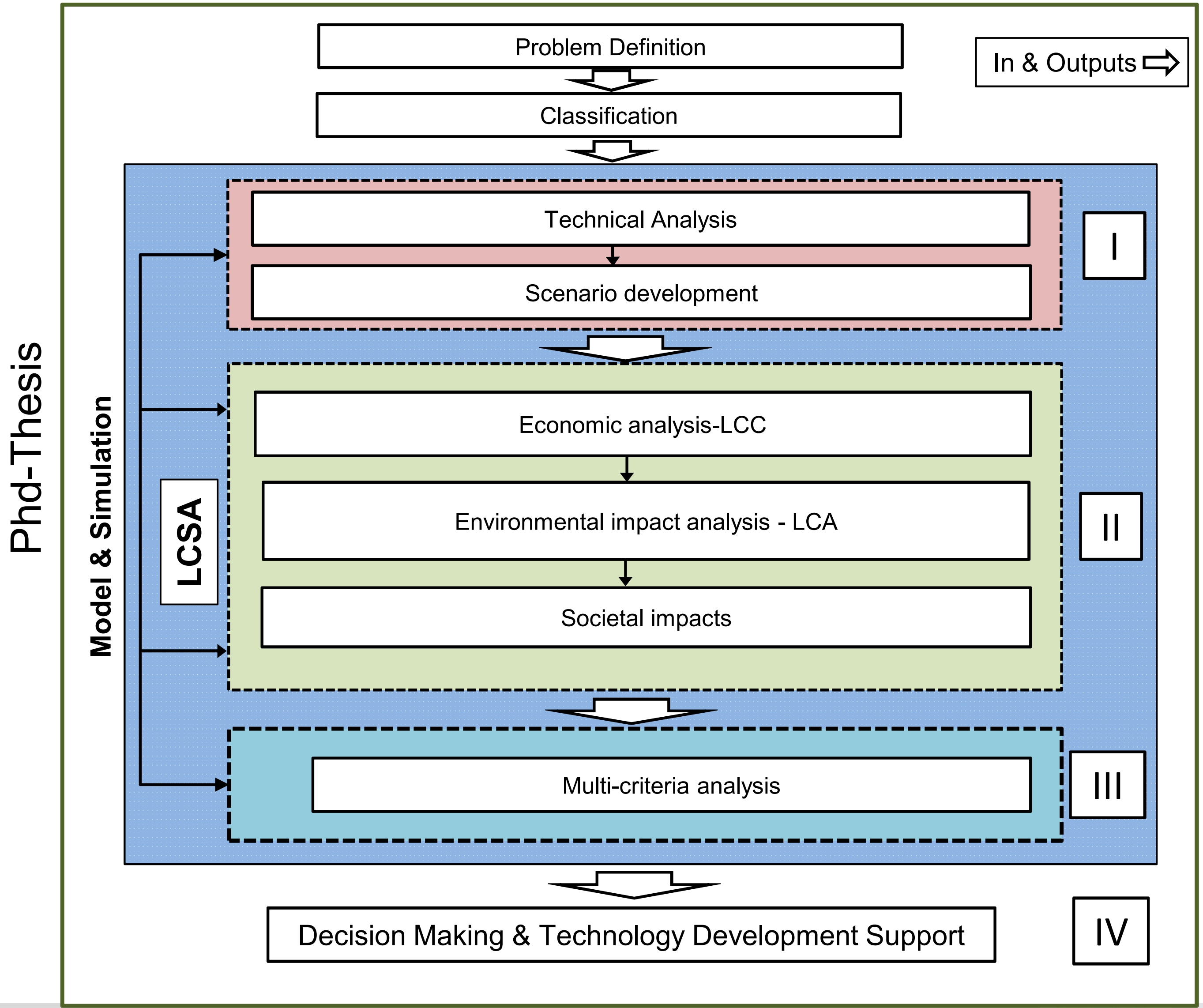
→ **methods most suitable to solve the problem?**

Source: de.123rf.com

- Example for a multi criteria evaluation of different storage technologies
- Equal weight (only techno-economic factors)



Comparison of different battery systems regarding technological aspects, without consideration of a specific application field and weighting system. (Weil, M.; Decker, M.; Fleischer, M.; Frankenberg, A. 2011)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Decision Making & Technology Development Support
IV

- **Technical:** usability regarding different application fields
- **Economical (LCC):** Costs of storage in €/kWh
- **Environmental (simplified LCA):** Env. impact factors
- **Societal (SLCA):** Impacts on society
- **Total (multi-criteria analysis)**: Evaluation and comparison

→ Form a base for decision making

→ **Complex, new approach.**

Source: team-24.biz

„Some“ Academic Claims

? Will this highly interdisciplinary approach work?

? Normativity of chosen criteria (consensus about economic and societal criteria within society)?

? Is the approach to complex?

? Multi-criteria weighting regarding the relevance?

? Is their data available?

? How cope with uncertainties?

? Trade offs (grade of detail)?

! Not enough space……..!

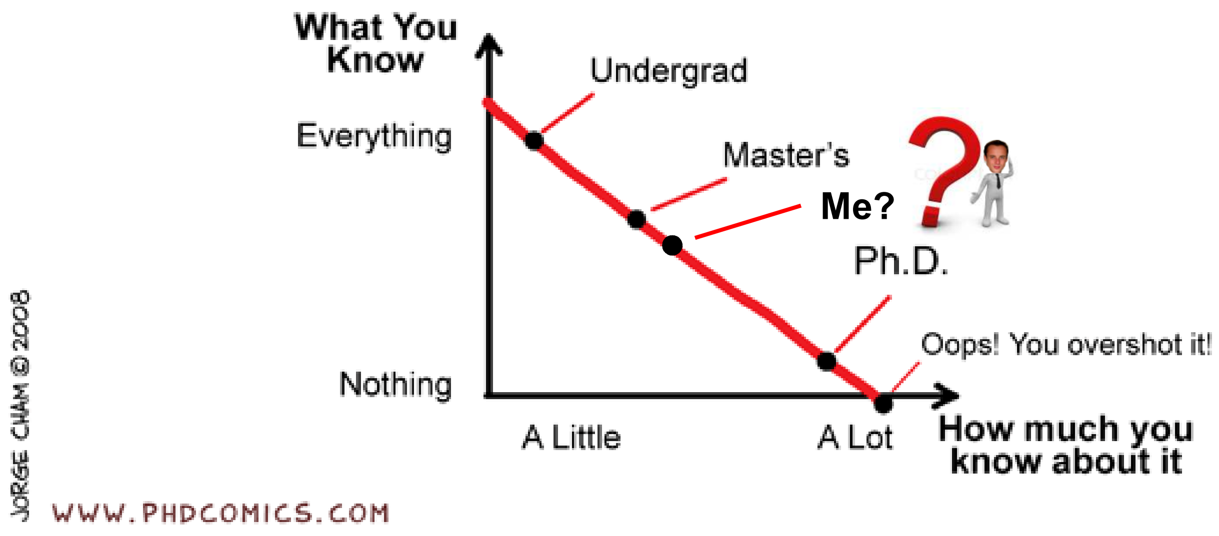
Source: fitness-aalen.de

Proposed Timetable

	Year	1st year				2ond year				year				
No.	Working packages													
1	Collecting of data	x	x											
2	Development of the model		x											
3	Calculations				x	x	x	x						
4	……					x	x	x	x					
5	………						x	x	x					
6	…….								x	x	x	x	x	x
7	……..								x	x	x	x	x	x
8	………										x	x	x	x
8	**Panic**										**X**	**X**	**X**	**X**

Not enough time……

What You Know vs How much you know about it



Muito Obrigado!
Perguntas?

Literature

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