Karlsruher Institut für Technologie

FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

Constructive Technology Assessment of Stationary electro-chemical Energy Storage Systems:
Methodological developments and first outcomes

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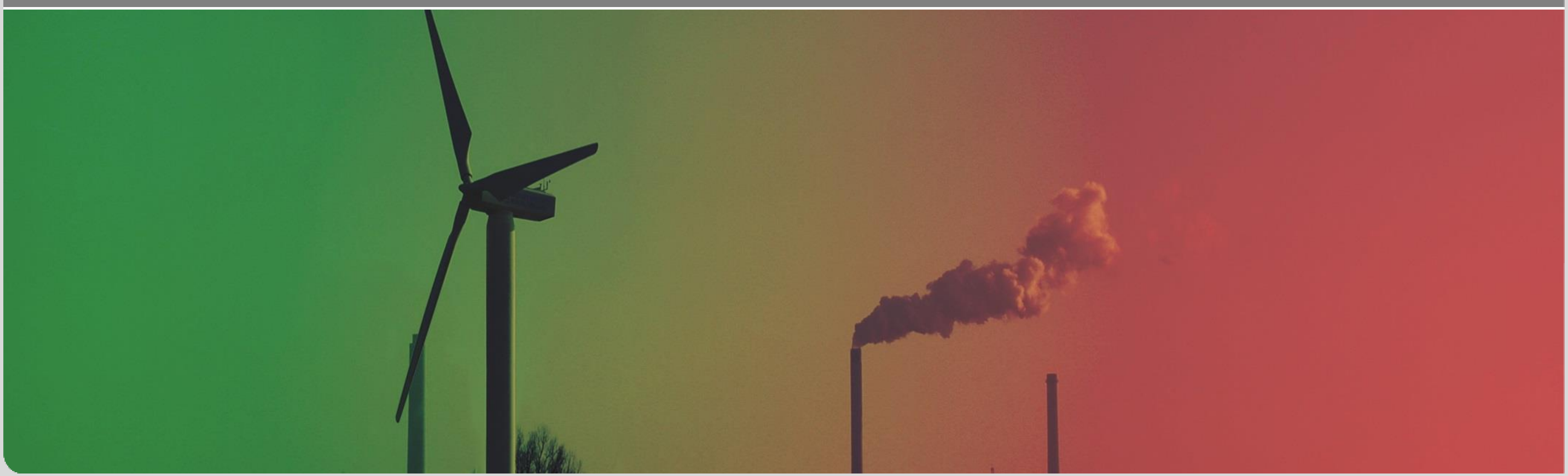

Agenda

- Introduction
- Methodology
- Technology development status (regulation, research & technical status)
- First Life Cycle Cost results
- Energy storage related Stakeholders
- Conclusions & Outlook

Introduction

- **Energy density**
- Safety
- ….

- **Safety**
- Power
- …..

- **Lifespan / costs**
- Power / Energy density
- ……

Criteria are the same but priorities are different

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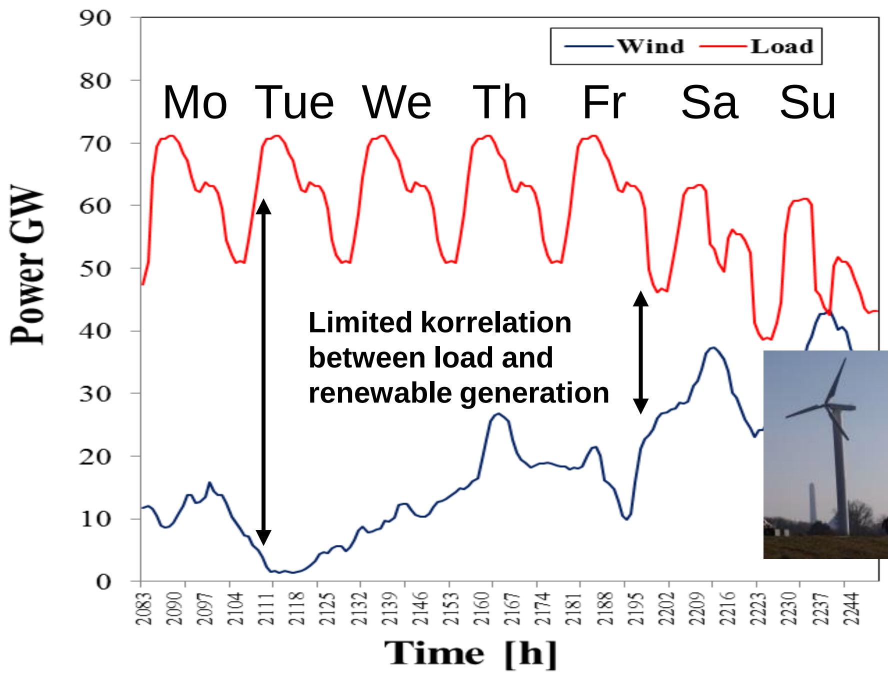
Stationary applications

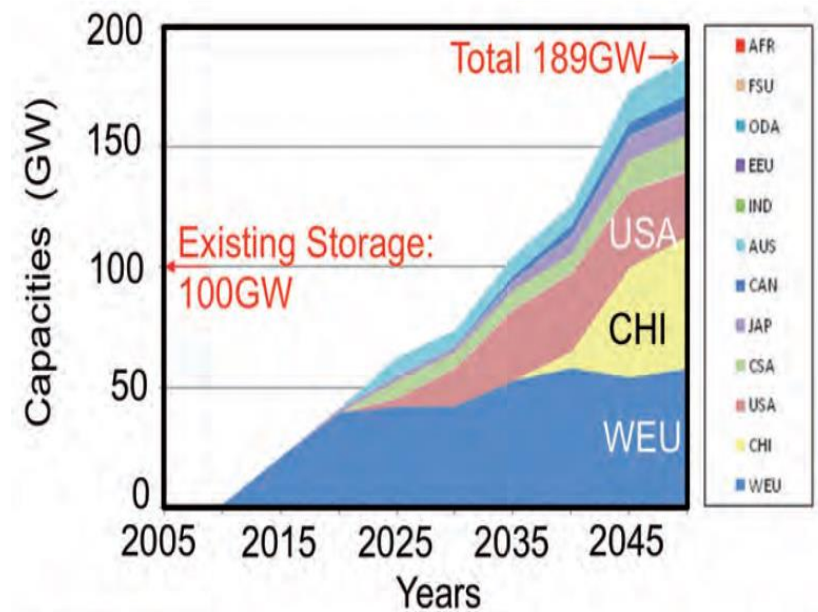
…Wh…. → **…..kWh……** → **…MWh…..**

Inspired by J.M. Tarascon, 2011

Introduction

- Increasing Solar and Wind capacities in Europe until 2050
- Wind & Solar energy cause fluctuations within the grid, which have to be managed



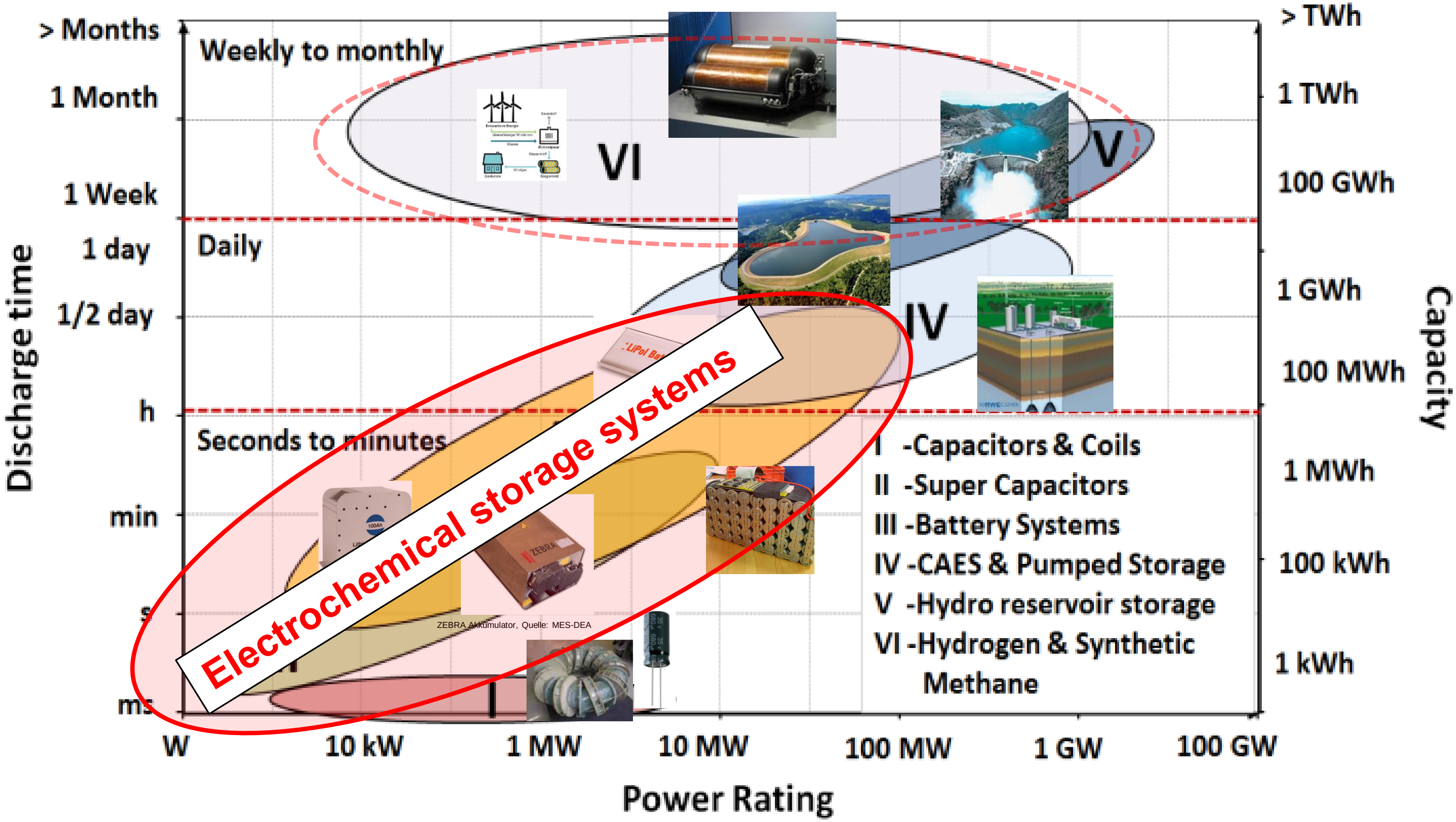


Source: IEC 2011

Exemplaric illustration (One Week in Frebruary - Germany in 2023)

Need for **energy storage** technologies

Introduction



Properties of different ESS based on B. Droste-Franke et al 2012 and D. U. Sauer 2011

Introduction

- Many different technologies available, Batteries have the biggest application range + high modularity

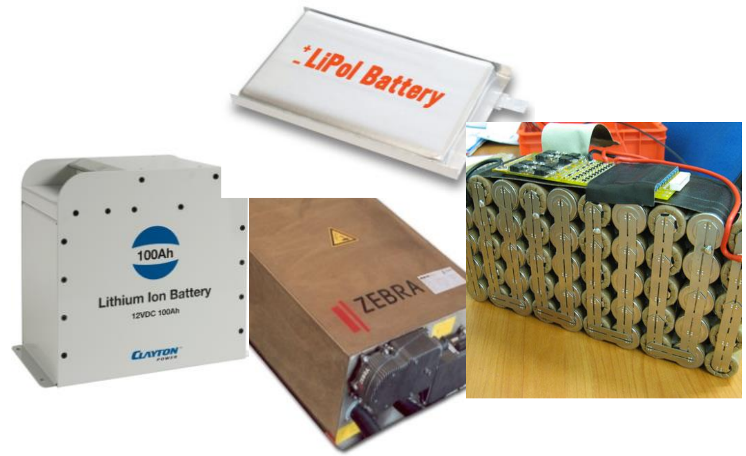
  Question: What technology?

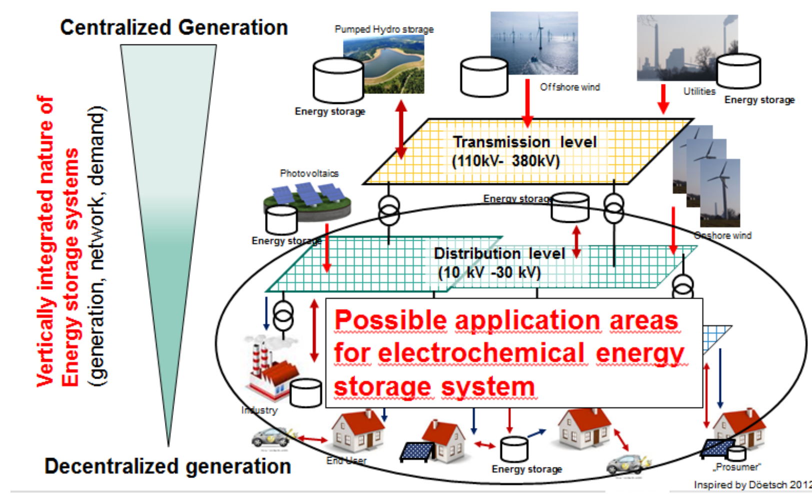
- Can be used in several application areas (short term - middle term storage)

  Question: What application?

- Have a highly integrated nature (from generation, transmission to demand)

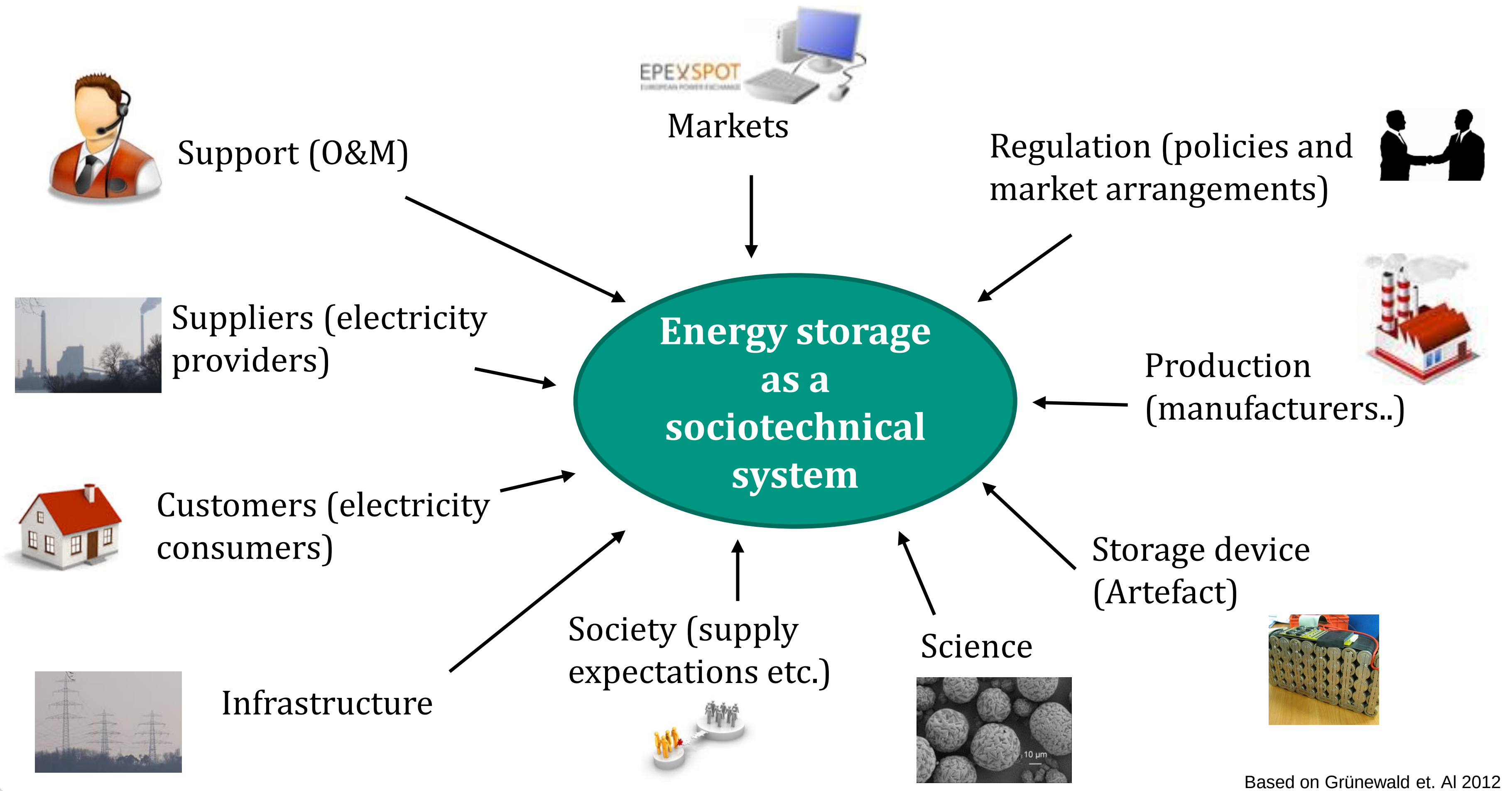
  Question: Where to integrate?





Introduction

- Can electricity storage be considered as a **socio-technical system** where **inter-sectoral perspectives have to be mentioned**?



Based on Grünewald et. Al 2012

Methodology

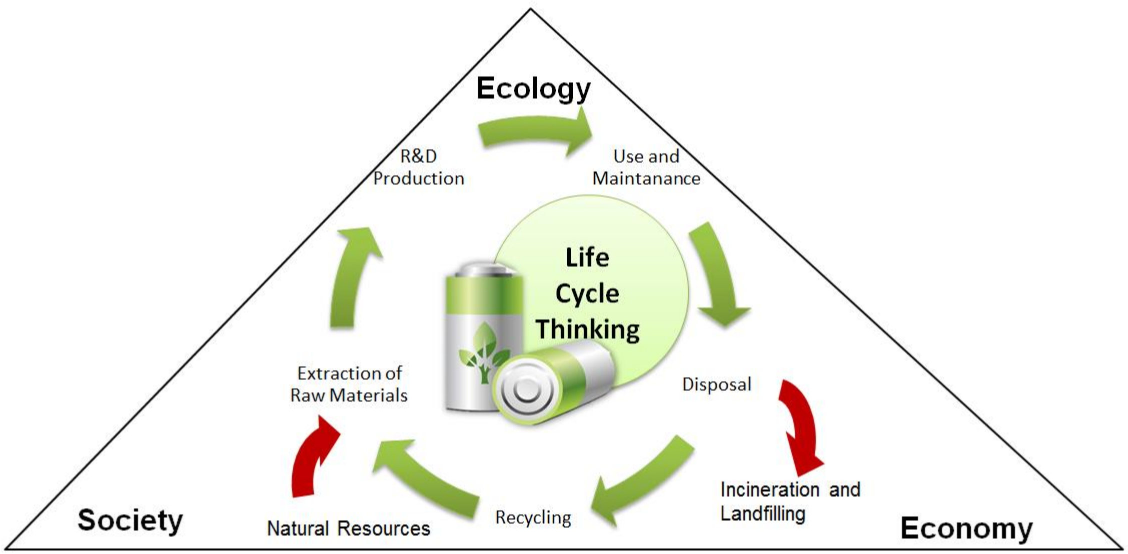
General Research Question:

How to evaluate stationary electro-chemical energy storage technologies in a prospective manner with a integrated model – CTA* approach to support technology development?

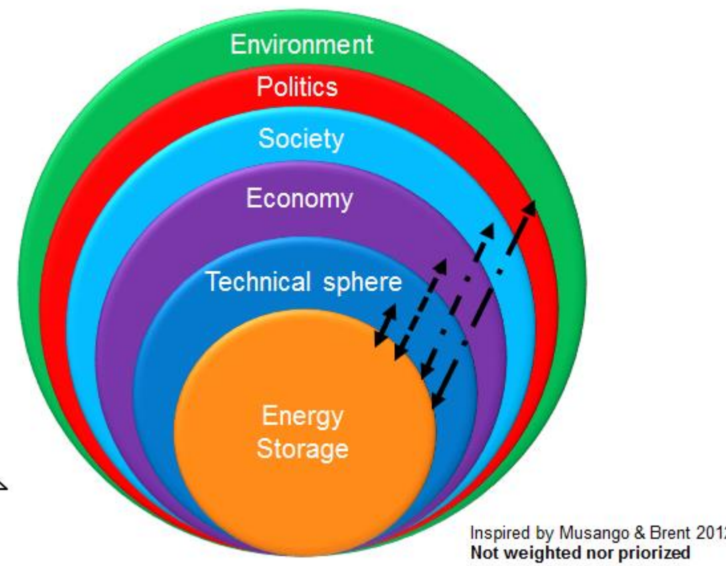
*Constructive Technology Assessment: Expectation of minimizing mismatches, wrong investments, possible social conflicts, and environmental impacts of a new technology in an early development stage (Shot & Rip, 1997)

Methodology

- Fokus on a life cycle approach in a integrative way (spheres of the socio technical-system)



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



Spheres of a socio-technical system

It is insufficient to exclusively look at the operation phase to assess a complex technology (Grunwald et. al 2002)

Methodology

„Sub-objectives?“

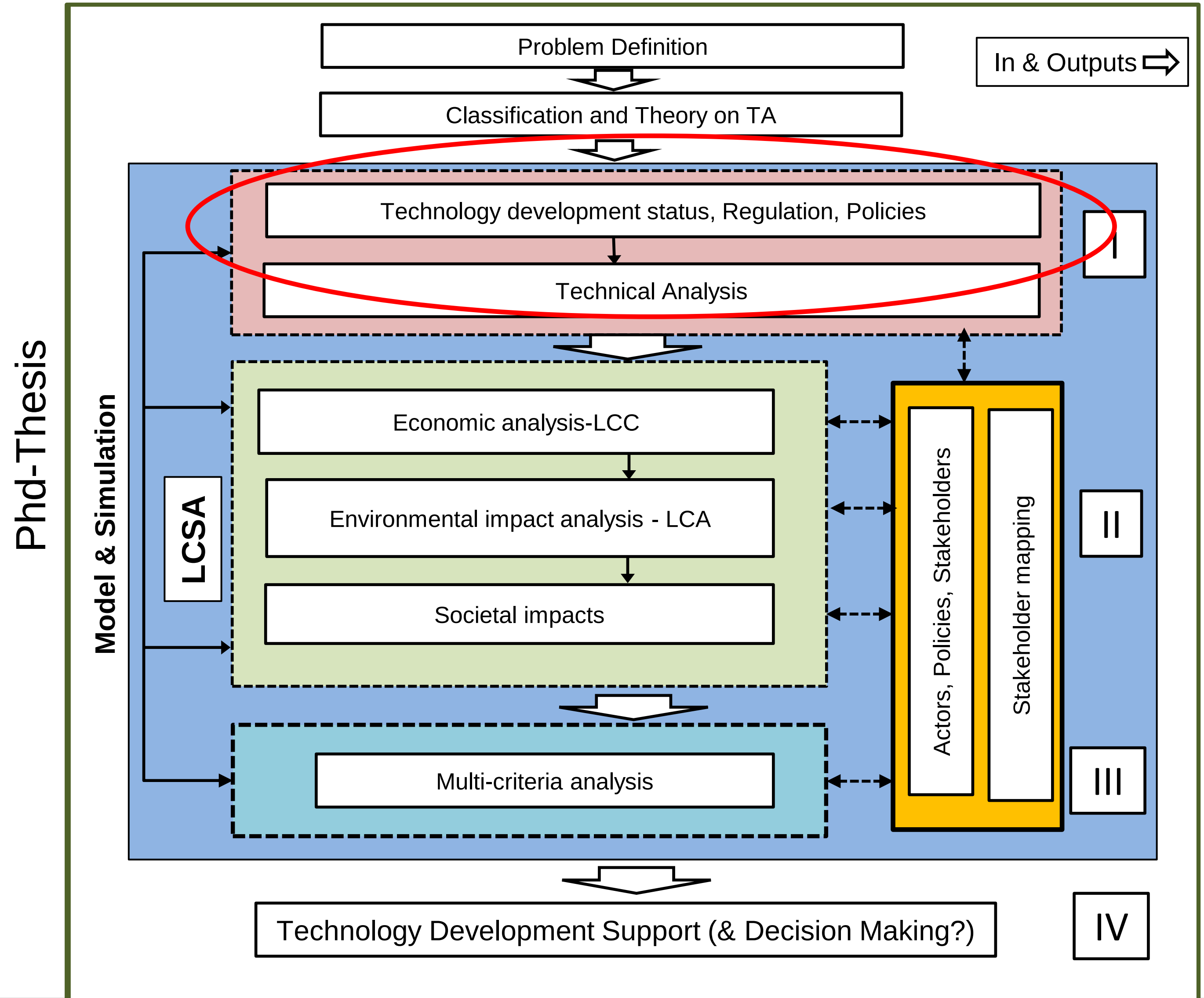
- Explain the role of electrochemical energy storage in today's and tomorrow's energy system
- Assess the state of play for main electrochemical energy storage technologies as well as future developments
- Identify barriers for further development and deployment (e.g. different spheres technical, political etc.)
- Compare different technologies
- Provide benchmarking

Methodology

Possible Results:

- **Regulatory:** Identify market hurdles
- **Technical:** Usability regarding different application fields
- **Economical (LCC):** Costs of storage in €/kWh and benchmarks
- **Environmental (LCA):** Different impact factors (KEA, GWP etc.), Resource availability
- **Societal (SLCA):** Identification of relevant impacts on society
- **Total (multi criteria analysis)**: Evaluation and comparison based on a comprehensive LCSA

Methodology



Technology development status

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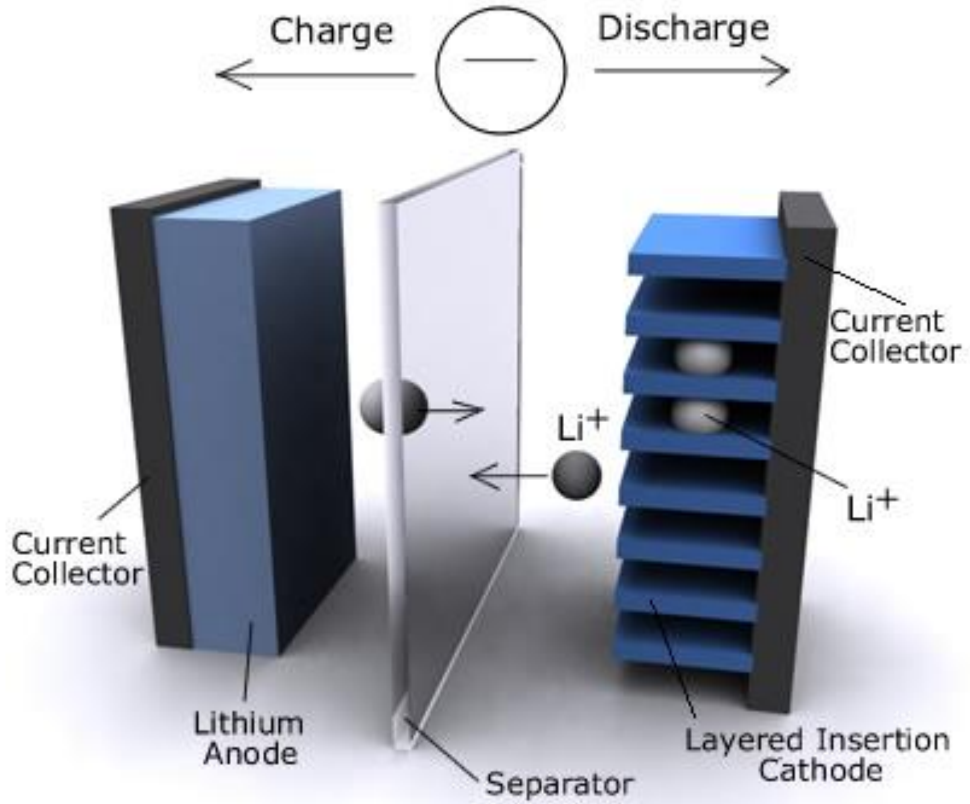
Challenges regarding further development of electrochemical energy storage

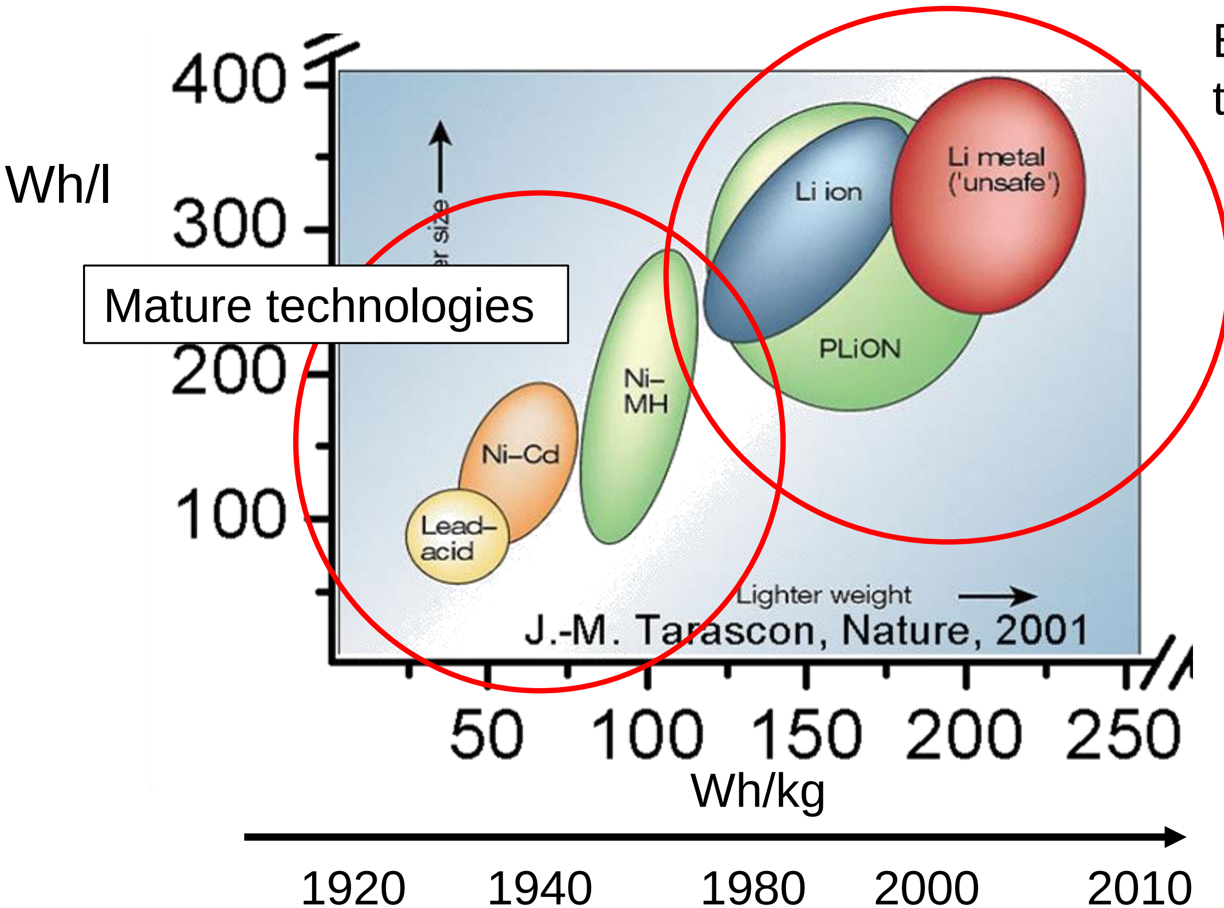
- **Cost**
- **Energy density**
- **Power density**
- **Life time**
- **Safety**
- **...**



M. Weil, 2012

Technology development status

- Available technologies and their development



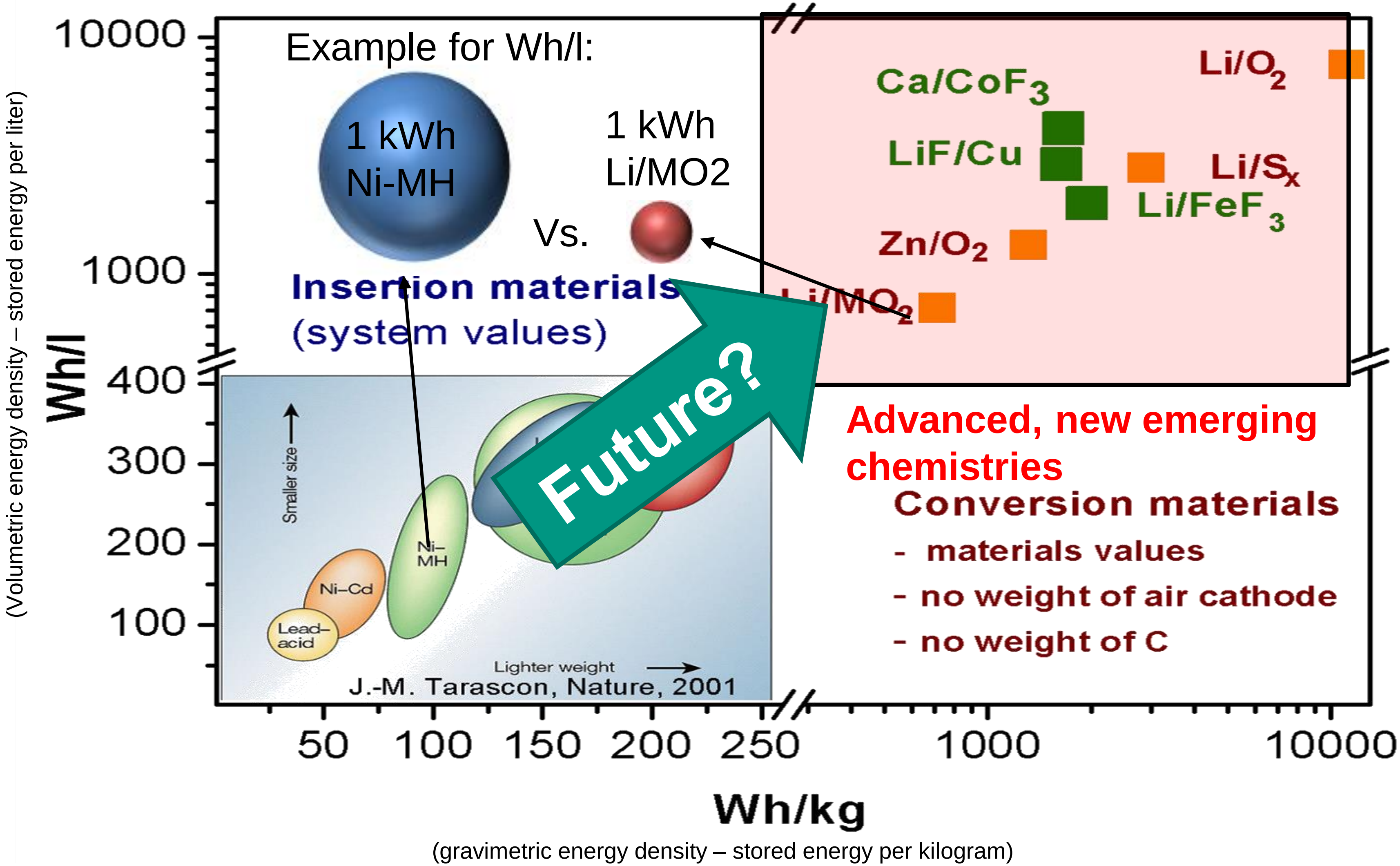
Biggest advance in the last 20 years

Not directly Moores Law

(for batteries doubling of the capacity every 18 months)

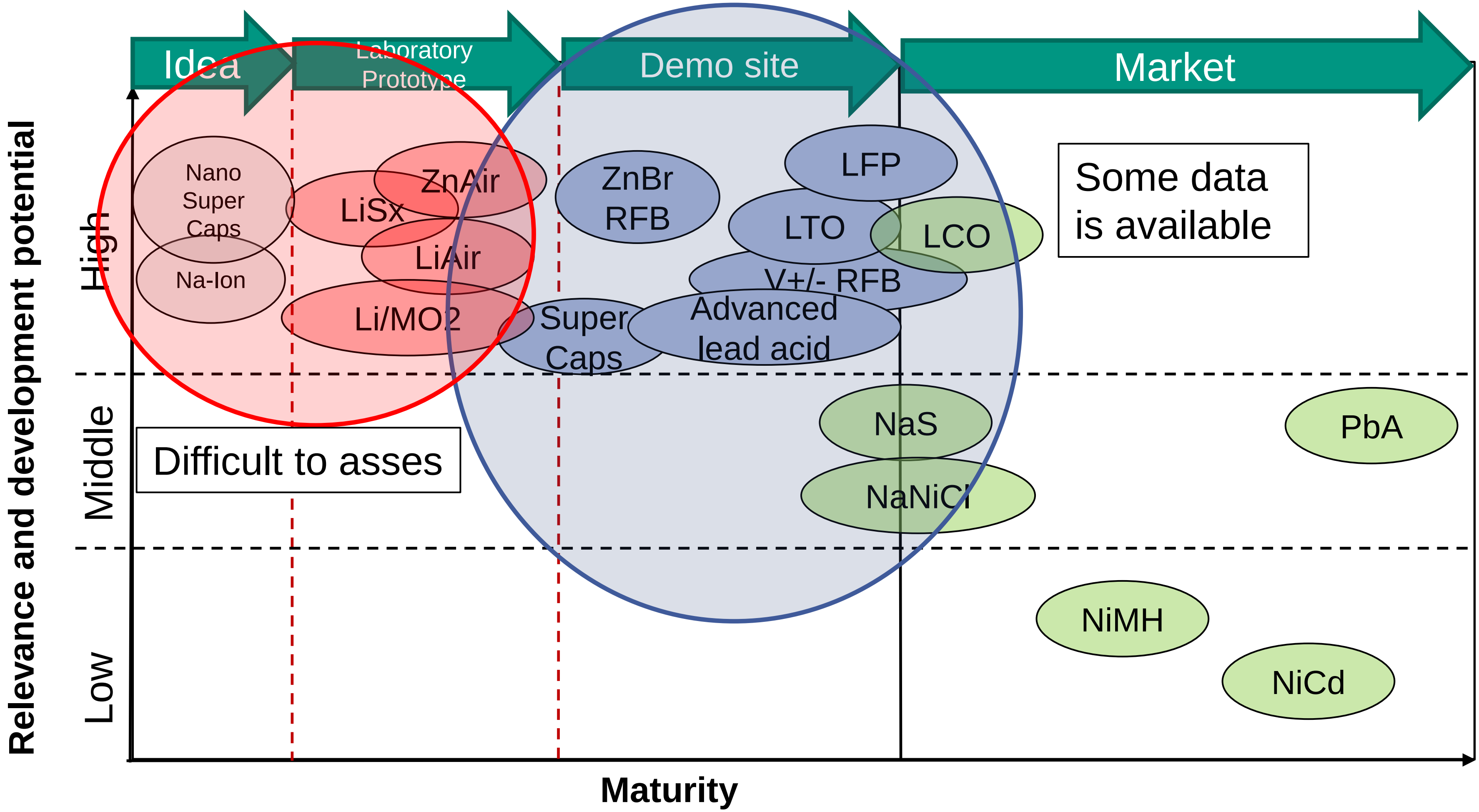
Inspired by J.M. Tarascon, 2011

Technology development status



M. Fichtner, JALCOM 509 (2011) S529

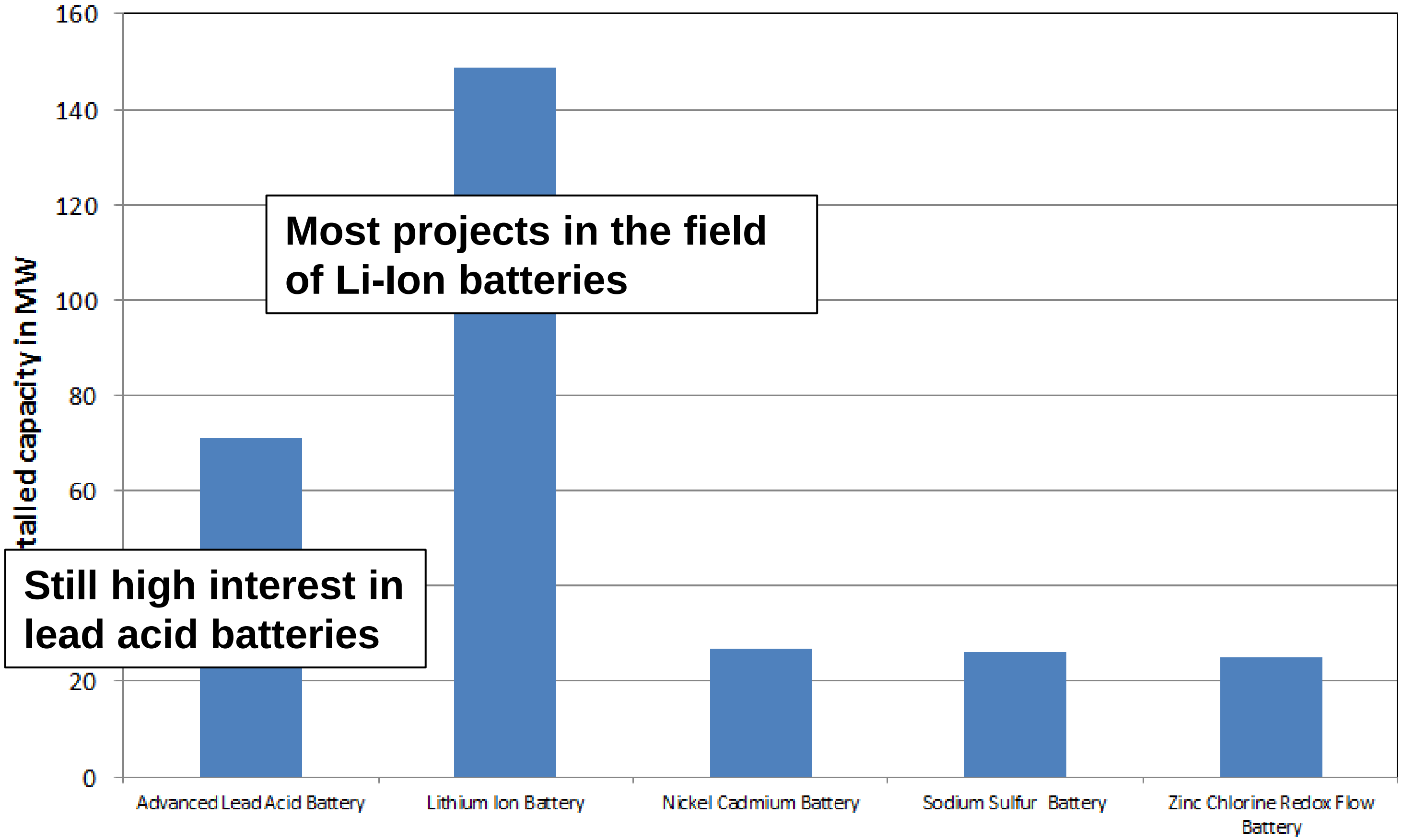
Technology development status



Initial qualitative classification of selected technoligies based on Wietschel et. Al . 2010, EASE 2012 and JRC 2011

Technology development status

- Overview of selected international energy storage projects (aggregated)*



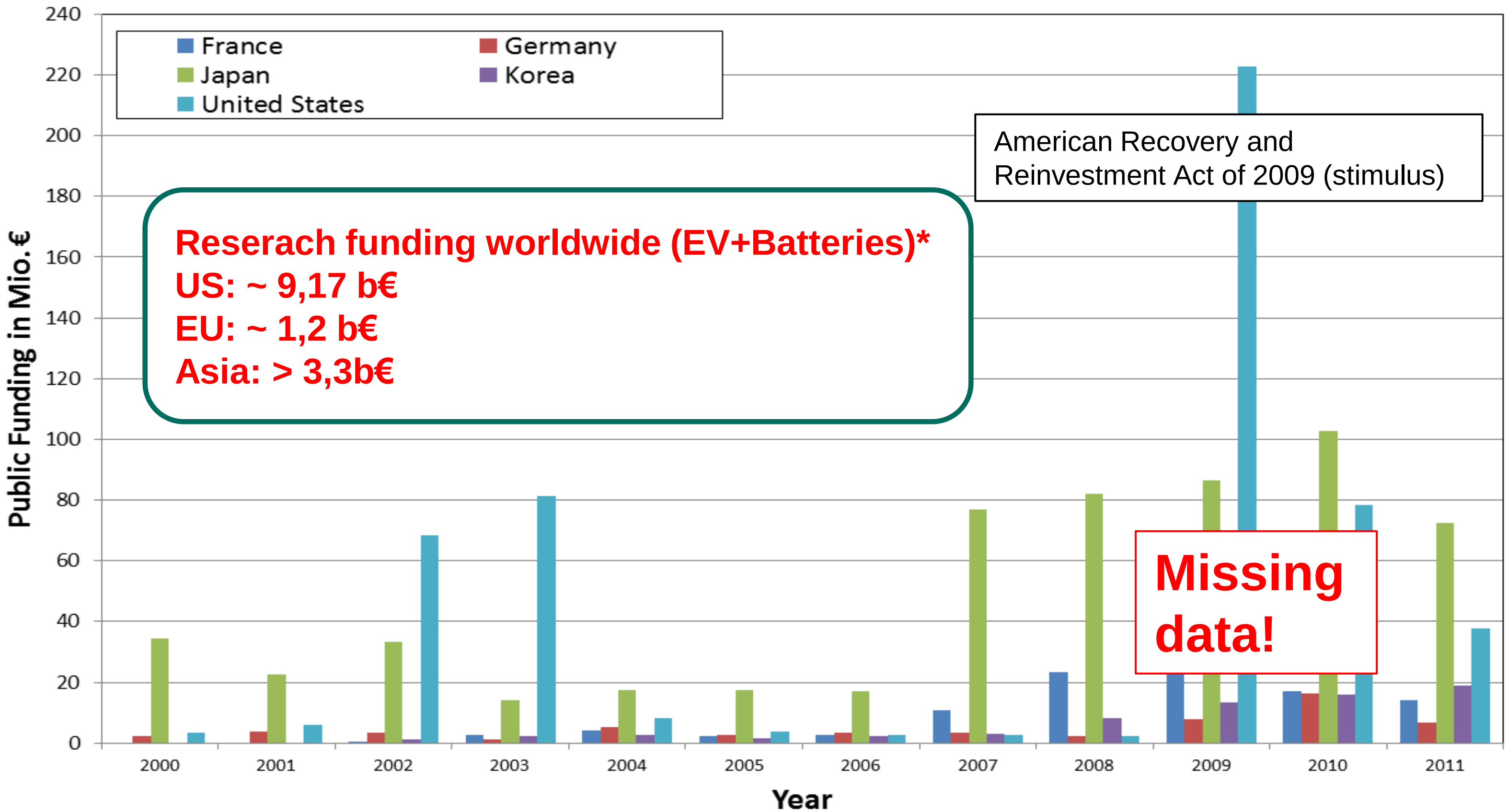
*Most projects are situated in the U.S.

Own figure (based on DOE International Energy Storage Database (beta))

Technology development status

Global research situation?

- Several programs on a international level to address energy storage



Only national public funding restricted on energy storage – EU funding excluded

Own figure source: IEA 2013
*J.M. Tarscon 2011

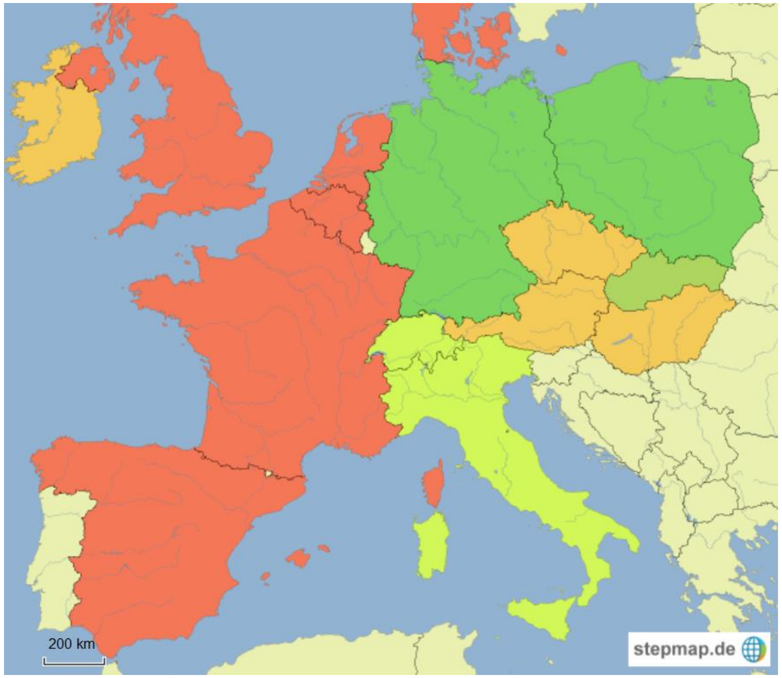
Technology development status

Technology development status out of a **regulation perspective**

- National legal frames related to Energy storage in Europe

European regulatory status

- Several regulatory and market uncertainties
- Energy storage is not defined
- Lack of administrative procedures, to develop energy storage facilities



Yes for gas & electricity | Not directly | Only Gas | No

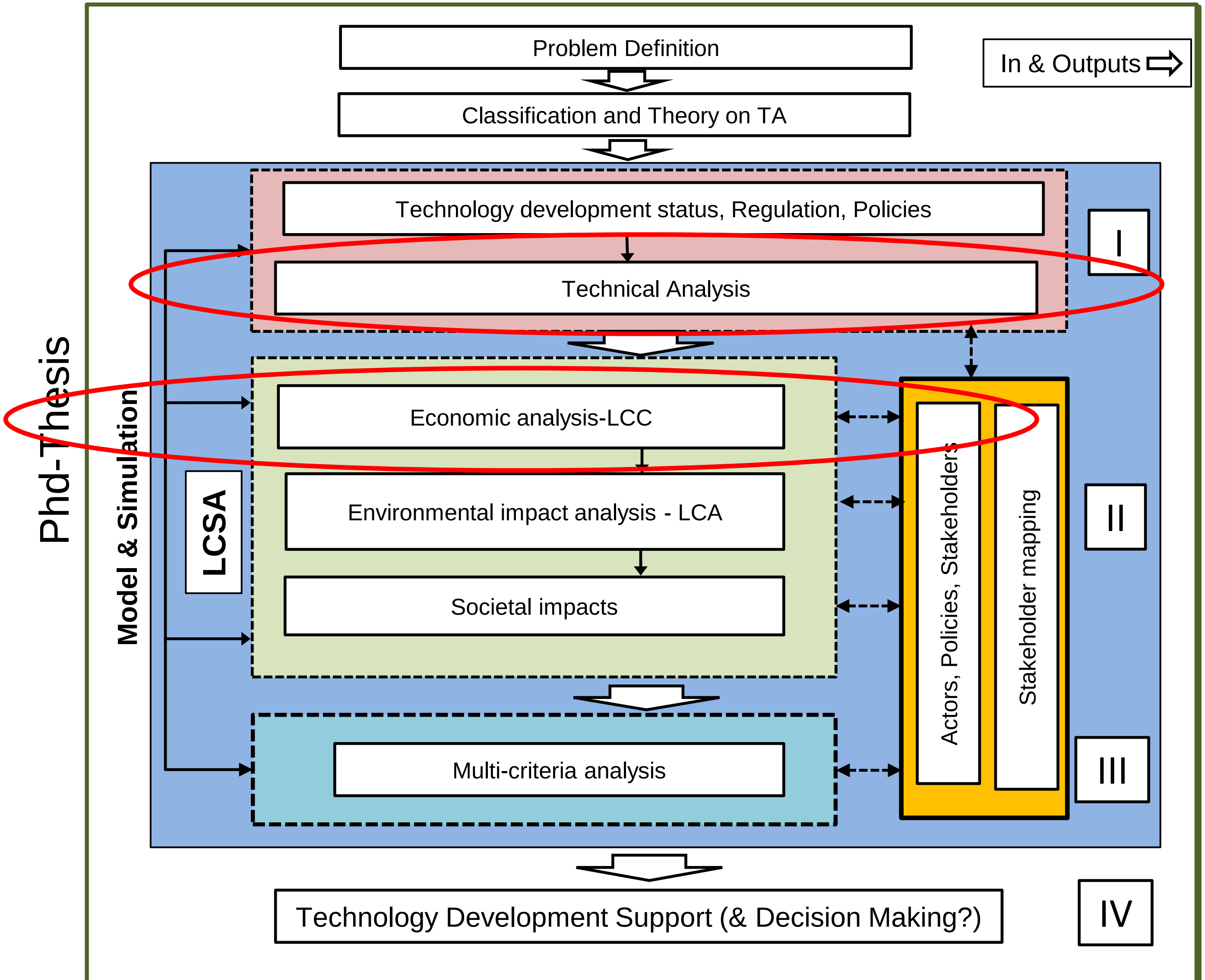
Source: Store-project.eu 2012, store-project.eu 2013, European Commission 2013, Bundesgesetz über die Stromversorgung, ElWOG, EnWG,

Technology development status

First lessons learned

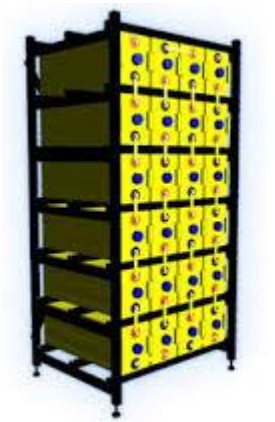
- Several research programs on a international level
- High lack of regulations within Europe and several member countries
- High amount of potentially relevant storage technologies on a demonstration level
- High potential of emerging new chemistries

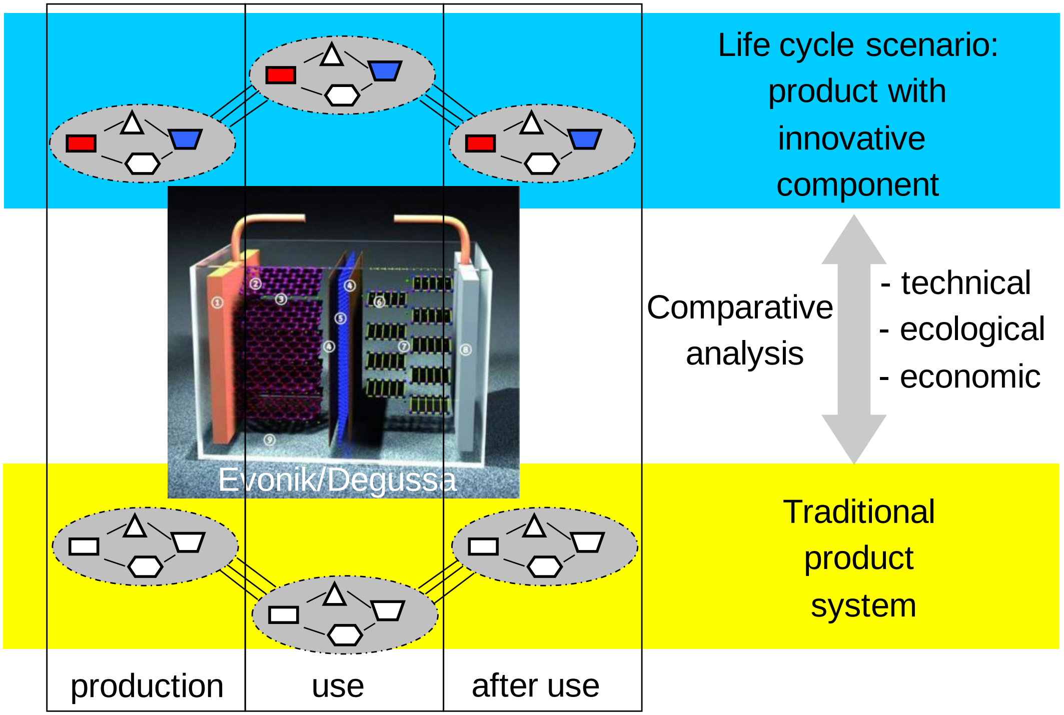
Life Cycle Costs



Life Cycle Costs

- Life cycle approaches as a tool to access technologies in a early development status
  - to compare different technologies over their whole life cycle
  - to identify possible risks

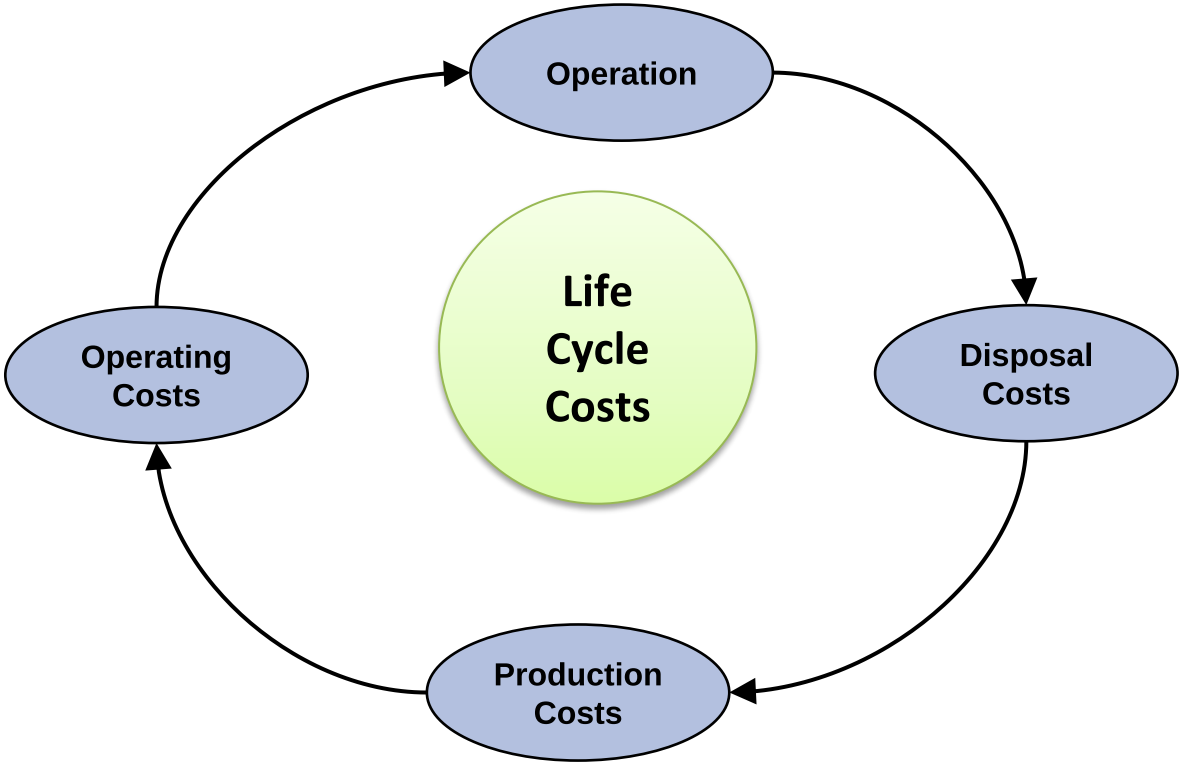




Weil 2012

Life Cycle Costs

- Techno-economic perspective based on conversion costs of energy (€ct./kWh)
- Can help to define cost benchmarks (e.g. influence choice of production materials etc.)



Source: freeenterprise.com

Uncertainty ahead!

Life Cycle Costs

- Multiple application fields possible
- Criteria are the same but priorities are different

Application A

- **Power**
- Energy density
- Lifespan/cost

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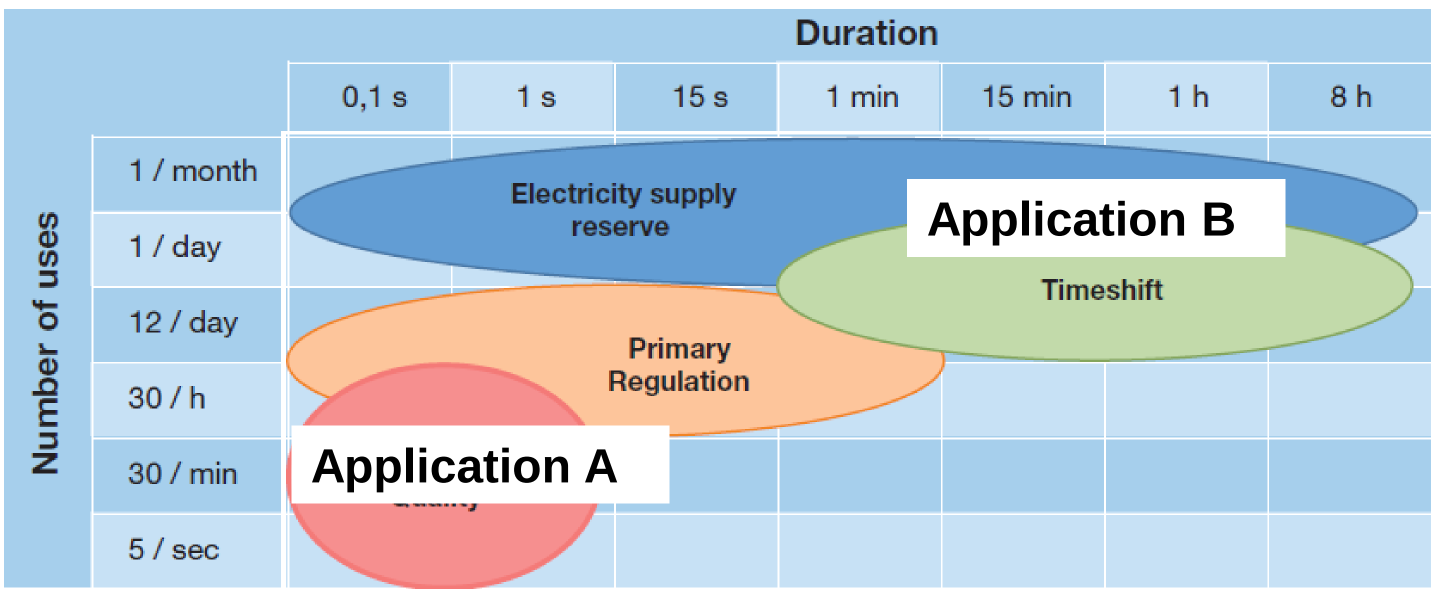
Application B

- **Lifespan / costs**
- Power / Energy density
- Safety



Source: IEC 2011

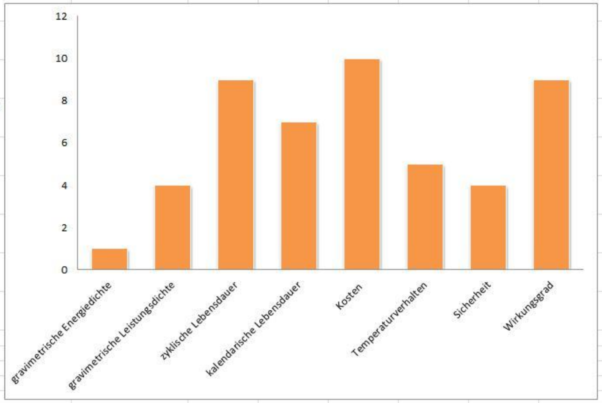
Life Cycle Costs

- Define „typical“ requirements from different stationary applications
- Weighting of properties for batteries based on different application areas

Application	Description	Size [MW]		Duration [h]		Cycles per year		Desired Life Time [a]	
	Yellow marked areas identified for closer research	min	max	min	max	min	max	min	max
	Arbitrage (Energy Time shift)	1	300	2	10	300	500	15	20
	Ancillary Services (Leistungs-Frequenz-Regelung -LFR)	1	10	0,01	4	dep. On kind		15	
	LFR Primary aka Spinning reserve (DTL)	1	10	0,0003	0,25	10.000		16	
Wholesale Energy Services	LFR Secondary aka Spinning reserve (DTL)	5	10	0,25	1	10.000		17	
	LFR Tertiary (DTL)	10	50	1	4	5.000		18	
	Wind Integration: ramp & voltage support	1	10	0.25	1	5000		20	
Renewables Integration	Wind Integration: Off Peak Storage	10							
Stationary T&D support	Photovoltaic Integration: time shift, voltage sag etc.	1							
Transportable T&D support	Urban and rural T&D deferral. Also ISO congestion mgt.	10							
	Urban and rural deferral. Also ISO								

Source: EPRI 2012, Sandia 2012 and others (noch ausarbeiten)

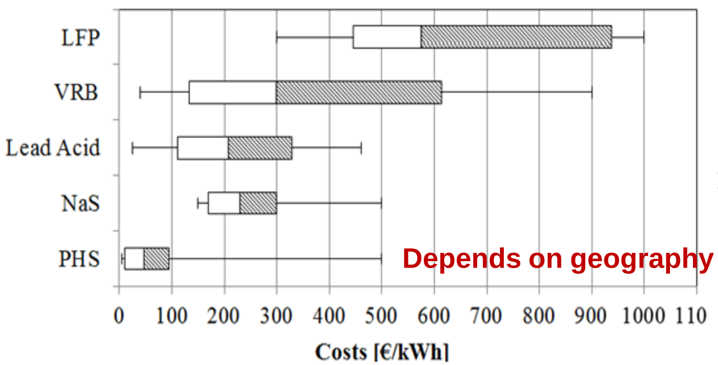
Kriterium	Bewertungsfaktor (1-10)		
gravimetrische Energiedichte	1	92	Wh/kg
gravimetrische Leistungsdichte	4	#DIV/0!	Watt/kg
zyklische Lebensdauer	9	3333,33	Zyklen bis 80% Kapazität
kalendarische Lebensdauer	7	10	Jahre bis 80% Kapazität
Kosten	10	949,048	US$/kWh
Temperaturverhalten	5	72,5	
Sicherheit	4	0	
Wirkungsgrad	9	91,375	% AC-AC

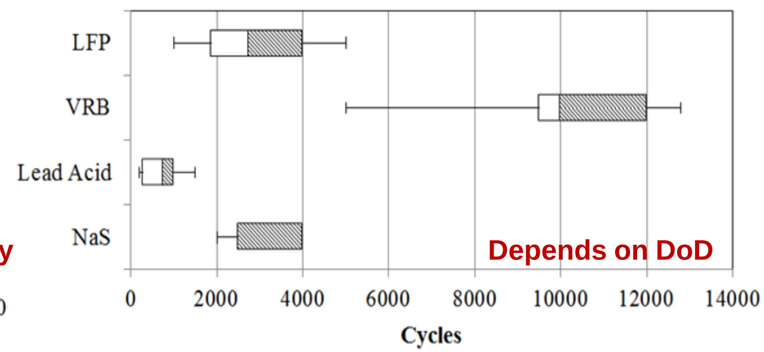


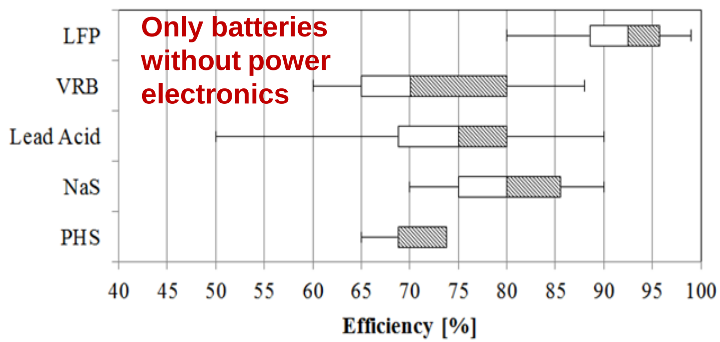
Source: Bachelor thesis Jonas Graus 2013

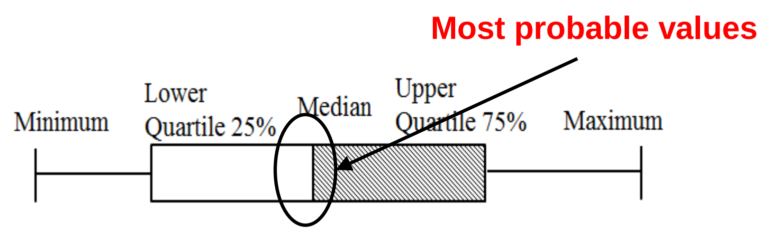
Life Cycle Costs

- Energy storage data base under progress (818 data points)
- Additional dates will be provided
- Gives overview about paramater deviations







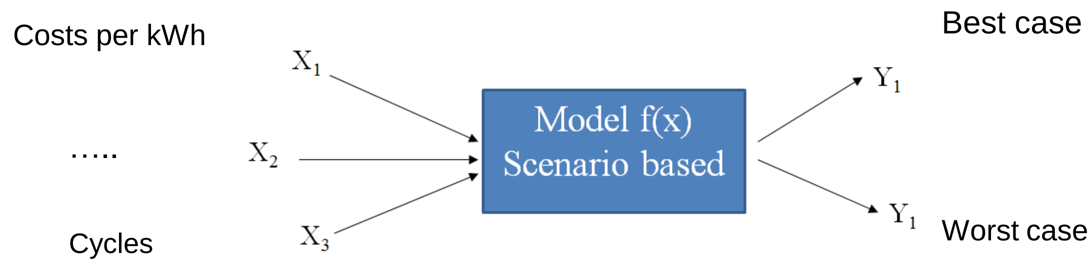


LFP=Lithium-Iron-Phosphate VRB=Vanadium-Redox-Flow
NaS=Sodium-Sulfur (NaS) PHS=Pumped Hydro Storage

Selection of some relevant parameters

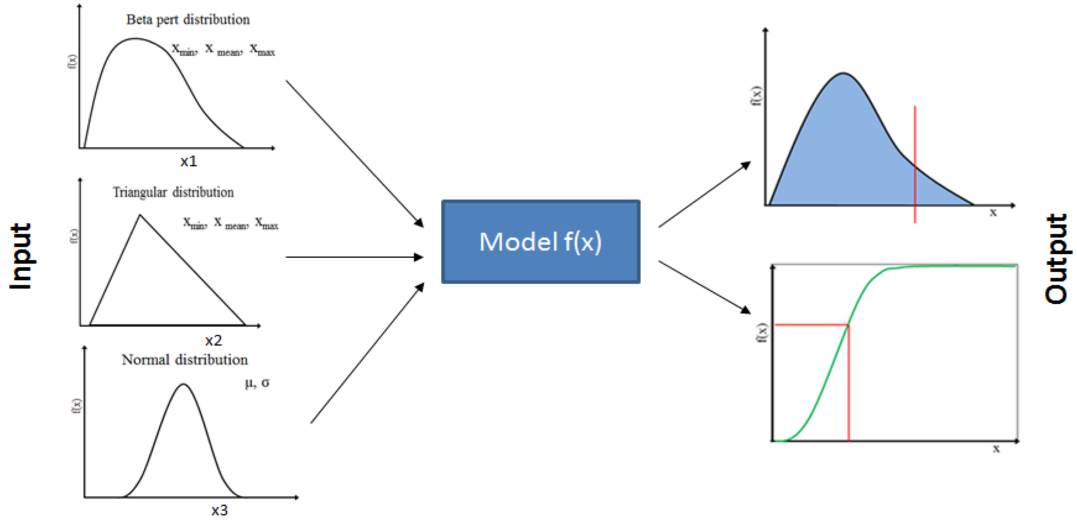
Life Cycle Costs

Analytical methods



- No information about variance/distribution
- High complexity with increasing number of assumptions

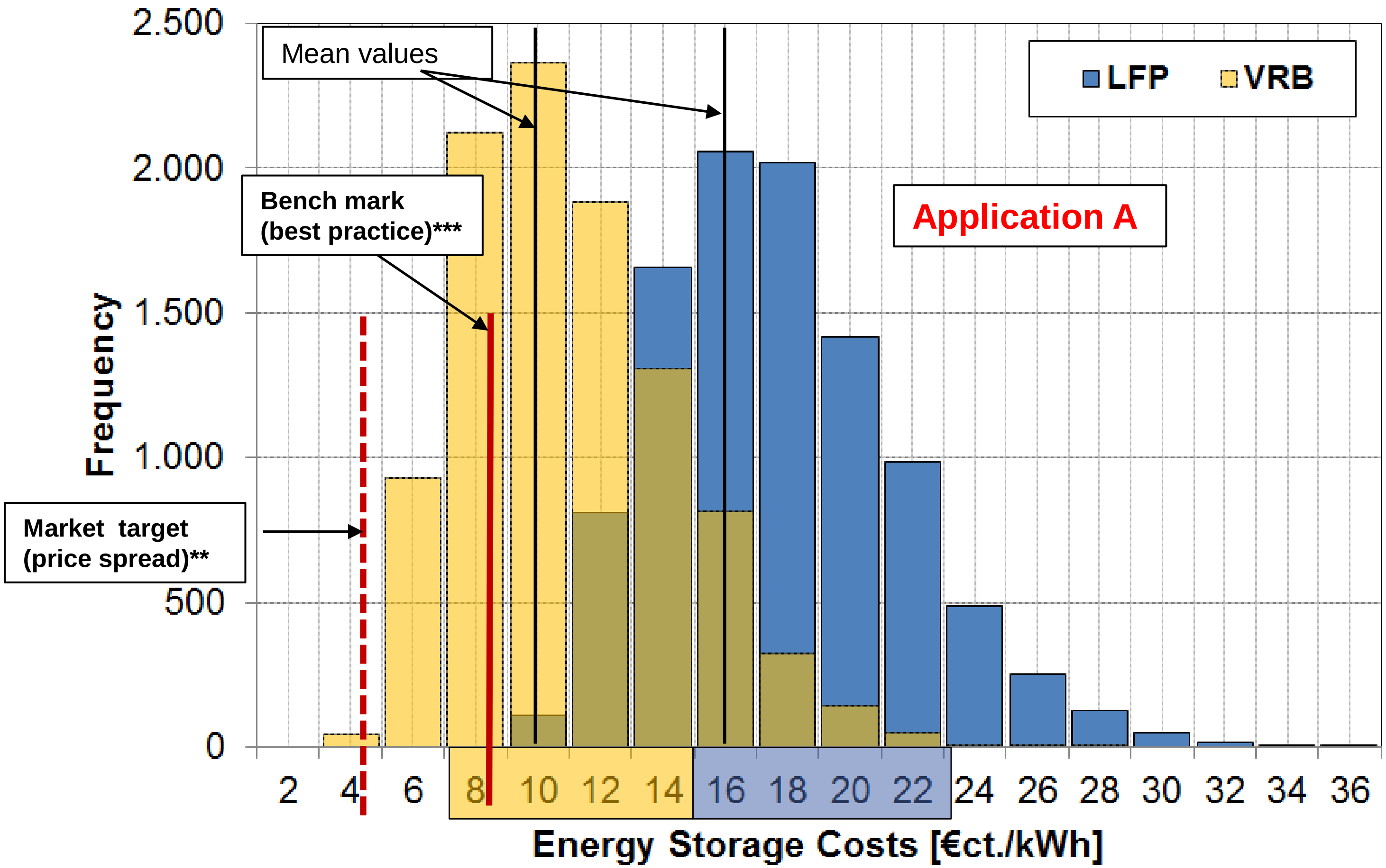
Probabilistic methods



Can solve complex analytical problems on a simplified numerical base to show bandwiths and uncertainties of cost assumptions

Life Cycle Costs

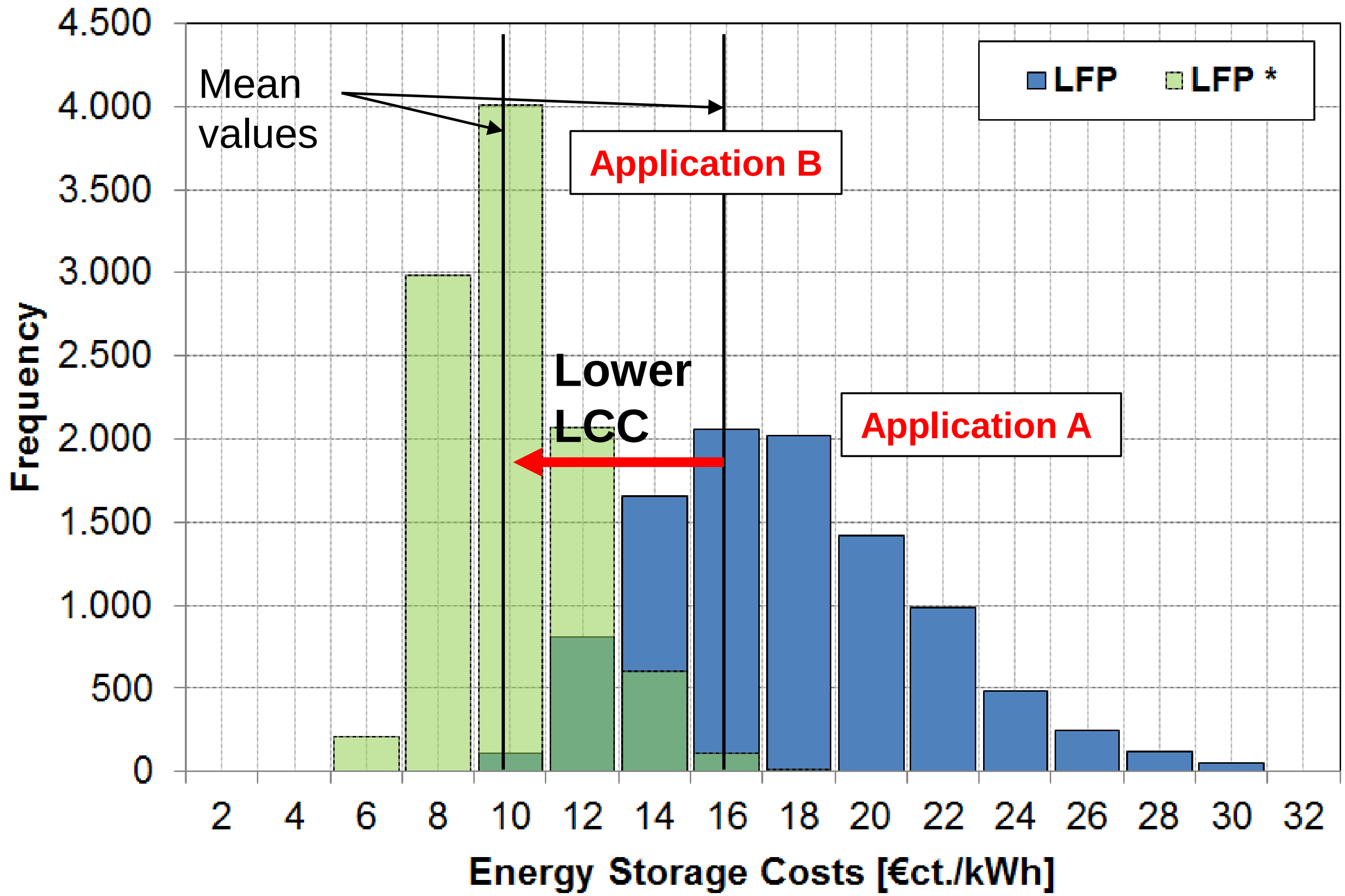
- Comparison of LCCs of **two different technologies**



*Carried out for Lithium-Iron Phosphate/$LiFePO_4$ – LFP and All-Vanadium-Redox-Flow-Battery
** EPEX 2012 average spread off- on peak, ***PbA Battery

Life Cycle Costs

- Example for **one Technology** and **two application fields**



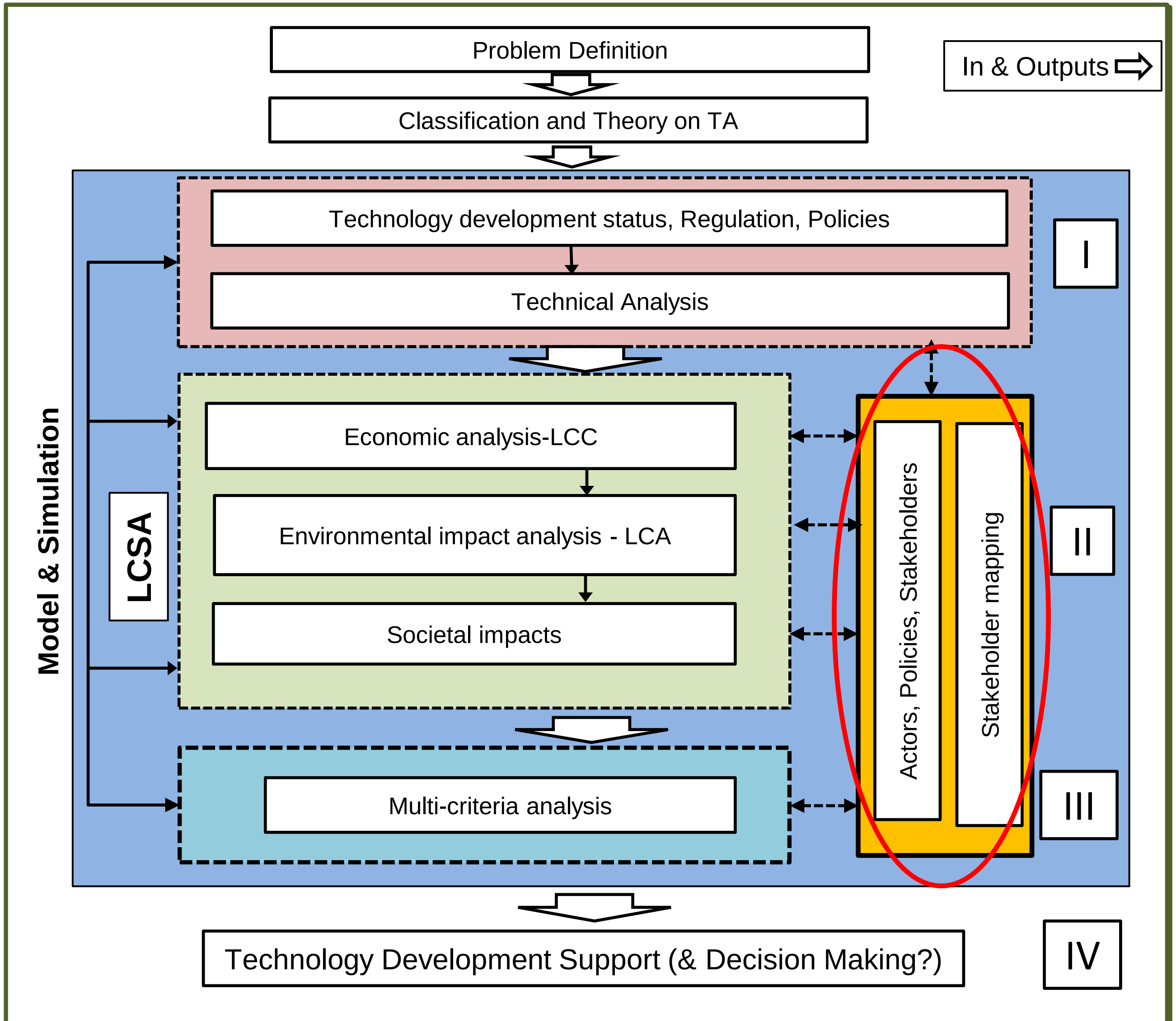
*Carried out for Lithium-Iron Phosphate/$LiFePO_4$ – LFP

Life Cycle Costs

First lessons learned from the LCC

- Gives information **about tendency** of costs and can help to define **needed targets**
- Probabilistic models **can help to minimize risks and uncertainties** for future investment or technology developments
- Data base can also be used for Life Cycle Assessment

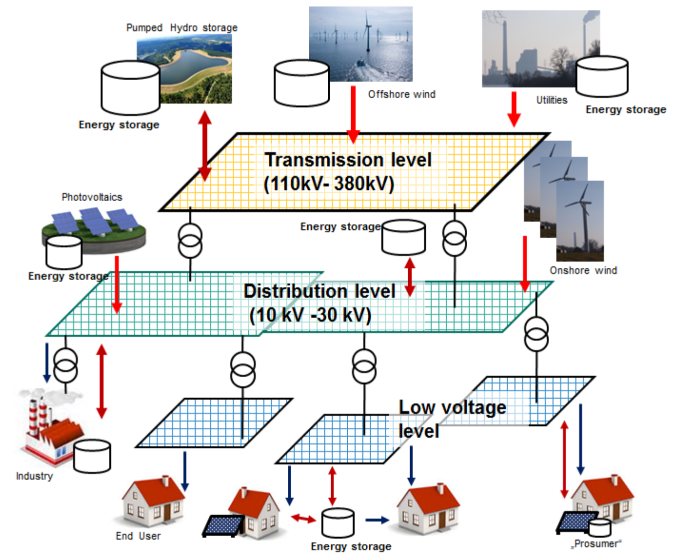
Introduction



Stakeholders

- **Vertically integrated nature** of storage technologies within generation, network and demand, requiring **inter-sectoral** perspectives

- Why explore the agency of stakeholders?
  - Identify possible market failures which represent a barrier for market diffusion
  - Identify favourable technology properties & application fields
  - And several other reasons

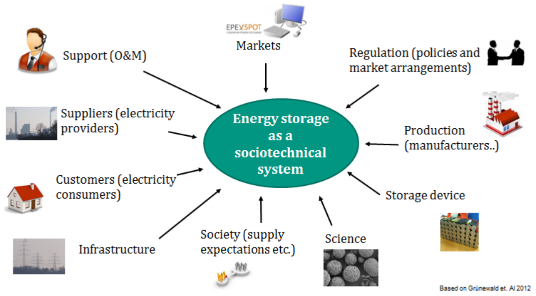


Inspired by Döetsch 2012

- Often **underestimated** factor in engineering modeling approaches

Stakeholders

- Dimensions of socio-technological regime and corresponding stakeholder groups in energy storage



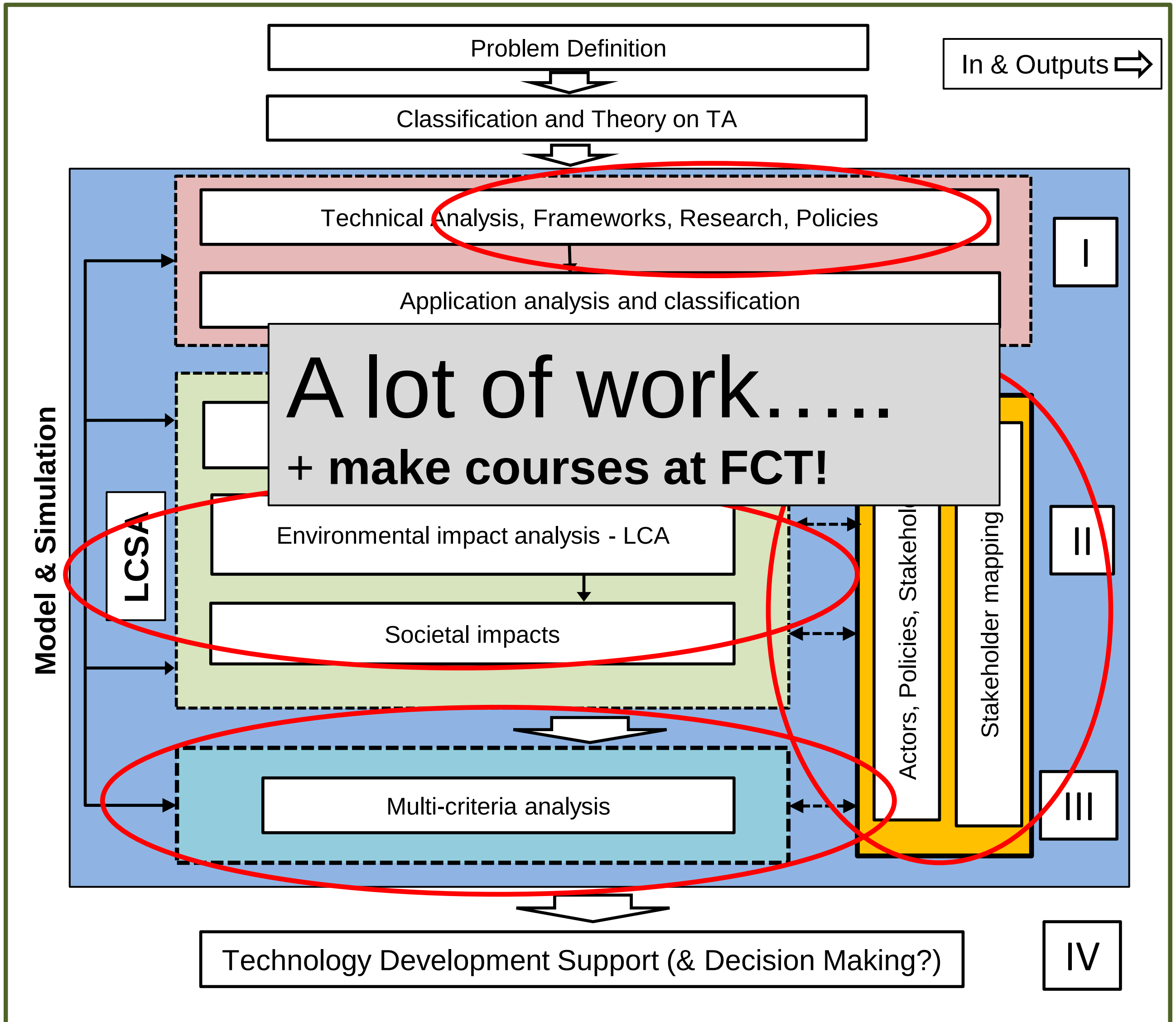
ST-regime dimension	Stakeholder group
Industry	Utility companies, networks operators, developers
Technology	Developers, Academia
Infrastructure	Transmission & Distribution System operators (TSO &DSO), utilities, academia
Policy	Policy makers, regulators, academia
Culture	Society
Science	Academia, Industry
Market User preferences	Utilities, TSO´s, DSO´s, demand Aggregators, End users,
……	……..

Based on Grünewald et. Al 2012

Stakeholders

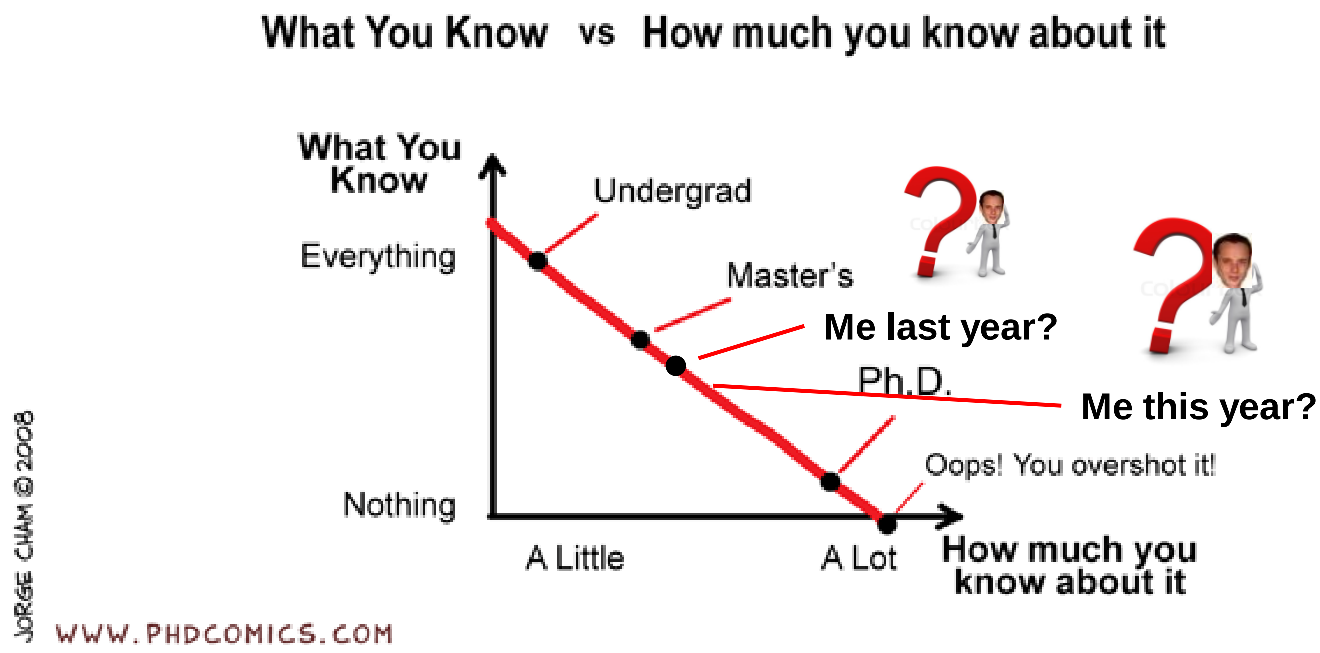
- How to integrate stakeholders?
- Organize international Workshop on CTA/Energy Storage?
  - Helps to generate new ideas or to maybe disperse actual approach
  - Who should be invited? Where, when? Funding?
- Carry out additional Interviews
  - Mainly with research related stakeholders?
- Make a preeliminary survey
  - Directed to industry or infrastructure related stakeholders?
- Fuzzy Logic to quantify qualitative stakeholder perspective**?**
  - Could be restrictive for whole approach

Future steps



A lot of work…..

+ **make courses at FCT!**



Muito Obrigado!
Perguntas?

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