FUTURE TRENDS OF THE AUTOMOTIVE LI-ION BATTERY SUPPLY CHAIN IN GERMANY

DYNAMIC EFFECTS ON RAW MATERIALS AND EMPLOYMENT

Tim Hettesheimer

Christian Lerch

Fraunhofer Institute for Systems and Innovations Research ISI, Karlsruhe, Germany

Cambridge, 2013/07/24

31st International Conference of the System Dynamics Society

EMOTOR

regional eco mobility 2030

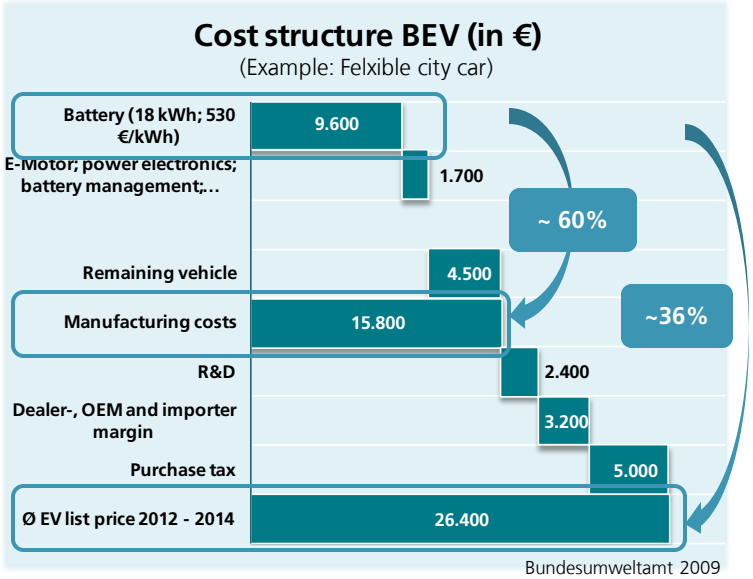
Fraunhofer ISI

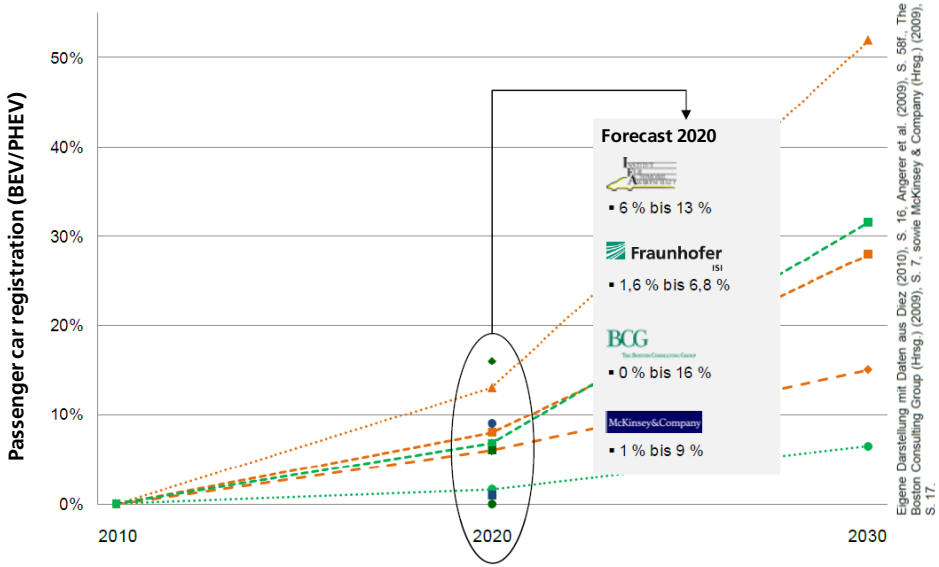
Content

- Initial situation and research questions
- Dynamic hypothesis
- Results
- Conclusions

Fraunhofer ISI

Initial situation- Importance of li-ion batteries and their potential of growth





- Battery is key component of electric vehicles
- Determine technical potential of the final car (speed, range,..)
- Represent major part of costs
- Contains critical raw materials

- Great uncertainty regarding future market share of EVs
- But a growing share of EV is expected

Difficult to predict the existing economic potential, the need of raw materials and recycling activities and the development of employment effects

Fraunhofer ISI

Research questions and aim of the simulation

- **Research questions for the system dynamics model**
  - How will the market demand for batteries develop in the upcoming decades?
  - Will there be a growing scarcity of critical raw materials?
  - Constitutes the availability of qualified employees a problem?

- **Aim of this dynamic analysis**

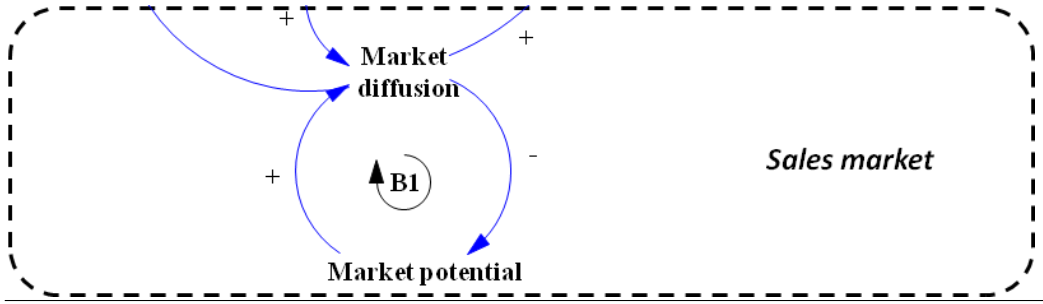
  Build up a first simulation model, which demonstrates the development of the automotive Li-ion battery supply chain in Germany over the next decades and to illustrate its impact on the need for raw materials and skilled employees.

Fraunhofer ISI

Sales market - Dynamic hypotheses for the battery supply chain model

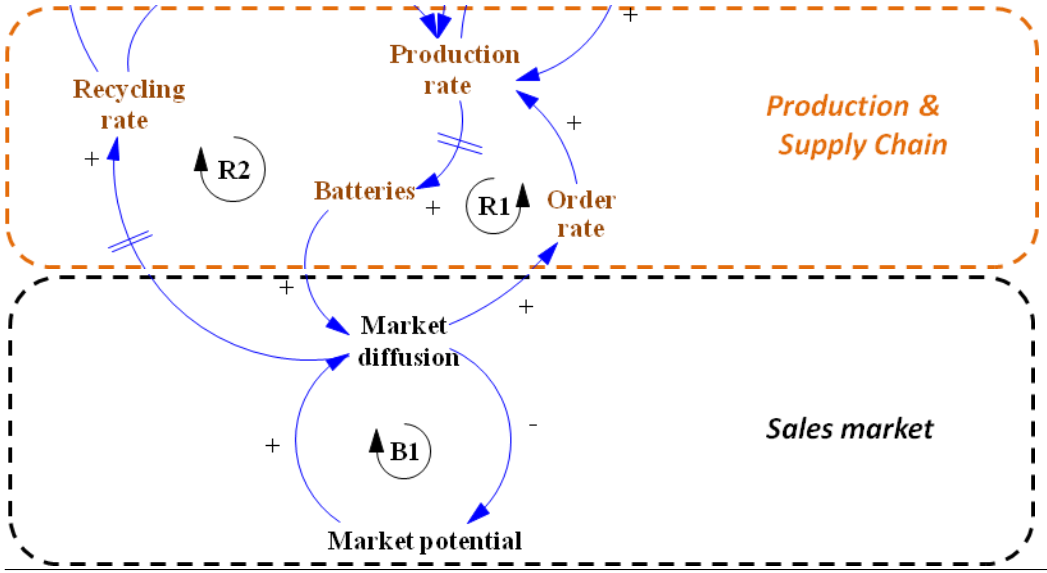
- The “Sales market” triggers the development in the other three sub-systems by the customers demand for electric vehicles
- Bass's diffusion model for demand development was used as initial point for the model and modified to take repeat purchases into consideration (adopted from Sterman 2000; Bass 1969)

- Three different types of electrically driven cars: The hybrid electric vehicle (HEV ~ 3-5 kWh), the plug-in hybrid electric vehicles (PHEV~10-15 kWh) and the battery electric vehicles (BEV~>20 kWh)
- The final output of the sales market are the total number of vehicles sold multiplied with their battery capacity, which results in the total demand for battery capacity in kWh as input for the following sub-systems
- Two specifics: Obsolete vehicles are the input for aged battery recycling. HEV cannot be repurchased

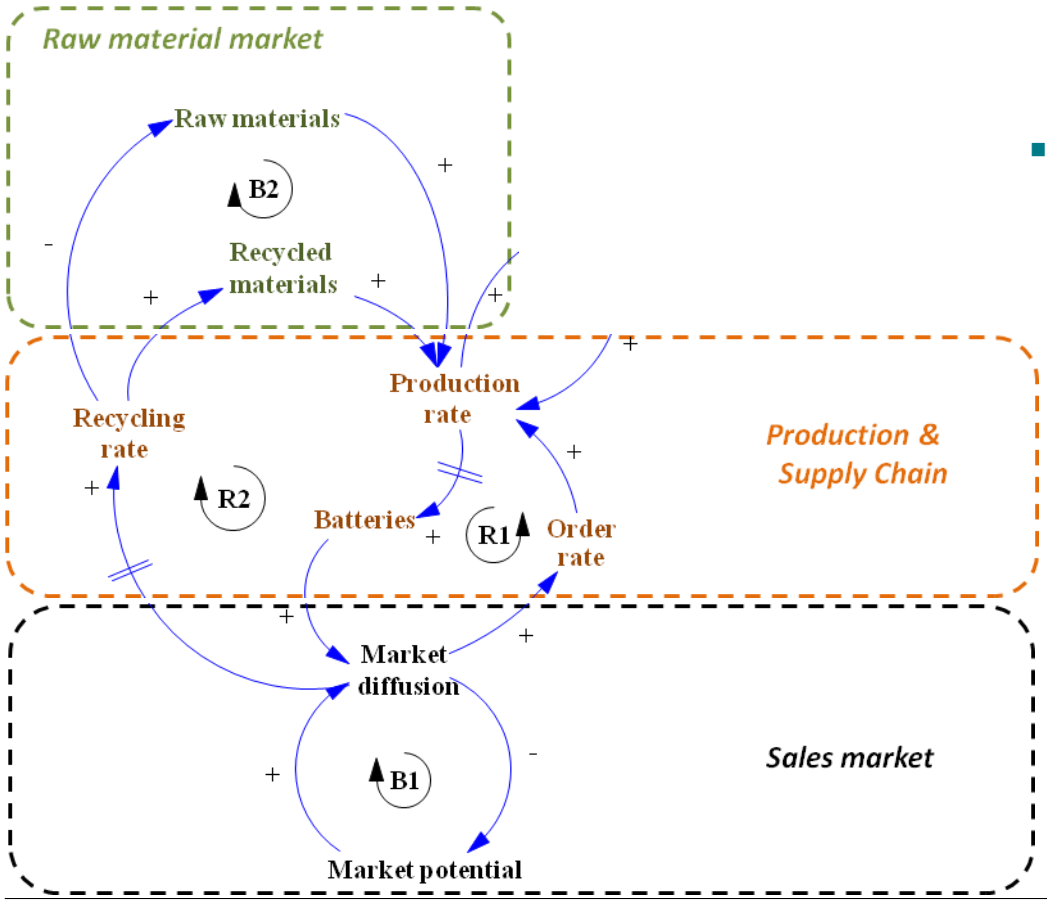


Production & Supply Chain- Dynamic hypotheses for the battery supply chain model

- The sub-system “Production & supply chain” has a common structure (e.g. see Sterman 2000) and is means to an end where raw materials, employees and battery demand come together
- The reinforcing loop (R1) demonstrates the interconnection between the demand for batteries and the production rate. Depending on the progress of the market diffusion, the order rate as well as the production rate increase over time
- After a long time of maybe a few years the obsolete battery gets recycled. Consequently, the growth of the market diffusion leads to a few year time-delayed increase of the recycling rate.



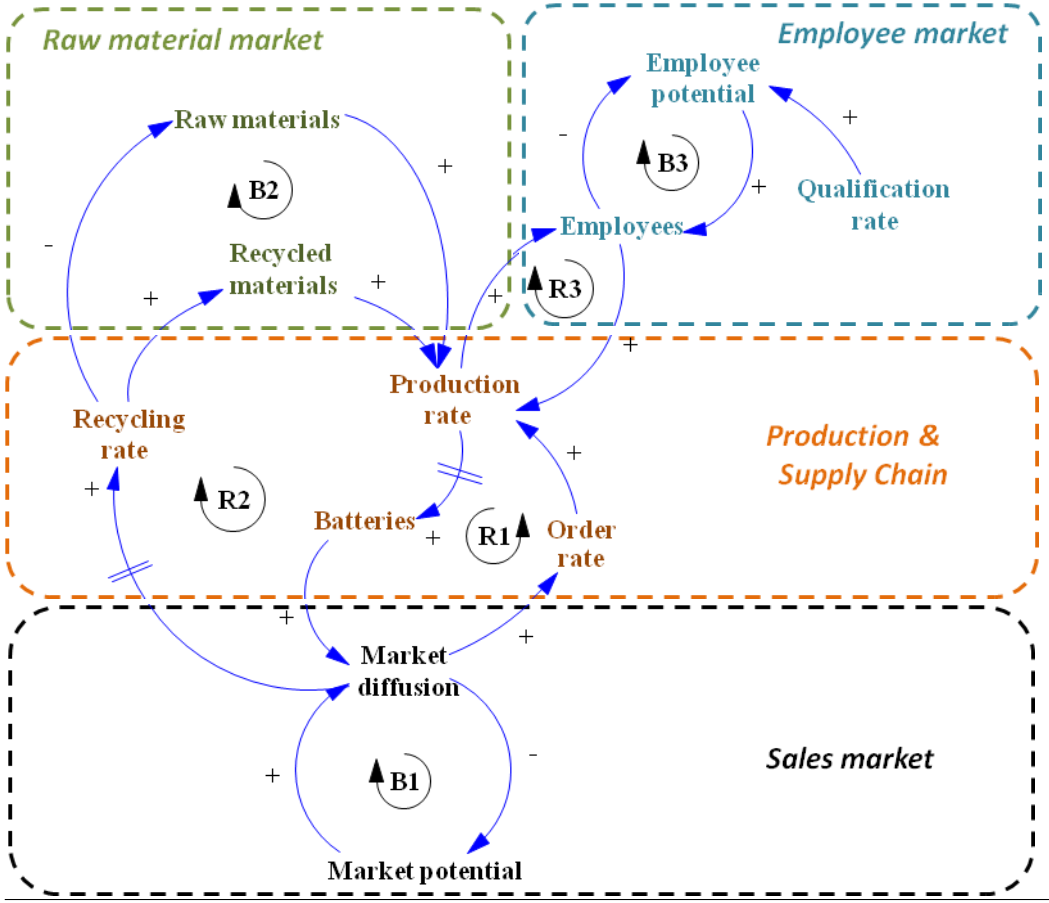
Raw material market - Dynamic hypotheses for the battery supply chain model



- A higher recycling rate leads on the one hand to a higher availability of recycled materials and on the other hand to a decreasing demand for new raw materials
- While recycled materials are pushed by an increasing production rate (R2), the need for raw materials is slowed down by a higher recycling rate (B2)

Fraunhofer ISI

Employee market- Dynamic hypotheses for the battery supply chain model



- The employee market is directly linked with the production rate.
- The growth of the production rate leads to an increase of the demand for employees (R3) and hence, to an exhaustion of the employee potential (B3)
- Possibility to raise the pool of qualified persons by modifying the external driven qualification rate.

Fraunhofer ISI

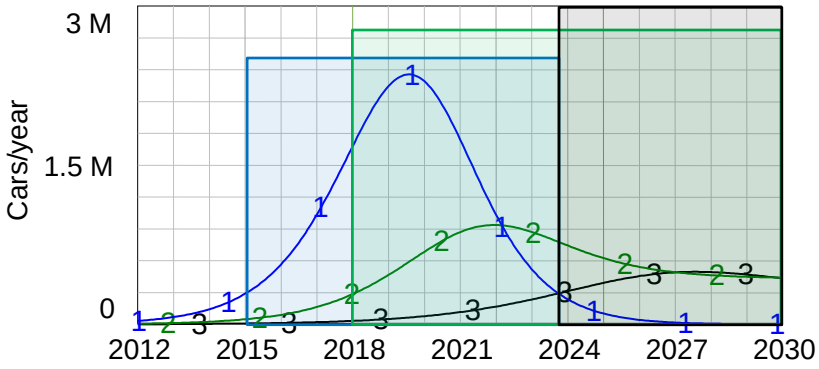
Results-Sales market

Diffusion of electrical vehicles and demand for li-ion batteries

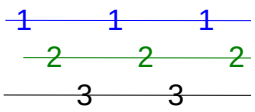
Fraunhofer ISI

Diffusion of electric vehicles and their impact on li-ion battery demand

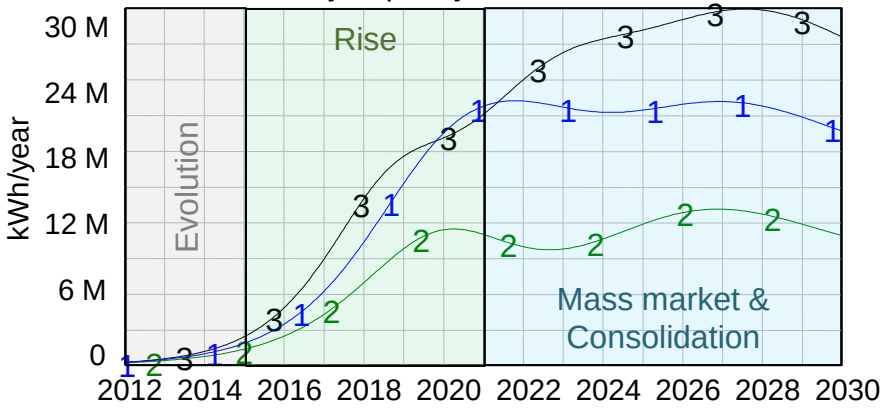
Diffusion of EV in scenario "Base run"



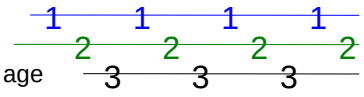
Production volume HEV : Base run
Production volume PHEV : Base run
Production volume BEV : Base run



Demand for battery capacity in kWh in different scenarios



Demand battery capacity kWh : Base run
Demand battery capacity kWh : Oil age
Demand battery capacity kWh : Electrical age

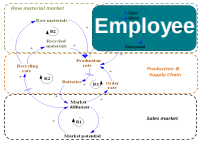


- Diffusion of the HEV shows the fastest growing curve→ lower costs for HEV batteries
- Peak between 2019 and 2020 before they steadily deplete
- PHEV are growing more slowly and peak in 2022.
- BEV is beginning to rise at the same time when the HEV declines. Develops slowly but constantly

- In all scenarios the demand follows the rise of the Hybrid electric vehicles but while their number declines, the demand for batteries stays on comparable level
- The lower number of PHEV and BEV is able to compensate the effect of falling demand for HEV
- Three stages can be identified independently from scenarios

Fraunhofer ISI

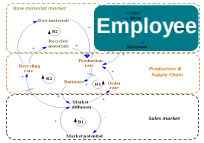
Results-Employee market



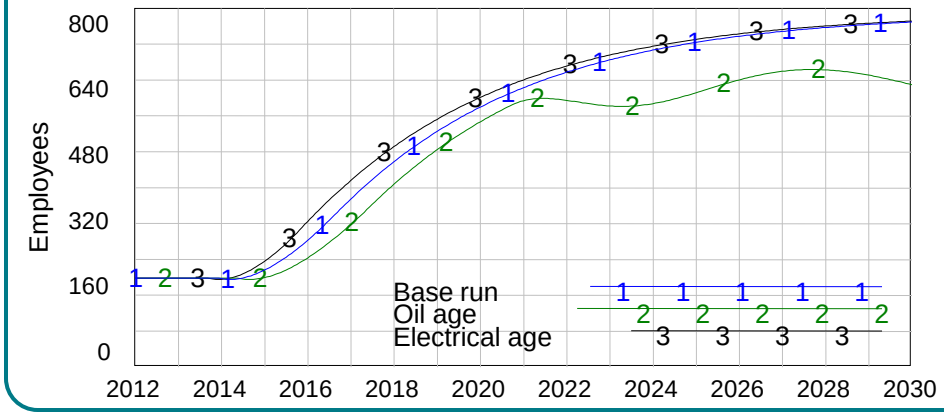
Impact on the availibility of qualified employees

Fraunhofer ISI

Employee availability

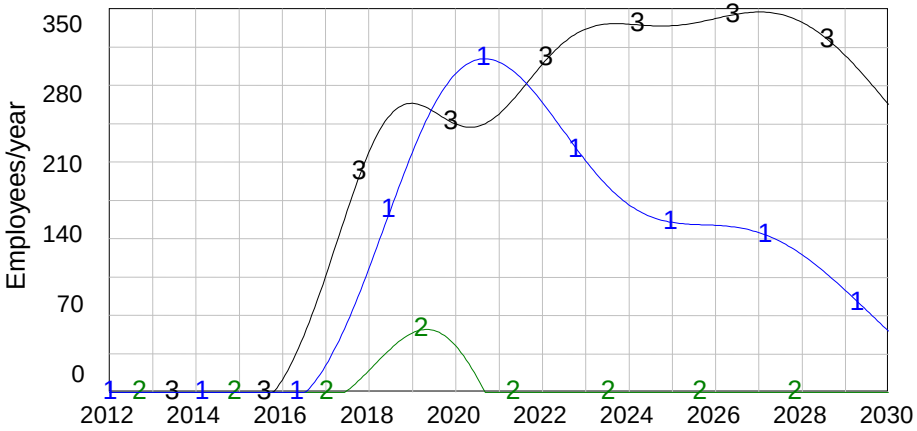


Direct cell staff in different scenarios



- Employees in the “Oil age (OA)” scenario follow the demand for batteries
- Employee rate in the “Base run (BR)” and “Electrical age (EA)” scenarios rise faster
- The two scenarios converge to an amount of ~800 employees.

Gap in cell staff employment

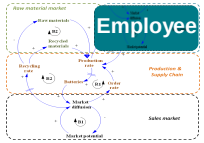


- All scenarios reveal gaps in the employment rate
- In the OA only a small gap appears between 2017 and 2021
- Stays on a high level till 2030 for the EA
- In the BR the gap declines until 2030

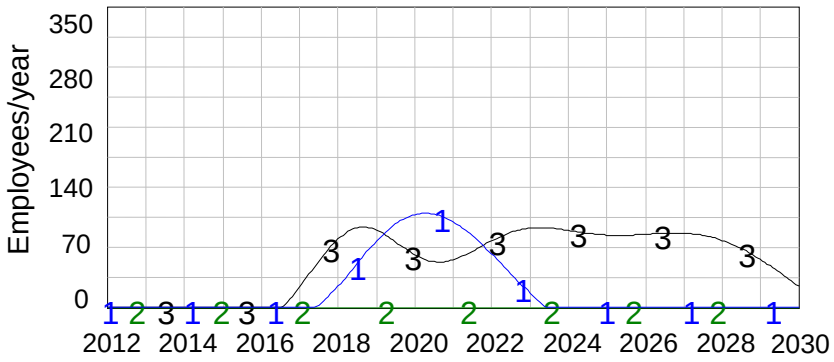
➢ **The demand for employees cannot be served for the BR and the EA scenario and only partly for the OA scenario**

Fraunhofer ISI

Measures to avoid the scarcity of workforce



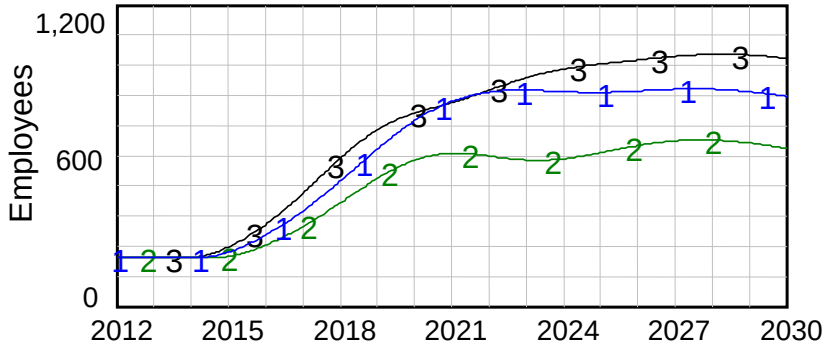
Measure 1: Higher productivity



Base run with higher productivity
Oil age with higher productivity
Electrical age with higher productivity

- Increased “scale factor productivity” from 0.1 to 0.5
- Gap in recruitment can be cleared in the OA scenario
- The deficit in the scenarios BR and EA can be reduced by a third
- Nevertheless there still exists a deficit in those scenarios

Measure 2: Increased qualification rate



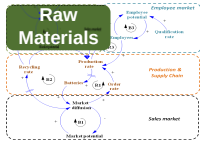
Base run with higher qualification rate
Oil age with higher qualification rate
Electrical age with higher qualification rate

- Increased qualification rate from 4 % to 6,25 % (150 %)
- OA scenario shows same behaviour as before
- The BR and EA scenario now follow the demand for batteries

➢ **While a higher productivity only can reduce the scarcity in employment (BR,EA), a higher qualification rate seems to be a adequate measure to completely avoid it**

Fraunhofer ISI

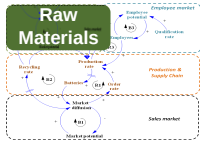
Results-Raw material market



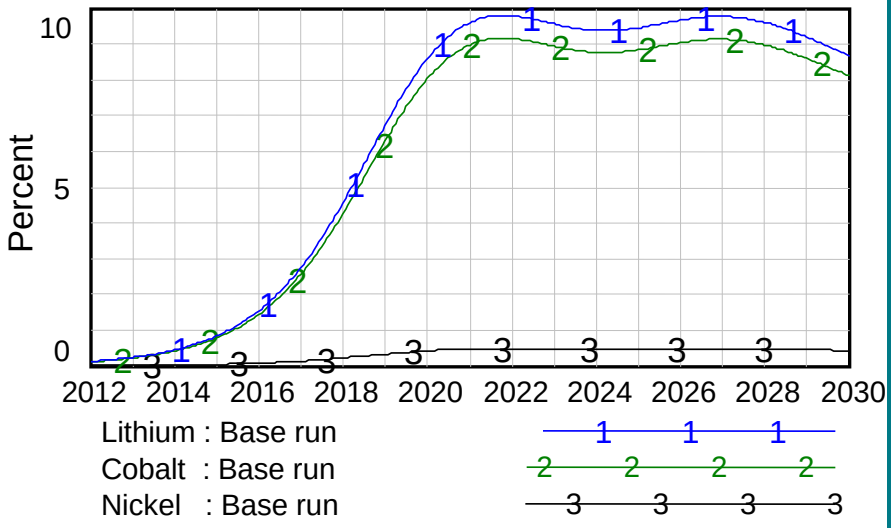
Demand for raw materials and ecological and economical effects of recycling measures

Fraunhofer ISI

Critical raw materials



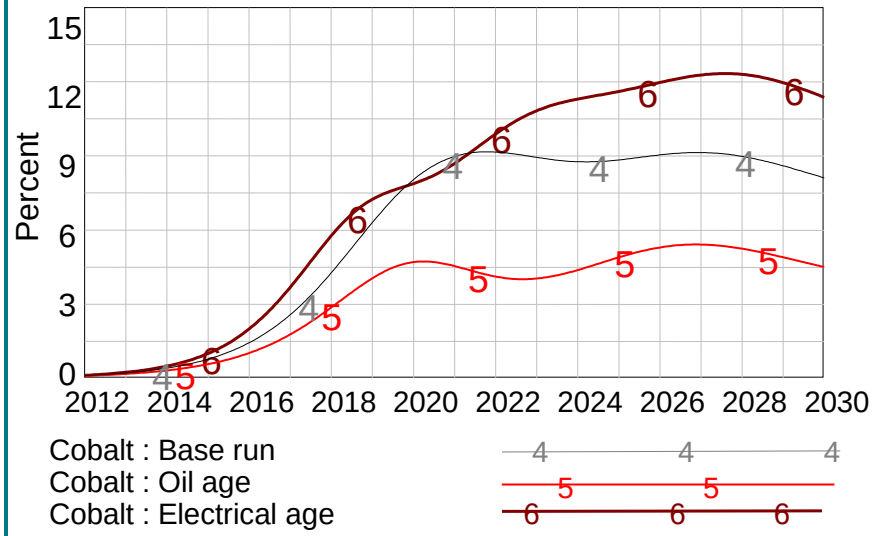
Share of required material in its annual global mining



- The total share of lithium needed to produce the desired amount of kWh only for Germany constitute ~10 % of global production in 2012
- The share of required cobalt is with ~ 9 % almost as high
- Nickel only plays a minor role

➢ Cobalt was categorized as critical raw material by the European Nation

Share of required cobalt in annual mining

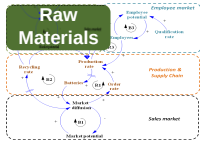


- The share of cobalt in the OA scenario ~ 5 %
- In the EA scenario the share even lies over 12 %

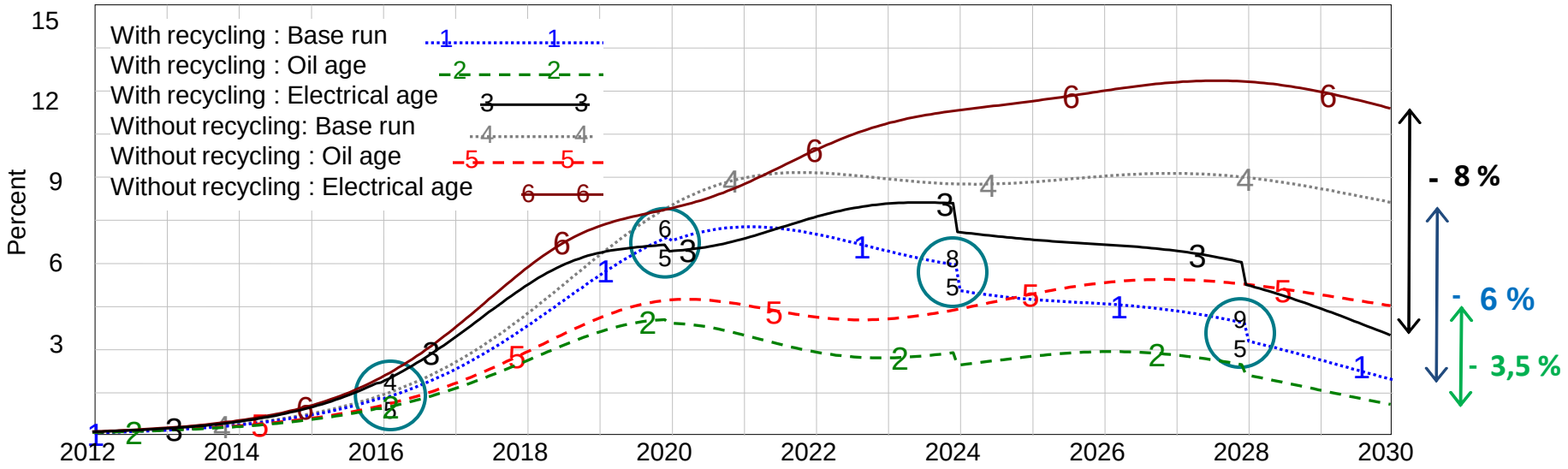
➢ **Based on 2012 cobalt mining rate a global shortage seems probable**

Fraunhofer ISI

Effect of recycling by collecting rates on the share of required cobalt



Share of required cobalt with collecting steps

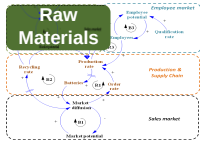


- Following the EU's "battery directive 2006/66/ec" and predicts a development of recycling rates after 2016 in the same manner
- Collecting rates are increased in 2016, 2020, 2024 and 2028
- The share of required material can be reduced by using recycled materials :
  - BR scenario by 6 % (2030)
  - OA scenario by 3,5 % (2030)
  - EA scenario by 8 % (2030)

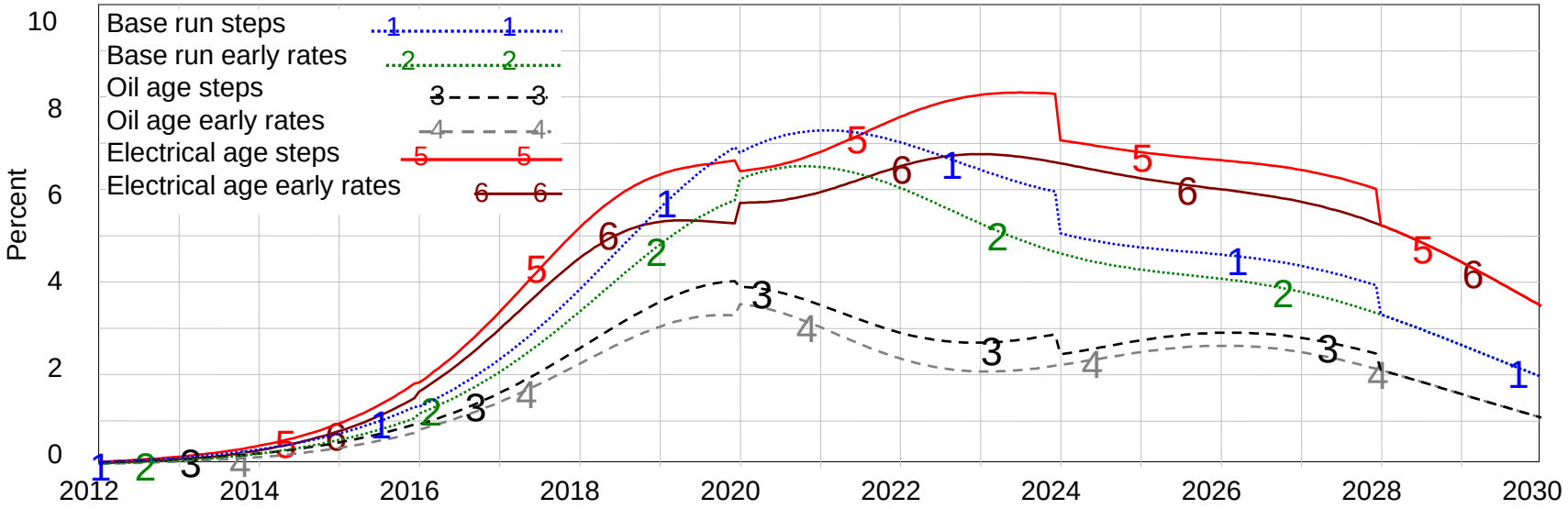
Depending on the scenario, the demand for raw materials may be reduced up to 75 % until the year of 2030 by means of recycling activities

Fraunhofer ISI

Effect of an early high recycling on the share of required cobalt



Share of required cobalt with and without early recycling rates

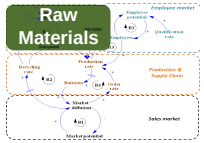


- Early recycling is starting in the year 2012 with a recycling rate of 95 %
- The early recycling concept leads to a lower share of cobalt in the middle of the observed period
- After 2028 the curves are identical due to the same collecting rate

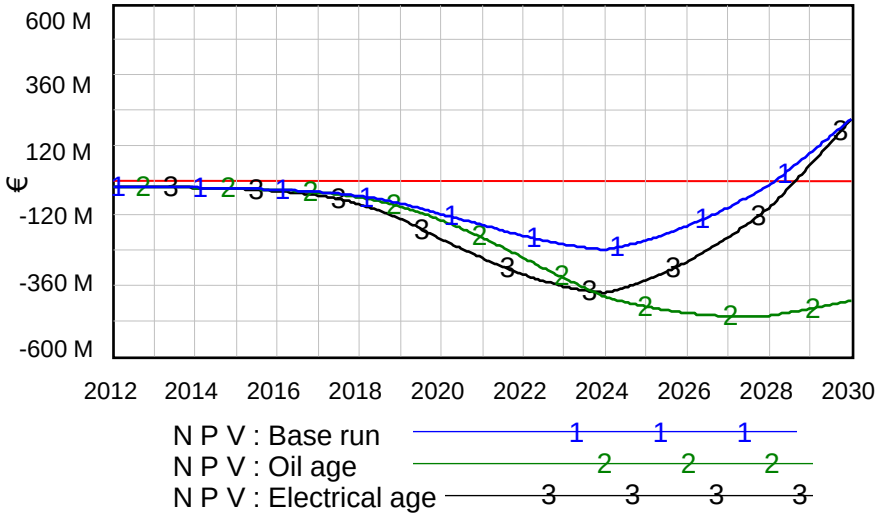
Both recycling policies make ecologically sense, while an early high recycling quote can reduce the required raw material during the stage of consolidation remarkably

Fraunhofer ISI

Economical potential of battery recycling



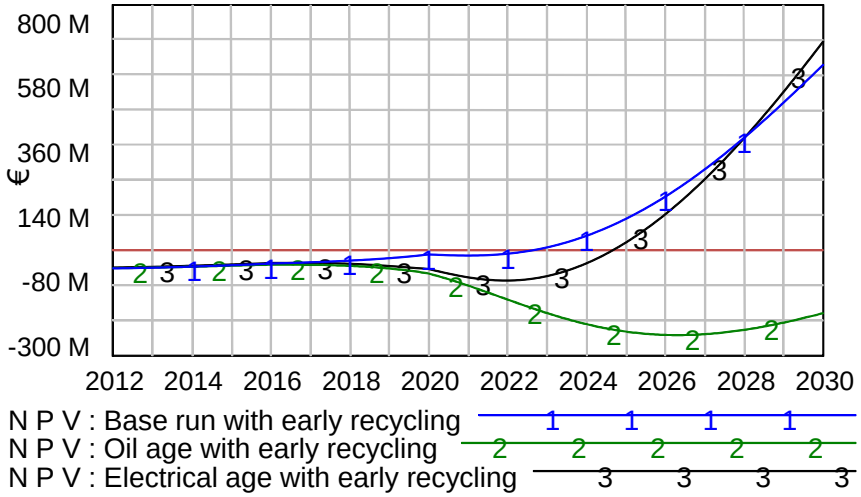
Net present value of recycling with collecting steps



- NPV in BR scenario stays negative until 2028
- NPV of the EA scenario declines faster than in the BR scenario → Higher initial number of HEV
- NPV reaches the same value in 2030 like in the BR scenario and show stronger growth
- NPV of the OA scenario stays constantly negative

➢ **Recycling is profitable in the long term (BR and EA)**

Net present value for early high recycling



- NPV in the BR scenario becomes positive in 2023
- NPV of EA scenario overcomes the BR curve in 2028
- NPV of OA scenario stays negative

An early introduction of high recycling quotes rises the economic potential of battery production extremely and is even economical in the mid-term

Fraunhofer ISI

Conclusiones

The model..

- is able to show the interconnections and bottlenecks in the system
- evaluates the impacts and dynamic effects of different policies to avoid these bottlenecks

Employees

- The employment gap in cell production may be slowed down by increasing the productivity level
- The gap may be closed completely by increasing the qualification rate up to 150 % compared to the value of 2012

Raw Materials and recycling

- Depending on the scenario, the demand for raw materials may be reduced up to 50 % in the year 2025 and 75 % until the year 2030 by means of recycling activities
- An early introduction of high recycling quotes rises the economic potential of battery production extremely

Fraunhofer ISI

Thank you for your attention!

Contact:
Tim Hettesheimer
Fraunhofer Institute ISI
Tim.Hettesheimer@isi.fraunhofer.de

Fraunhofer ISI