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The Need for Lithium – an Upcoming Problem for Electric Vehicles?

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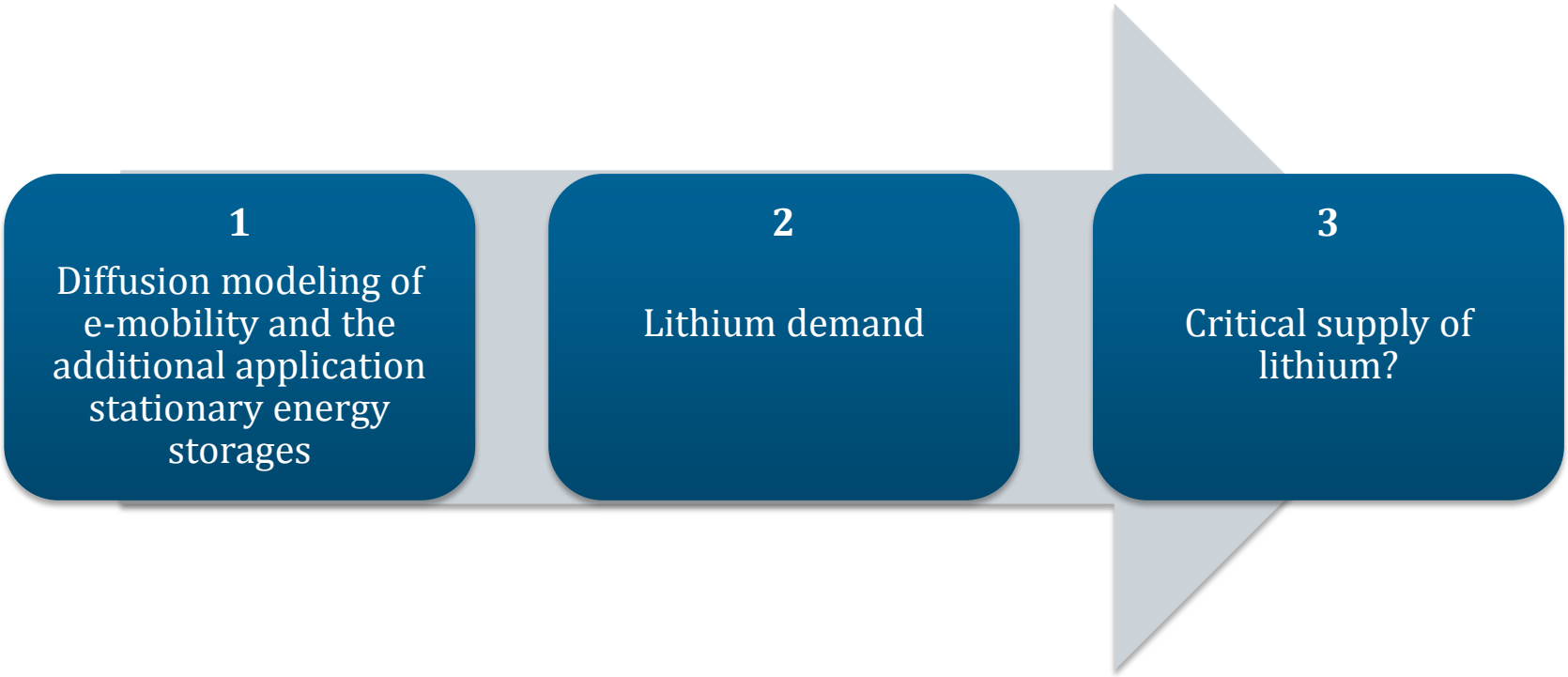
Outline



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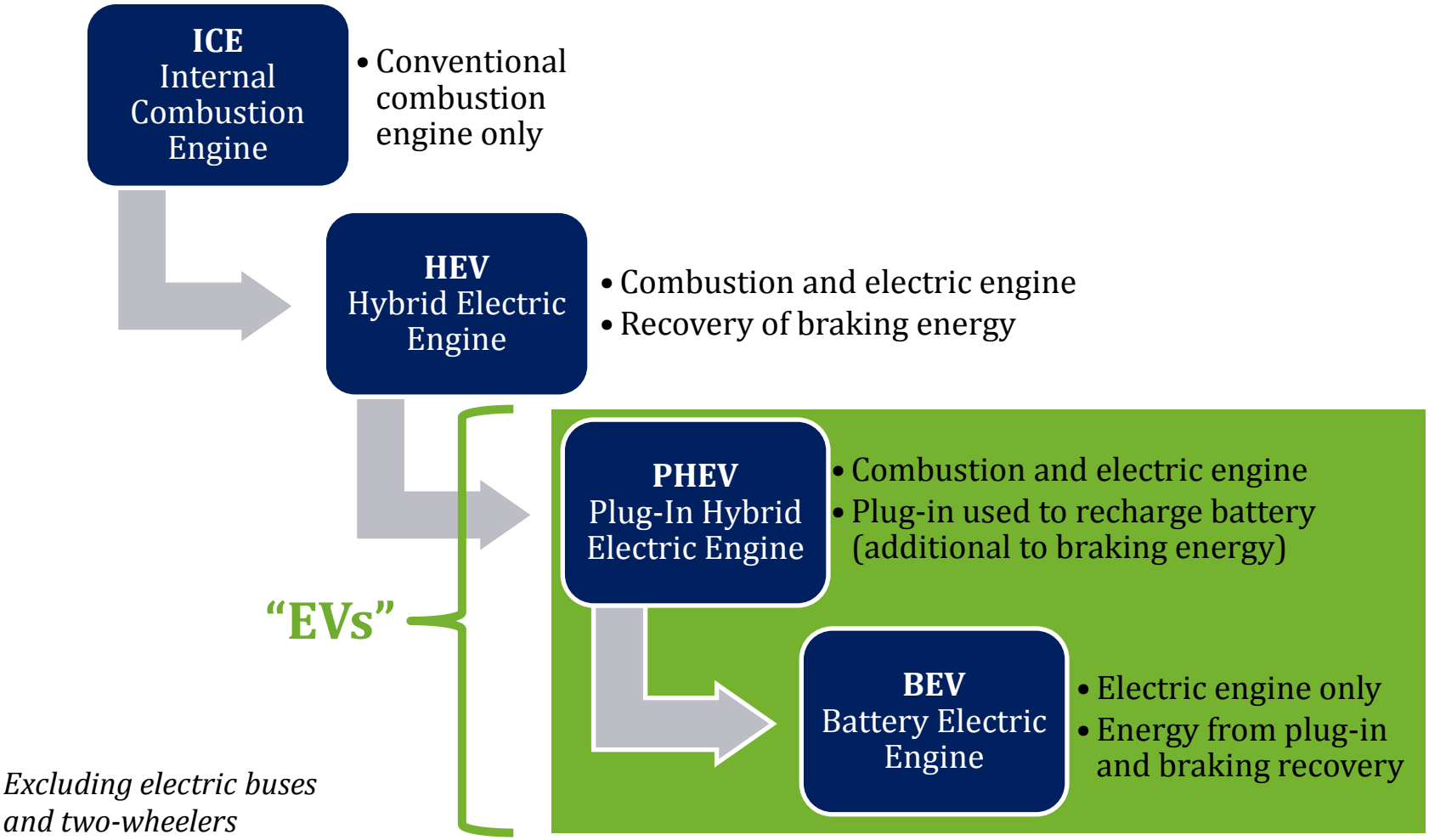
1 Kinds of Electric Vehicles



Excluding electric buses and two-wheelers

1 Examples of Electric Vehicles

Tesla Model S
- 2014: 31,000 units
- 2015 exp: ~55,000 units

Nissan-Renault-Alliance
- Globally sold to date: >200,000
- 2014: 61,000 Nissan Leaf

BEV

Chevrolet Volt: Pioneer of Plug-In Hybrids
- Europe: Opel/Vauxhaul Ampera
- Globally sold to date: ~90,000 units
- 2014: 21,000 units

PHEV

1 Stationary energy storages

- Apart from EVs possibly another high-scaled battery application
- Depends on e.g.
  - future paths of renewable energy technologies
  - technical options to balance power supply fluctuation
  - political support, compared to pumped storage plants, stand-by power station capacities, demand side management, etc.

Younicos/WEMAG, Schwerin (2014)
- Lithium ion battery, 5 MW / 5 MWh

Younicos/Vattenfall, Berlin (2012)
- Sodium sulfur battery, 1 MW / 6 MWh

BYD, Zhangbei, China (2014)
- Lithium ion battery, 20 MW / 36 MWh

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1 Modeling of Diffusion

We just do not know how the future market will look like!

EV

Boost	Moderate
From 800m to 2,000m cars in 2050	From 800m to 1,500m cars in 2050
Average life-time: 10y	Average life-time: 15y
EV-quota for new cars: From 0% to 75% in 2050	EV-quota for new cars: From 0% to 40% in 2050

2 scenarios

↓

Net construction (additional to stock) p.a.*

↓

End-of-life replacements

↓

Electric share*

↓

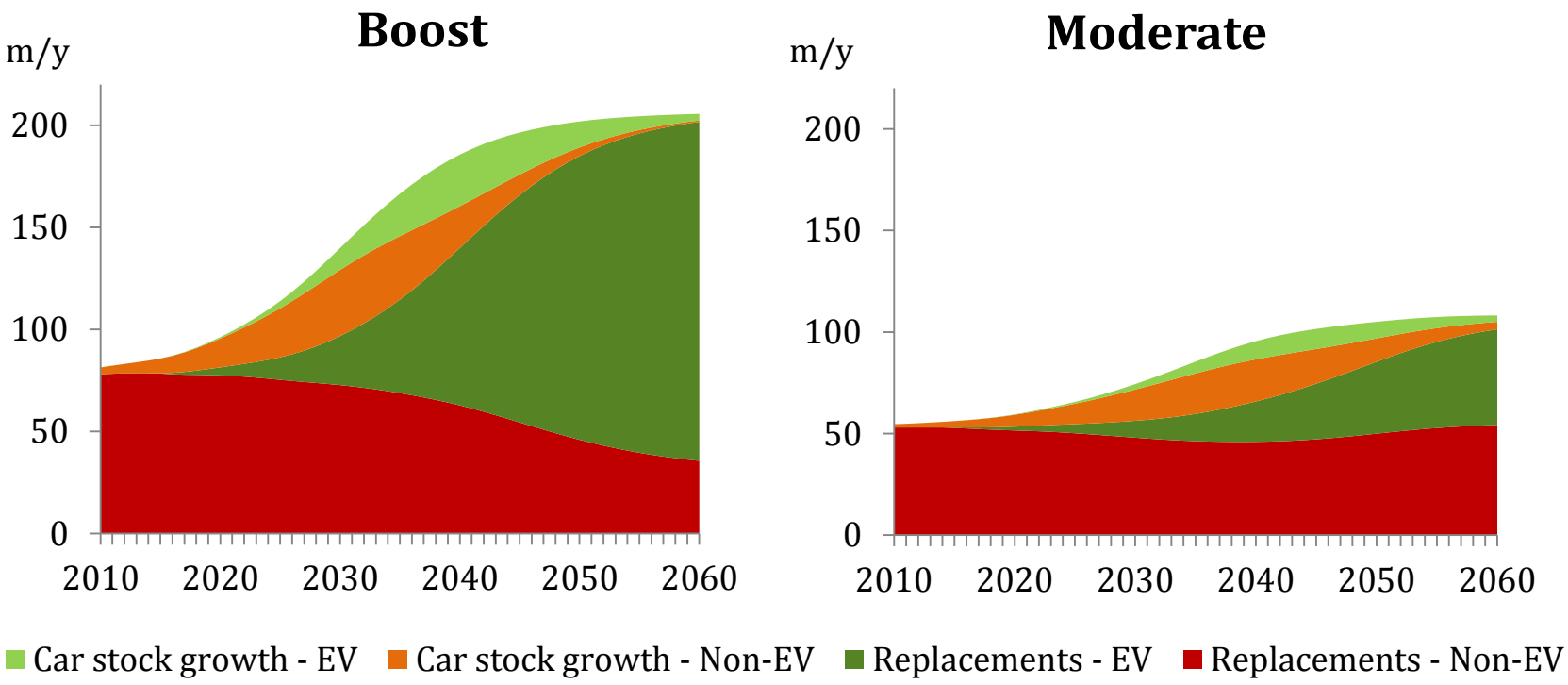
Total production p.a.

Stationary energy storages

Boost	Market Niche
From ~0 to 1,000 GWh in 2050	From ~0 to 300 GWh in 2050
Average life-time: 14y	Average life-time: 20y

* A sigmoid function / S-curve is deployed in both cases.

1 EV Diffusion: Results



Stock of EVs at the end of 2050:

1,250,000,000 units

350,000,000 units

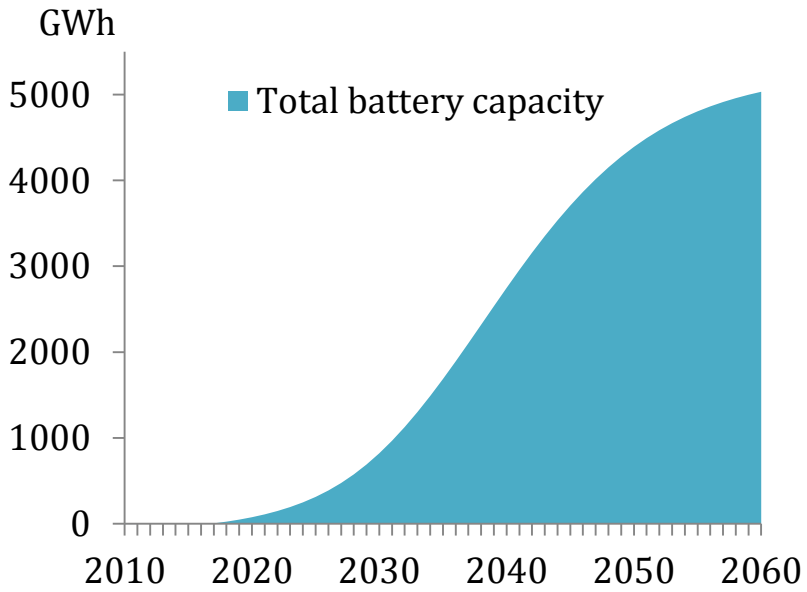
1 EV Diffusion: Battery capacity

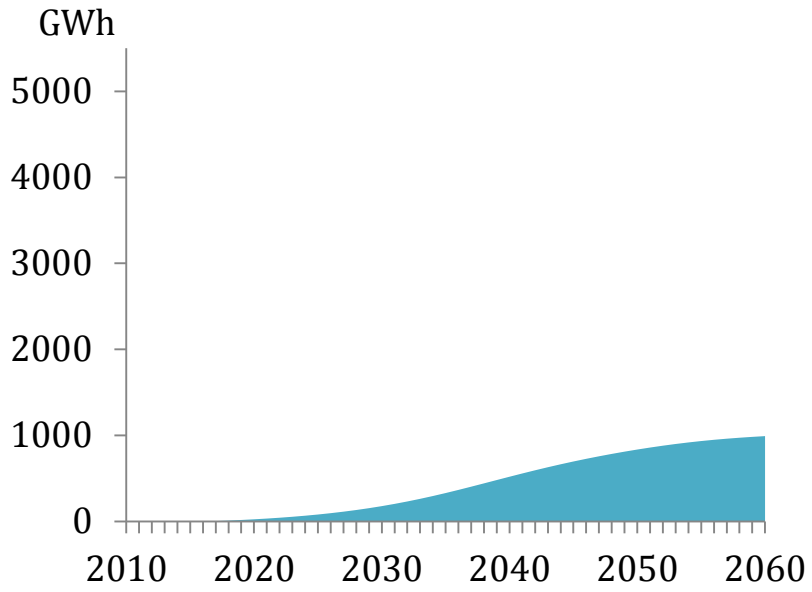
Boost

- Higher share of BEVs
- All kinds of cars, incl. premium class
- 30 kWh/EV

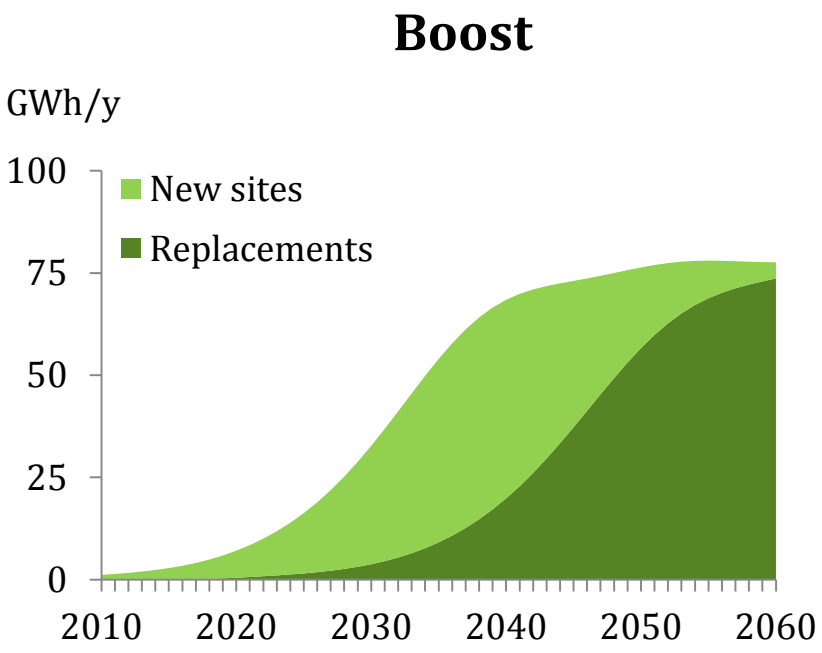
Moderate

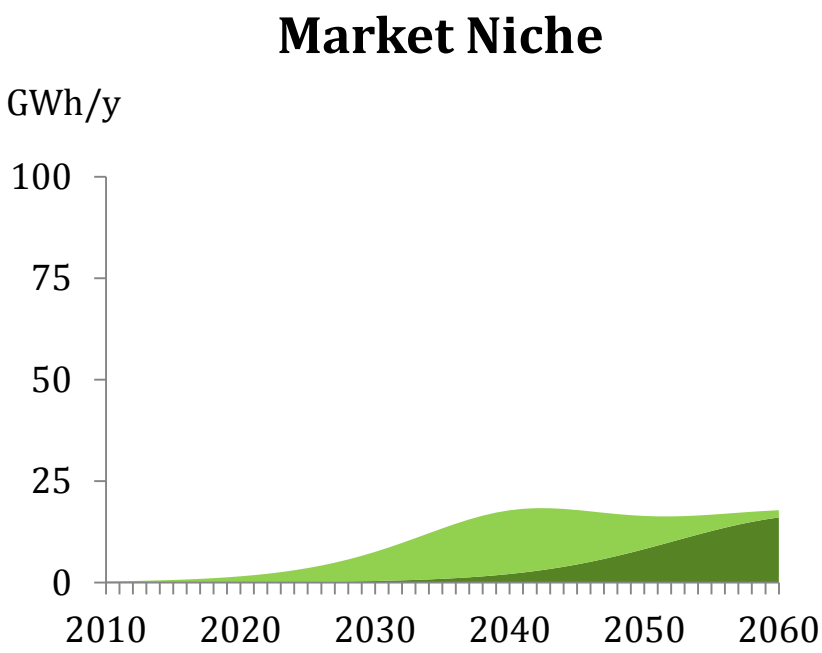
- Higher share of PHEVs
- Focus on compact class
- 20 kWh/EV





1 Stationary Energy Storages Diffusion: Results

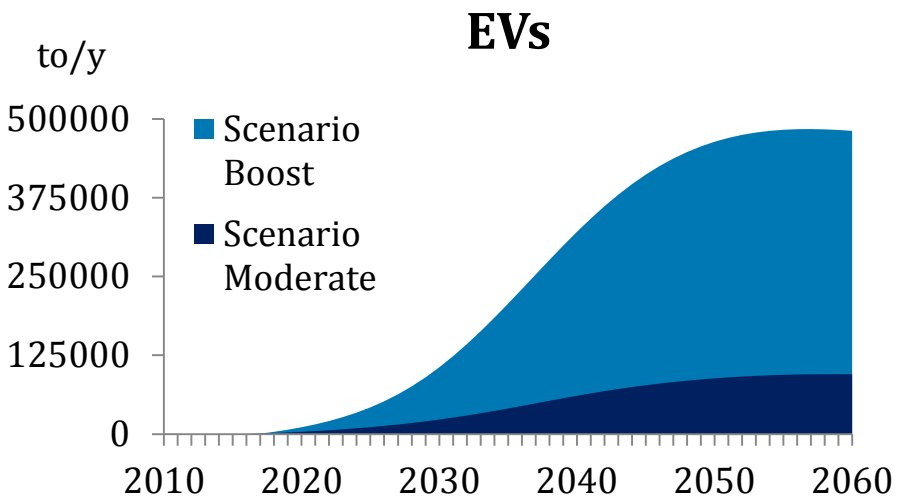


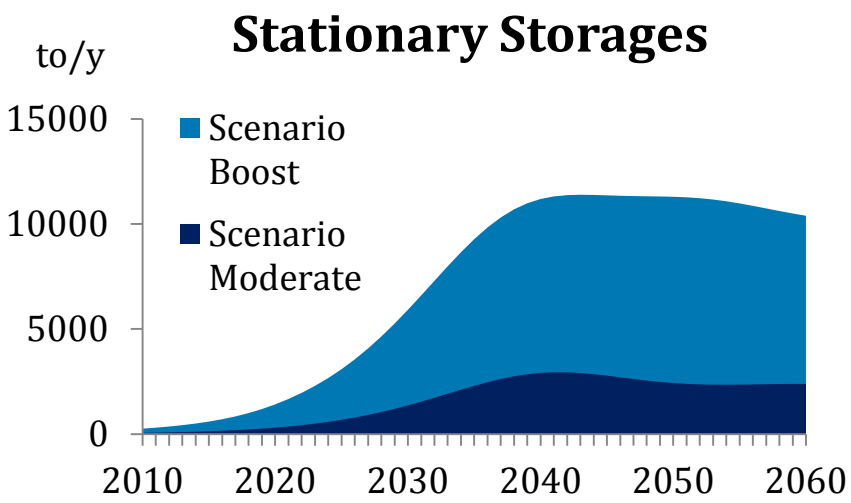


2 Lithium Demand: The Battery Question

- Lithium-ion batteries appear to be promising
  - High energy density
  - Already in use (notebooks, smartphones etc., also most EVs)
  - Decreasing manufacturing cost
    - 2011: 600 $/kWh to 2013: 300 $/kWh (EVI/IEA 2015)
    - Further improvement of energy density
  - **Model parameters**
    - Technological progress of 1 % p.a. in terms of lithium needed
    - Starting levels 2015:
      - EVs: 150g / kWh (Mohr 2012)
      - Stationary energy storages: 210kg / MWh (Koj et al./Younicos 2015)

2 Modeling of Lithium Demand: Results





Accumulated demand

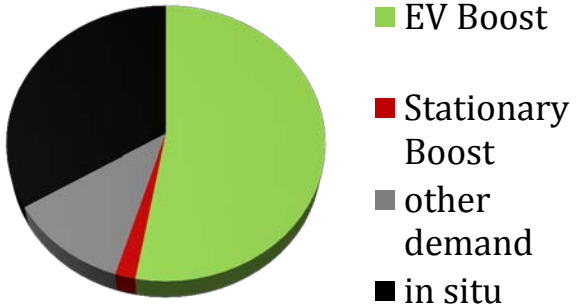
	Boost + Boost	Moderate + Market Niche
Until 2030	600,000 tons	150,000 tons
Until 2050	7,100,000 tons	1,400,000 tons

3 Lithium Resources

- Demand for other uses: 35,000 tons p.a. (USGS 2014, Angerer et al. 2009)
  - ceramics and glass, portable batteries, greases, air treatment
  - Model: Increase of 1% p.a. assumed
- Reserves: 13m tons (USGS 2014)
  - (Nearly) secure existence and at today's market price profitably extractible
  - ➢ Reserves-to-production ratio: 370 years!
- Resources: approx. 40m tons (USGS 2014)
  - Existence only assumed and/or extraction today technically not possible/too costly

➢ Assuming both Boost scenarios become real, in 2050 still 1/3 of today's reserves will be unused

➢ New discoveries, technical progress at mining techniques, etc. not included



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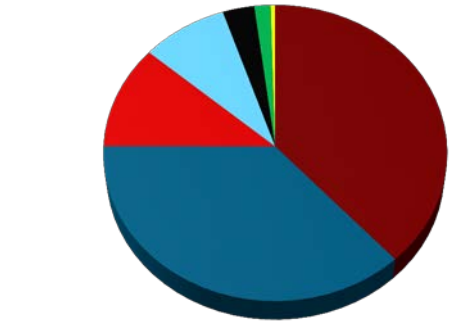
3 Lithium Supply

- Large additional extraction capacities will be needed
  - ❖ Capital and know-how required
    - Bottlenecks at markets for input factors?
    - Increasing cost for investment/extraction?
  - ❖ Regional concentration of resources
    - South America: >50% reserves, >40% resources
      - Growing world trade imbalance
      - Abuse of market power, even cartelization?
    - Huge deposits in Bolivia (so far unused)
      - Impending nationalization
      - Unfavorable climate for foreign engagement

Today's lithium supply



USGS (2014)
Note: US production withheld

Due to potentially booming demand the lithium market faces the serious risk of an deficit in supply with (temporary?) high prices.

3 Relaxing through recycling?

- Up to 98% recycling rate technically possible (Miedema & Moll 2013)
- **Feasibility and profitability require**
  1. a certain stock of lithium waste, especially through scraping of EVs,
  2. a collection system
     - A collection system for acid car batteries is already in place and covers nearly 100% in Europe: Extend it!?
     - A governmental commitment to sellers to collect batteries (e.g. EU directive 2006/66/EC)
  3. a product design paying attention to subsequent recycling

- A secondary lithium market would arise

  (1) Dynamic market for primary extraction

  (2) Time lagged recycling market

  ➢ Leads also to an increase of security of supply for net-importers like Europe