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The business position and opportunities in the battery value chain for the Netherlands

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Ministry of Economic Affairs and Climate Policy
Ministry of Infrastructure and Water Management

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Ministry of Economic Affairs and Climate Policy
Bezuidenhoutseweg 73
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Strategic positioning of the Netherlands in the battery ecosystem
Reference: IUC-202107114

Dear Messrs. Bosdijk, Steendam, and Jagt,

We report on the strategic positioning of the Netherlands in the battery ecosystem in accordance with our Engagement Letter dated 16 September 2021. The report has been prepared to give an overview of the Dutch strategic position in the battery ecosystem, using a four-step methodology to baseline business opportunities, assess Dutch competitiveness, estimate economic potential and to define an overall strategic direction.

This report contains analyses based on public information, expert interviews, and feedback and input from the battery expert group, setup by the Ministry of Economic Affairs and Climate Policy. Given the available time and resources, and the reliance on publicly available information, the analyses and results should be treated with due care.

We accept no liability (including for negligence) to anyone else but you or for use of this report for any other than the stated purpose and it may not be provided to anyone else.

If you have any questions please contact us at your convenience.

Yours faithfully,

Dr. Paul Nillesen
Partner

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Our scope and process

Depth of assessment

Limited **Extensive**

Due to the very tight timeframe and broad range of activities covered, the depth of our assessment is limited. Our findings are based on publicly available information published by various reputable sources and expert interviews. Where analysis has been performed by Strategy&, it is high level in nature and only intended to provide directional guidance. The assessment has been completed over seven weeks

Access to experts

None **Good**

In general, we have had good access to battery experts recommended by the Ministry of Economic Affairs and Climate Policy. However, most of experts interviewed in this assessment are based out of The Netherlands and access to global experts has been limited

Access to information

Limited **Extensive**

This report is based primarily on publicly available and high level information. No confidential information has been used. Access to publicly available information has been good with no restriction

Clarity of information

Poor **Good**

Clarity of publicly available information has been generally good, albeit with variation of data and projections between sources. Where discrepancy in publicly available information sources was noted, an assessment of the most appropriate data to use was made

Certainty of estimations

Poor **Good**

The estimations made throughout the document use quantitative and qualitative input (from multiple experts). The economic potential calculation methodology follows a high level top-down approach and is sensitive to market demand, technology maturity, value pool estimations and potential market share which can be captured by Dutch companies

Important scope comments and guidelines for use of this report

The information contained in this report is high level by nature and should not be relied on for decision making. The report is intended to provide only a high level and directional overview of the strategic position of The Netherlands in the battery ecosystem. Strategy&, part of PricewaterhouseCoopers Advisory N.V., (“PwC”) has not performed an audit, verification or independent validation of the aforementioned data and thus does not undertake any responsibility or liability and does not give and must not be interpreted as to be giving any (explicit or implicit) assurance for the accuracy or the completeness of the data. This report does not constitute investment and/or legal advice. We accept no liability (including for negligence) to anyone else but you or for use of this report for any other than the stated purpose and it may not be provided to anyone else

Content

1 Executive summary

EZK[1] has requested for an international benchmark to validate and quantify the distinct position of the Netherlands in the battery landscape

Executive summary (1/4)

Background and context

- The production and usage of batteries will grow exponentially during the global transition from fossils to renewable energy
- Batteries enable the electrification of mobility (mainly road transport and certain applications in aviation and navigation) and the stabilization of the electricity grid (balance demand with intermittent energy supply from solar PV and wind)
- However, technological advancements are required as current generation batteries have a number of limitations with regards to scarcity of materials used, safety and performance (e.g. energy density, charge capacity, lifetime)
- To avoid dependence on other countries, the European Commission is investing billions to establish a (largely) independent value chain for next generation batteries
- The Netherlands has specific capabilities in the development of next generation batteries, mostly related to research & development of specific niches of next generation batteries
- The Netherlands commits to a critical role in the EU battery ecosystem and works on its own battery strategy
- In the request for proposals, 12 subthemes have been identified by EZK along the battery value chain that are believed to be the basis for unlocking economic potential of the Dutch battery ecosystem
- The 12 identified subthemes are
  - The development of new battery materials for anodes, cathodes, electrolytes and separators
  - Production equipment for battery cells, modules or packs
  - Parts/subprocesses (in particular si-anodes, coatings and deposition techniques) for 3B generation batteries
  - Generation 4 solid state batteries
  - Battery management systems and software
  - Pack assembly and integration, especially for heavy duty transport
  - Mechanical and chemical recycling
  - Bulk battery concepts, in particular redox flow batteries, hydro(gen) and salt batteries
  - Data-driven solutions for stationary batteries
  - System approach as competence for circularity
  - Safe storage and transport
  - Measurement and control techniques, quality assurance

Study objectives

- The objective of this study is to specify the economic opportunities for Dutch businesses and knowledge institutions along the direction of the 12 identified subthemes
- More specifically, the ministry is looking for:
  - An international benchmark to illustrate the competitive position of the Netherlands on each of the subthemes
  - The identification of the specific business opportunities arising from the subthemes and an estimation of their economic potential and time to market while taking into account the competitive international landscape
  - Initial strategic direction on short and long term next steps to capitalize on the identified business opportunities
- Parallel to this study, the ministry has setup a battery expert group and works on a national action plan / roadmap
- This research serves as an important input for that action plan

1) Ministry of Economic Affairs and Climate Policy

Sixteen unique business opportunities have been identified from the various subthemes for NL to consider

Executive summary (2/4)

A four step approach is used to assess competitiveness, estimate economic potential and define a strategic direction for the identified business opportunities

- Baselining business opportunities: The identified subthemes are broad in scope, cover multiple parts of the battery value chain and are difficult to explain in commercial business language. Hence, they are translated to concrete business opportunities to facilitate better benchmarking and estimation of economic potential
- Assessing Dutch competitiveness: For each identified business opportunity, the Netherlands is compared to a leading set of reference countries to understand Dutch competitiveness on a global scale
- Determining economic potential of the Netherlands: The 2030 economic potential is estimated for each business opportunity to identify the most lucrative opportunities
- Defining an overall strategic direction: Business opportunities with high competitiveness and economic potential are identified, ecosystem synergies between them are highlighted and a high level strategic action plan is defined

Sixteen unique business opportunities have been identified from the various subthemes

- Four conversion lenses, which are: relevant market context, capabilities of the Dutch ecosystem, specification along the battery value chain and judgement from experts, have been used to convert the subthemes into business opportunities
- For example, in the case of the subtheme – development of new battery materials for anodes, cathodes, electrolytes and separators:
  - The relevant market context centers around the importance of material science in battery technology performance, current limitations of used materials due to scarcity and safety issues and the need for new materials (incl. silicon) to overcome the current challenges and improve battery performance
  - The capabilities of the Dutch ecosystem are evident in nanotechnology and the high tech sector, R&D activities at companies and universities, and the presence of a strong polymer ecosystem
  - Combining the relevant market context with the Dutch capabilities and using further expert validation, four unique business opportunities are identified for this subtheme, which are, production of silicon anodes, selling/ leasing of patents related to material science or production methodologies of new battery concepts, producing polymeric materials for new battery electrodes and electrolytes and producing equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries
  - A value chain lens is finally used to ensure that the chosen business opportunities apply to specific battery value chain steps to facilitate better economic potential estimation
- Using the same methodology, sixteen unique business opportunities have been identified from the various subthemes, which are:
  - Production of silicon anodes
  - Selling/ leasing of patents related to material science or production methodologies of new battery concepts
  - Producing materials for new battery electrodes and electrolytes (e.g. polymer concepts)
  - Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries (e.g. deposition/ coating techniques)
  - Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production
  - Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system
  - Manufacturing testing equipment required in cell production process

1) Ministry of Economic Affairs and Climate Policy

The opportunities with highest potential competitiveness are related to high-tech equipment and electric heavy duty mobility

Executive summary (3/4)

  - Offering data-driven solutions as a service to owners and developers of storage systems (e.g. remote monitoring, forecasting, predictive maintenance, charge/discharge optimization etc.)
  - Developing recycling techniques related to the chemical separation of batteries
  - Recycling/ dismantling of end-of-life mobility batteries
  - Production of solid state batteries
  - Production of electric heavy duty commercial vehicles
  - Production of e-drive train for heavy duty vehicles
  - Production of integrated membrane stacks to be used in redox flow batteries
  - Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)
  - Integration of stationary battery storage into the grid
- The identified business opportunities mainly apply to the cell component and cell production part of the battery value chain covering all activities from production, equipment supply, R&D, to component supply

Business opportunities related to high-tech equipment and electric heavy duty mobility appear to have the highest competitiveness

- We created a reference list of countries per business opportunity (based on number of active companies and expert input) and then benchmarked NL against those countries using a 5-point scale
- We applied a combination of qualitative and quantitative indicators to assess the competitiveness of NL for every business opportunity against the reference list. The indicators which have been used are:
  - Number of companies currently operating in a country specific to a business opportunity which helps determine the relative size of an industry and the dominance of the country in that industry
  - Maturity of the industry in the country, related to the business opportunity, which helps distinguish startups from established companies
  - High technology exports as % of total exports for manufacturing related opportunities or research and development expenditure as % of GDP for research related opportunities which helps understand the potential ecosystem capabilities to support manufacturing and research in the larger battery ecosystem
  - Number of patents in the fields related to the business opportunity which is a proxy for the technological advancements in a specific field in a country
  - Research strength of countries in the fields related to the business opportunity which gives an indication of the knowledge in the educational institutions and R&D centers in a country
  - Competitive position of country compared to rest of the market using expert judgement
- The overall competitiveness is then calculated based on an average with equal weights across the individual indicators. The business opportunities which appear to have the highest competitiveness are:

1. Business opportunities related to high-tech equipment manufacturing
   - Production of equipment for specific process steps in the manufacturing of current generation of batteries
   - Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production
   - Production of hardware components which go into a battery management system
2. Business opportunities related to heavy duty mobility
   - Production of electric heavy duty commercial vehicles
   - Production of e-drive trains for heavy duty vehicles

- These opportunities correspond with the traditional and existing expertise of The Netherlands in the high tech sector, extensive experience in equipment manufacturing and state of the art bus and truck production

Combining competitiveness and economic potential, the ecosystem related to heavy duty mobility scores high on both indicators

Executive summary (4/4)

- Although the chosen indicators are methodologically sound, it has not been possible, given the scope of the study, to account for aggressive growth potential of start-ups and scale-ups with disruptive technologies

Production related business opportunities appear to have the highest economic potential as they capture the maximum revenue pools in the battery value chain

- The future Dutch economic potential of various business opportunities is estimated using a 4-step approach, which covers:
  - Value chain alignment: The business opportunities are aligned to either the battery pack, battery electric vehicle (heavy duty) or stationary storage systems value chain depending on whether they are upstream, midstream or downstream opportunities
  - Global market size estimation: The global market size depends on the value chain of the business opportunity and the technology in focus and is calculated using Strategy& estimation models and cross-checked with published reports
  - Revenue pool identification of business opportunity: Revenue pool depends on the value chain step the business opportunity is present in and revenue pool percentages are taken from published reports and expert interviews
  - Potential future NL market share estimation: The market share which can be captured by Dutch companies is calculated depending on the results of the competitive benchmarking exercise undertaken in the previous phase of the study
- The calculation methodology follows a high level top-down approach and is sensitive to market demand, technology maturity, value pool estimations and potential market share which can be captured by Dutch companies
- Using the high level calculation methodology, the business opportunities with the highest estimated annual Dutch economic potential in 2030 appear to be:
  - Production of electric heavy duty commercial vehicles (~$1,950 M)
  - Production of e-drive trains (~$1,000 M)
  - Production of solid state batteries (~$250 M)
  - Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system (~$180 M)
  - Integration of stationary battery storage into the grid (~$150 M)

The overall strategic recommendation for the Netherlands is potentially to double down on opportunities related to heavy duty mobility, grow the ones related to equipment manufacturing and incubate the ones relating to new battery concepts and stationary storage systems

- Combining the competitiveness and economic potential assessment yields three regions with distinct strategic characteristics:
  - Double down: high competitiveness and high economic potential - Explore how NL could capitalize on strong competitive positioning
  - Grow: high competitiveness and low economic potential or low competitiveness and high economic potential - Seek for ways to improve NL competitive position or explore possibility of increasing economic potential through backward or forward value chain integration
  - Incubate: low competitiveness and low economic potential - Monitor potential of relevant opportunities, given the disruptive nature and development speed of the battery market
- Potential economies of scale and/ or skill can be identified by clustering the business opportunities into four ecosystems, which are electric heavy duty mobility, equipment manufacturing, new battery concepts and stationary storage systems
- Clear strategic directions emerge when comparing the ecosystems against each other on competitiveness and economic potential with a recommendation to potentially double down on heavy duty mobility, grow equipment manufacturing and incubate new battery concepts and stationary storage systems

2 Overview of key findings

A four step approach is used to assess competitiveness, estimate economic potential and define a strategic direction for the business opportunities

Summary of our methodology

Process	1 Baseline business opportunities	2 Assess Dutch competitiveness	3 Determine economic potential for the Netherlands	4 Define strategic direction
	Details on pages: 35-79	*Details on pages: 80-105*	*Details on pages: 106-135*	*Details on pages: 136-148*
Research question	*"What are the specific business opportunities per subtheme?"*	*"What are key determinants of a country's competitiveness per business opportunity and how distinctive are the Dutch strengths internationally?"*	*"What is the economic potential for the Netherlands for these business opportunities?"*	*"What steps should be taken to capitalize on the economic potential for the Netherlands?"*
Activities	• Per subtheme, **formulate** the specific **business opportunities** in the battery value chain for the Netherlands • **Gather existing information** that proves the strength of the NL position around the formulated opportunities • Place **opportunities in relevant market context** (qualitative assessment around competitive landscape, replacements, alternatives, entry barriers etc.)	• **Formulate indicators** that can express a country's competitiveness on the specific business opportunities (qualitative and quantitative) • Per business opportunity, **determine which countries are most relevant** for comparison (reference countries) • **Populate indicators** per business opportunity for the reference countries through desk research and expert judgement • **Determine the relative competitive position of the Netherlands** in the business opportunities through qualitative and quantitative assessment	• Per business opportunity, **determine the relevant market size** (quantitative) based on the position and revenue pool in the battery value chain • **Estimate potential market** share (qualitative) of the Netherlands using the determined competitiveness from step 2	• **Map business opportunities** in a two-by-two matrix to identify most relevant strategic directions • **Determine possible synergies** between business opportunities using an ecosystem approach • **Determine next steps** for industry, knowledge institutes and government **to capitalize on the identified economic potential** per ecosystem including time frame • **Integrate findings** in coherent strategic advice
Deliverable	• Per business opportunity: clear description, Dutch capabilities, market context and value chain positioning	• Per business opportunity: reference countries, raw data on indicators and conclusions on Dutch competitiveness	• Per business opportunity: estimated market size, market share and economic potential	• Short and long term next steps for all business opportunities and integrated report with project findings

With the introduction of the baseline step, the methodology deviates from the 3 steps in the RFP – translating the (sometimes broad) subthemes into concrete business opportunities allows for more detailed benchmarking which results in better assessment of the Dutch competitive position

In the request for proposals, 12 subthemes have been identified as potentially relevant for the Dutch battery ecosystem

Identified themes in the request for proposals

Broader theme	Subtheme	Focus battery technology
New cells and materials	The development of new battery materials for anodes, cathodes, electrolytes and separators	General
	Production equipment for battery cells, modules or packs	General
	Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries	Lithium-ion
	Generation 4 Solid State Batteries	Lithium-ion
Packs and systems	Battery management systems and software	General
	Pack assembly and integration, especially for heavy duty transport	General
Reuse, second-use and recycling	Mechanical and chemical recycling	General
Grid support	Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries	Bulk batteries
	Data-driven solutions for stationary batteries	General
Circularity	System approach as competence for circularity	General
Safety	Safe storage and transport	General
	Measurement and control techniques, quality assurance	General

Details on pages: 38-52

These subthemes are translated to concrete business opportunities to be able to benchmark vs. other countries and assess economic potential

Methodology to formulate business opportunities from subthemes

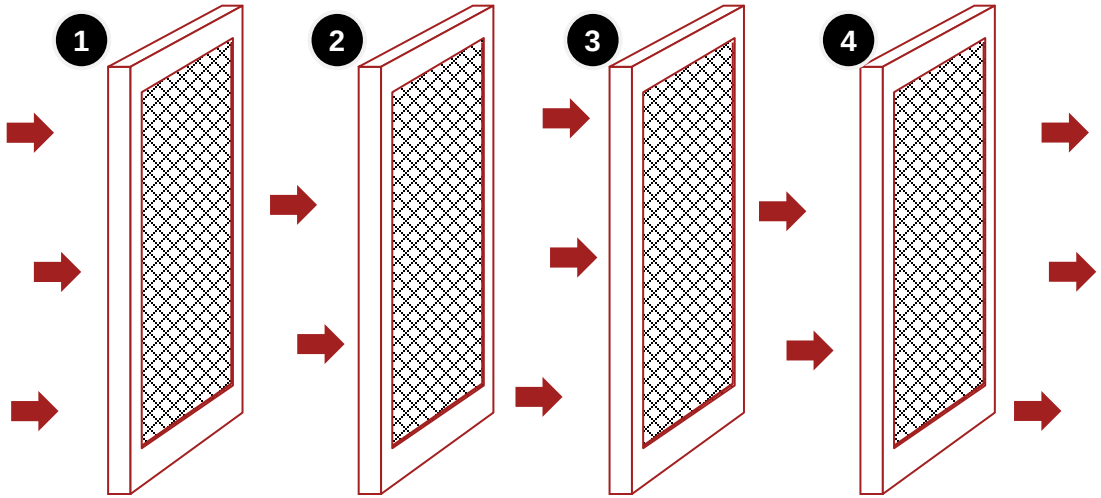
Subtheme approach

Subtheme definitions are broad in scope and prevent accurate benchmarking against other countries and assessing economic potential

Subtheme characteristics

- X Too broad
- X Cover multiple parts of value chain
- X Difficult to translate to commercial business language
- X Makes it difficult to benchmark on a country level and assess economic potential

Conversion lenses



Business opportunity approach

Business opportunities are defined to be value chain focused activities to better facilitate benchmarking amongst countries and assessment of economic potential

Business opportunity characteristics

- ✓ Narrow in scope
- ✓ Cover specific part of value chain
- ✓ Easy to understand in commercial language
- ✓ Facilitates country benchmarking and assessment of economic potential

1 **Relevant market context**

2 **Capabilities of Dutch ecosystem**

3 **Specification along the battery value chain**

4 **Judgement from experts**

Details on pages: 53-75

As a result, sixteen unique business opportunities have been identified from the various subthemes which could be potentially relevant for NL

Identified business opportunities (1/2)

1 Production of Silicon anodes

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries

2 Selling/ leasing of patents related to material science or production methodologies of new battery concepts

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries
- 10 Generation 4 Solid State Batteries
- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

3 Producing materials for new battery electrodes and electrolytes (e.g. polymer concepts)

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators

4 Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries (e.g. deposition/ coating techniques)

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 2 Production equipment for battery cells, modules or packs
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries

5 Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production

- 2 Production equipment for battery cells, modules or packs
- 10 Generation 4 Solid State Batteries
- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

6 Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system

- 3 Battery management systems and software
- 8 Measurement and control techniques, quality assurance

Identified business opportunity *Subtheme to which the business opportunity belongs*

Details on pages: 53-75

As a result, sixteen unique business opportunities have been identified from the various subthemes which could be potentially relevant for NL

Identified business opportunities (2/2)

7 Manufacturing testing equipment required in cell production process

- 3 Battery management systems and software
- 8 Measurement and control techniques, quality assurance

8 Offer data-driven solutions as a service to owners and developers of storage systems (e.g. remote monitoring, forecasting, predictive maintenance, charge/discharge optimization)

- 4 Data-driven solutions for stationary batteries

9 Developing recycling techniques related to the chemical separation of batteries

- 5 Mechanical and chemical recycling
- 6 System approach as competence for circularity
- 7 Safe storage and transport

10 Recycling/ dismantling of end-of-life mobility batteries

- 5 Mechanical and chemical recycling
- 6 System approach as competence for circularity
- 7 Safe storage and transport

11 Production of solid sate batteries

- 10 Generation 4 Solid State Batteries

12 Production of electric heavy duty commercial vehicles

- 11 Pack assembly and integration, especially for heavy duty transport

13 Production of e-drive train for heavy duty vehicles

- 11 Pack assembly and integration, especially for heavy duty transport

14 Production of integrated membrane stacks to be used in redox flow batteries

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

15 Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

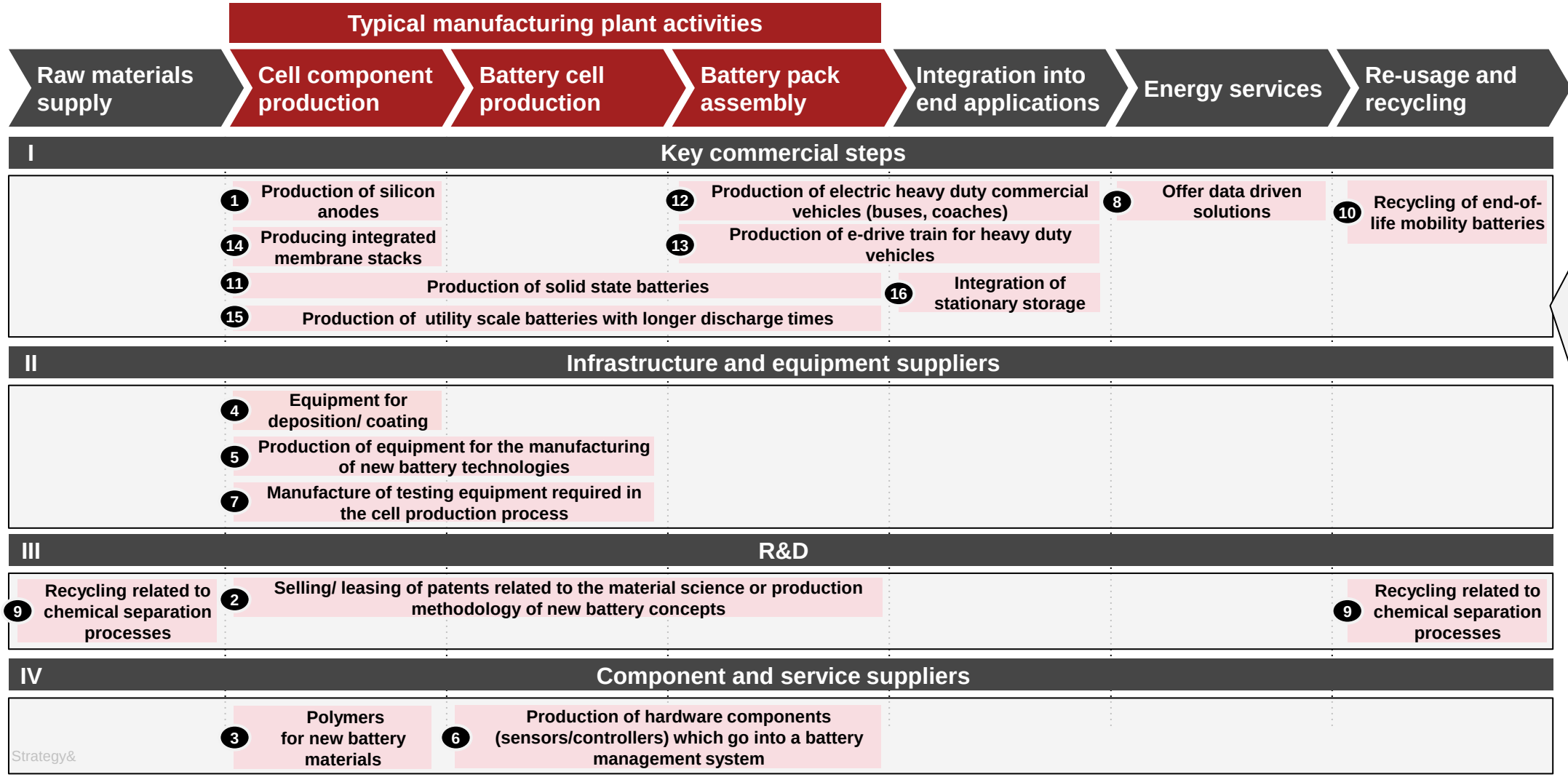
16 Integration of stationary battery storage into the grid

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

Identified business opportunity *Subtheme to which the business opportunity belongs*

The identified business opportunities mainly apply to the cell component and cell production part of the battery value chain

Mapping business opportunities to the value chain



- The high level battery chain covers mobility and stationary applications with a focus on battery packs
- Assessment of the economic potential for mobility and stationary opportunities is based on specific value chains

We created a reference list of countries per business opportunity and then benchmarked NL against those countries using a 5-point scale

Benchmarking methodology

Steps in the benchmarking process by business opportunity

1. **Create reference list of countries per business opportunity using keyword search from database Orbis**
2. **Refine reference list using desktop research and expert interviews**
3. **Benchmark NL against the reference list using the competitive indicators and a 5-point scale**
4. **Visually compare NL against the 3 leading countries to understand competitive potential**

Deep dive

5-point scale to assess Dutch competitiveness

1. **No right-to-win:** No/ very few companies active in the business opportunity. NL is far behind its peers and lacks an ecosystem to compete
2. **Moderate competitive potential:** Ecosystem surrounding the business opportunity exists and NL can supply to the local and regional market
3. **Good competitive potential:** Mature companies and R&D institutes operate in NL with potential to compete at a global level
4. **Substantial competitive potential:** NL has a thriving ecosystem surrounding the business opportunity and has a high market share globally
5. **Market leader:** NL dominates the global market pertaining to the business opportunity with established companies operating and doing R&D

Since NL is compared against the leading countries, the relationship between scores and competitiveness is non linear; Scores above 2 already indicate average competitiveness in the total market

We applied a combination of qualitative and quantitative indicators to assess the competitiveness of NL for every business opportunity

Overview of competitive indicators

Type	Indicators	Source	Rationale
Lagging indicators - strength of current industry	**Number of companies** currently operating in a country specific to a business opportunity	Database 'Orbis' and google search and expert interviews	*The number of active companies in a country determines the relative size of an industry and the dominance of the country in that industry*
	Maturity of the industry in the country, related to the business opportunity	FTE estimates per company from database 'Factiva' and company profiles and expert opinion	*Assessment of the industry maturity as a whole is based on multiple levers; amount of FTE's employed in a market serves as an initial indication, which is refined with qualitative assessment of company profiles and expert judgement (e.g. to compensate for high levels of automation)*
	High technology exports as % of total exports for manufacturing related opportunities or **Research and development expenditure as % of GDP** for research related opportunities	Database 'World Bank'[1)]	*Quantifiable indicators such as high-tech exports and R&D spend help determine the potential capabilities of the ecosystem in a particular country to support manufacturing and research in the larger battery ecosystem*
Leading indicators - potential for future competitiveness	**Number of patents** in the fields related to the business opportunity	Database 'WIPO IP Statistics Data Center'[2)]	*The number of patents is a proxy for the technological advancements in a specific field in a country and shows potential for future technology dominance*
	Research strength of countries in the fields related to the business opportunity	Database 'Scimago Journal & Country Rank'[3)]	*The research strength gives an indication of the knowledge in the educational institutions and R&D centers in a country which is crucial for future innovations*
Expert judgement	**Competitive position of country** compared to rest of the market	Expert interviews	*Expert judgement provides specific context regarding the competitive position of a country*

The overall competitiveness is calculated based on an average with equal weights across the individual indicators

⚠ **The current methodology does not account for some of the aggressive growth rates foreseen by start-ups and scale-ups depending on the commercialization of new technologies**

Sources: 1) The World Bank (a, b); 2) WIPO (2021); 3) Scimago (2020)

Details on pages: 84-100

The Netherlands appears to have good competitive potential in producing production equipment for the battery ecosystem

Overview of business opportunity benchmark (1/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
1 **Production of silicon anodes**	3	3	3	1	2	2	**2,3**	*Moderate competitive potential* – In the US and China, the ecosystem of companies appears to be much more developed compared to NL
2 **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**	3	3	2	2	2	3	**2,5**	*Moderate competitive potential* - Research on new battery concepts is mainly performed by existing battery manufacturers, which are concentrated in South East Asia and the US
3 **Producing materials for new battery electrodes and electrolytes** (e.g. polymer concepts)	3	2	3	2	3	2	**2,5**	*Moderate competitive potential* - Potential exists given the expected future demand for batteries in Europe combined with the historical expertise of The Netherlands in material sciences
4 **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	3	3	4	2	2	3	**2,8**	*Good competitive potential* – New deposition and coating processes require high precision which could provide The Netherlands a right to play given the strong expertise in high-tech machinery and manufacturing equipment
5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**	4	4	4	2	2	3	**3,2**	*Good competitive potential* – New battery concepts are expected to require new production equipment, which could create a possibility for The Netherlands to leverage it's strong positioning in the high-tech sector

Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

Details on pages: 84-100

In addition, good competitive potential possibly exists in producing hardware components for battery management systems and recycling

Overview of business opportunity benchmark (2/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
6 **Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system**	3	4	4	1	2	3	**2,8**	*Good competitive potential* – Expertise of companies such as NXP, which is a major supplier, could potentially provide The Netherlands a right to play in this field
7 **Manufacturing testing equipment required in the cell production process**	1	2	4	2	2	2	**2,2**	*Moderate competitive potential* – Testing equipment is generally produced in close proximity to the vehicle OEMs, which are concentrated in the US, China and Germany
8 **Offer data-driven solutions as a service to owners and developers of storage systems** (e.g. remote monitoring, forecasting, predictive maintenance, charge/ discharge optimization)	3	3	2	1	3	2	**2,3**	*Moderate competitive potential* – Large corporates are already active in this space in the US and South East Asia, making it a challenging market for The Netherlands to enter
9 **Developing recycling techniques related to the chemical separation of batteries**	3	3	2	2	3	2	**2,5**	*Moderate competitive potential* – Market is developing, The Netherlands could play a role if it could capitalize on a potential first mover advantage
10 **Recycling/ dismantling end-of-life mobility batteries**	3	2	4	2	3	2	**2,7**	*Good competitive potential* – Strict guidelines on battery transport can possibly create a domestic recycling market, volumes are expected to be limited to the regional market

Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

Details on pages: 84-100

Finally, the fields of heavy duty mobility yield good competitive potential for The Netherlands

Overview of business opportunity benchmark (3/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
11 **Production of solid sate batteries**	2	3	4	2	2	2	**2,5**	*Moderate competitive potential* – Development and production is mainly driven by mature markets such as battery manufacturers and vehicle OEMs in South East Asia and the US
12 **Production of electric heavy duty commercial vehicles**	4	3	4	2	3	3	**3,2**	*Good competitive potential* – There is a strong ecosystem of companies active in the heavy duty mobility sector in The Netherlands
13 **Production of e-drive train for heavy duty vehicles**	4	3	4	2	2	3	**3,0**	*Good competitive potential* – Closely related to the heavy duty mobility sector, providing a right to play for The Netherlands
14 **Production of integrated membrane stacks to be used in redox flow batteries**	3	2	4	1	2	3	**2,5**	*Moderate competitive potential* – Interest of large countries in this expected growth market results in strong competition for active companies in The Netherlands
15 **Production of utility scale batteries with longer discharge times** (redox flow, salt water, other technologies)	3	3	4	2	2	2	**2,7**	*Good competitive potential* - Upcoming and developing market which offers potential but also strong competition from Asia and Australia
16 **Integration of stationary battery storage into the grid**	3	3	4	2	1	2	**2,5**	*Moderate competitive potential* – Stationary storage market is growing but realization of integration projects is expected to be contracted and executed locally

Legend

1 *No right-to-win*

2 *Moderate competitive potential*

3 *Good competitive potential*

4 *Substantial competitive potential*

5 *Market leader*

The opportunities with highest potential competitiveness are related to high-tech equipment and heavy duty mobility

Key findings of benchmark

Promising business opportunities

1. Business opportunities related to high-tech equipment manufacturing

- Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries *(e.g. deposition/ coating techniques)*
- Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production
- Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system

2. Business opportunities related to heavy duty mobility

- Production of electric heavy duty commercial vehicles
- Production of e-drive train for electric heavy duty vehicles

Additional promising opportunities may arise from recycling/circularity concepts and stationary storage

- Recycling/ dismantling end-of-life mobility batteries
- Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)

These opportunities correspond with the traditional and existing expertise of The Netherlands

Leading position in the high-tech sector

- ASML and NXP are leading companies in the semiconductor industry, the latter also supplies components for battery management systems

Extensive experience in equipment manufacturing

- Demcon Industrial Systems and VDL ETG are global suppliers of high-tech solutions for the manufacturing industry

State-of-the art bus and truck production

- DAF is one of the major truck manufacturers
- VDL Bus & Coach and EBUSCO among first companies to produce fully electric buses

For recycling/circularity concepts and stationary storage, although Dutch competitive position is moderate or slightly above, societal and market demands may account for additional promising opportunities

Non-exhaustive

Details on pages: 108-114

We used a 4-step approach to estimate the future Dutch economic potential of the identified business opportunities

Dutch economic potential assessment methodology

Economic potential (2030) calculation	Sources	Description
1 **Value chain alignment**	Research and expert interviews	The business opportunities are aligned to either the battery pack, battery electric vehicle (heavy duty) or stationary storage systems value chain
2 **Global market size**	Estimation models and published reports and expert interviews	The global market size depends on the value chain of the business opportunity and the technology (solid state, redox flow etc.) in focus
X		
3 **Revenue pool of business opportunity**	Published reports and expert interviews	The revenue pool depends on the value chain step the business opportunity is present in and the relevant activity in the value chain step applicable to the business opportunity
X		
4 **Potential future market share of Dutch companies**	Competitive benchmarking results from phase 2 of this study	The potential future market share of Dutch companies is calculated depending on the results of the competitive benchmarking exercise undertaken in phase 2 of the study
=		
Dutch economic potential		

Calculation steps

⚠ **The calculation methodology follows a high level top-down approach and is sensitive to market demand, technology maturity, value pool estimations and potential market share which can be captured by Dutch companies. As a result, the market might be underestimated for some of the new battery concepts where start-ups and scale-ups can witness aggressive growth rates depending on the commercialization of new technologies**

Details on pages: 115-131

The estimated Dutch economic potential in 2030 appears to be good for opportunities relating to equipment manufacturing and BMS systems

Overview of economic potential assessment (1/2)

Business opportunity	Average estimated annual economic potential (2030)	Rationale
1 **Production of silicon anodes**	**~ $ 10 M**	*Limited economic potential* - Only 10-20% of the lithium-ion batteries are expected to have silicon anodes in 2030 and the production of anodes is estimated to only contribute to 1-2% of the total revenue pool in battery pack manufacturing
2 **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**	**~ $ 40 M**	*Moderate economic potential* - Battery production steps of the value chain are estimated to collectively account for 45-50% of the total revenue pools and R&D accounts for a significant 4-10% of that
3 **Producing materials for new battery electrodes and electrolytes** (e.g. polymer concepts)	**~ $ 5 M**	*Limited economic potential* - Polymer concepts apply to solid state battery concepts, which are estimated to account for only 5-10% of the battery demand in 2030, additionally polymer is a fraction of the total materials used in these concepts
4 **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	**~ $ 50 M**	*Moderate economic potential* - Battery manufacturing is estimated to account for a substantial part of the total revenue pool (45-50%) with machinery accounting for 5-15% of it and coating processes are among the key drivers (12-17%) of machinery investments
5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**	**~ $ 80 M**	*Moderate economic potential* - New battery concepts are estimated to take 10-20% of total battery demand in 2030, cell component and cell production are a significant (45-50%) part of the revenue pool – equipment is 5-15% of total revenue pool in these steps
6 **Production of hardware components** (sensors/ controllers/ chip sets) **which go into a battery management system**	**~ $ 180 M**	*Good economic potential* - Battery management systems apply to the total battery pack market and within the battery manufacturing revenue pool, BMS accounts for 5-8%
7 **Manufacturing testing equipment required in the cell production process**	**~ $ 25 M**	*Limited economic potential* - Testing equipment is estimated to only be 8-12% of the total equipment required for cell production, which accounts for only 5-15% of the total revenue pool in the cell production process
8 **Offer data-driven solutions as a service to owners and developers of storage systems** (e.g. remote monitoring, forecasting, predictive maintenance etc.)	**~ $ 60 M**	*Moderate economic potential* – Data driven solutions are estimated to account for 3-7% of the total revenue pool in the stationary energy storage market

Note: LeydenJar, a Dutch scale-up involved in the production, selling/leasing patents and producing manufacturing equipment related to silicon anodes, estimates annual revenue in 2030 to be €1.2 B

Details on pages: 115-131

In addition, the opportunities related to solid state batteries, electric heavy duty vehicles and stationary storage systems also stand out

Overview of business opportunity benchmark (2/2)

Business opportunity	Average estimated annual economic potential (2030)	Rationale
9 **Developing recycling techniques related to the chemical separation of batteries**	**~ $ 20 M**	*Limited economic potential* - Estimated recycling market in 2030 is only 3-8% of the battery pack demand that year, developing R&D and equipment only account for a limited fraction of the market
10 **Recycling/ dismantling of end-of-life mobility batteries**	**~ $ 20 M**	*Limited economic potential* - Estimated recycling market in 2030 is only 3-8% of the battery pack demand that year, the limited revenue pool of performing the recycling reduces the economic potential
11 **Production of solid sate batteries**	**~ $ 250 M**	*Good economic potential* - Solid state batteries are estimated to take 5-10% of the total mobility market, of which battery production is a significant share of the total revenue pool
12 **Production of electric heavy duty commercial vehicles** (buses, coaches)	**~ $ 1,950 M**	*Good economic potential* - The total electric heavy duty commercial vehicle market is substantial ($ 90k-120k M), of which vehicle production accounts for a significant share (44-49%) – strong positioning of NL results in relatively high market shares
13 **Production of e-drive train for heavy duty vehicles**	**~ $ 1,000 M**	*Good economic potential* - E-drive train production accounts for a significant share (22-27%) of the revenue pool across the electric vehicle value chain and is a subset of the previous opportunity
14 **Production of integrated membrane stacks to be used in redox flow batteries**	**~ $ 5 M**	*Limited economic potential* - Redox flow batteries are expected to take 5-10% of the battery storage market, the membrane stacks account for only 8-15% of the total costs
15 **Production of utility scale batteries with longer discharge times** (redox flow, salt water, other technologies)	**~ $ 25 M**	*Limited economic potential* - With 5-10% new battery technologies take a significant share of the total battery storage market
16 **Integration of stationary battery storage into the grid**	**~ $ 150 M**	*Good economic potential* - The revenue pool of grid integration compared to the total energy storage value chain is substantial (18-22%)

Strategy&

Note: Elestor, a Dutch scale-up developing and producing redox flow batteries, estimates annual revenue in 2026 to be in the range of €800-900 M

Production related opportunities appear to have the highest economic potential as they capture larger revenue pools in the battery value chain

Key findings of economic potential assessment

Promising business opportunities

1. **Production of electric heavy duty commercial vehicles** *(buses, trucks)* — ~$1.950 M
2. **Production of electric drivetrains** (subset of electric heavy duty vehicle production) — ~$1.000 M
3. **Production of solid state batteries** — ~$250 M
4. **Production of hardware components** (sensors/ controllers/ chip sets) **which go into a battery management system** — ~$180 M
5. **Integration of stationary battery storage into the grid** — ~$150 M

Average estimated annual economic potential (2030)

For details on **calculation methodology and assumptions**, see pages 108-131

Key drivers for economic potential

Revenue pools

- Opportunities that span across multiple steps of the value chain yield higher economic potential – e.g. cell component production only accounts for 5-10%, where component production to pack assembly is 63-68%
- Within value chain steps, more specific activities result in lower economic potential – e.g. producing polymer materials relates to material costs within cell component production, and polymers are only a share of the total material costs

Market share

- Opportunities with a higher competitiveness score yield higher market share which contribute to economic potential – the average potential market share varies between 2-5%
- The size of the European market impacts the obtainable market share – e.g. on a global scale the European market for electric heavy duty mobility is smaller than the stationary energy storage systems market, which limits the global market share

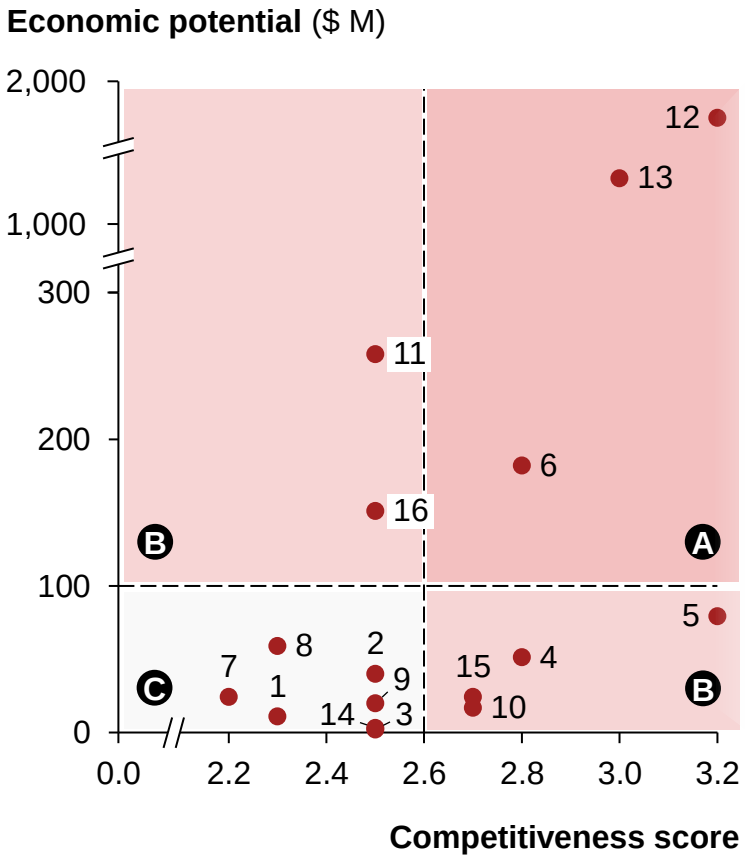
Combining the competitiveness and economic potential assessment yields three regions with distinct strategic characteristics

Combined assessment of competitiveness and economic potential (1/5)

Business opportunities

1. Production of silicon anodes
2. Patents for new battery concepts
3. Producing materials for new battery components
4. Production equipment for current battery technologies
5. Production equipment for new battery technologies
6. Production of battery management system hardware
7. Manufacturing of testing equipment
8. Data-driven solutions for battery storage
9. Chemical separation techniques for battery recycling
10. Recycling end-of-life mobility batteries
11. Production of solid-state batteries
12. Production of electric heavy duty commercial vehicles
13. Production of e-drive train for heavy duty vehicles
14. Integrated membrane stacks for redox flow battery
15. Production of bulk batteries
16. Integration of stationary storage into the grid

Competitiveness vs. economic potential



Strategic decisions based on identified regions

A – Double down

High economic potential and high competitiveness – Explore how NL could capitalize on strong competitive positioning

B – Grow

High economic potential and low competitiveness – Seek for ways to improve NL competitive position

OR

Low economic potential and high competitiveness – Explore possibility of increasing economic potential through backward or forward value chain integration

C – Incubate

Low economic potential and low competitiveness – Monitor potential of relevant opportunities, given the disruptive nature and development speed of the battery market

Opportunities surrounding heavy duty transport and BMS systems appear to be the most promising ones for NL to focus on

Combined assessment of competitiveness and economic potential (2/5)

Strategic decisions	Identified business opportunities	Rationale
Double Down *High economic potential and high competitiveness – Explore how NL could capitalize on strong competitive positioning*	**Production of electric heavy duty commercial vehicles (buses, coaches)**	Electrification of heavy duty transport is needed to meet the ambitious energy transition targets and Dutch companies like DAF and VDL are major players in the EU market for heavy duty transport
	Production of e-drive train	New business models are emerging with vehicle OEM's outsourcing specialized e-drive train manufacturing to third parties and Dutch players can utilize existing expertise to supply to vehicle OEM's globally
	Production of hardware components which go into a battery management system	The market for BMS systems is anticipated to increase significantly in line with battery demand and high potential exists for companies like NXP which already have a large global presence
Grow *High economic potential and low competitiveness – Seek for ways to improve NL competitive position* *OR* *Low economic potential and high competitiveness – Explore possibility of increasing economic potential through backward or forward value chain integration*	**Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	Rise of giga factories in EU will require a localized supply chain where companies like ASML can manufacture specialized equipment required for cell component production (e.g. deposition/ coating techniques)
	Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production	Though battery production has been commoditized in China, this has not been the case for specialized equipment manufacturing. New batteries will potentially require new equipment which can yield potential for Dutch manufacturers
	Production of solid sate batteries	Battery demand for mobility applications is anticipated to increase significantly with the uptake of EVs. Solid state shows promise and NL can capture a large value chain share if production is realized locally
	Integration of stationary battery storage into the grid	High renewable energy (RES) ambitions in EU will require stationary storage systems to integrate the renewable energy sources into the grid and since the ecosystem is very regional specific, Dutch companies can play a role if acted upon early
Incubate *Low economic potential and low competitiveness – Keep an eye out on future potential relevance of the opportunities*	**Multiple opportunities**	Opportunities like Redox-flow batteries, research into new battery technologies and recycling concepts show good potential due to market demand and presence of relevant startups and scaleups; future commercial attractiveness depends on how ecosystem evolves

Mapping opportunities to the overarching themes, identified in previous studies, shows battery packs as potentially the most promising theme

Combined assessment of competitiveness and economic potential (3/5)

Theme	Business opportunities	Competitiveness	Avg. estimated economic potential[1]	Key comments
New cells and materials	1 Production of silicon anodes 2 Patents for new battery concepts 3 Producing materials for new battery components 5 Production equipment for new battery technologies 11 Production of solid-state batteries	2,6	~$370 M	The opportunities focus on relatively small shares of manufacturing revenue pool and new battery technologies are expected to take only a minor share of the total battery market in 2030
Battery packs and systems	4 Production equipment for current battery technologies 12 Production of electric heavy duty commercial vehicles 13 Production of e-drive train for heavy duty vehicles	3,1	~$2.000 M	The production of electric commercial vehicles (including e-drive trains) covers a significant share of the manufacturing revenue pool and NL's strong position also increases the estimated economic potential
Recycling, second-use and reuse	9 Chemical separation techniques for battery recycling 10 Recycling end-of-life mobility batteries	2,6	~$40 M	The relatively small volume of end-of-life batteries available for recycling reduces the estimated economic potential
Grid support	14 Integrated membrane stacks for redox flow battery 15 Production of bulk batteries 16 Integration of stationary storage into the grid	2,5	~$180 M	The economic potential is driven by integration of stationary storage, which accounts for significant share of the stationary storage revenue pool
Safety	6 Production of battery management system hardware 7 Manufacturing of testing equipment 8 Data-driven solutions for battery storage	2,6	~$270 M	The production of battery management systems hardware applies to the whole battery market, yielding significant economic potential

1) Double counting of economic potential has been avoided in the broader themes

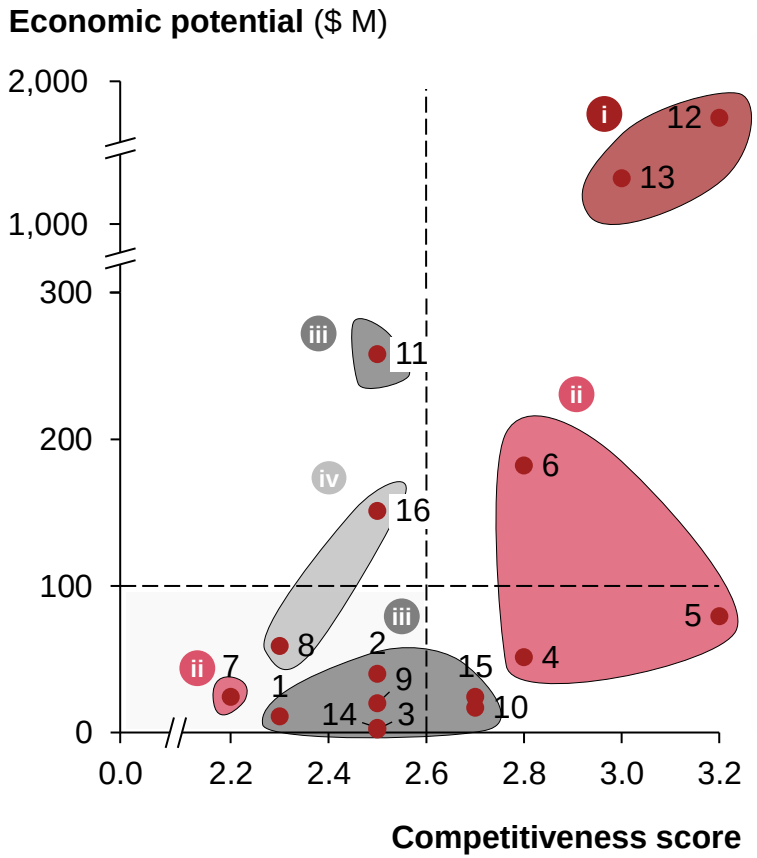
In addition, potential economies of scale and/ or skill can be identified by clustering the business opportunities into ecosystems

Combined assessment of competitiveness and economic potential (4/5)

Opportunity per ecosystem

- **i Electric heavy duty mobility**
  - 12 Production of electric heavy duty commercial vehicles
  - 13 Production of e-drive train for heavy duty vehicles
- **ii Equipment manufacturing**
  - 4 Production equipment for current battery technologies
  - 5 Production equipment for new battery technologies
  - 6 Production of battery management system hardware
  - 7 Manufacturing of testing equipment
- **iii New battery concepts**
  - 1 Production of silicon anodes
  - 2 Patents for new battery concepts
  - 3 Producing materials for new battery components
  - 9 Chemical separation techniques for battery recycling
  - 10 Recycling end-of-life mobility batteries
  - 11 Production of solid-state batteries
  - 14 Integrated membrane stacks for redox flow battery
  - 15 Production of bulk batteries
- **iv Stationary storage systems**
  - 8 Data-driven solutions for battery storage
  - 16 Integration of stationary storage into the grid

Competitiveness vs. economic potential



Potential ecosystem economies of scale/ skill

I – Electric heavy duty mobility
Through producing both electric drivetrains and heavy duty vehicles, NL could strength the competitive position and capitalize on the collective economic potential

II – Equipment manufacturing
NL could use its traditional manufacturing expertise to manufacture a range of equipment for current generation and new generation battery technologies – which all require high-tech equipment

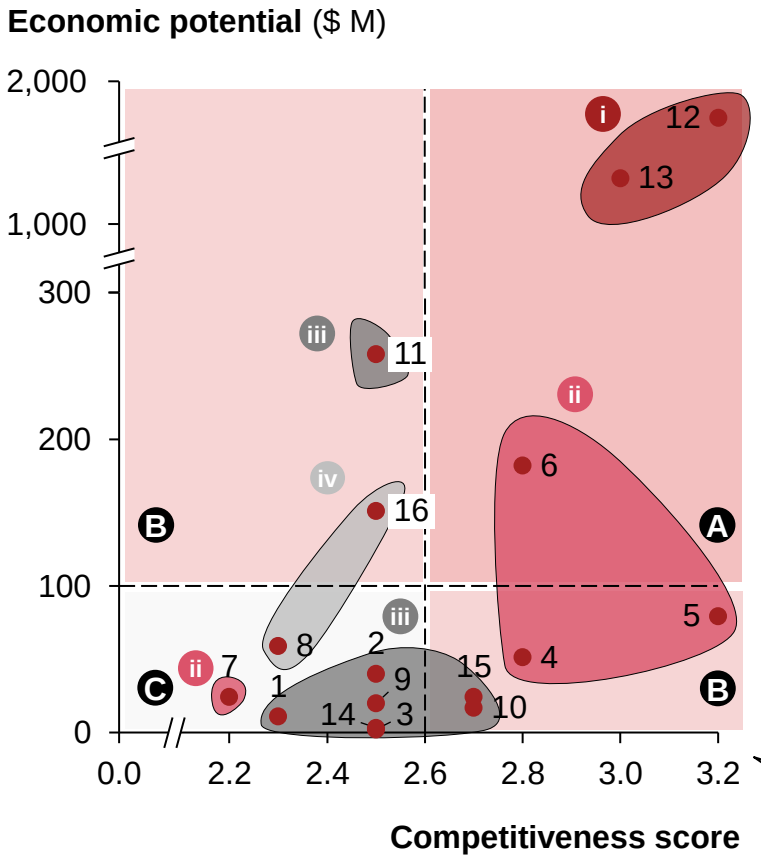
III – New battery concepts
NL could focus on research, developing and producing new battery technologies as well as recycling – all opportunities require significant R&D investments and close collaboration between research institutes and startups

IV – Stationary storage systems
Owing to the large amounts of RES development in EU, NL could spearhead the stationary storage growth in Europe

Clear strategic directions emerge when comparing the ecosystems against each other on competitiveness and economic potential

Combined assessment of competitiveness and economic potential (5/5)

Competitiveness vs. economic potential



Identified ecosystems

Ecosystem	Average competitiveness	Total economic potential, $ M	Strategic decision	Rationale
i **Electric heavy duty mobility**	3,1	~1.950	Double down	The ecosystem has the highest economic potential with already a strong presence of Dutch players competing in the regional and global space
ii **Equipment manufacturing**	2,9	~340	Grow	The ecosystem competitiveness is high due to the traditional Dutch capabilities in manufacturing and a sizeable portion of economic potential can be attained if the companies focus efforts towards batteries
iii **New battery concepts**	2,5	~330	Incubate	High level of collaboration is required between startups, universities and research institutes; high upside is possible if new technologies are commercialized
iv **Stationary storage systems**	2,4	~210	Incubate	Mainly a local and regional play but high upside is possible due to the projected increase in the share of intermittent RES in the energy mix

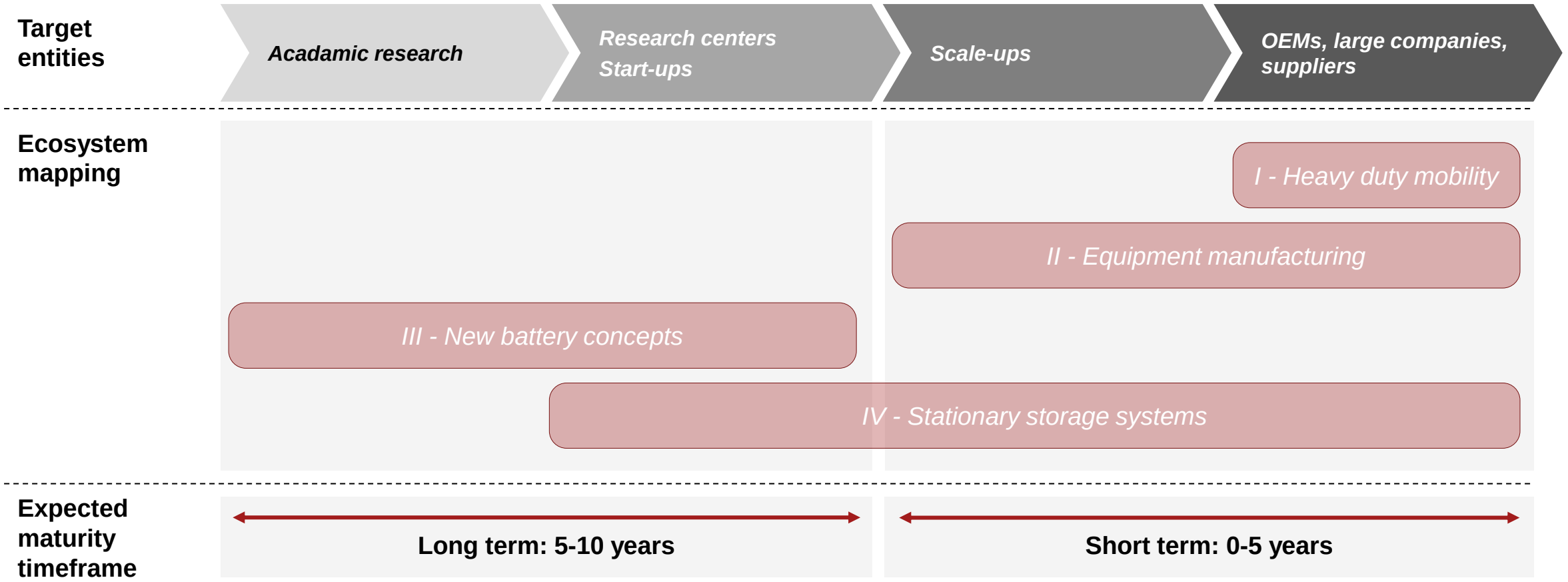
Strategic decisions based on identified regions
A – Double down **B – Grow** **C – Incubate**

Incubate

1) Double counting of economic potential has been avoided in the ecosystems

These ecosystems target different entities with different expected maturity timeframes

Ecosystem mapping to development funnel



In addition, the ecosystems have different challenges to overcome in order to achieve the strategic direction

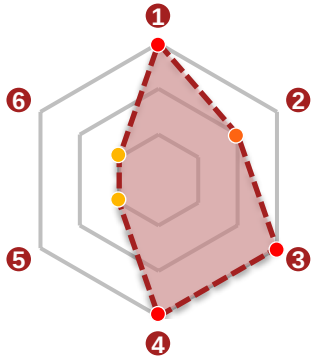
Challenges foreseen per ecosystem

Non-exhaustive

Challenges foreseen

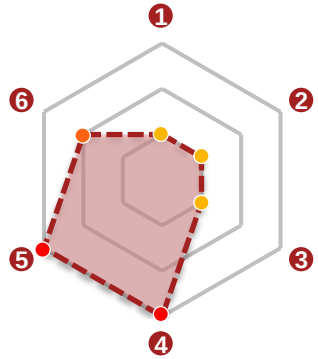
① Technology	Lack of a clear technology development path; it is unclear which technology can mature and become dominant in the market
② Costs	Ecosystems is insufficiently cost competitive compared to alternatives in the market
③ Legislation	Legislative environment is not conducive enough to stimulate faster uptake in the market
④ Competition	Strong competition from experienced and potent companies/ countries within the market
⑤ Commitment	Ecosystem focus is on current lucrative solutions, less effort on investing in growth of battery market
⑥ Capabilities	Lack of R&D focus, skilled workforce and technical knowhow to realize ecosystem growth

Ecosystem mapping



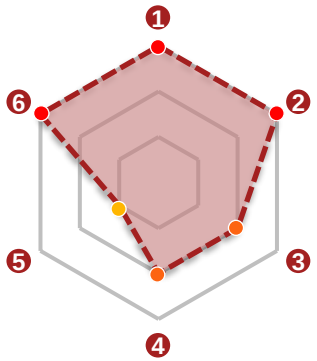
I – Electric heavy duty mobility

- **Technology** – Battery pack energy density needs to improve to facilitate long haul transport
- **Legislation** – Potential to increase incentives for cities and companies to become net-zero
- **Competition** – Germany, United States and South East Asia are well-positioned due to existing large manufacturers



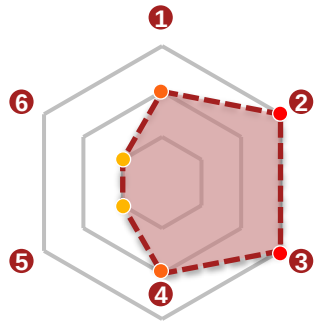
II – Equipment manufacturing

- **Competition** – Established manufacturers already exist supplying to current battery companies
- **Commitment** – Battery market is not sufficiently high on the agenda of existing high-tech companies
- **Capabilities** – Resources allocated to battery technology is limited compared to market



III - New battery concepts

- **Technology** – Uncertain which technology will become the main substitute for lithium-ion batteries
- **Costs** – Decreasing lithium-ion battery costs make it difficult for new technologies to compete
- **Capabilities** – Ecosystem of start-ups, scale-ups and research institutes is currently not sufficient to realize strong uptake



IV – Stationary battery storage

- **Cost** – Current high costs of utility scale storage prevent mass deployment to integrate RES
- **Legislation** – Unclarity around the role of stationary battery storage in the energy policy hinders deployment

Legend ● Minor challenge ● Moderate challenge ● Main challenge

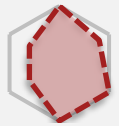
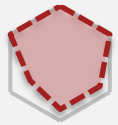
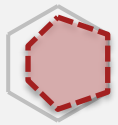
! **Based on expert interviews and subjective assessment**

Details on pages: 144-148

A variety of possible next steps exist that can contribute to overcoming the ecosystem challenges

Summary of strategic direction

Non-exhaustive

Ecosystem	I - Electric heavy duty mobility	II - Equipment manufacturing	III - New battery concepts	IV - Stationary storage systems
Overall strategic direction	**"Double down"**	**"Grow"**	**"Incubate"**	**"Incubate"**
Expected time to maturity	Short term: 0-5 years	Short term: 0-5 years	Long term: 5-10 years	Medium term: 0-7.5 years
Target entities	OEM's, suppliers, large companies	Scale-ups, OEM's, suppliers, large companies	Academia, start-ups, research centers	Start-ups, academia, scale-ups, OEM's, suppliers, large companies
Challenges foreseen	 • Technology • Legislation • Competition	 • Competition • Commitment • Capabilities	 • Technology • Costs • Capabilities	 • Costs • Legislation
Possible next steps	• **Consider providing financial support** that could enable OEMs and research institutes to improve on technology • **Explore legislation possibilities for stimulating electric vehicle adoption**; e.g. zero emission zones in cities • **Review and potentially improve participation of Dutch OEMs** in European tenders	• **Advocate building of regional supply chains** for the upcoming European Gigafactories • **Engage active companies to focus on battery technologies** by showcasing future battery potential • **Stimulate research at R&D centers** of corporates through financial support	• **Stimulate faster technology development** by promoting collaboration within the ecosystem, e.g. intensify information sharing between universities and companies • **Explore possibilities for reducing the financial barriers** for developing new battery concepts • **Attract top talent** with strong credentials in battery research	• **Use legislative mechanisms to incentivize project developers** to co-locate RES and storage to realize cost synergies • **Consider providing financial support** to stimulate deployment till cost parity is achieved • **Highlight the role of stationary storage** in managing flexibility in the grid by connecting with TSO's and utility companies

3 Baselining business opportunities

Baselining business opportunities - Subsections

- **Framework overview**
- General context
  - Market context
  - Dutch capabilities
  - Battery value chain
- Business opportunity formulation
- Summary of identified business opportunities

In the request for proposals, 12 subthemes have been identified as potentially relevant for the Dutch battery ecosystem

Identified themes in the request for proposals

Broader theme	Subtheme	Focus battery technology
New cells and materials	The development of new battery materials for anodes, cathodes, electrolytes and separators	General
	Production equipment for battery cells, modules or packs	General
	Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries	Lithium-ion
	Generation 4 Solid State Batteries	Lithium-ion
Packs and systems	Battery management systems and software	General
	Pack assembly and integration, especially for heavy duty transport	General
Reuse, second-use and recycling	Mechanical and chemical recycling	General
Grid support	Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries	Bulk batteries
	Data-driven solutions for stationary batteries	General
Circularity	System approach as competence for circularity	General
Safety	Safe storage and transport	General
	Measurement and control techniques, quality assurance	General

These subthemes are translated to concrete business opportunities to be able to benchmark vs. other countries and assess economic potential

Methodology to formulate business opportunities from subthemes

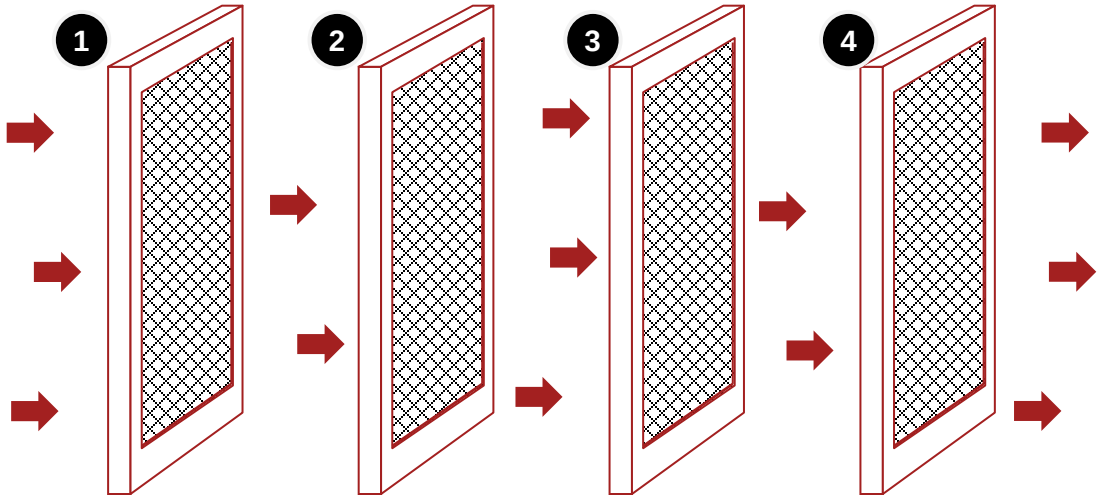
Subtheme approach

Subtheme definitions are broad in scope and prevent accurate benchmarking against other countries and assessing economic potential

Subtheme characteristics

- X Too broad
- X Cover multiple parts of value chain
- X Difficult to translate to commercial business language
- X Makes it difficult to benchmark on a country level and assess economic potential

Conversion lenses



Business opportunity approach

Business opportunities are defined to be value chain focused activities to better facilitate benchmarking amongst countries and assessment of economic potential

Business opportunity characteristics

- ✓ Narrow in scope
- ✓ Cover specific part of value chain
- ✓ Easy to understand in commercial language
- ✓ Facilitates country benchmarking and assessment of economic potential

1 **Relevant market context**

2 **Capabilities of Dutch ecosystem**

3 **Specification along the battery value chain**

4 **Judgement from experts**

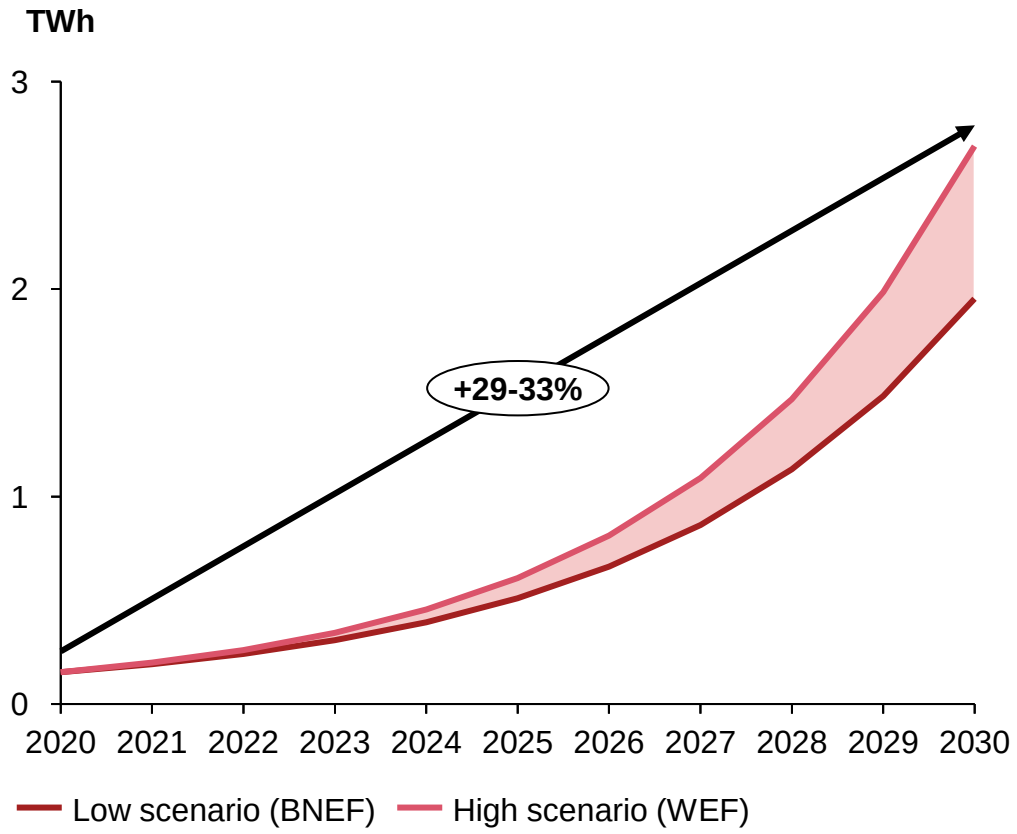
Baselining business opportunities - Subsections

- Framework overview
- **General context**
  - **Market context**
  - Dutch capabilities
  - Battery value chain
- Business opportunity formulation
- Summary of identified business opportunities

The battery market is set for unprecedented growth over the next decade creating opportunities and disruptive threats

Battery storage growth potential

Global battery storage annual growth, TWh (2020-2030E)



Key market characteristics

Growing demand

- Global battery demand is on the verge of massive growth over the next decade and **historic forecasts have tended to underestimate demand**
- **Unprecedented growth expectations (+29-33% year on year),** even compared to iPhones (7%) and semi-conductors (13%)

Emerging opportunity

- **Growing demand will result in a large and attractive market**
- **According to some forecasts, European battery ecosystem could amount to €250 billion a year from 2025 onwards** and current trend of capital investments indicate that abundant capital is available

Strategic asset

- **Territories are starting to consider batteries to a strategic asset** with a highly consolidated Asia dominant supplier base and a potential supply gap in Europe
- Need for additional control over the supply chain and the manufacturing process **further increases the strategic importance of batteries**

Development uncertainty

- **Battery technologies are constantly evolving** and new cathode and anode chemistries have the potential to replace the dominant Li-ion
- New battery markets will also emerge**, including recycling and second life**

Source: BloombergNEF (2020a), WEF (2019), Enerdata (2021), Strategy& analysis

Demand is driven by three main application areas with mobility accounting for majority (~88%) of the battery demand in 2030

Global battery storage demand by application area

Mobility

88% of demand

Description

Energy storage used in all types of mobility applications including last mile delivery

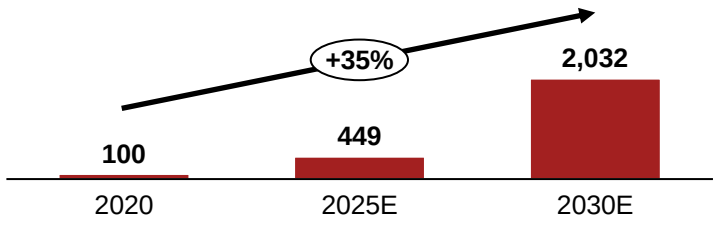
Battery characteristics

High performance batteries required from large scale manufacturers; likely to drive product innovation

Growth driver

Electrification of cars and buses expected to drive battery demand

Estimated average battery demand, GWh (2020-2030E)



Portables

4% of demand

Description

Energy storage used in portables devices and the most mature battery market

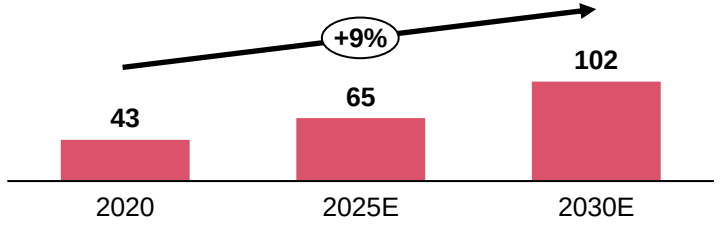
Battery characteristics

Niche battery solutions from smaller scale manufacturers

Growth driver

New consumer electronics (e.g., wearables) and growing electrification of power tools and medical applications expected to drive battery demand

Estimated average battery demand, GWh (2020-2030E)



! **In the economic potential assessment only mobility and storage will be considered –** these markets the have highest estimated growth and are most relevant for the Dutch battery ecosystem

Stationary storage (ESS[1])

8% of demand

Description

Stationary energy storage used in grid-related applications

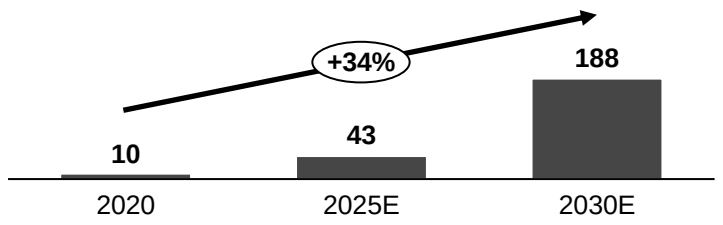
Battery characteristics

Typically large size and must have millisecond response time. Opportunity for second life EV batteries

Growth driver

Increase in residential, commercial and utility-scale storage, due to growth in renewable energy installations, expected to drive battery demand

Estimated average battery demand, GWh (2020-2030E)



! **Share of ESS can potentially further increase in the next decade** on account of RES growth (supply side) and electrification of heating, mobility etc. (demand side) which further increases the need for storage

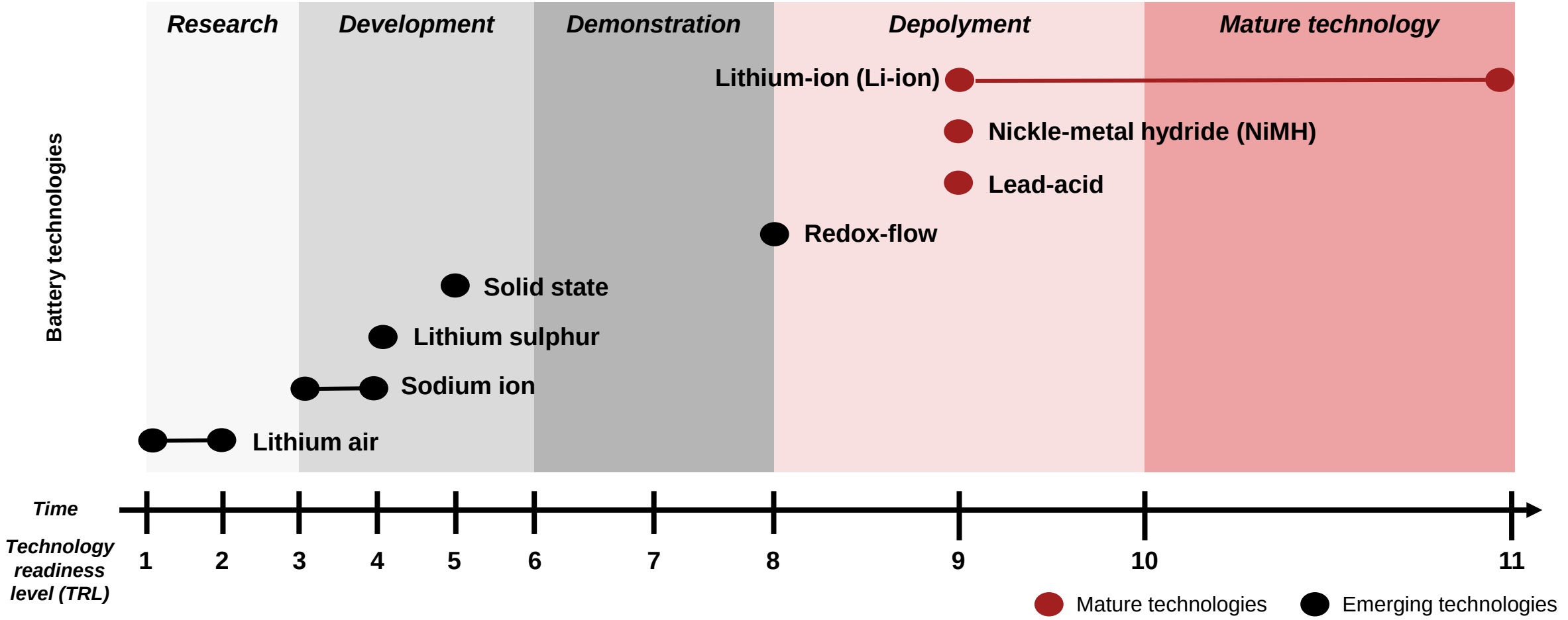
Strategy&

1) Energy Storage Systems; Source: BloombergNEF (2020a), US DOE (2020), IEA (2021), WEF (2019), Strategy& analysis

Battery technologies are constantly evolving with several emerging technologies in the research phase

Battery technology by TRL

Non exhaustive



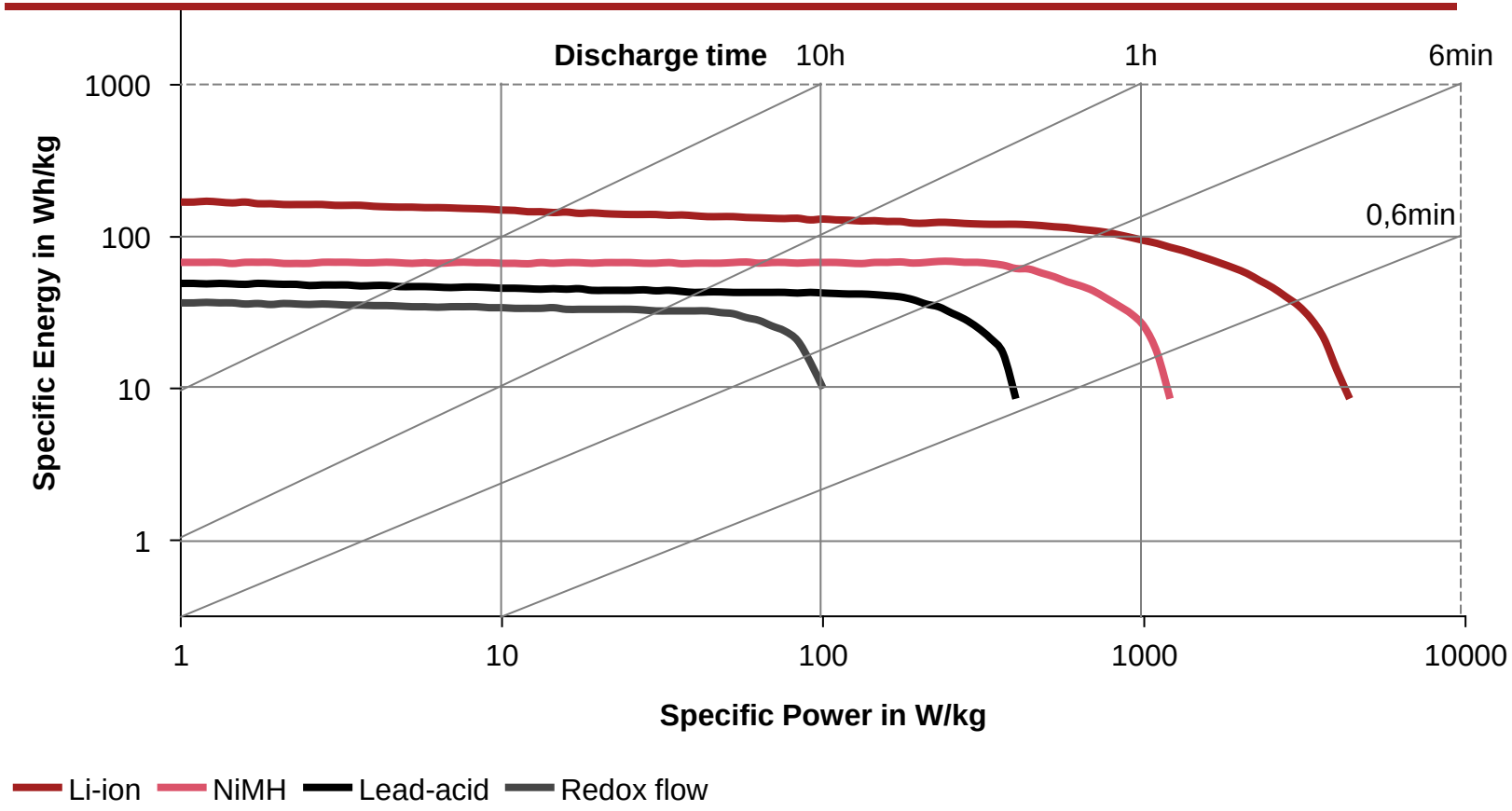
Sources: IEA (2020), TNO (2021), Expert interviews, Strategy& analysis

Amongst the mature technologies, Li-ion currently dominates due to its superior power and energy density

Battery technologies comparison

Non exhaustive

Specific power (W/kg) **and specific energy** (Wh/kg) **by battery technology type**



Key comments

- **Mobility and portable applications currently represent the largest share** (~90%) of the total current battery demand
- Both these segments require battery technologies with **high energy and power densities**
- **Li-ion battery technologies have the highest energy densities** (100 - 265 Wh/kg) amongst other mature technologies such as Lead-acid
- **This has made Li-ion the preferred battery type** for use in applications such as mobile phones, laptops, cameras and automobiles
- **Li-ion batteries are the biggest focus area in EV development** with ongoing research in new cathode chemistries to customize their temperature range, cycle rates, and extending pack life

Sources: European Commission (2020a), Strategy& analysis

In mobility applications (highest demand area), solid state batteries show the highest potential for commercialization in the near future

Advantages and challenges of emerging battery technologies

Non exhaustive

Main application	Battery technology	Description	Battery generation	Advantages	Current challenges	Potential for commercialization
Mobility	**Solid state**	**A Li-ion conducting solid is used as electrolyte** and separator instead of a liquid electrolyte	**Generation 4**	• **High energy density** • **Improved safety** • **High power density** • **Longer shelf life**	• **Commercial performance is unproven** across many indicators (stability, conductivity, sensitivity to water vapor etc.)	◔ (>2025)
	Lithium Sulphur	Lithium is used as anode and electron-transfer material, **while the cathode is made of Sulphur**	**Generation 4**	• **High energy density** • **Inexpensive** as Sulphur is cheap • **Less toxic**	• **Poor conductivity** • **Safety concerns** • **Significant volume expansion** during lithiation of Sulphur	◑ (>2025)
	Lithium air	**Oxygen in the air would act as the cathode** with lithium as anode	**Generation 5**	• Potentially very **high energy density** (similar to liquid fuels)	• **Practical feasibility still to be demonstrated**	◔ (>2030)
ESS	**Redox flow**	**Composed of two electrolytes separated** by an ion-selective membrane that allows only specific ions to pass during the charging or discharging process	**n.a.**	• **Very high scalability** and flexibility • **Longer life cycle** • **Higher depth of discharge** • **Unlimited energy capacity**	• **Lower energy densities**	◔ (current)
	Sodium ion	**Charge transfer relies on sodium ions** instead of lithium ions	**n.a.**	• **Potentially inexpensive** as sodium is cheap • **High energy efficiency** • **Abundant availability** of sodium	• **High diffusion barriers** • **Low energy density**	◔ (>2030)

Sources: IEA (2020), European Commission (2020a), European Commission (2020b), Jianmin Ma *et al* (2021), Expert interviews, Strategy& analysis

● **High** ○ **Low**

Baselining business opportunities - Subsections

- Framework overview
- **General context**
  - Market context
  - **Dutch capabilities**
  - Battery value chain
- Business opportunity formulation
- Summary of identified business opportunities

NL appears to be well positioned to play in the battery ecosystem with a presence of high-tech companies, universities, battery startups and funds

Favorable characteristics of the Netherlands to play in the battery market

Non-exhaustive

Well developed high tech industry

- Home to major multinationals like Philips, NXP and ASML, the Netherlands' high tech industry is among the most innovative in the world
- The semiconductor equipment sector is an important market in the Netherlands and almost all chips around the world contain components produced in The Netherlands or are manufactured with Dutch tools

Strong research focus at technical universities

- Strong knowledge base exists at Dutch universities in the field of Physical Science and Engineering, with 4 out of 11 universities present amongst the top 10% EU universities with the highest scientific impact, further supplemented by knowledge of material sciences at UU and RUG
- University of Twente has a dedicated research center for battery technologies (Twente Centre for advanced battery technology)

Large number of companies in battery ecosystem

- Looking at the European Battery Alliance network, The Netherlands appears to have a good number of companies active in the battery ecosystem
- However, the lack of a large automotive industry in the country reduces the ecosystem maturity when compared to countries like Germany and France

Availability of subsidies and grants

- NL available subsides per capita for renewable technologies is comparable to EU avg. and high higher than other international countries
- The Netherlands did not participated in a second IPCEI that supports research and innovation in the battery value chain

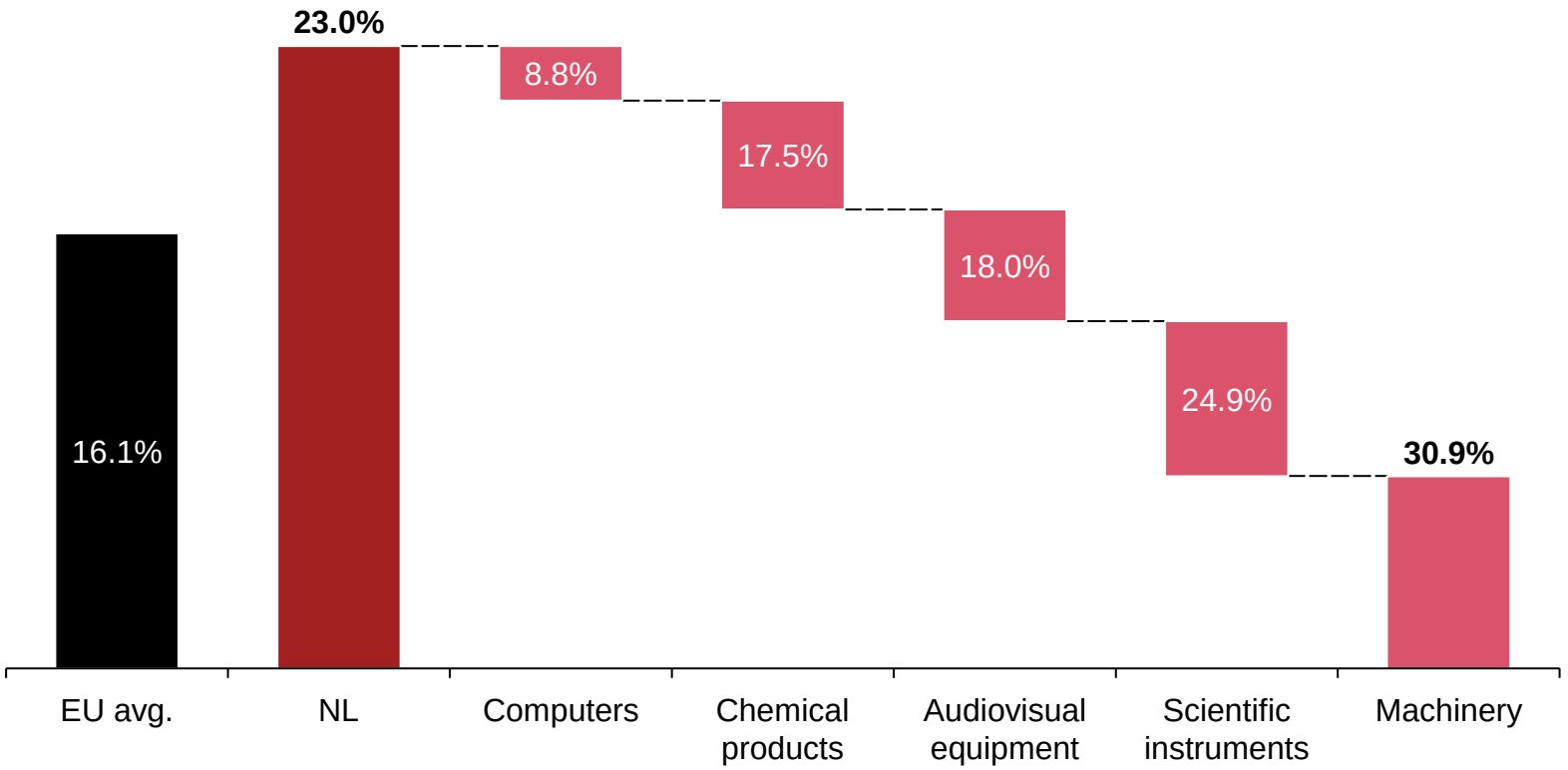
SDE++ 2020
Stimulation of Sustainable Energy Production and Climate Transition

Sources: The World Bank (a), CWTS (2021), EBA (2021), European Commission (2021), Strategy& analysis

NL has a higher % of high tech exports as a share of manufactured exports compared to EU avg., with machinery being the main sector

High tech industrial focus of the Netherlands

High tech exports as a share of manufactured exports, % (2019)



Key comments

- The **total export value** of Dutch manufactured **high tech goods is greater than €20 Bn**
- **The machinery and scientific instruments sector** combine constitute **~55% of the total high tech export value**
- **The semiconductor equipment sector is one of the focus sectors** with companies like **ASML having a market share of over 80% in lithography** and conducting cutting edge research in the field of extreme ultraviolet lithography
- The Dutch high-tech sector's focus on machinery constitutes **strong capabilities to play in the wider battery ecosystem** where specialized machinery is required in the cell production process
- In addition, the substantial forecasted **battery production increase in EU** will provide a **healthy regional market for suppliers**

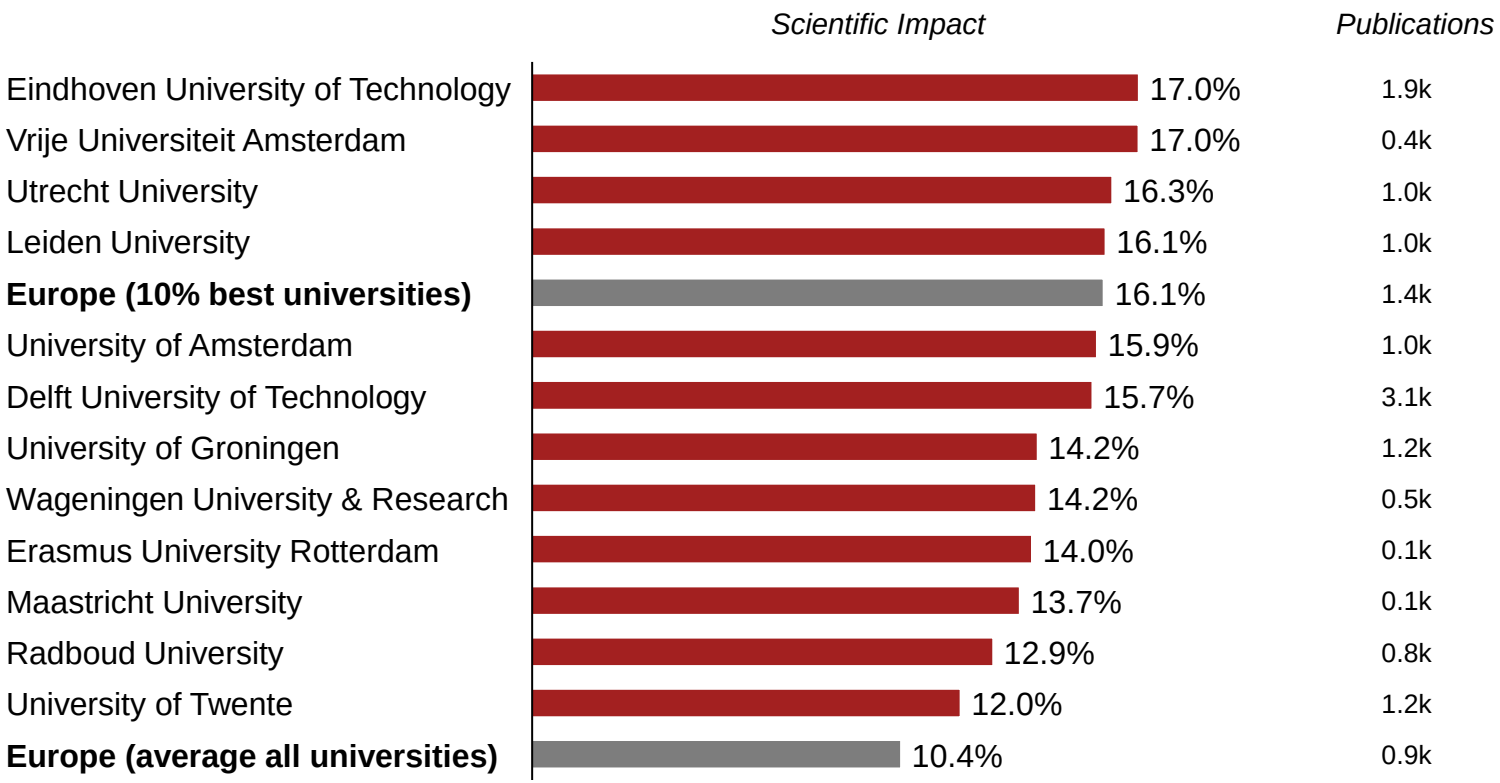
Strategy&

Sources: The World Bank (a), CBS (2017), Strategy& analysis

All Dutch universities have a scientific impact that is above the European average; 4 universities are, in fact, amongst the top 10% in Europe

Competitive position of Dutch universities

Scientific impact of Dutch Universities in Physical Sciences and Engineering[1], % (2016-2019)



Key comments

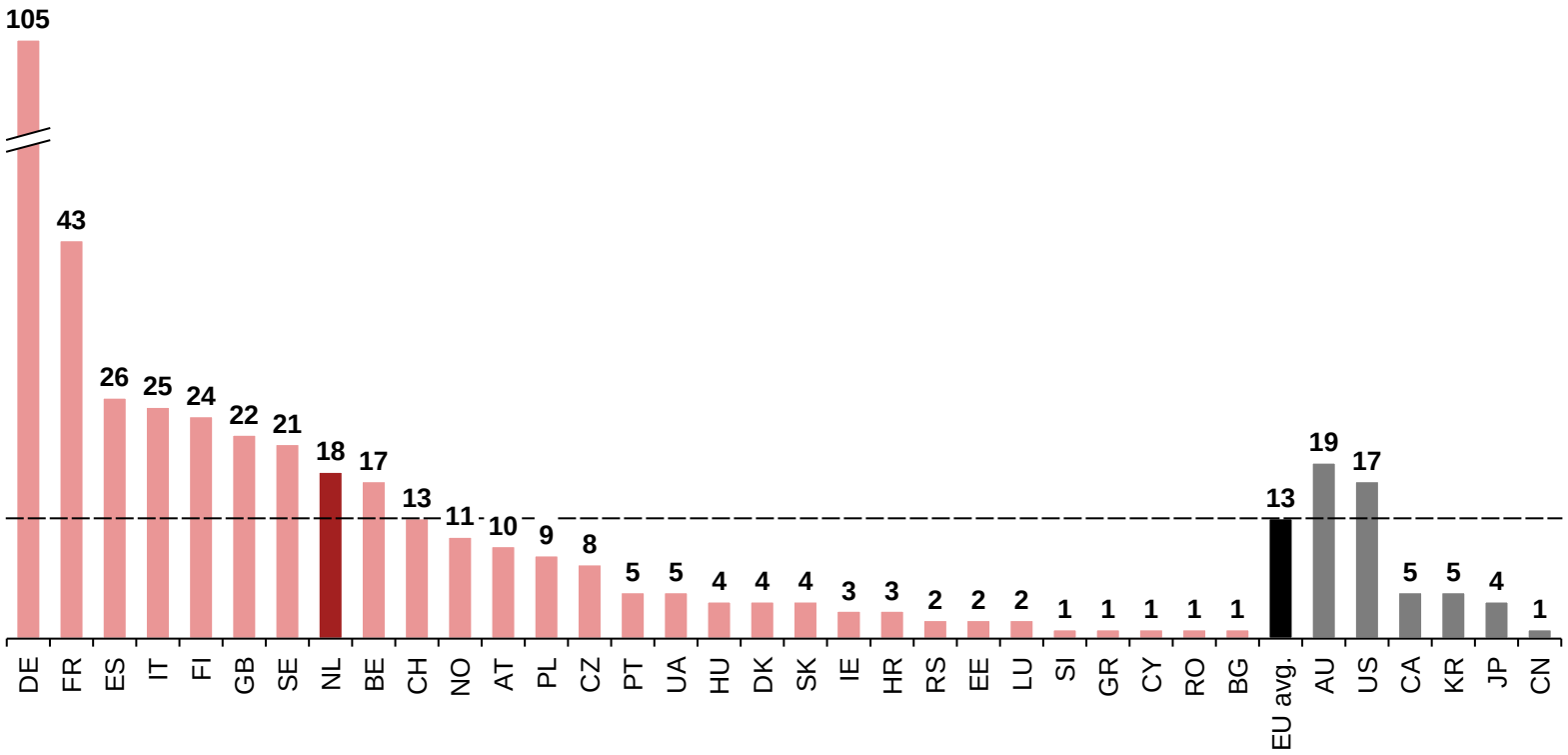
- **Scientific impact is the proportion of a university's publications that**, compared with other publications in the same field and in the same year, **belong to the top 10% most frequently cited**
- **All Dutch universities perform better than the European average**
- **In a global context Europe's average scientific impact is significant**, only North-America (12.2%) and Oceania (13.3%) have bigger scientific impact
- **Eindhoven University is the best ranked Dutch university** in terms of scientific impact with 6th place in Europe
- **Delft and Eindhoven stand out form other universities in terms of number of publications**, 3.1k and 1.9k publications respectively between 2016-2019

1) Only universities with more then 100 publications in the field of Physical Science and Engineering are included
Sources: CWTS (2021), Strategy& analysis

Looking at the European Battery Alliance, The Netherlands appears to have a good number of companies present in the battery ecosystem

Dutch companies related to the battery market

Public and private companies per country active in the European Battery Alliance, Nr (current)



Key comments

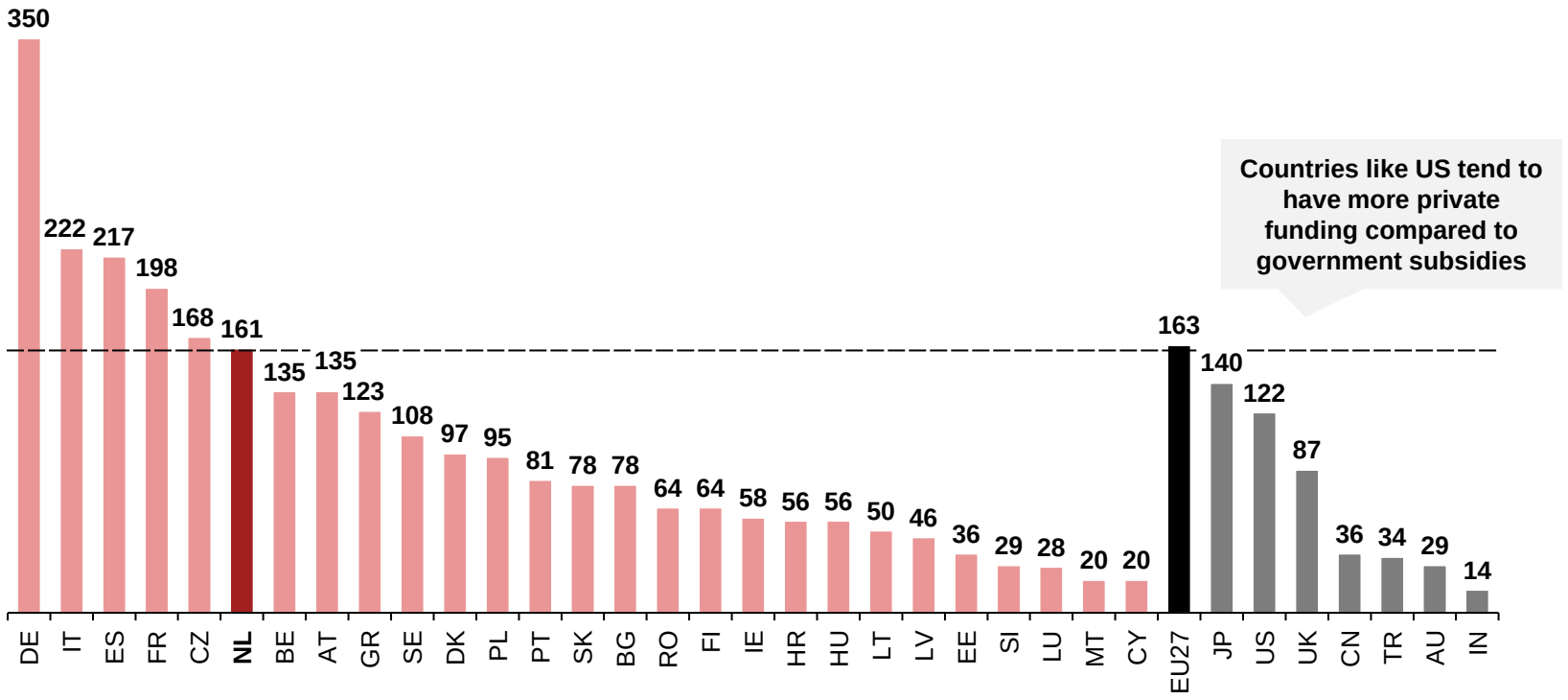
- **The European Battery Alliance network (EBA250) is a unique platform for key stakeholders throughout the entire battery value chain** – from mining to recycling – **with the common objective to build a strong, sustainable and competitive European battery industry**
- **Germany has the strongest presence in the network** which is partly driven by the high concentration of vehicle OEMs
- **A good number of Dutch companies are also participants of the EBA** which could potentially indicate the potential of a future battery ecosystem in the country
- **The number of Asian and American companies in the network are underrepresented** due to the European focus of the network

Sources: EBA (2021), Strategy& analysis

Availability of subsidies for renewable technologies in the Netherlands is comparable to EU avg. and higher than other international countries

Subsidies and grants in NL compared to Europe

Per capita subsidies for renewable technologies by country, €/capita (2018)



Key comments

- Per capita **renewable technology subsides in the Netherlands are close to the EU average**
- **Subsidies are mainly provided through income or price support**, but also tax benefits. Direct transfers and **R&D budgets remain marginal** (together only 9%) of total
- In 2019 and 2021 the European Commission approved two Important Projects of Common European Interest (IPCEI), jointly **€6.1 billion of public support,** to stimulate research and innovation in the battery value chain
- **NL is not participating in the IPCEI**, which is a **missed opportunity as IPCEIs contribute to economic growth, job creation and competitiveness** – the project will bring together knowledge, expertise, financial resources and economic actors throughout the EU

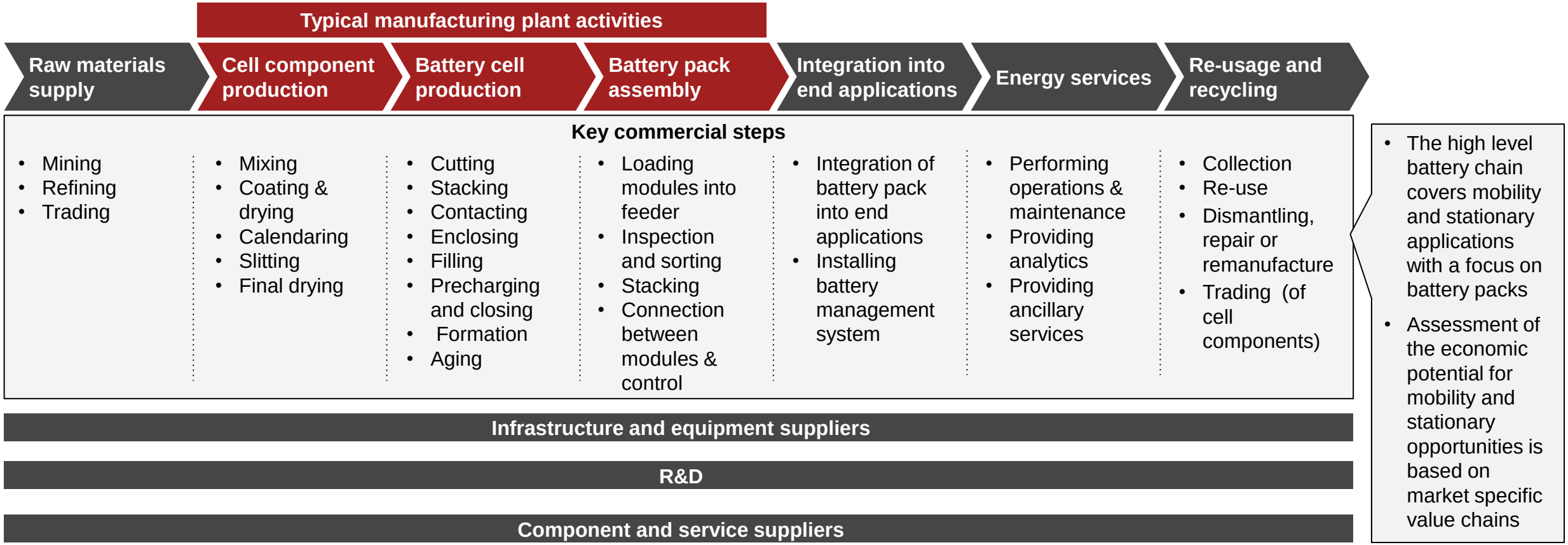
Source: European Commission (2021)

Baselining business opportunities - Subsections

- Framework overview
- **General context**
  - Market context
  - Dutch capabilities
  - **Battery value chain**
- Business opportunity formulation
- Summary of identified business opportunities

Mapping business opportunities to specific value chain steps is necessary to determine the economic potential of the business opportunities

High level battery value chain



Sources: Strategy& analysis

Baselining business opportunities - Subsections

- Framework overview
- General context
  - Market context
  - Dutch capabilities
  - Battery value chain
- **Business opportunity formulation**
- Summary of identified business opportunities

NL could leverage its strong position in material science and equipment manufacturing to contribute to new cell component development

Subtheme 1: formulation of business opportunities from subthemes

Subtheme 1

The development of new battery materials for anodes, cathodes, electrolytes and separators

Relevant market context

- **Material science is fundamental in battery technology -** Material choice has a significant impact on the performance of batteries. Main drivers in this field are increasing the energy density, lowering costs, improving cycle life and increasing safety
- **Currently used materials have limitations -** Battery components consist of rare materials which are mined in countries that do not consistently respect human rights and the broader environment. In addition, the materials used are scarce which drives the costs higher and the use of flammable materials (liquid electrolyte) imposes safety issues.
- **New materials are needed -** Research is focused on new design and alternative materials
- **Application dictates requirements -** The design criteria and material choice depends on the specific application of the battery. For example, limiting battery weight is highly relevant in EVs, but for stationary storage it is less important
- **Silicon has potential -** Silicon could replace graphite as a preferred material for anodes. It not only has a higher energy density but also can be a solution to the graphite scarcity problem

Capabilities of Dutch ecosystem

Non-exhaustive

- **Strong capabilities in nanotechnology and material science in the high-tech sector** (e.g. ASML, DSM)
- **R&D activities at companies and universities**; LeydenJar and E-magy are producing Silicon anodes and silicon anode material respectively and TU Delft, RUG, University of Twente and Utrecht university are researching new chemistries for anodes and cathodes
- **Traditional chemistry companies** that at some point might step into battery technology (e.g. Shell is already doing research activities related to batteries)
- **Strong polymer ecosystem** (e.g. Dutch Polymer Institute, AkzoNobel, Nouryon) and research done at universities

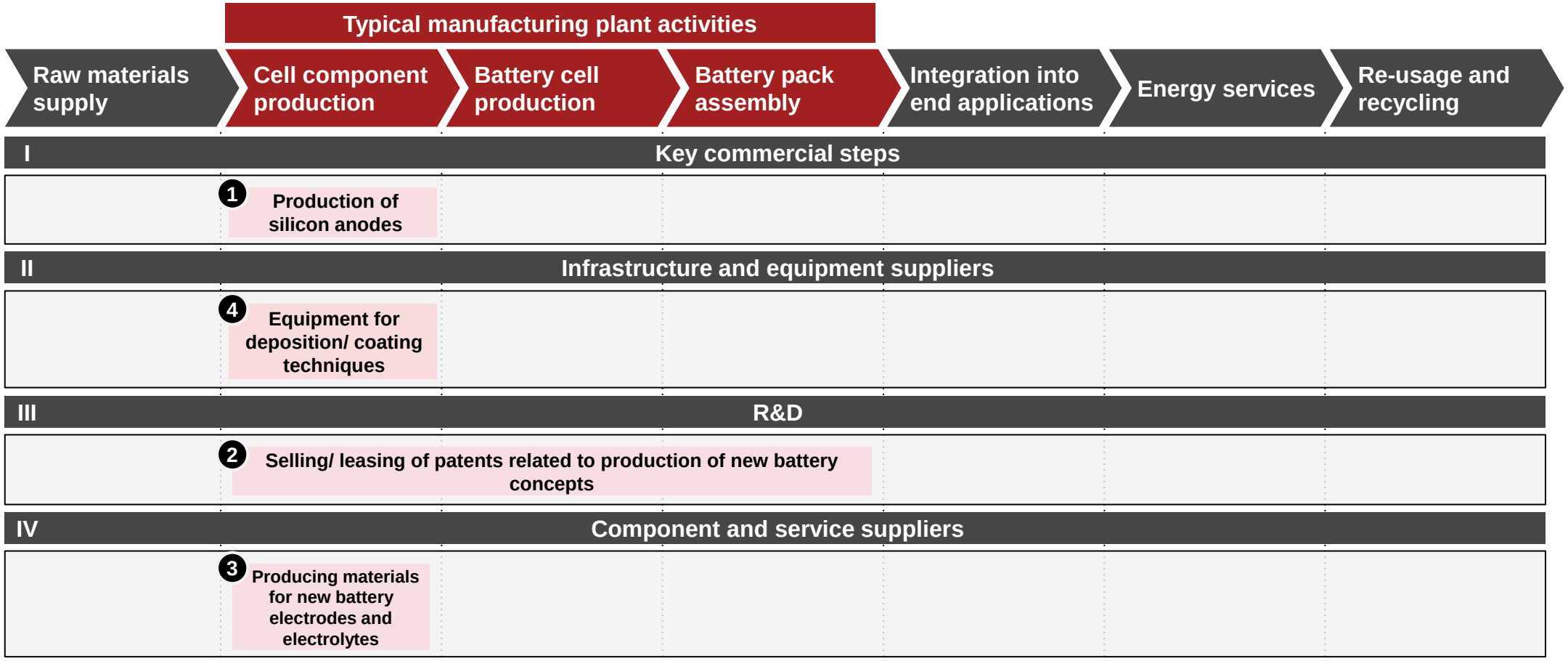
Identified business opportunities

1. **Production of Silicon anodes**
2. **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**
3. **Producing materials for new battery electrodes and electrolytes** (e.g. polymer concepts)
4. **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities in subtheme 1, mainly focus on the cell component part of the battery value chain

Subtheme 1: mapping business opportunities to the value chain



Sources: Strategy& analysis

NL could produce high-tech equipment which will be required for the manufacture of new generation battery technologies

Subtheme 2: formulation of business opportunities from subthemes

Subtheme 2

Production equipment for battery cells, modules or packs

Relevant market context

- **Growth of batteries market unlocks potential for equipment manufacturers –** With the demand for batteries growing, the market for production equipment will grow
- **Europe is gaining share in battery production –** Multiple giga factories are being developed in Europe to localize battery value chain which increase potential for a localized supply chain to avoid higher transportation costs
- **New battery technologies make the current equipment obsolete** – Manufacturing equipment does not exist for battery generations from 3B onwards. For example, in the case of solid state batteries, 30% production equipment will remain (mainly the pack assembly part) the same but 70% will need to be replaced
- **Europe has competitive potential for high-tech manufacturing equipment** – China leads the way for established value chain steps like battery pack assembly but cell production for new generation batteries will require more specialized equipment where Europe could potentially have an advantage

Capabilities of Dutch ecosystem

Non-exhaustive

- **ASML is one of the world-leading manufacturers of chip-making equipment** and produces equipment for chip factories all over the world. ASML relies on an extended value chain of local suppliers in the Eindhoven region and is the driving force behind the manufacturing equipment and semiconductor ecosystem in NL
- Next to ASML there are a number of **other companies in NL that are global leaders in** manufacturing of **production equipment** such as: Eurotron (back-end PV modules), VDL ETG etc.
- **Strong collaboration exists in the Netherlands in fundamental and applied research** being done by universities, research organizations and companies

Identified business opportunities

5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**

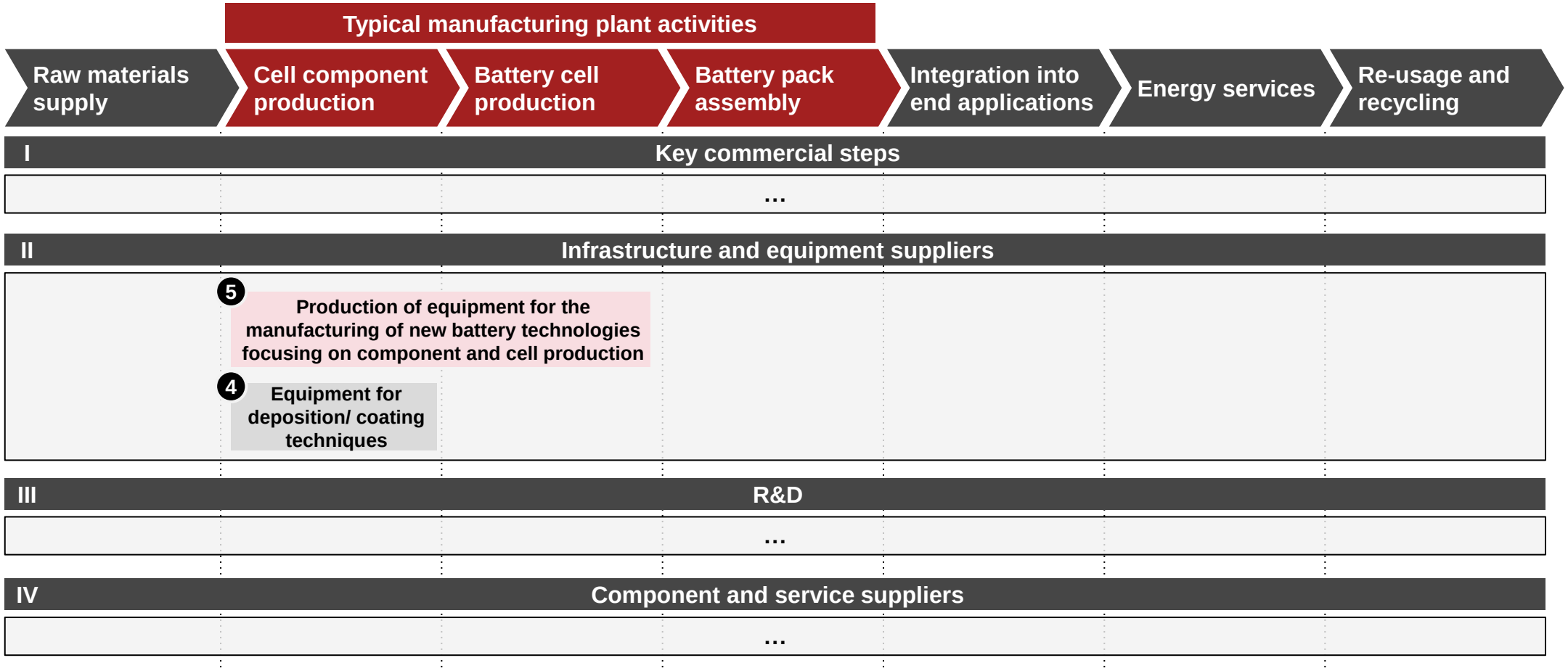
4 **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The equipment manufacturing opportunities are centered around the cell component and cell production part of the battery value chain

Subtheme 2: mapping business opportunities to the value chain



Sources: Strategy& analysis

Note: Subthemes 3 & 8 have been evaluated together due to the strong overlap in business opportunities

NL could produce both hardware components related to battery management systems

Subtheme 3 & 8: formulation of business opportunities from subthemes

Subtheme 3 & 8

Battery management systems and software and measurement and control techniques, quality assurance

Relevant market context

- **Batteries need management systems –** Management systems are needed to control (dis)charging of the battery, monitor battery performance and to prevent thermal run-away (caused by electric, mechanical, or heat abuses)
- **BMS requirements depend on applications –** Requirements differ by end application (for e.g. in stationary storage applications, requirements for quality and space are less stringent compared to EV applications)
- **BMS solutions involve both hardware and software –** Hardware components like controllers, sensors, chipsets must be in perfect sync with the software to make a BMS system work efficiently
- **Cost is key –** Battery manufacturers do not wish to integrate maintenance systems that make batteries more expensive, heavier or more bulky
- **Growing market for smart maintenance/ AI applications -** This facilitates the rise of software and artificial intelligence applications that monitor battery performance and proactively warns for risks

Capabilities of Dutch ecosystem

Non-exhaustive

- **Companies like NXP in NL is already a major supplier** of chipsets to BMS companies
- **Strong knowledge base on battery management systems at universities** (Delft, Eindhoven, Twente)
- Universities and companies are well-positioned in **the field of electrical and thermal engineering**
- NL has **a strong ecosystem in nanotechnology and production equipment** especially from the chip industry

Identified business opportunities

6 **Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system**

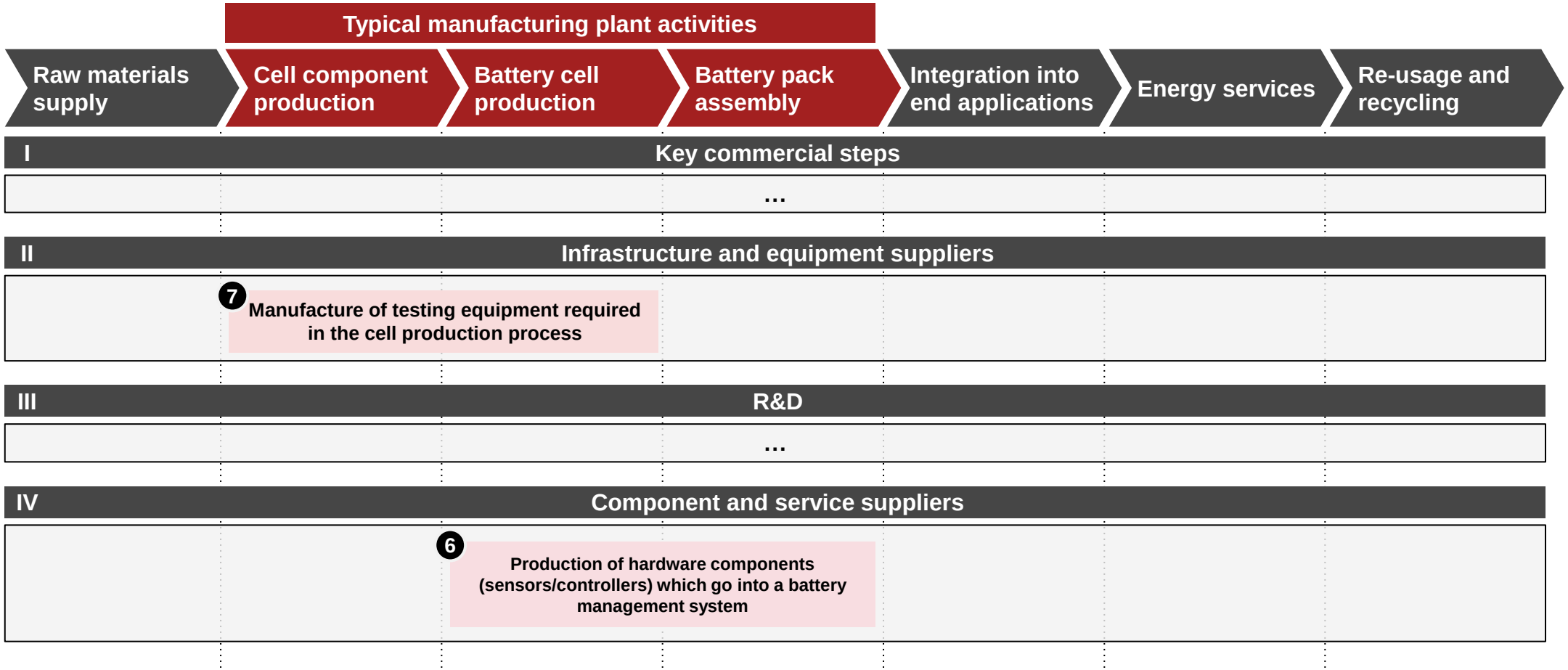
7 **Manufacturing testing equipment required in the cell production process**

Sources: Expert interviews, Desktop research, Strategy& analysis

Note: Subthemes 3 & 8 have been evaluated together due to the strong overlap in business opportunities

The business opportunities in subtheme 3 & 8 cover equipment supply, software development and component supply in battery manufacturing

Subthemes 3 & 8: mapping business opportunities to the value chain



Sources: Strategy& analysis

NL could offer data driven solutions as a service to owners and developers of energy storage systems

Subtheme 4: formulation of business opportunities from subthemes

Subtheme 4

Data-driven solutions for stationary batteries

Relevant market context

- **Need for data driven solutions is increasing –** In the case of stationary storage, the increasing share of intermittent power generation across the world makes the challenge of balancing the grid more difficult (grid balancing is also relevant on a local scale - for example behind-the-meter congestion prevention)
- **Data-driven solutions can unlock potential through value stacking –** It can be used to forecast prices in markets, optimize charging and discharging, weather and demand prediction and to maintain stable performance
- **Rising potential for virtual power plants:** Energy solutions can connect various behind the meter storage devices and convert them into a virtual power plant and reduce reliance on dispatchable generation
- **Broad set of capabilities required –** Strong capabilities in the field of mathematics, modelling, control engineering, electronics and programming are needed for the development of these data-driven solutions
- **Not necessary to be concentrated near battery manufacturers** – As these concepts are software driven, having a strong knowledge based is more relevant than having a strong battery production value chain

Capabilities of Dutch ecosystem

Non-exhaustive

- There are **Dutch companies which already offer energy storage solutions** (e.g. Scholt Energy) **and forecasting services** (e.g. Dexter Energy Services)
- iwell and Alius **offer battery storage on a smaller scale**, behind-the-meter (which also involves data driven solutions)
- Ecosystem of universities doing **research on stationary energy storage** and battery value stacking (Delft, Eindhoven, Twente)

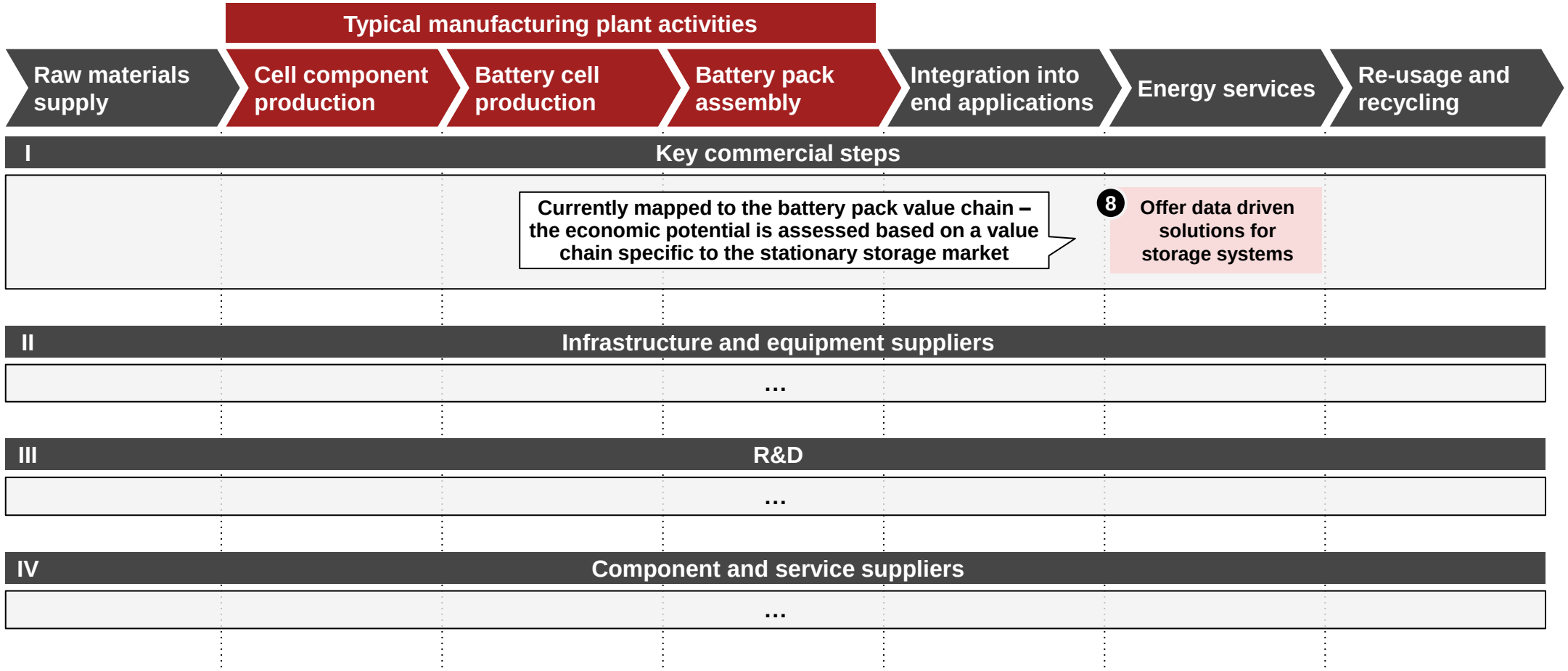
Identified business opportunities

8 **Offer data-driven solutions as a service to owners and developers of storage systems** (e.g. remote monitoring, forecasting, predictive maintenance, charge/discharge optimization)

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunity around data-driven solutions for stationary batteries is focused on the energy services step in the value chain

Subtheme 4: mapping business opportunities to the value chain



Sources: Strategy& analysis

NL could develop recycling techniques related to the chemical separation of batteries to address the sustainability issues

Subtheme 5: formulation of business opportunities from subthemes

Subtheme 5

Mechanical and chemical recycling

Relevant market context

- **Main drivers are sustainability and circularity –** Sustainability is ultimately about reducing what is harmful to the environment and circularity is about reducing the use of raw materials
- **Profitability remains a bottleneck –** Economies of scale are needed to make battery recycling economically-viable, US and Europe instead ship batteries to China and South-Korea for recycling
- **Legislation impacts where recycling takes place –** National targets can determine the minimum required level of recycling, and stricter regulations can help kickstart the landscape
- **Collaboration is needed to develop battery recycling market –** A collection system and extraction chemistry is key as this is difficult for a single company to do, thus the need for collaboration between involved parties
- **Increased focus on circularity and scarcity of materials further stimulate need for recycling** – Many of the battery materials used are scarce and the significant anticipated growth will further compound the problem

Capabilities of Dutch ecosystem

Non-exhaustive

- **Leading position in logistics and collection of residual flows**, and the processing capacity in other material flows, such as metal, electronics and plastics (including research at TNO)
- **Dutch harbors can be central locations for collection and processing of end-of-life batteries** because of the already enormous flow of goods
- However, The Netherlands is behind peers like Germany, France, Belgium etc. in battery recycling due to the lack of a car industry

Identified business opportunities

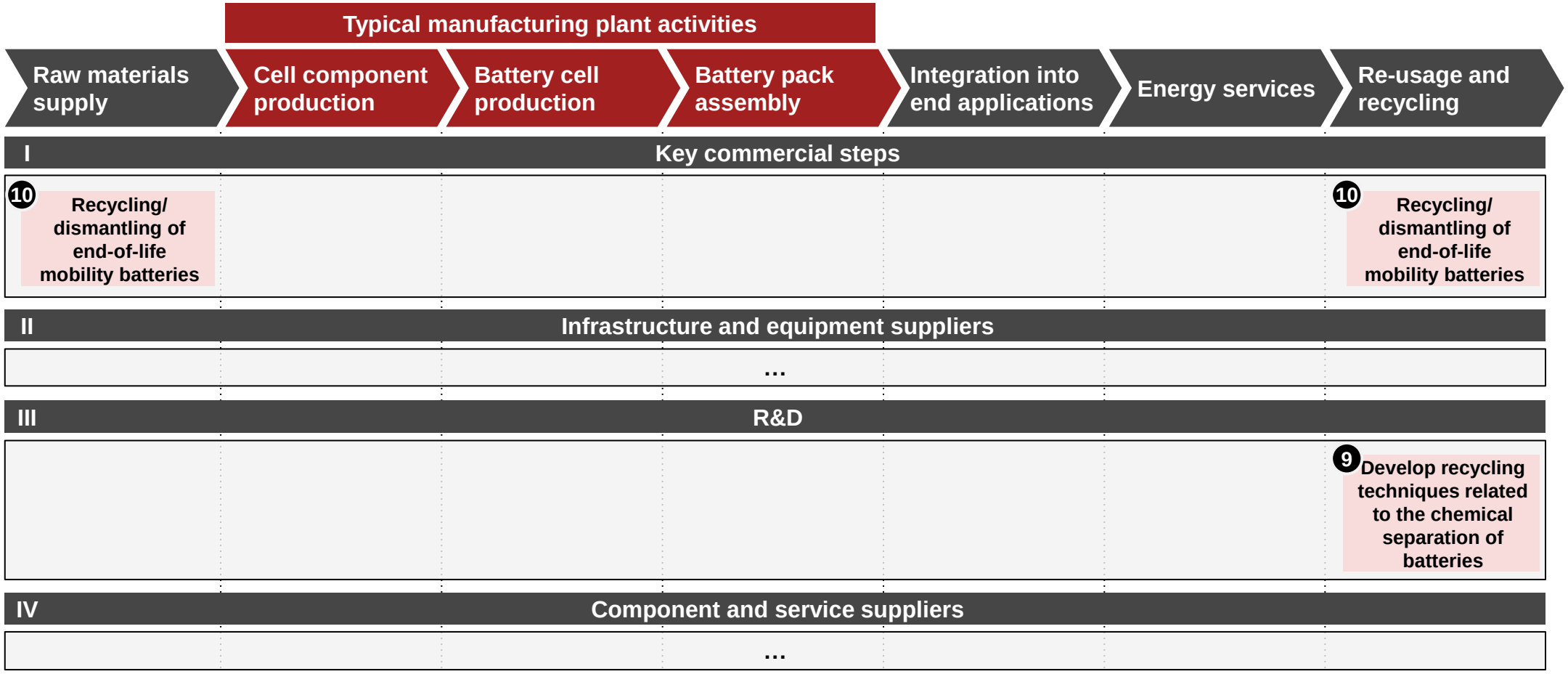
9 **Developing recycling techniques related to the chemical separation of batteries**

10 **Recycling/ dismantling of end-of-life mobility batteries**

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities for recycling are at the last step of the battery value chain

Subtheme 5: mapping business opportunities to the value chain



Sources: Strategy& analysis

NL could recycle and dismantle end-of-life mobility batteries which can be used in stationary storage systems

Subtheme 6: formulation of business opportunities from subthemes

Subtheme 6

Systems approach as competence for circularity

Relevant market context

- **Lack of ownership –** The biggest current challenge in circularity is the lack of ownership between countries and companies. Once a product is sold, the company or country takes their hands off it
- **Holistic view required –** Systems approach is looking at materials, components and products from integrated view, and then explore how they better can be restored, retained and redistributed as you can only understand a system when you see it as a whole and how it interacts with its environment
- **Material degradation is a main technical challenge –** One of the main challenges for circularity is to devise ways to delay the degradation process of materials/ components/ products in the value chain and prevent their 'cascading' into waste
- **Smart technologies help in circularity –** Advanced 'smart' technologies are important tools in promoting the traceability and recovery of components and products in many sectors and essentially supporting circularity

Capabilities of Dutch ecosystem

Non-exhaustive

- The Netherlands has a good ecosystem in place to **fund research into the use of circular sustainable materials in various applications**
- Dutch universities of **Delft, Leiden and Wageningen are doing fundamental research in circularity** and the wider circular economy

Identified business opportunities

9 **Developing recycling techniques related to the chemical separation of batteries**

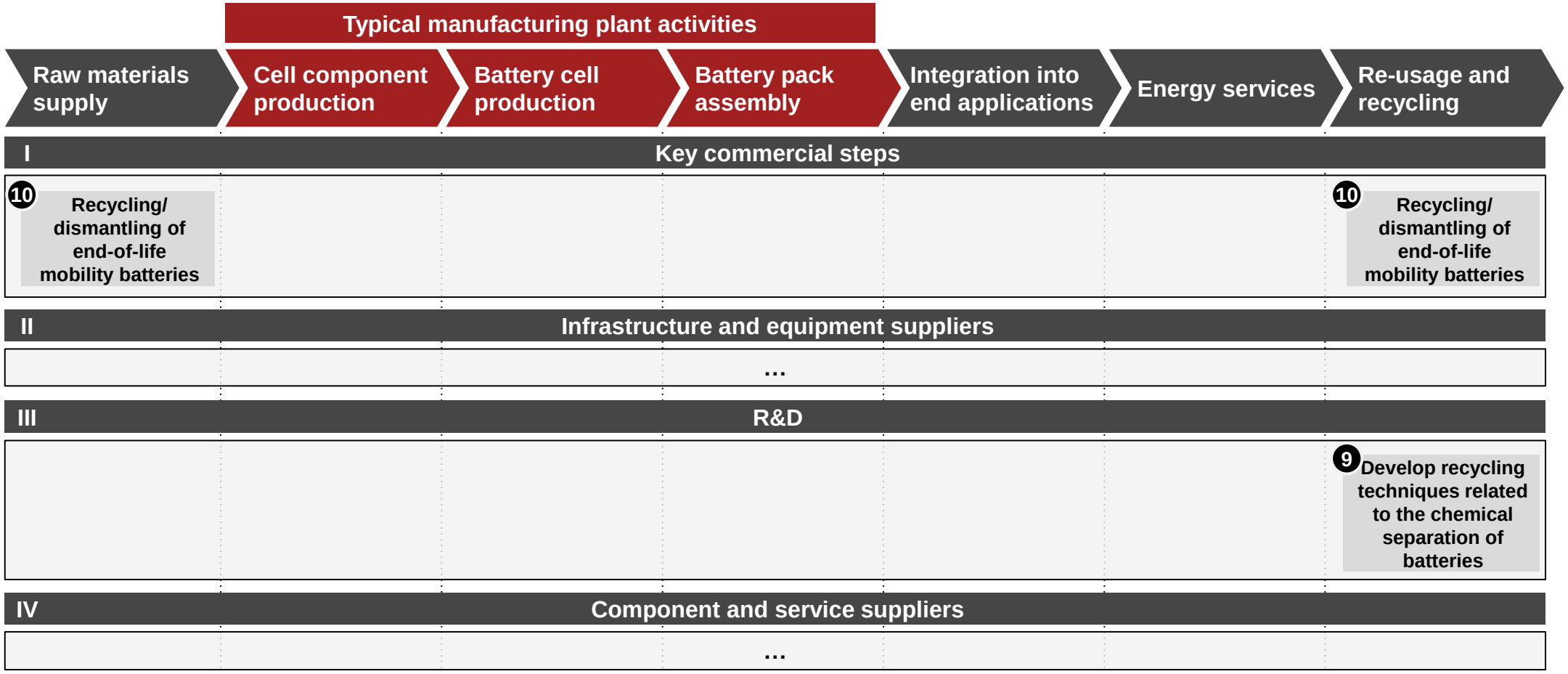
10 **Recycling/ dismantling of end-of-life mobility batteries**

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities for circularity focus on the reusage and recycling part of the value chain

Subtheme 6: mapping business opportunities to the value chain



Opportunity already identified in previous subthemes

Sources: Strategy& analysis

NL could develop recycling techniques to reuse lithium from current batteries and reduce the need for long distance transport

Subtheme 7: formulation of business opportunities from subthemes

Subtheme 7

Safe storage and transport

Relevant market context

- **Long distance transport required –** Currently majority of batteries are manufactured in China and long distance sea transport is needed to cater to a global demand. In addition, reverse transport is required for battery disposal as recycling and reuse methodologies are not mature. However, in future need for transport will reduce as localized ecosystems for manufacturing and recycling will likely be developed
- **Li-ion recognized as a dangerous transport good** – Due to its inflammable nature, Li-ion batteries are recognized as dangerous goods which require additional safety measures during transport and storage
- **Carriers rely on dedicated container manufacturers** - Regulations prescribe use of packaging, which are developed by specialized manufacturers
- **Supply chains are tight** – This increases the need for local production and coming up with new recycling methods to reduce dependance on scare raw material supply

Capabilities of Dutch ecosystem

Non-exhaustive

- **Broekman logistics is a global logistics and storage provider** based in the Netherlands having transport of lithium ion batteries are one of their lines of services
- Other Dutch companies like **Lithium Safety Solutions, Yando** etc. also provide safe transport solutions
- **Netherlands has strong capabilities** in recycling with research being done at TNO

Identified business opportunities

9 **Developing recycling techniques related to the chemical separation of batteries**

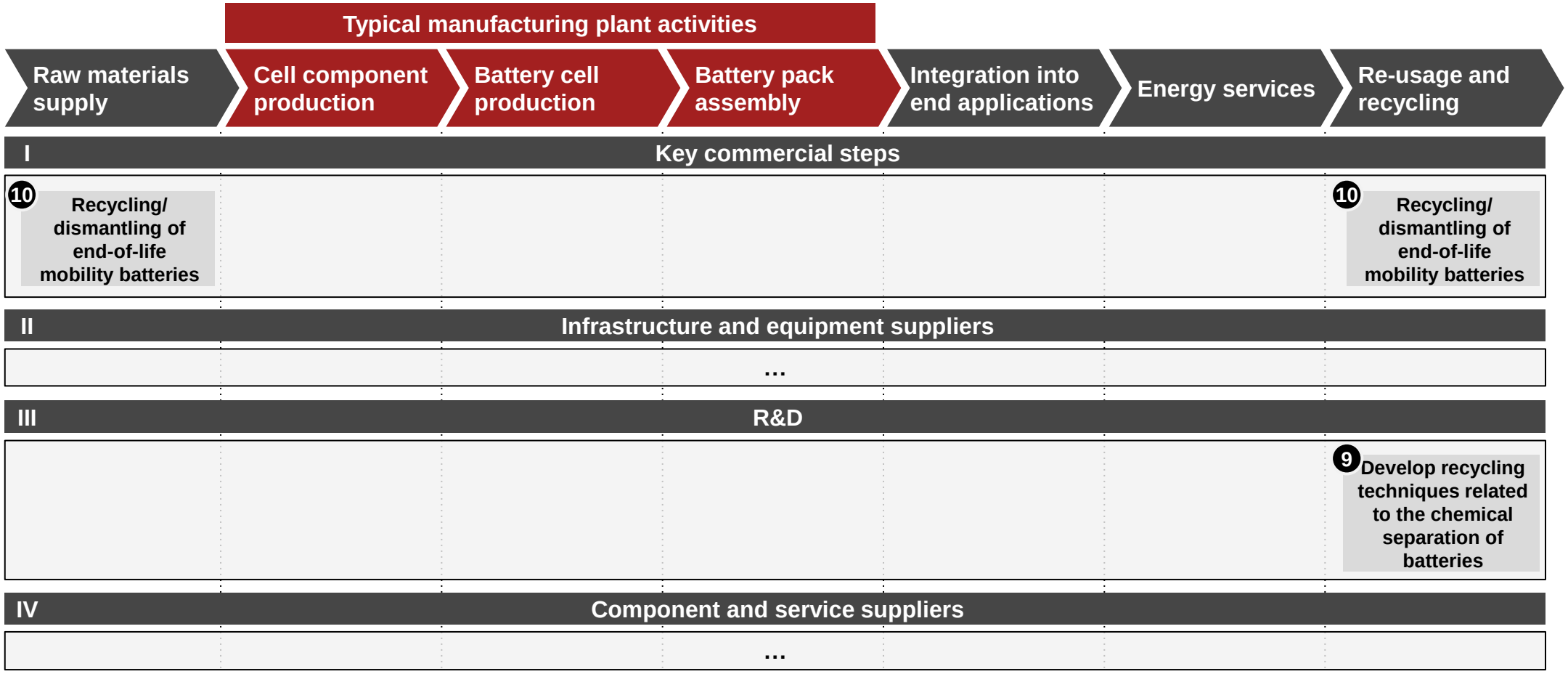
10 **Recycling/ dismantling of end-of-life mobility batteries**

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunity for safe storage and transport are at the last step of the battery value chain

Subtheme 7: mapping business opportunities to the value chain



Sources: Strategy& analysis

For generation 3B batteries, opportunities center around developing/ manufacturing Silicon anodes and producing coating equipment

Subtheme 9: formulation of business opportunities from subthemes

Subtheme 9

Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries

Relevant market context

- **Costs, cycle life and energy density are key in battery manufacturing** – Main drivers in the development of battery production are increasing the energy density, improving cycle life and reducing the costs. Hence, research efforts are directed towards finding the right material chemistries with low cost and higher energy density, while improving cycle life and overall manufacturing process efficiency
- **Silicon anodes can reduce cost and enhance performance** - Silicon is less scarce then graphite or cobalt, which lowers material price. Additionally, silicon anodes have a higher energy density and can charge/discharge faster
- **New coating and deposition techniques have potential to increase cycle life as well as performance**– New coating and deposition techniques (such as Atomic Layer Deposition) can potentially reduce degradation and therefore increase cycle life and performance
- **New battery technologies and process need to compete with established ecosystem** – Any new change in materials or manufacturing process needs to be cost effective in order to compete with the established ecosystem

Capabilities of Dutch ecosystem

Non-exhaustive

- **NL has a strong ecosystem in nanotechnology and manufacturing of precision equipment; ASML** is one of the world-leading manufacturers of chip-making equipment and **is the driving force behind the manufacturing equipment**
- **Delft IMP and Eindhoven SALD sell reactors that can powder coat anodes and cathodes** using the (spatial) atomic layer deposition technique
- **LeydenJar and E-magy are developing and producing Silicon anodes**

Identified business opportunities

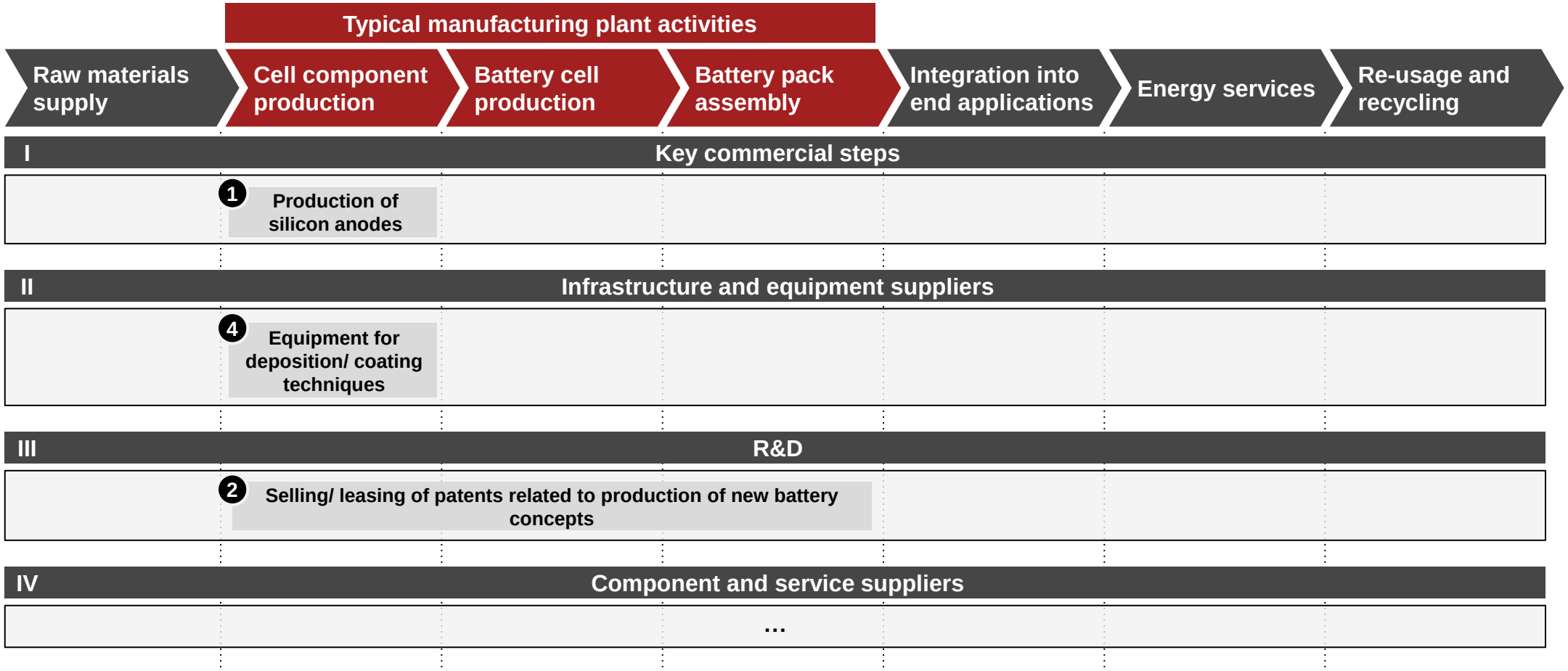
1. **Production of Silicon anodes**
2. **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**
4. **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities in subtheme 9, mainly focus on the cell component part of the battery value chain

Subtheme 9: mapping business opportunities to the value chain



Sources: Strategy& analysis

In case of solid state batteries (SSB's), business opportunities are present in the areas of R&D, equipment production and actual production of SSB's

Subtheme 10: formulation of business opportunities from subthemes

Subtheme 10

Generation 4: solid state batteries (SSB's)

Relevant market context

- **Higher energy density and safety are required –** The main reason for development of SSB's is that they have higher energy densities than the tradition liquid electrolyte batteries with better safety
- **Development phase –** SSBs are still in development phase, with multiple concepts being researched. There is not yet a holy grail that dominates the market and costs are still a prohibitive barrier to commercialization
- **Competition with existing ecosystem –** Commercial acceptance of SSB's will also face challenge from the large investments in the current ecosystems of batteries and some experts doubt whether they can truly replace the liquid electrolyte batteries
- **Cross company cooperation needed –** Close collaboration is needed between companies and research institutes to commercialize solid state batteries and compete with the existing ecosystem

Capabilities of Dutch ecosystem

Non-exhaustive

- **Strong knowledge base in the development of new battery materials** at the universities (Delft, Eindhoven, Twente, Groningen, Utrecht)
- **Spinoff of TNO dedicated to development of solid state battery concepts** (LionVolt)
- **Shared innovation model** in the Netherlands with close collaboration between government, research institutes and corporations

Identified business opportunities

2 **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**

5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**

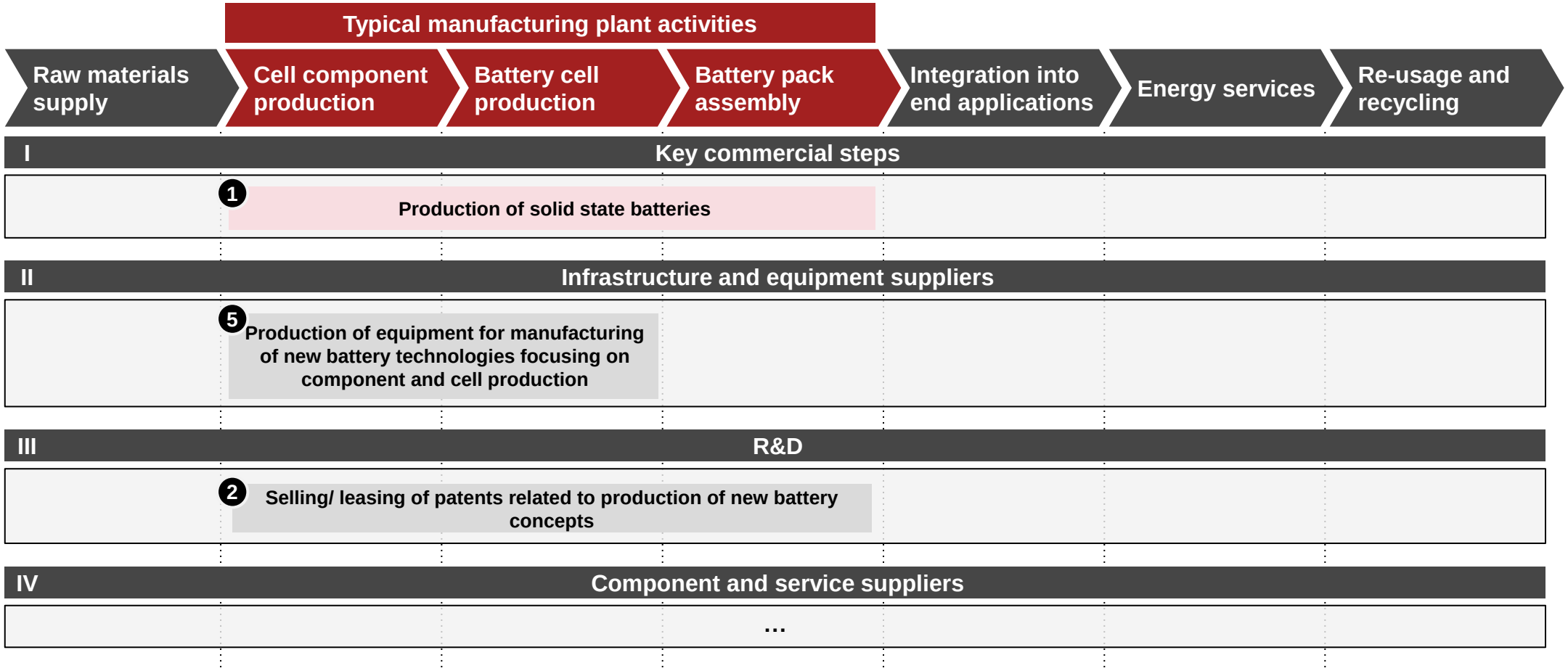
11 **Production of solid state batteries**

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities in subtheme 10 focus on the battery production part of the battery value chain

Subtheme 10: mapping business opportunities to the value chain



Sources: Strategy& analysis

The Netherlands could produce electrical heavy duty vehicles, or focus on the production of e-drive trains

Subtheme 11: formulation of business opportunities from subthemes

Subtheme 1

Pack assembly and integration, especially for heavy duty transport

Relevant market context

- **Significant market potential –** Battery market for commercial vehicles is currently third of EV market, but has potential to become equally large as the batteries for commercial vehicle are 2-3 times the capacity
- **Innovations needed –** High costs and low energy density currently limits the application of batteries in heavy duty transport. Improvements in battery capacity, or innovations that allow for fast-charging, can improve competitiveness of battery electric heavy duty vehicles
- **Established OEMs leading** - Development of battery electric trucks mainly done in-house at established truck manufacturers, although some new companies enter the market with electric vehicles only (e.g. Nikola)
- **Europe has a strong position** – Significant number of truck/bus manufacturers have extensive knowledge and experience that they can leverage in developing battery solutions for heavy duty transport, especially NL has tremendous potential to design and manufacture electric buses

Capabilities of Dutch ecosystem

Non-exhaustive

- **Highly competitive ecosystem of bus/truck OEMs** located in the Netherlands; VDL, Ebusco and DAF are producing EV busses/trucks and are experienced with integrating battery packs into heavy duty transport. The Netherlands also has a leading position within Europe in electric busses and VDL and DAF also cooperated to develop a truck platform
- Leading companies that **produce** (and customizing) **specialized heavy duty trucks** (GINAF, Terberg Group)
- Damen shipyards **develops and manufacturers electric vessels**

Identified business opportunities

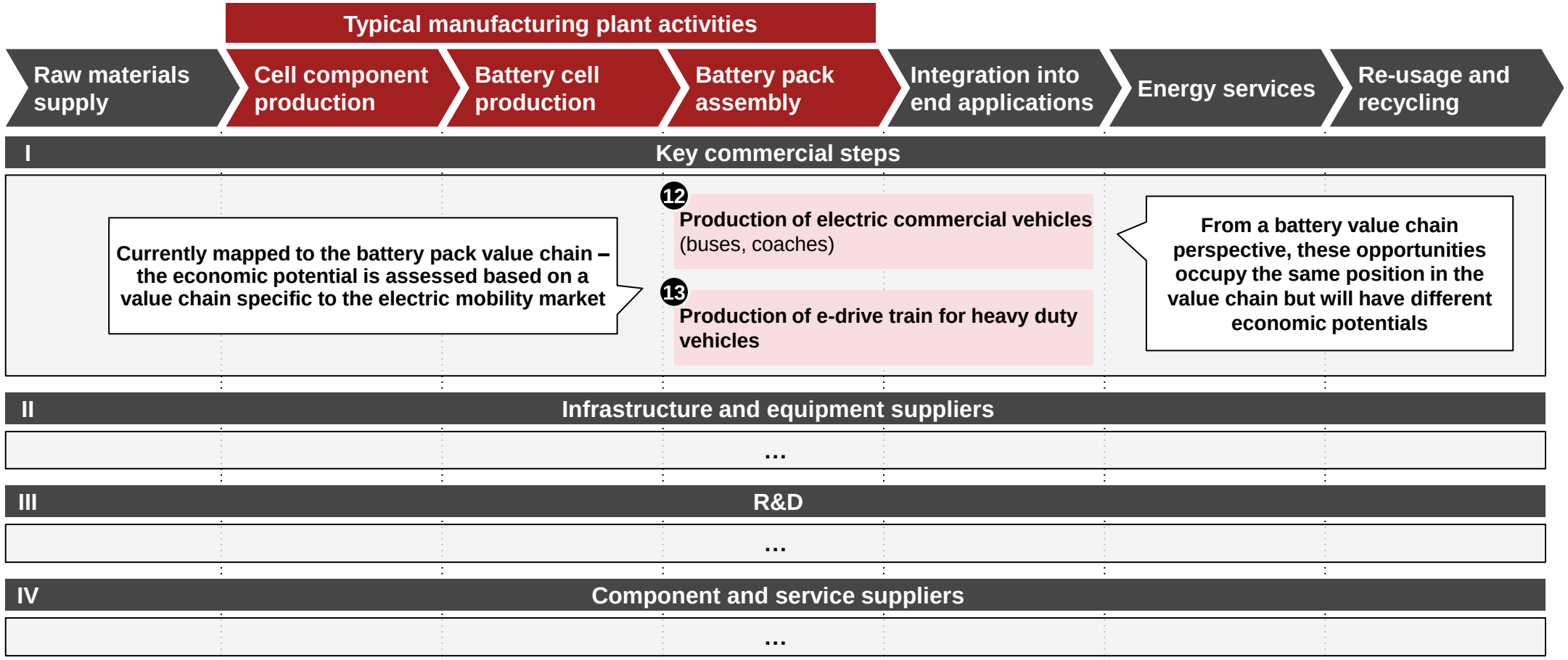
12 **Production of electric heavy duty commercial vehicles** (buses, coaches)

13 **Production of e-drive train for heavy duty vehicles**

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities for heavy duty transport cover the battery pack assembly and integration steps in the value chain

Subtheme 11: mapping business opportunities to the value chain



Sources: Strategy& analysis

NL could play a role in designing, developing and commercializing bulk batteries with longer discharge times

Formulation of business opportunities from subthemes

Subtheme - 12

Bulk Battery concepts, in particular redox flow batteries, hydro and salt batteries

Relevant market context

- **Renewables create demand for bulk batteries** – Demand for utility-scale bulk batteries is likely to increase significantly due to forecasted deployment of intermittent renewable generation which will require storage for integration in the energy infrastructure
- **Longer storage durations are required** – The energy storage requirements in future will not only be for hours but actually for days and months as the share of renewables increase
- **New battery concepts are required to fulfill need** – The scalability of lithium-ion technology is limited, bulk batteries are assumed to be a cheaper and easier solution
- **Specific applications could create opportunity for new battery concepts** – Generally new battery concepts have to compete with an established market, therefore none of processes or materials can be expensive. However, if a new concepts significantly improve storage duration, market might be willing to pay more for it. This could improve competitiveness of new concepts and boost development

Capabilities of Dutch ecosystem

Non-exhaustive

- Universities in Eindhoven, Twente and Delft are performing **research on redox batteries and salt batteries** – in collaboration with companies active in this field
- Elestor is cooperating with VOPAK to **develop redox batteries with high capacity**
- AquaBattery is an **battery initiative** developed on Delft University of technology that **stores electricity solely using water and table salt**

Identified business opportunities

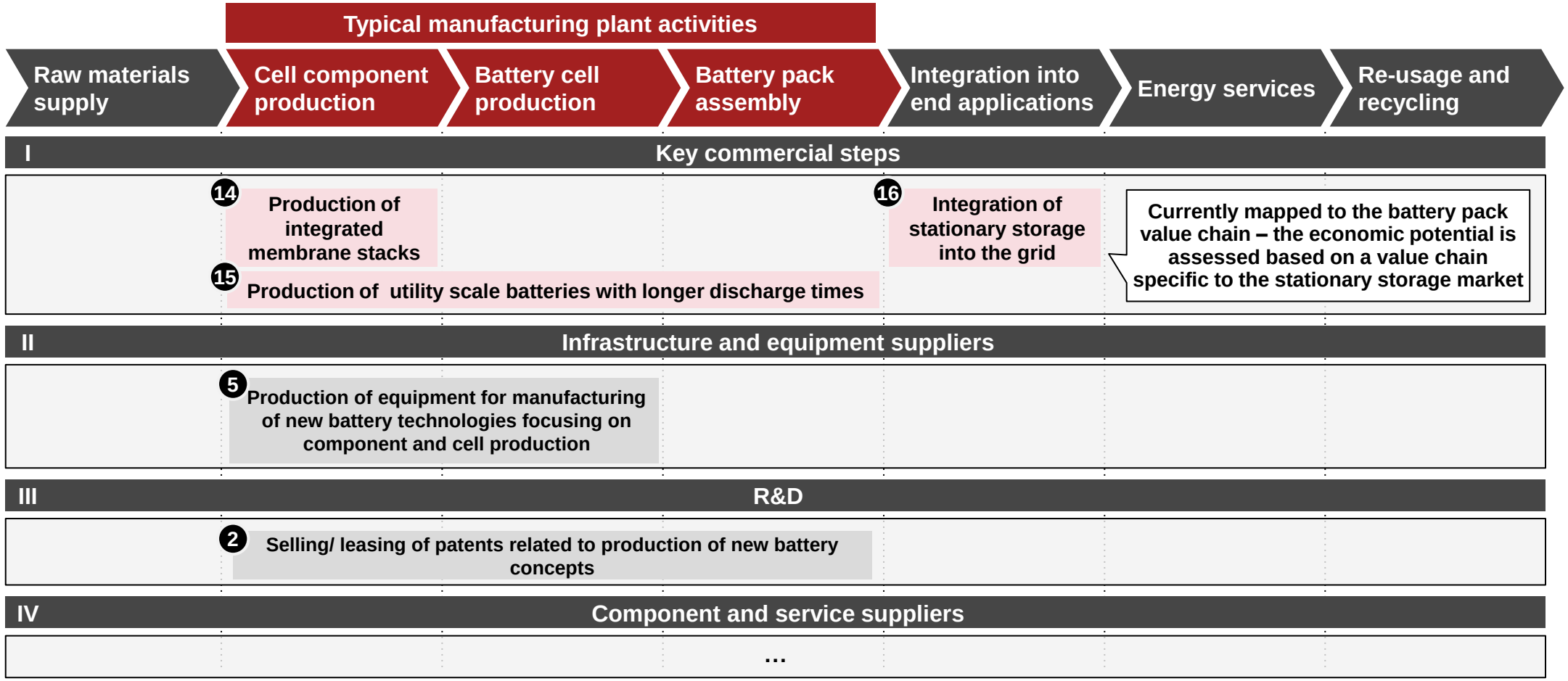
2. **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**
5. **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**
14. **Production of integrated membrane stacks to be used in redox flow batteries**
15. **Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)**
16. **Integration of stationary battery storage into the grid**

Opportunity already identified in previous subthemes

Sources: Expert interviews, Desktop research, Strategy& analysis

The business opportunities in subtheme 12 cover value chain steps from cell component production to integration into end applications

Subtheme 12: mapping business opportunities to the value chain



Sources: Strategy& analysis

Baselining business opportunities - Subsections

- Framework overview
- General context
  - Market context
  - Dutch capabilities
  - Battery value chain
- Business opportunity formulation
- **Summary of identified business opportunities**

As a result, sixteen unique business opportunities have been identified from the various subthemes which could be potentially relevant for NL

Identified business opportunities (1/2)

1 Production of Silicon anodes

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries

2 Selling/ leasing of patents related to material science or production methodologies of new battery concepts

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries
- 10 Generation 4 Solid State Batteries
- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

3 Producing materials for new battery electrodes and electrolytes (e.g. polymer concepts)

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators

4 Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries (e.g. deposition/ coating techniques)

- 1 The development of new battery materials for anodes, cathodes, electrolytes and separators
- 2 Production equipment for battery cells, modules or packs
- 9 Parts/subprocesses (in particular Si-anodes, coatings and deposition techniques) for 3B generation batteries

5 Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production

- 2 Production equipment for battery cells, modules or packs
- 10 Generation 4 Solid State Batteries
- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

6 Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system

- 3 Battery management systems and software
- 8 Measurement and control techniques, quality assurance

Identified business opportunity *Subtheme to which the business opportunity belongs*

As a result, sixteen unique business opportunities have been identified from the various subthemes which could be potentially relevant for NL

Identified business opportunities (2/2)

7 Manufacturing testing equipment required in cell production process

- 3 Battery management systems and software
- 8 Measurement and control techniques, quality assurance

8 Offer data-driven solutions as a service to owners and developers of storage systems (e.g. remote monitoring, forecasting, predictive maintenance, charge/discharge optimization)

- 4 Data-driven solutions for stationary batteries

9 Developing recycling techniques related to the chemical separation of batteries

- 5 Mechanical and chemical recycling
- 6 System approach as competence for circularity
- 7 Safe storage and transport

10 Recycling/ dismantling of end-of-life mobility batteries

- 5 Mechanical and chemical recycling
- 6 System approach as competence for circularity
- 7 Safe storage and transport

11 Production of solid sate batteries

- 10 Generation 4 Solid State Batteries

12 Production of electric heavy duty commercial vehicles

- 11 Pack assembly and integration, especially for heavy duty transport

13 Production of e-drive train for heavy duty vehicles

- 11 Pack assembly and integration, especially for heavy duty transport

14 Production of integrated membrane stacks to be used in redox flow batteries

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

15 Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

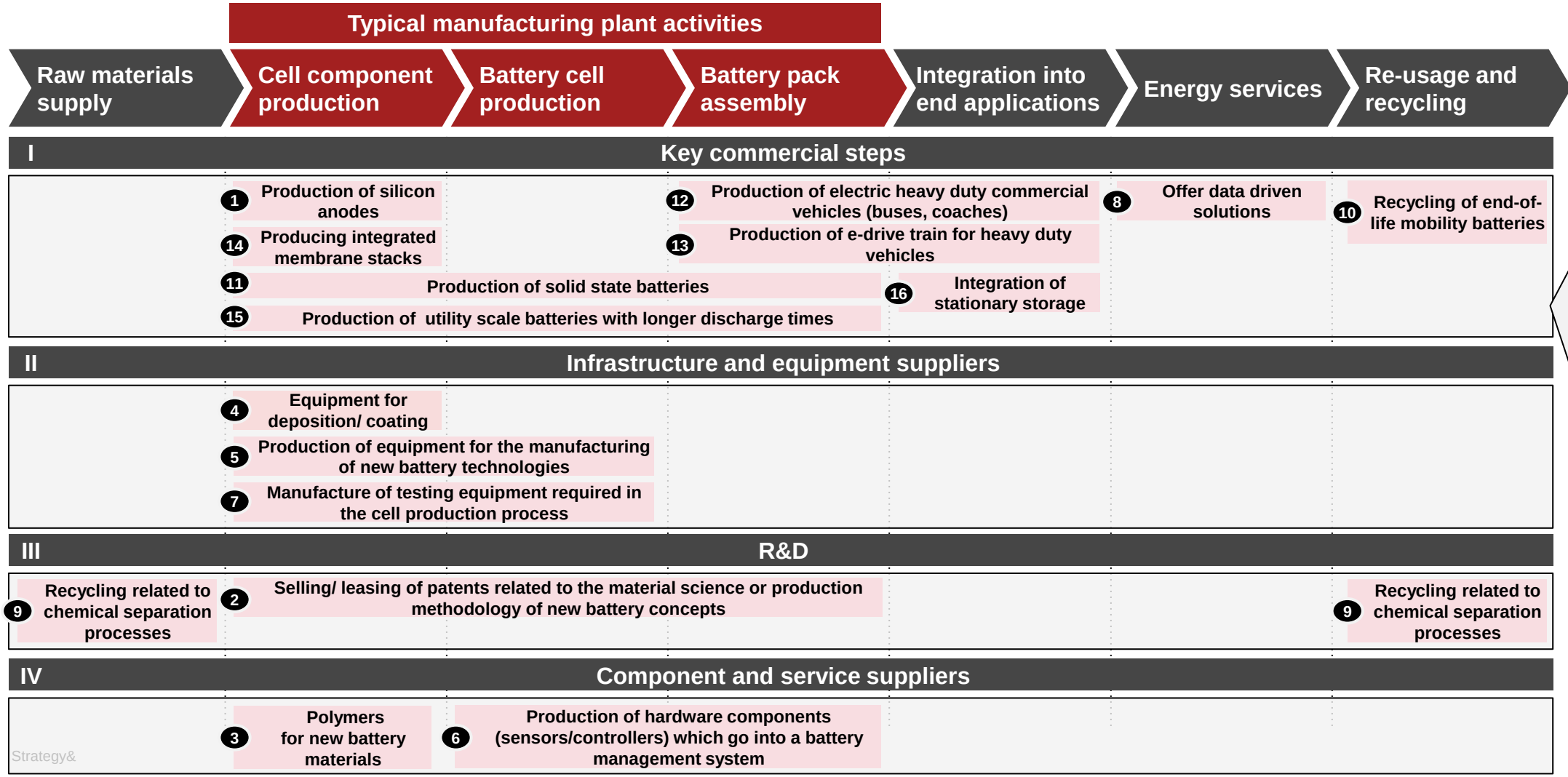
16 Integration of stationary battery storage into the grid

- 12 Bulk Battery concepts, in particular redox flow batteries, Hydro(gen) and salt batteries

Identified business opportunity *Subtheme to which the business opportunity belongs*

The identified business opportunities mainly apply to the cell component and cell production part of the battery value chain

Mapping business opportunities to the value chain



- The high level battery chain covers mobility and stationary applications with a focus on battery packs
- Assessment of the economic potential for mobility and stationary opportunities is based on specific value chains

4 Assessing Dutch competitiveness

Assessing Dutch competitiveness - Subsections

- **Framework overview**
- Competitive potential assessment per business opportunity
- Summary of Dutch competitive potential

We created a reference list of countries per business opportunity and then benchmarked NL against those countries using a 5-point scale

Benchmarking methodology

Steps in the benchmarking process by business opportunity

1. **Create reference list of countries per business opportunity using keyword search from database Orbis**
2. **Refine reference list using desktop research and expert interviews**
3. **Benchmark NL against the reference list using the competitive indicators and a 5-point scale**
4. **Visually compare NL against the 3 leading countries to understand competitive potential**

Deep dive

5-point scale to assess Dutch competitiveness

1. **No right-to-win:** No/ very few companies active in the business opportunity. NL is far behind its peers and lacks an ecosystem to compete
2. **Moderate competitive potential:** Ecosystem surrounding the business opportunity exists and NL can supply to the local and regional market
3. **Good competitive potential:** Mature companies and R&D institutes operate in NL with potential to compete at a global level
4. **Substantial competitive potential:** NL has a thriving ecosystem surrounding the business opportunity and has a high market share globally
5. **Market leader:** NL dominates the global market pertaining to the business opportunity with established companies operating and doing R&D

Since NL is compared against the leading countries, the relationship between scores and competitiveness is non linear; Scores above 2 already indicate average competitiveness in the total market

We applied a combination of qualitative and quantitative indicators to assess the competitiveness of NL for every business opportunity

Overview of competitive indicators

Type	Indicators	Source	Rationale
Lagging indicators - strength of current industry	**Number of companies** currently operating in a country specific to a business opportunity	Database 'Orbis' and google search and expert interviews	*The number of active companies in a country determines the relative size of an industry and the dominance of the country in that industry*
	Maturity of the industry in the country, related to the business opportunity	FTE estimates per company from database 'Factiva' and company profiles and expert opinion	*Assessment of the industry maturity as a whole is based on multiple levers; amount of FTE's employed in a market serves as an initial indication, which is refined with qualitative assessment of company profiles and expert judgement (e.g. to compensate for high levels of automation)*
	High technology exports as % of total exports for manufacturing related opportunities or **Research and development expenditure as % of GDP** for research related opportunities	Database 'World Bank'[1)]	*Quantifiable indicators such as high-tech exports and R&D spend help determine the potential capabilities of the ecosystem in a particular country to support manufacturing and research in the larger battery ecosystem*
Leading indicators - potential for future competitiveness	**Number of patents** in the fields related to the business opportunity	Database 'WIPO IP Statistics Data Center'[2)]	*The number of patents is a proxy for the technological advancements in a specific field in a country and shows potential for future technology dominance*
	Research strength of countries in the fields related to the business opportunity	Database 'Scimago Journal & Country Rank'[3)]	*The research strength gives an indication of the knowledge in the educational institutions and R&D centers in a country which is crucial for future innovations*
Expert judgement	**Competitive position of country** compared to rest of the market	Expert interviews	*Expert judgement provides specific context regarding the competitive position of a country*

The overall competitiveness is calculated based on an average with equal weights across the individual indicators

⚠ **The current methodology does not account for some of the aggressive growth rates foreseen by start-ups and scale-ups depending on the commercialization of new technologies**

Sources: 1) The World Bank (a, b); 2) WIPO (2021); 3) Scimago (2020)

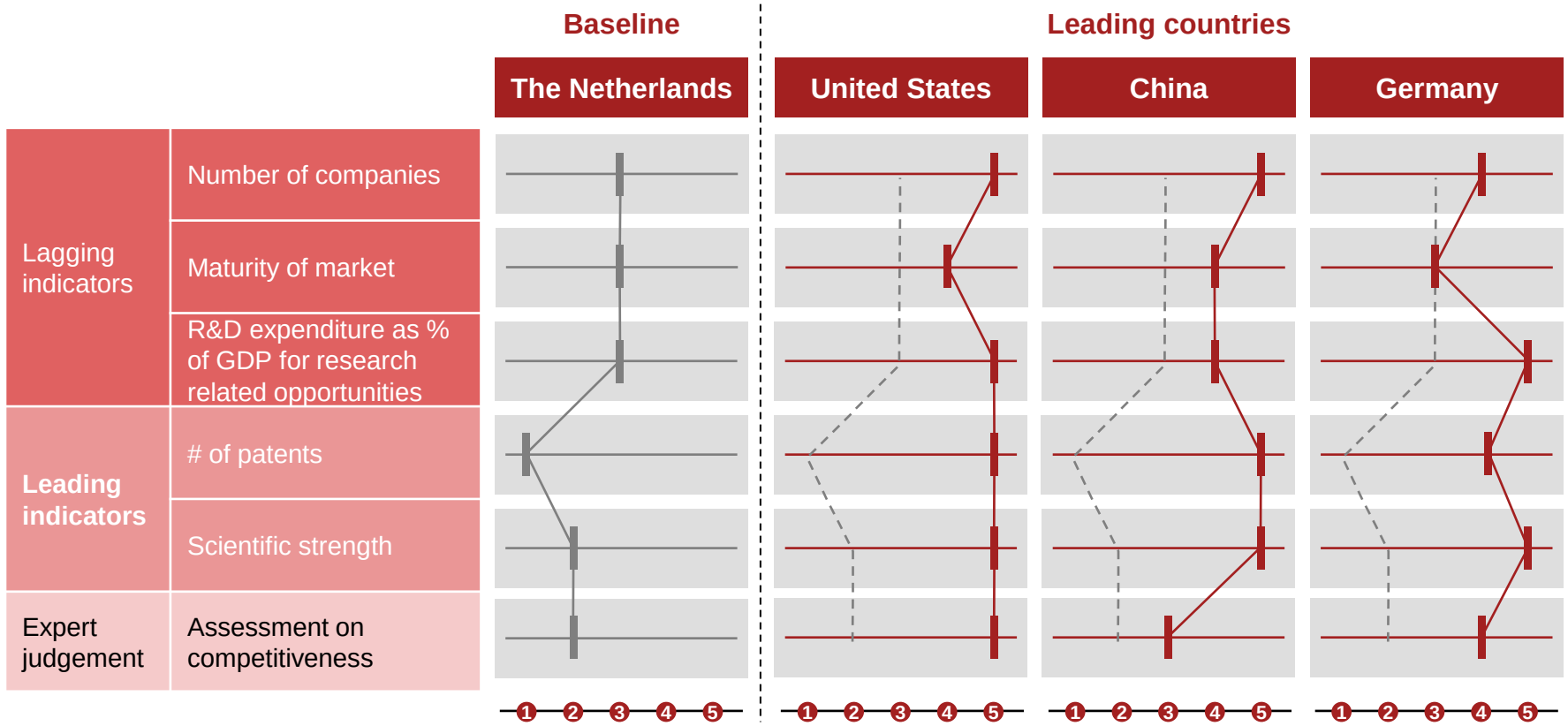
Assessing Dutch competitiveness - Subsections

- Framework overview
- **Competitive potential assessment per business opportunity**
- Summary of Dutch competitive potential

The Netherlands appears to have moderate competitive potential in producing silicon anodes

Assessing Dutch competitive potential

Business opportunity: Production of silicon anodes



Competitiveness of The Netherlands[1]:

2,3 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *United States, China, India, France, Australia, Norway, Great Britain, Canada, Japan, Germany*

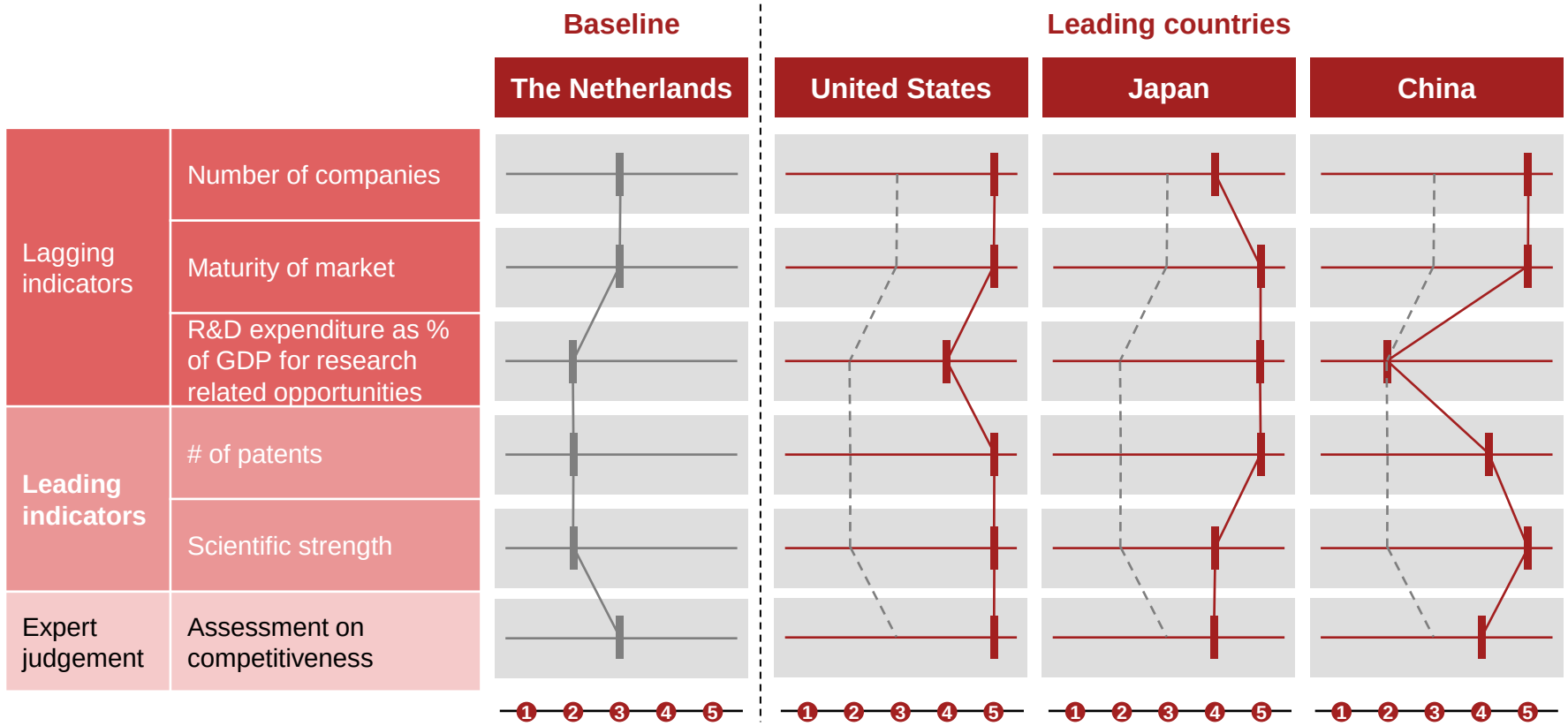
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in selling/ leasing of patents related to new battery concepts

Assessing Dutch competitive potential

Business opportunity: Selling/ leasing of patents related to material science or production methodologies of new battery concepts



Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators, and good on the expert judgement

Reference countries in long list: *United States, Great Britain, China, Japan, Germany, Australia, Austria, South Korea, Belgium, France, Sweden, Norway*

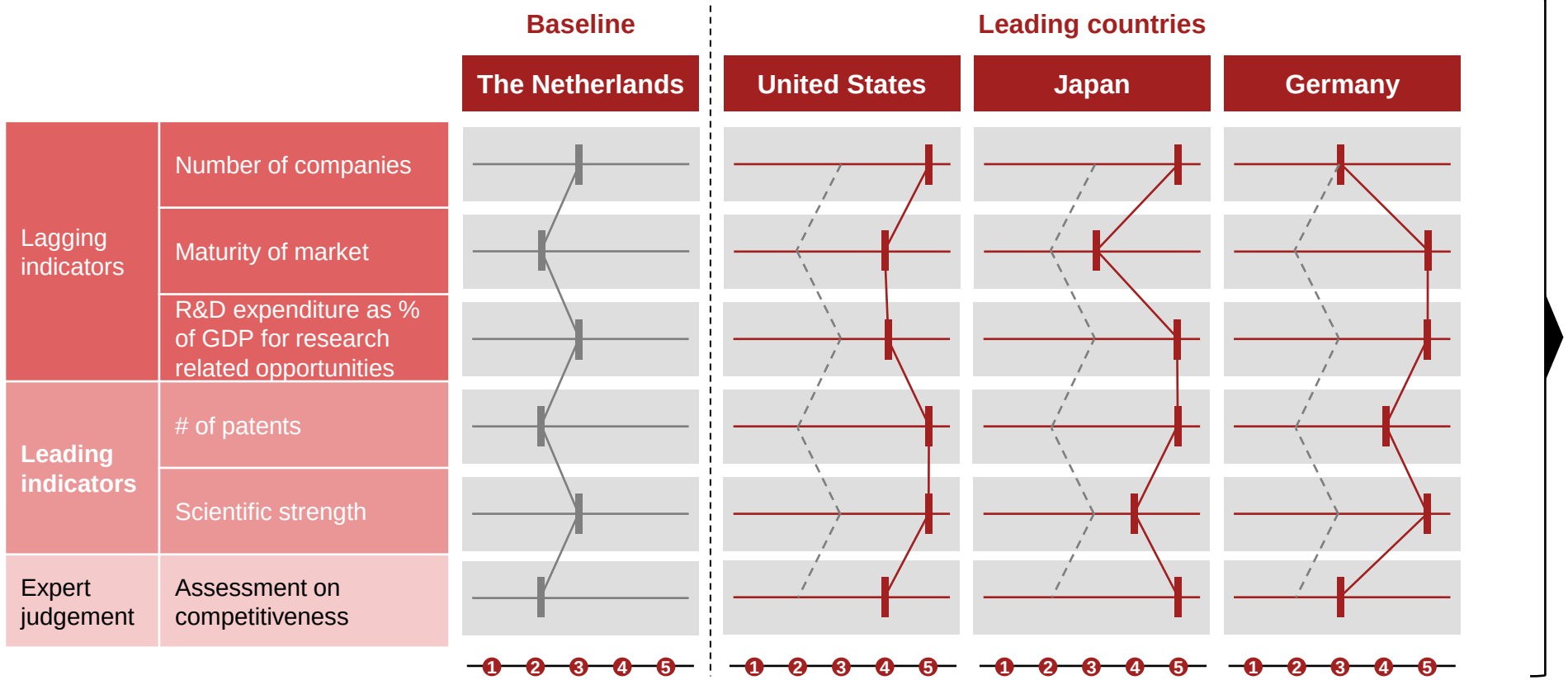
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in producing materials for new battery electrodes and electrolytes

Assessing Dutch competitive potential

Business opportunity: Producing materials for new battery electrodes and electrolytes (e.g. polymer concepts)



Reference countries in long list: *Japan, United States, South Korea, Great Britain, Belgium, Germany, Saudi Arabia, China, Portugal, Hong Kong*

Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, and moderately on the leading indicators and the expert judgement

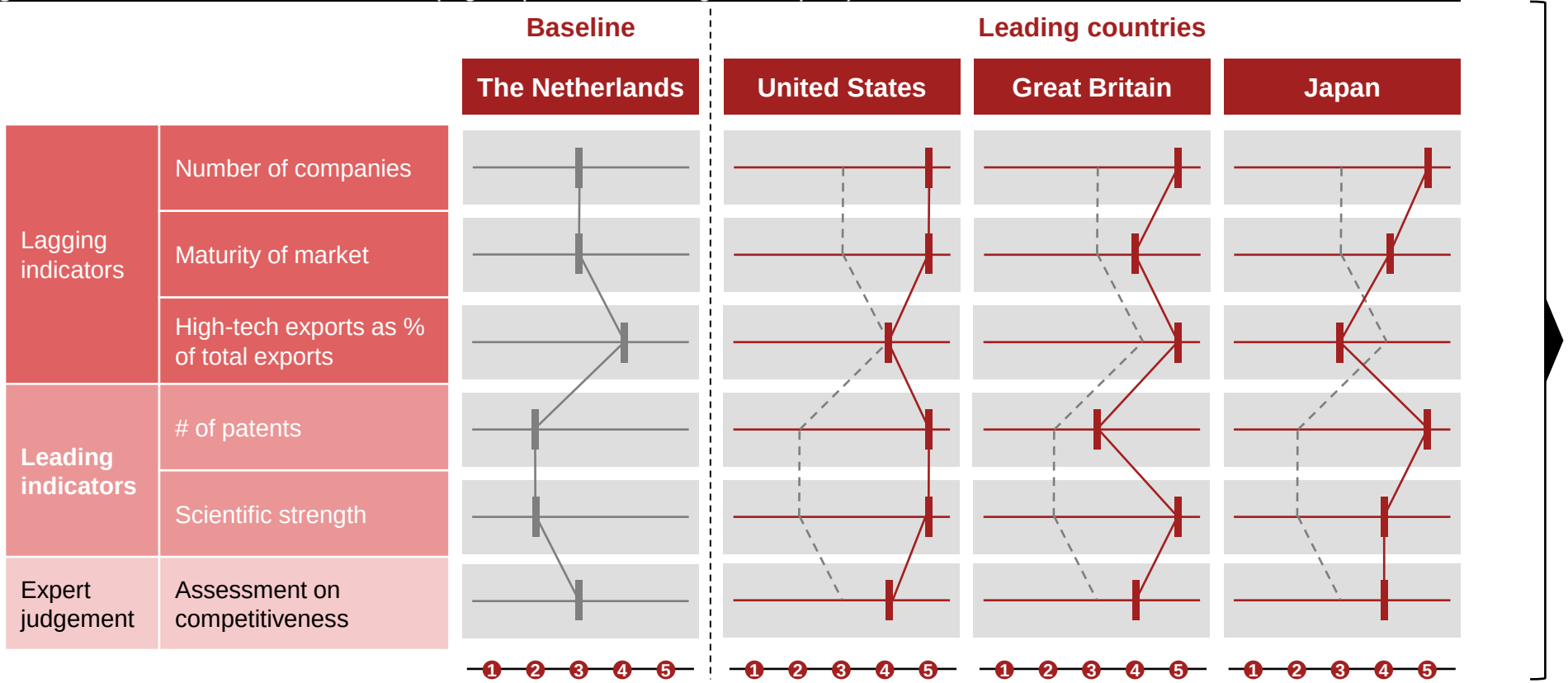
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing manufacturing equipment for current generation batteries

Assessing Dutch competitive potential

Business opportunity: Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries (e.g. deposition/ coating techniques)



Reference countries in long list: *United States, Great Britain, Germany, Finland, Belgium, Switzerland, Spain, South Korea, Japan*

Competitiveness of The Netherlands[1]:

2,8 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators, and good on the expert judgement

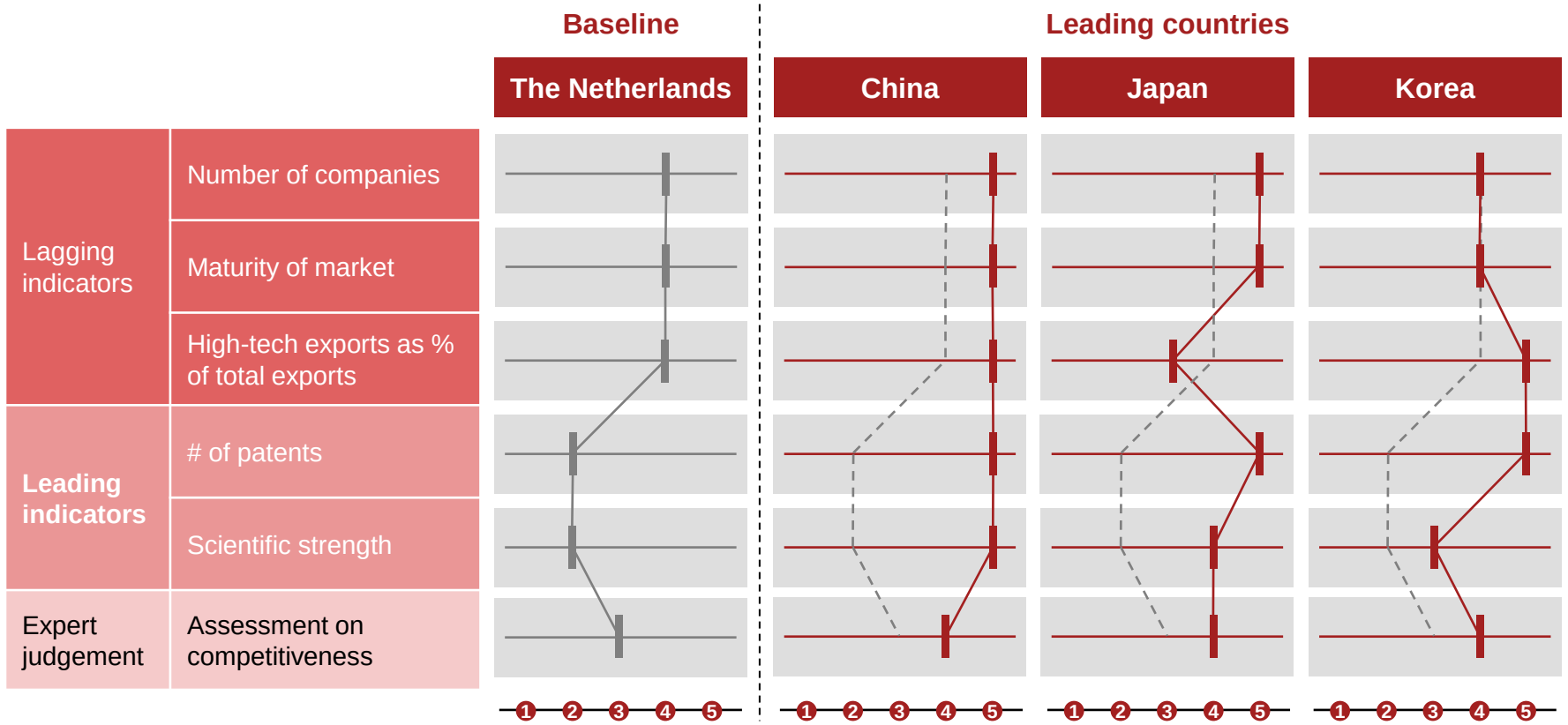
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing manufacturing equipment for new battery technologies

Assessing Dutch competitive potential

Business opportunity: Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production



Competitiveness of The Netherlands[1]:

3,2 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores substantial on the existing industry indicators, moderately on the leading indicators, and good on the expert judgement

Reference countries in long list: *Germany, China, United States, Italy, Great Britain, Canada, France, Spain, Belgium, Switzerland, Sweden, Japan, South Korea*

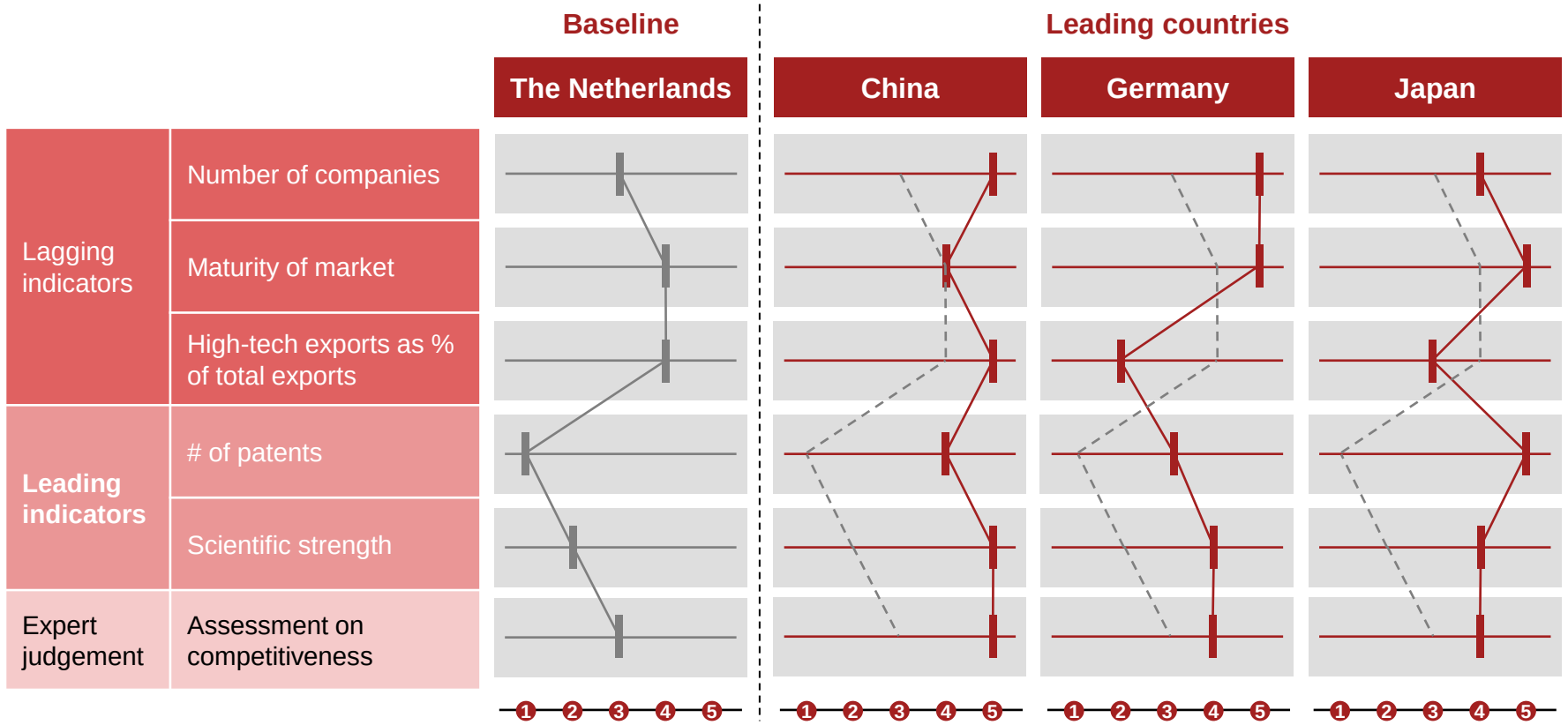
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing hardware components for battery management systems

Assessing Dutch competitive potential

Business opportunity: Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system



Reference countries in long list: *China, Germany, South Korea, Japan, India, Switzerland, France, United States, Denmark*

Competitiveness of The Netherlands[1]:

2,8 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores substantial on the existing industry indicators, moderately on the leading indicators and good on the expert judgement

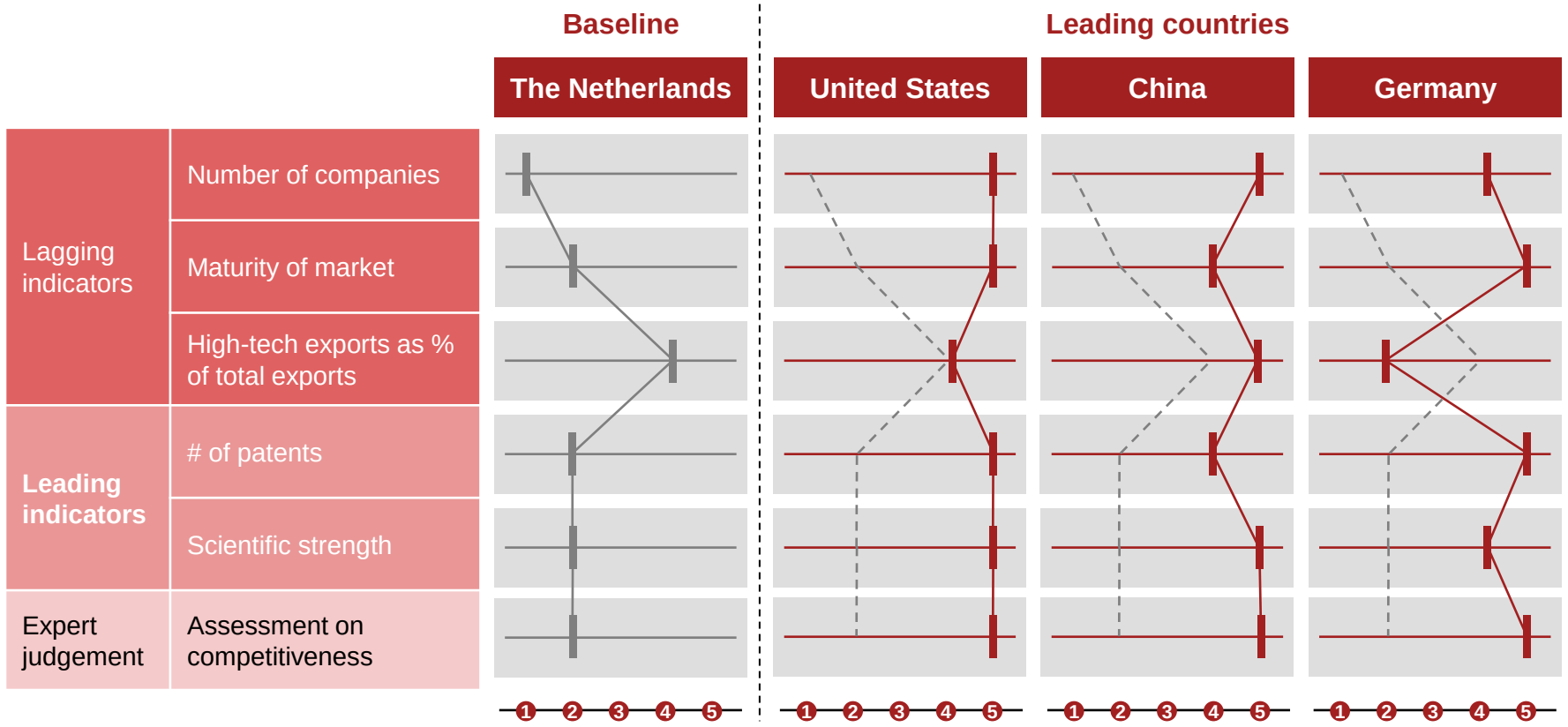
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in producing testing equipment for cell components

Assessing Dutch competitive potential

Business opportunity: Manufacturing testing equipment required in the cell production process



Competitiveness of The Netherlands[1]:

2,2 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores moderately on the existing industry indicators, the leading indicators and the expert judgement

Reference countries in long list: *United States, Canada, Belgium, China, Germany, France, India*

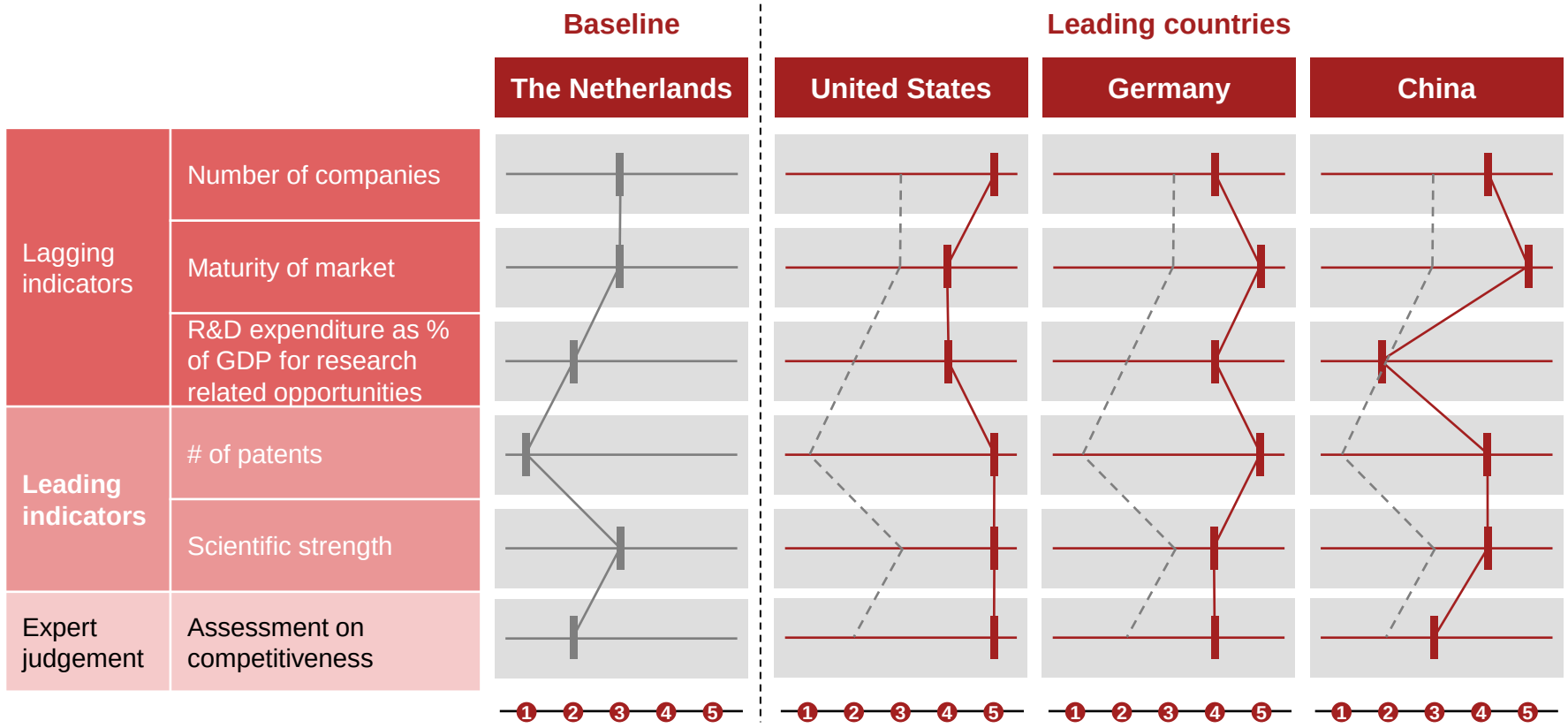
Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in developing data-driven solutions for storage systems

Assessing Dutch competitive potential

Business opportunity: Offer data-driven solutions as a service to owners and developers of storage systems
(remote monitoring, forecasting, predictive maintenance, charge/discharge optimization)



Competitiveness of The Netherlands[1]:

2,3 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators, and the expert judgement

Reference countries in long list: *United States, Germany, Great Britain, Sweden, China, France, Finland, South Korea*

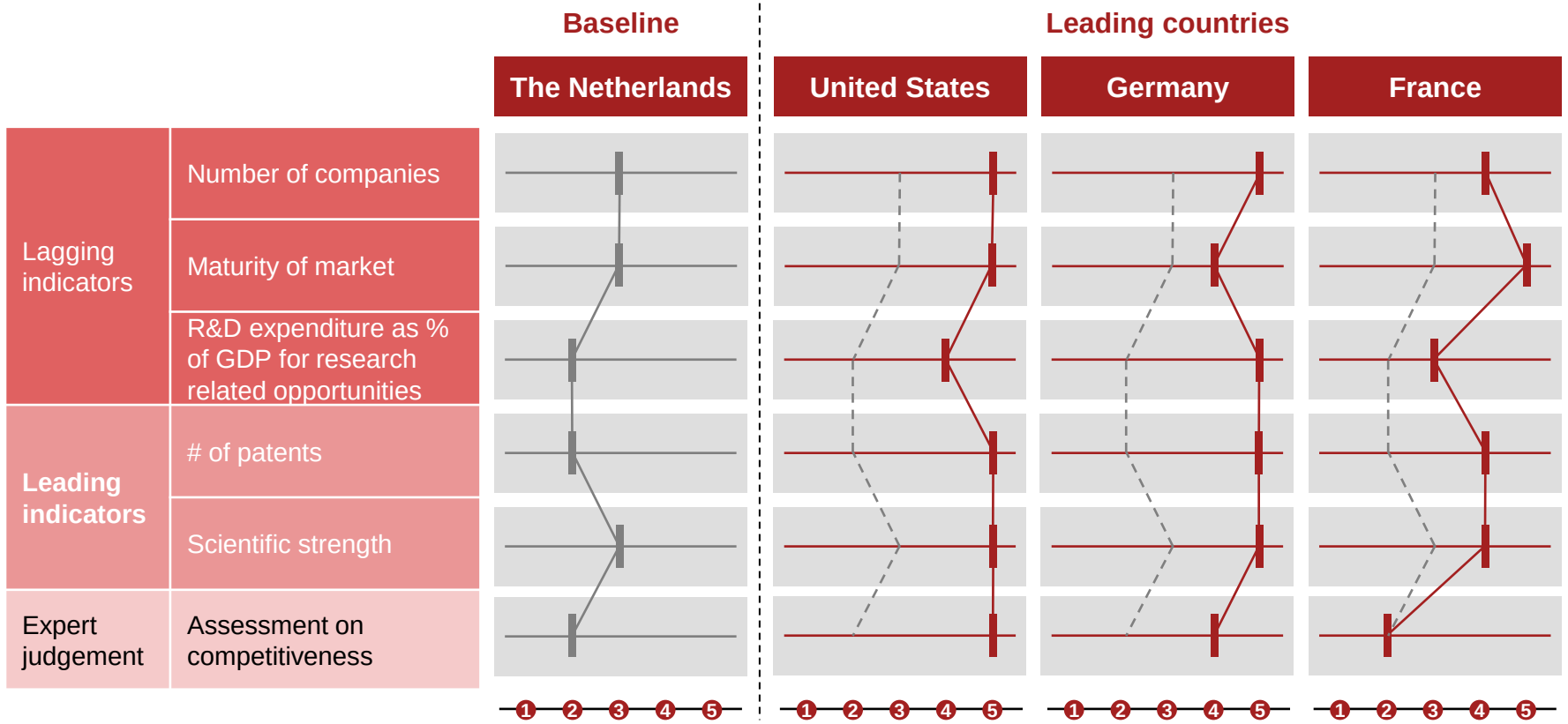
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in developing recycling techniques related for batteries

Assessing Dutch competitive potential

Business opportunity: Developing recycling techniques related to the chemical separation of batteries



Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *United States, Belgium, Germany, France, Great Britain, Japan, Canada, Switzerland, Finland, Sweden*

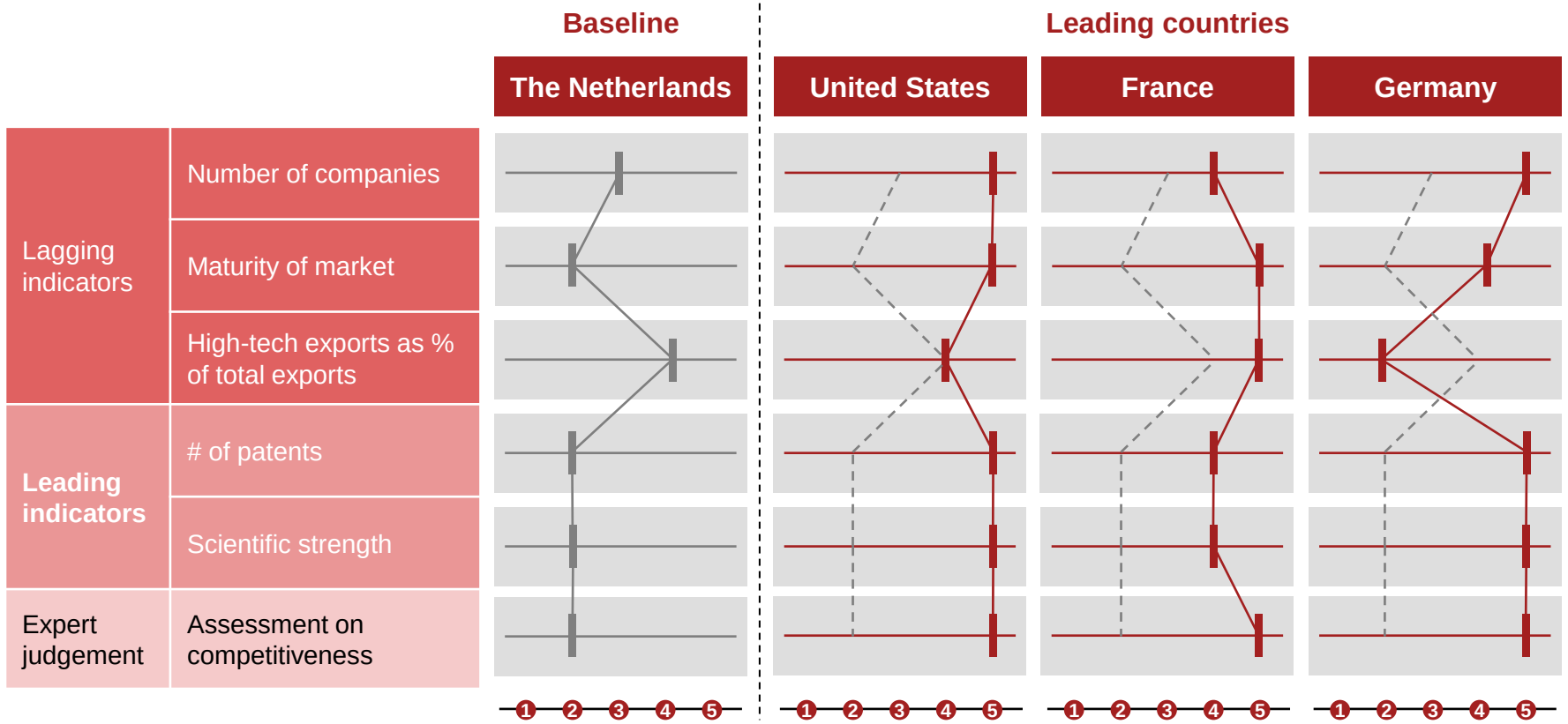
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in recycling/ dismantling end-of-life batteries

Assessing Dutch competitive potential

Business opportunity: Recycling/ dismantling of end-of-life batteries



Competitiveness of The Netherlands[1]:

2,7 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *Germany, Belgium, United States, France, Finland, Canada, Great Britain, Sweden*

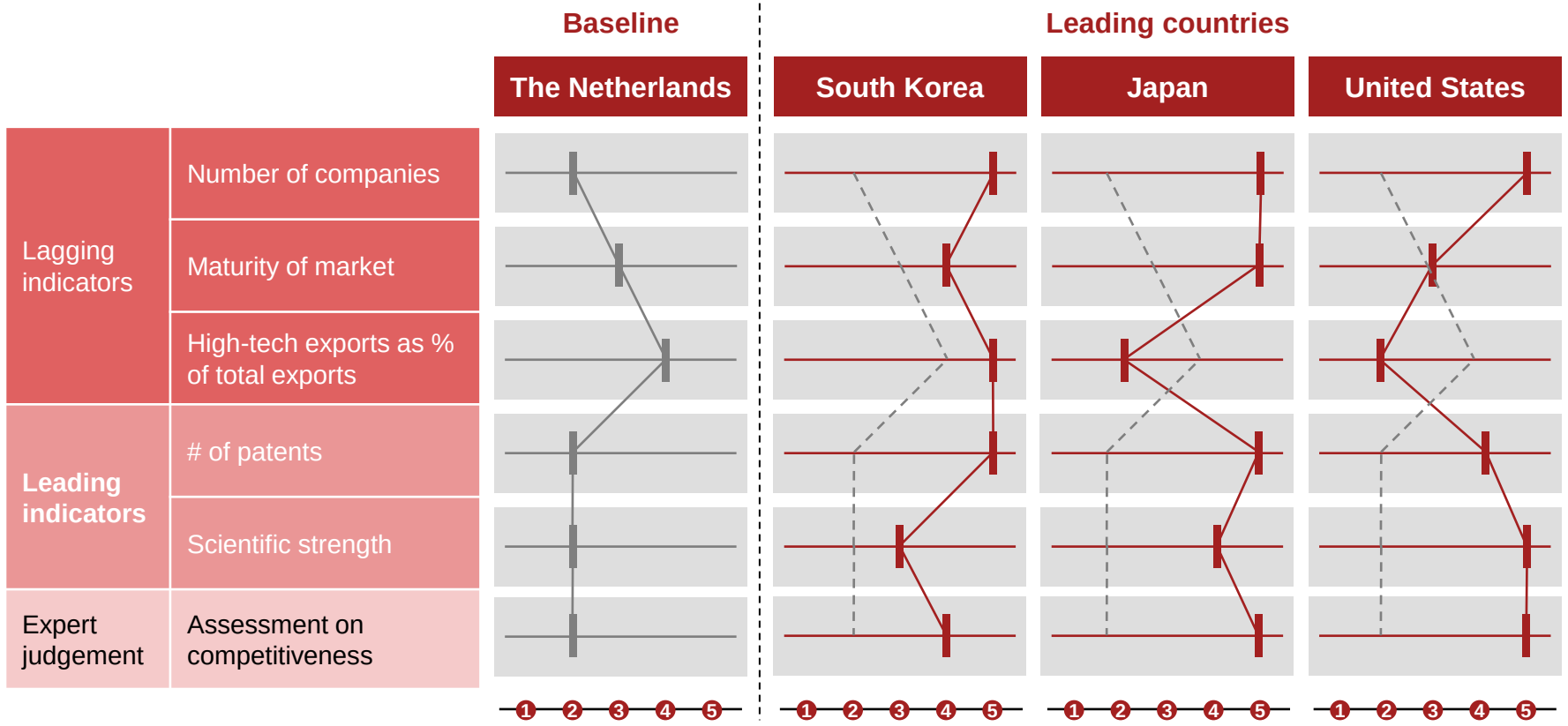
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in producing solid state batteries

Assessing Dutch competitive potential

Business opportunity: Production of solid state batteries



Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *United States, Japan, South Korea, Norway, China, Great Britain, India*

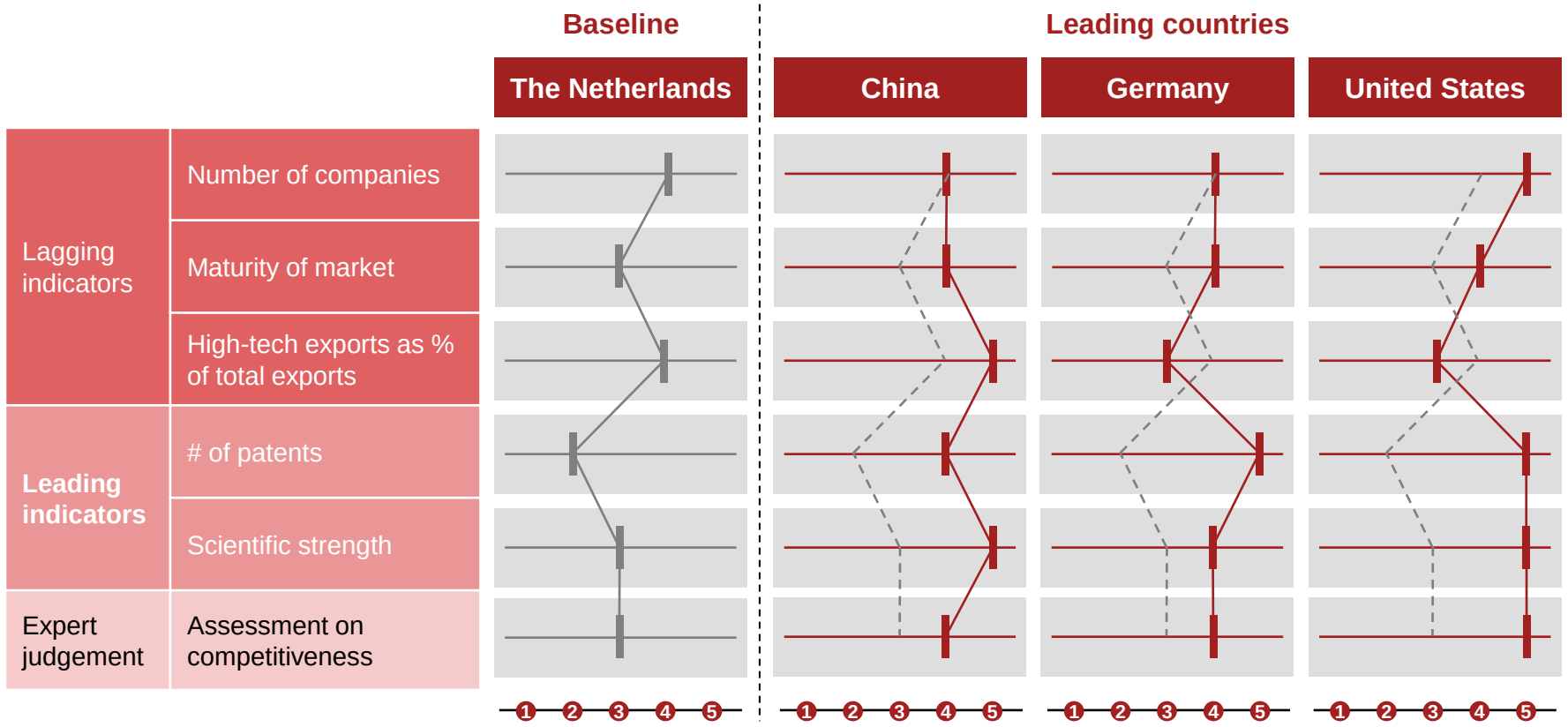
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing electric heavy duty commercial vehicles

Assessing Dutch competitive potential

Business opportunity: Production of electric heavy duty commercial vehicles



Competitiveness of The Netherlands[1]:

3,2 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores substantial on the existing industry indicators, average on the leading indicators and the expert judgement

Reference countries in long list: *United States, France, China, Sweden, Great Britain, Germany, Turkey, Indonesia*

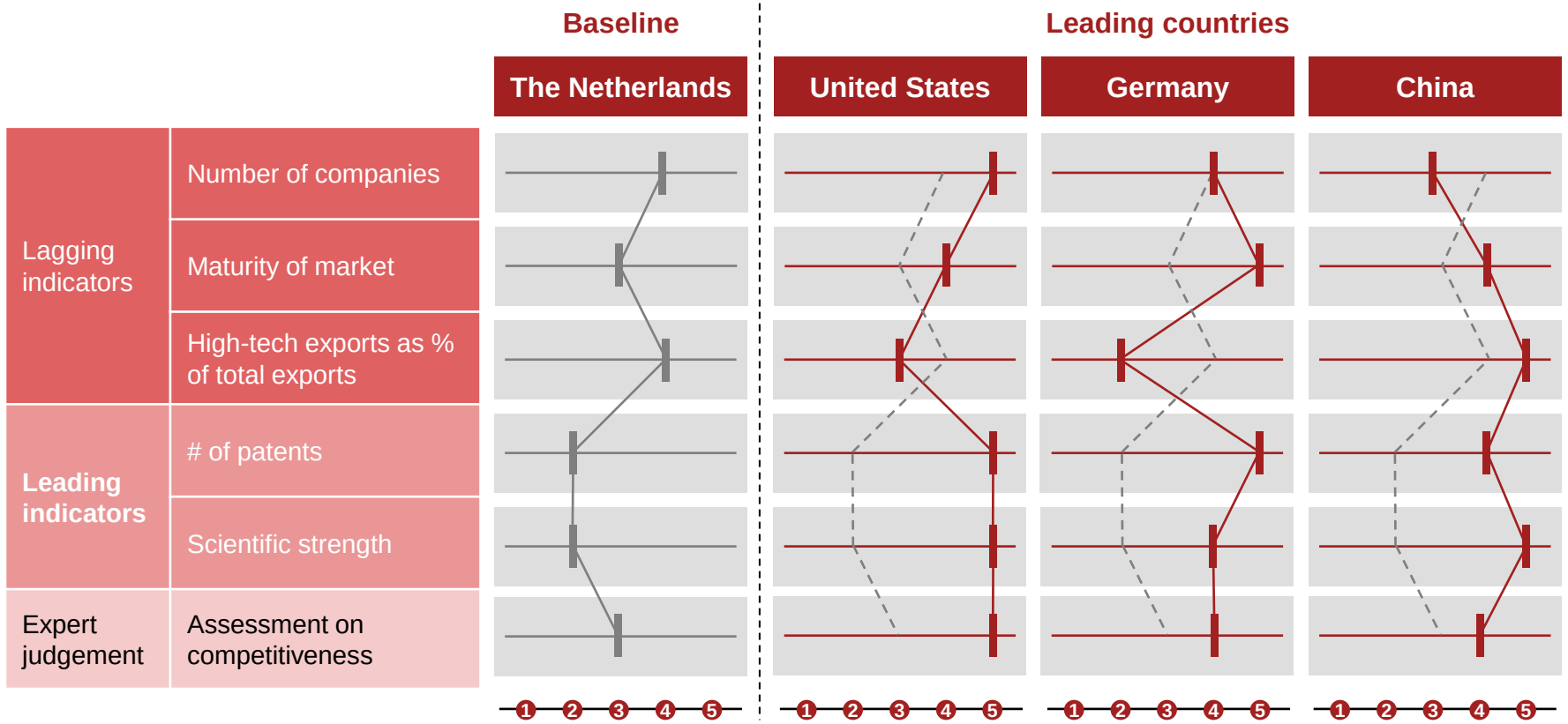
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing e-drive trains for heavy duty vehicles

Assessing Dutch competitive potential

Business opportunity: Production of e-drive train for heavy duty vehicles



Reference countries in long list: *United States, Germany, Japan, Denmark, Great Britain, France, Indonesia, China, Sweden*

Competitiveness of The Netherlands[1]:

3,0 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores substantial on the existing industry indicators, moderately on the leading indicators and good on the expert judgement

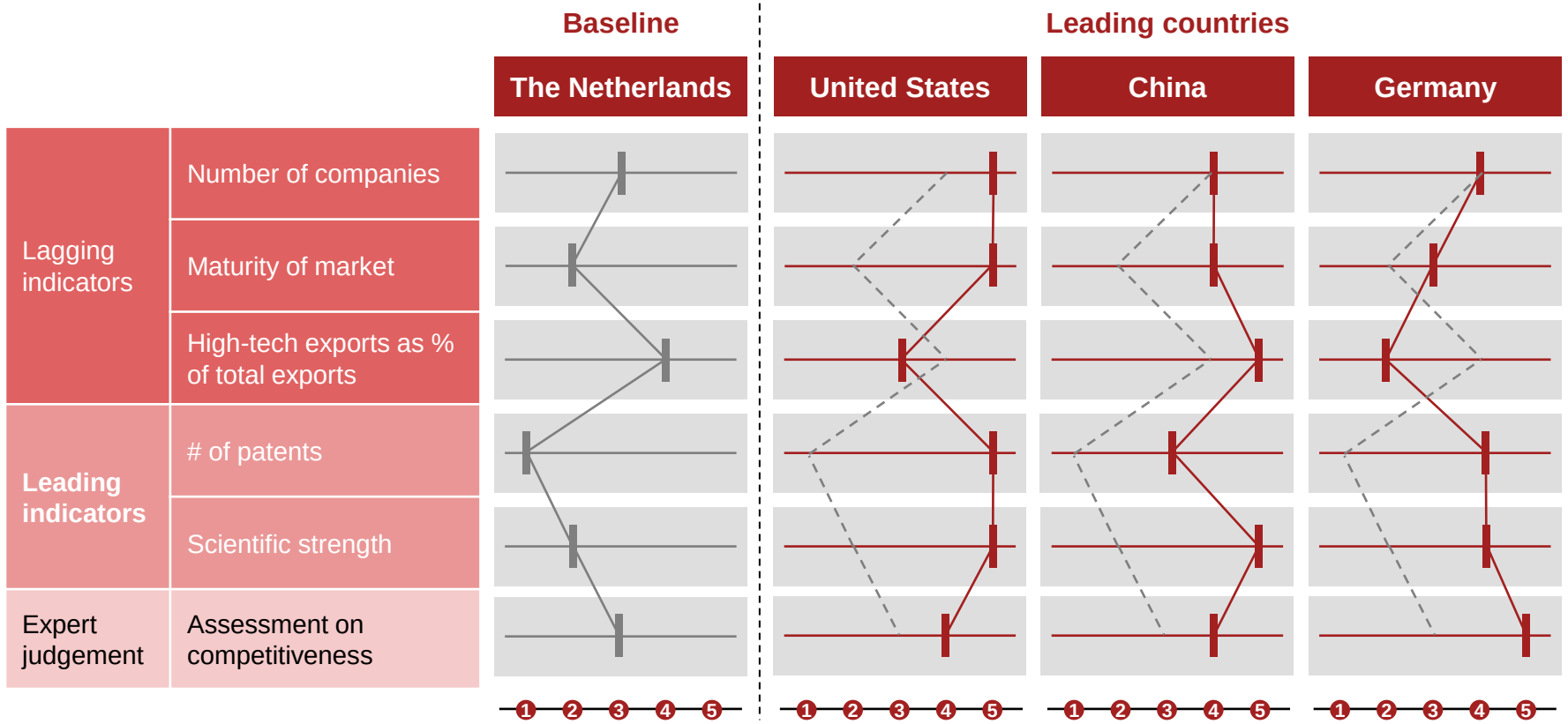
Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in producing integrated membrane stacks for redox flow batteries

Assessing Dutch competitive potential

Business opportunity: Production of integrated membrane stacks to be used in redox flow batteries



Reference countries in long list: *United States, Germany, China, Japan, Austria, France*

Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators, and good on the expert judgement

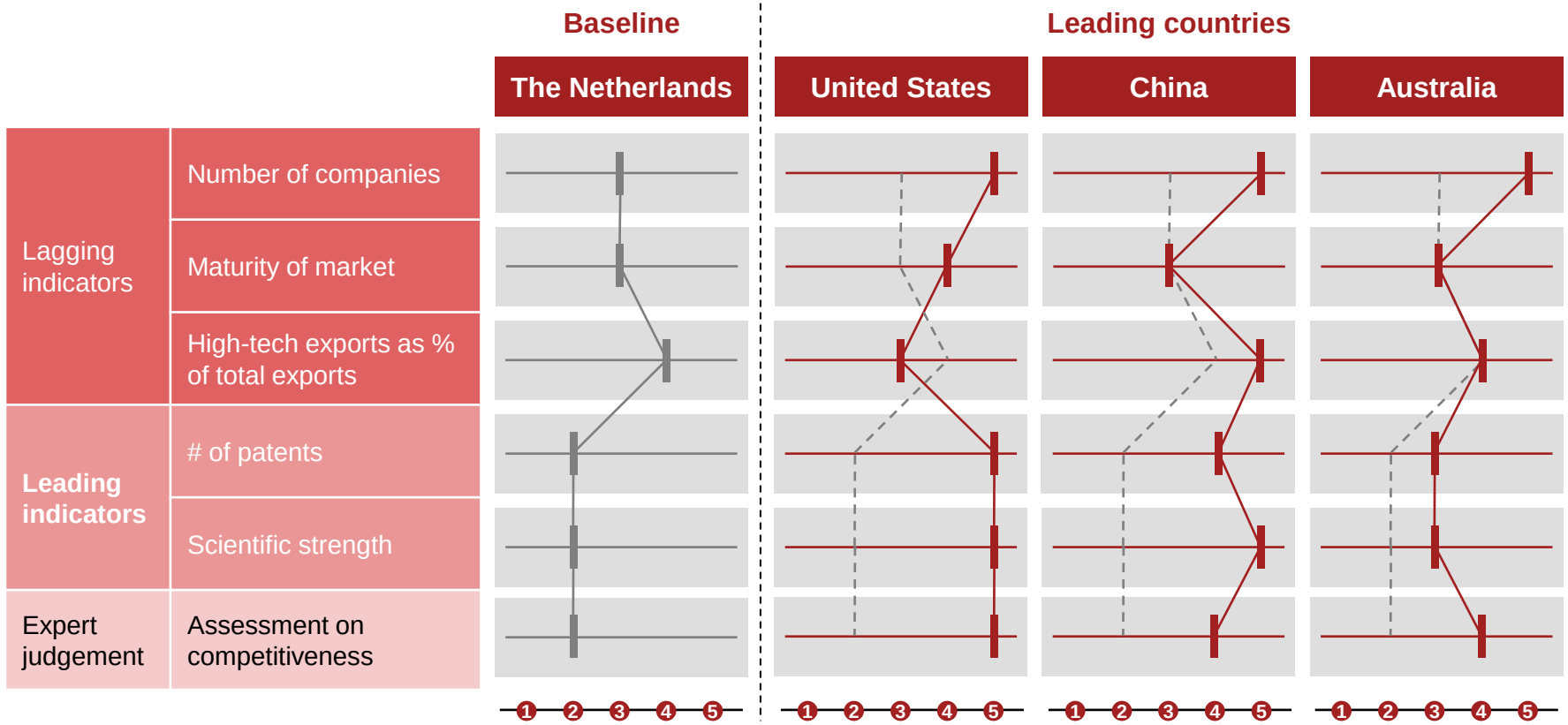
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have good competitive potential in producing utility scale batteries

Assessing Dutch competitive potential

Business opportunity: Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)



Competitiveness of The Netherlands[1]:

2,7 **"Good competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *United States, Australia, Germany, China, Austria, Japan, Sweden, Great Britain*

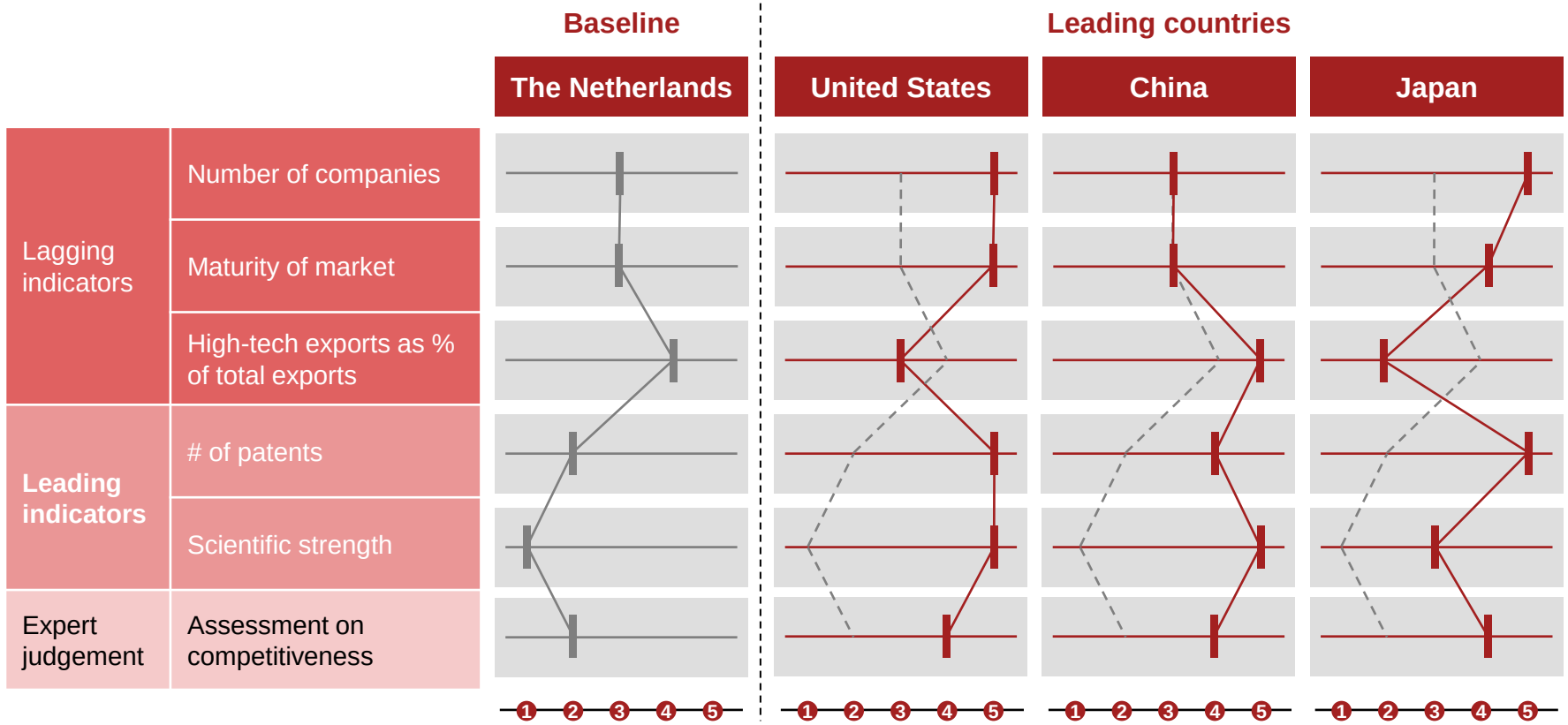
Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

The Netherlands appears to have moderate competitive potential in integrating stationary storage into the grid

Assessing Dutch competitive potential

Business opportunity: Integrating stationary storage into the grid



Competitiveness of The Netherlands[1]:

2,5 **"Moderate competitive potential"**

Rationale:
Compared to the long list of countries in the business opportunity, NL scores good on the existing industry indicators, moderately on the leading indicators and the expert judgement

Reference countries in long list: *United States, Japan, Great Britain, Germany, South-Korea, China, Sweden, Australia, Italy*

Legend ❶ *No right-to-win* ❷ *Moderate competitive potential* ❸ *Good competitive potential* ❹ *Substantial competitive potential* ❺ *Market leader*

1) Based on an average with equal weights across the individual indicators

Assessing Dutch competitiveness - Subsections

- Framework overview
- Competitive potential assessment per business opportunity
- **Summary of Dutch competitive potential**

The Netherlands appears to have good competitive potential in producing production equipment for the battery ecosystem

Overview of business opportunity benchmark (1/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
1 **Production of silicon anodes**	3	3	3	1	2	2	**2,3**	*Moderate competitive potential* – In the US and China, the ecosystem of companies appears to be much more developed compared to NL
2 **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**	3	3	2	2	2	3	**2,5**	*Moderate competitive potential* - Research on new battery concepts is mainly performed by existing battery manufacturers, which are concentrated in South East Asia and the US
3 **Producing materials for new battery electrodes and electrolytes** (e.g. polymer concepts)	3	2	3	2	3	2	**2,5**	*Moderate competitive potential* - Potential exists given the expected future demand for batteries in Europe combined with the historical expertise of The Netherlands in material sciences
4 **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	3	3	4	2	2	3	**2,8**	*Good competitive potential* – New deposition and coating processes require high precision which could provide The Netherlands a right to play given the strong expertise in high-tech machinery and manufacturing equipment
5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**	4	4	4	2	2	3	**3,2**	*Good competitive potential* – New battery concepts are expected to require new production equipment, which could create a possibility for The Netherlands to leverage it's strong positioning in the high-tech sector

Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

In addition, good competitive potential possibly exists in producing hardware components for battery management systems and recycling

Overview of business opportunity benchmark (2/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
6 **Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system**	3	4	4	1	2	3	**2,8**	*Good competitive potential* – Expertise of companies such as NXP, which is a major supplier, could potentially provide The Netherlands a right to play in this field
7 **Manufacturing testing equipment required in the cell production process**	1	2	4	2	2	2	**2,2**	*Moderate competitive potential* – Testing equipment is generally produced in close proximity to the vehicle OEMs, which are concentrated in the US, China and Germany
8 **Offer data-driven solutions as a service to owners and developers of storage systems** (e.g. remote monitoring, forecasting, predictive maintenance, charge/ discharge optimization)	3	3	2	1	3	2	**2,3**	*Moderate competitive potential* – Large corporates are already active in this space in the US and South East Asia, making it a challenging market for The Netherlands to enter
9 **Developing recycling techniques related to the chemical separation of batteries**	3	3	2	2	3	2	**2,5**	*Moderate competitive potential* – Market is developing, The Netherlands could play a role if it could capitalize on a potential first mover advantage
10 **Recycling/ dismantling end-of-life mobility batteries**	3	2	4	2	3	2	**2,7**	*Good competitive potential* – Strict guidelines on battery transport can possibly create a domestic recycling market, volumes are expected to be limited to the regional market

Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

Finally, the fields of heavy duty mobility yield good competitive potential for The Netherlands

Overview of business opportunity benchmark (3/3)

Business opportunity	Number of companies	Industry maturity	R&D/ high tech exports	Number of patents	Research strength	Expert judgement	Average score	Rationale
11 **Production of solid sate batteries**	2	3	4	2	2	2	**2,5**	*Moderate competitive potential* – Development and production is mainly driven by mature markets such as battery manufacturers and vehicle OEMs in South East Asia and the US
12 **Production of electric heavy duty commercial vehicles**	4	3	4	2	3	3	**3,2**	*Good competitive potential* – There is a strong ecosystem of companies active in the heavy duty mobility sector in The Netherlands
13 **Production of e-drive train for heavy duty vehicles**	4	3	4	2	2	3	**3,0**	*Good competitive potential* – Closely related to the heavy duty mobility sector, providing a right to play for The Netherlands
14 **Production of integrated membrane stacks to be used in redox flow batteries**	3	2	4	1	2	3	**2,5**	*Moderate competitive potential* – Interest of large countries in this expected growth market results in strong competition for active companies in The Netherlands
15 **Production of utility scale batteries with longer discharge times** (redox flow, salt water, other technologies)	3	3	4	2	2	2	**2,7**	*Good competitive potential* - Upcoming and developing market which offers potential but also strong competition from Asia and Australia
16 **Integration of stationary battery storage into the grid**	3	3	4	2	1	2	**2,5**	*Moderate competitive potential* – Stationary storage market is growing but realization of integration projects is expected to be contracted and executed locally

Legend 1 *No right-to-win* 2 *Moderate competitive potential* 3 *Good competitive potential* 4 *Substantial competitive potential* 5 *Market leader*

The opportunities with highest potential competitiveness are related to high-tech equipment and heavy duty mobility

Key findings of benchmark

Promising business opportunities

1. **Business opportunities related to high-tech equipment manufacturing**
   - Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries *(e.g. deposition/ coating techniques)*
   - Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production
   - Production of hardware components (sensors/ controllers/ chip sets) which go into a battery management system

2. **Business opportunities related to heavy duty mobility**
   - Production of electric heavy duty commercial vehicles
   - Production of e-drive train for electric heavy duty vehicles

Additional promising opportunities may arise from recycling/circularity concepts and stationary storage

- Recycling/ dismantling end-of-life mobility batteries
- Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)

These opportunities correspond with the traditional and existing expertise of The Netherlands

Leading position in the high-tech sector

- ASML and NXP are leading companies in the semiconductor industry, the latter also supplies components for battery management systems

Extensive experience in equipment manufacturing

- Demcon Industrial Systems and VDL ETG are global suppliers of high-tech solutions for the manufacturing industry

State-of-the art bus and truck production

- DAF is one of the major truck manufacturers
- VDL Bus & Coach and EBUSCO among first companies to produce fully electric buses

For recycling/circularity concepts and stationary storage, although Dutch competitive position is moderate or slightly above, societal and market demands may account for additional promising opportunities

Non-exhaustive

5 Determining economic potential

Determining economic potential - Subsections

- **Framework overview**
- Economic potential assessment per business opportunity
- Summary of Dutch economic potential

We used a 4-step approach to estimate the future Dutch economic potential of the identified business opportunities

Dutch economic potential assessment methodology

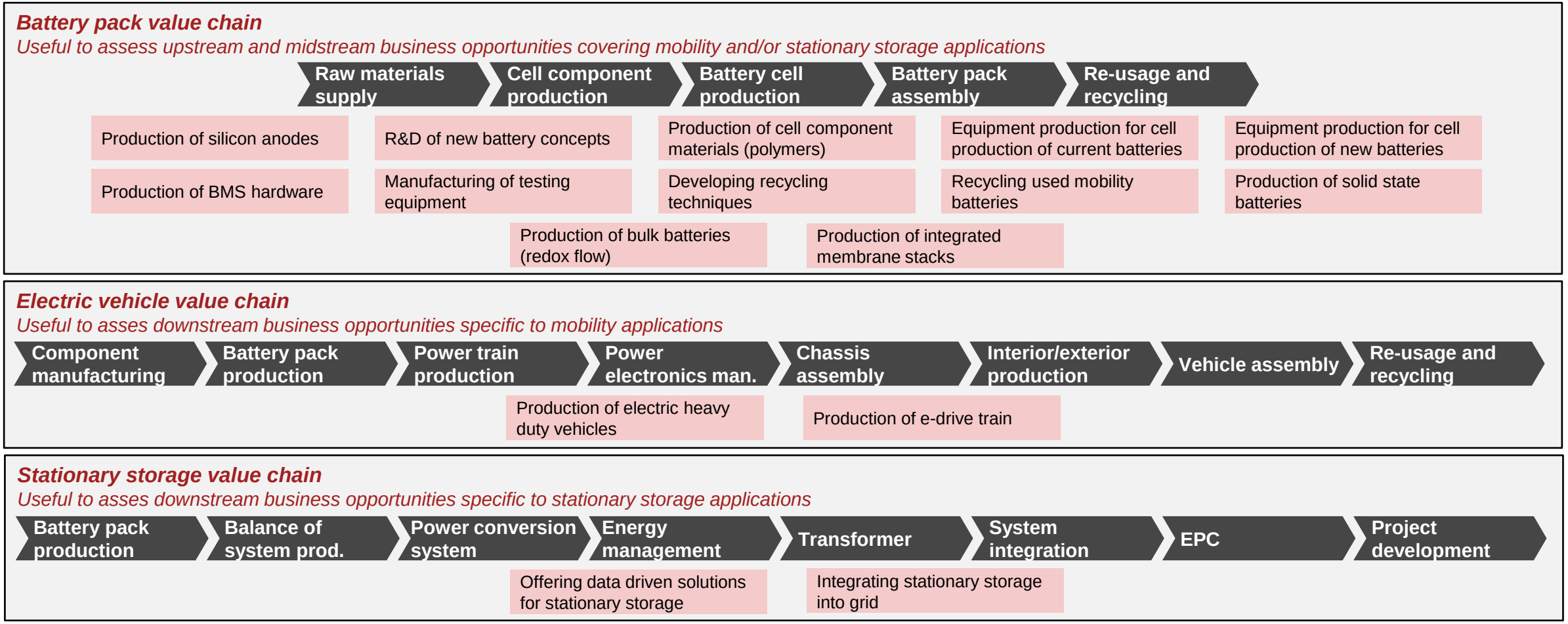
Economic potential (2030) calculation	Sources	Description
1 **Value chain alignment**	Research and expert interviews	The business opportunities are aligned to either the battery pack, battery electric vehicle (heavy duty) or stationary storage systems value chain
2 **Global market size**	Estimation models and published reports and expert interviews	The global market size depends on the value chain of the business opportunity and the technology (solid state, redox flow etc.) in focus
X		
3 **Revenue pool of business opportunity**	Published reports and expert interviews	The revenue pool depends on the value chain step the business opportunity is present in and the relevant activity in the value chain step applicable to the business opportunity
X		
4 **Potential future market share of Dutch companies**	Competitive benchmarking results from phase 2 of this study	The potential future market share of Dutch companies is calculated depending on the results of the competitive benchmarking exercise undertaken in phase 2 of the study
=		
Dutch economic potential		

Calculation steps

⚠ **The calculation methodology follows a high level top-down approach and is sensitive to market demand, technology maturity, value pool estimations and potential market share which can be captured by Dutch companies. As a result, the market might be underestimated for some of the new battery concepts where start-ups and scale-ups can witness aggressive growth rates depending on the commercialization of new technologies**

Twelve business opportunities align with the battery pack, two with the electric vehicle and two with the stationary storage value chain

Value chain alignment

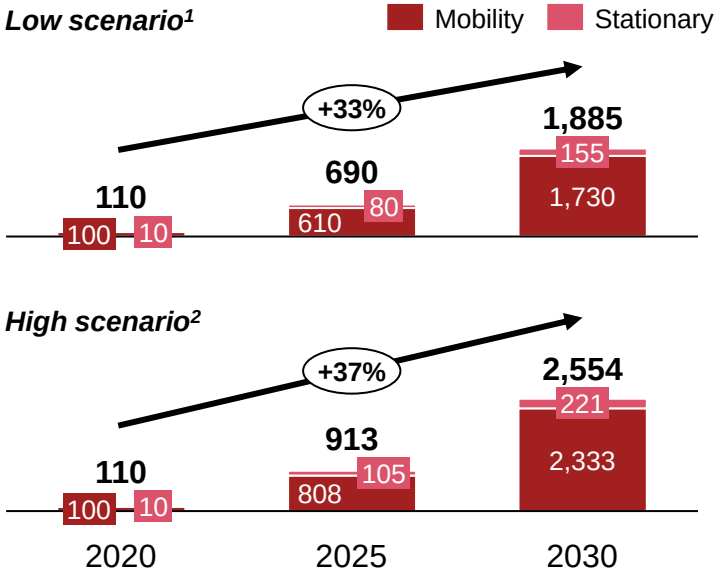


Sources: Rystad Energy (2021), WEF (2019), NREL (2019), The World Bank (2020), Expert interviews, Strategy& analysis

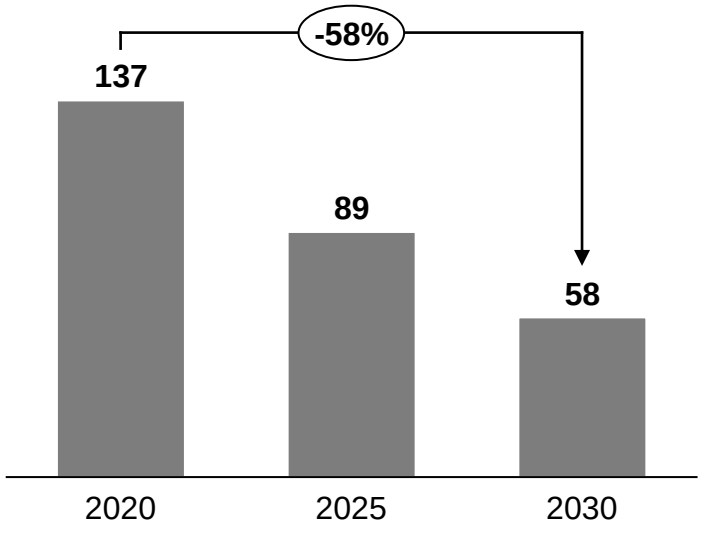
The battery pack market is expected to become a $110-150 Bn annual market by 2030 with the mobility market being ~10x that of stationary

Estimated global battery pack market size

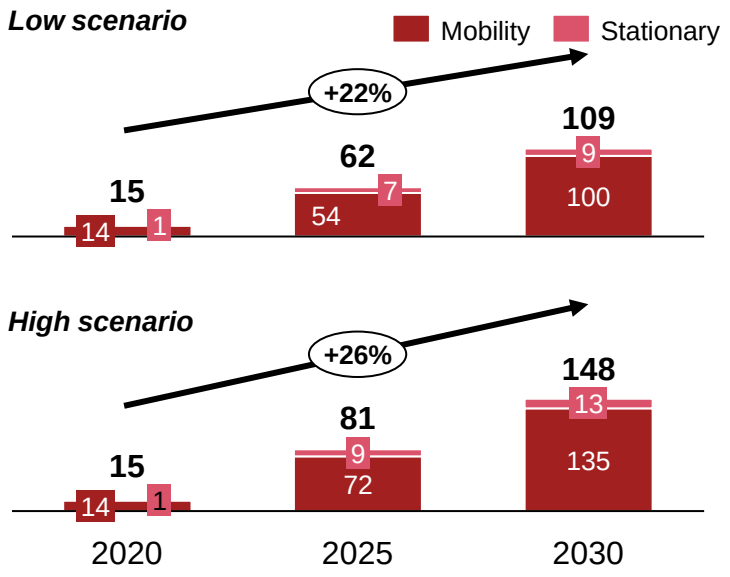
Battery capacity demand *[GWh]*



Battery pack price3,4 *[$/kWh]*



Annual market size *[$Bn]*



- **Growth of RES and EVs** as part of the ongoing energy transition **will significantly increase stationary and mobility battery demand**
- **The battery market is expected to be dominated by Li-ion** but emerging technologies like solid state can gain market share if commercialized

- The battery pack price has **reduced by ~80% from 2013 – 2020** largely driven by the increase in EV manufacturing
- **Further significant price reductions are anticipated till 2030** due to larger economies of scale and process optimization in manufacturing

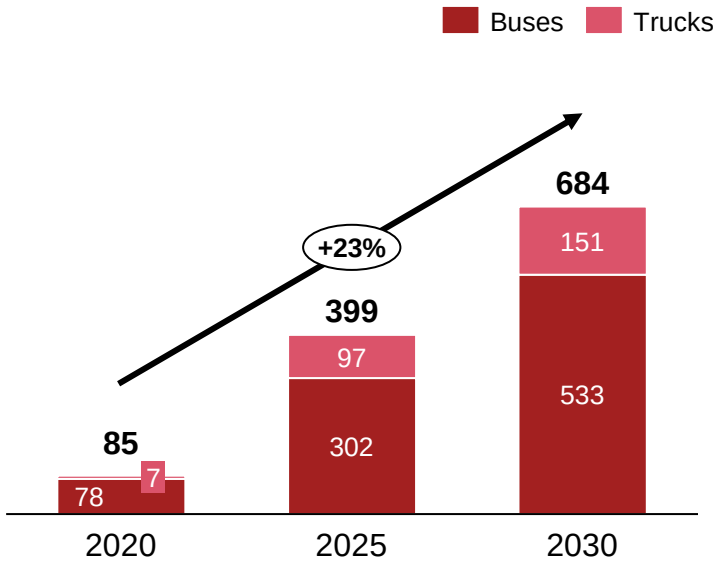
- The annual market size results from **multiplying battery demand by pack price**
- **The mobility battery pack market** size is expected to be **~10x that of the stationary** market by 2030

1) Low scenario based on projections from BNEF, 2) High scenario based on projections from the World Economic Forum; 3) Battery pack price projections taken from BNEF,
4) A similar battery pack price has been assumed for stationary and mobility battery packs
Sources: BloombergNEF (2020a, 2020b), WEF (2019), Strategy& analysis

The heavy duty electric vehicles market is expected to become a $90-120 Bn annual market by 2030

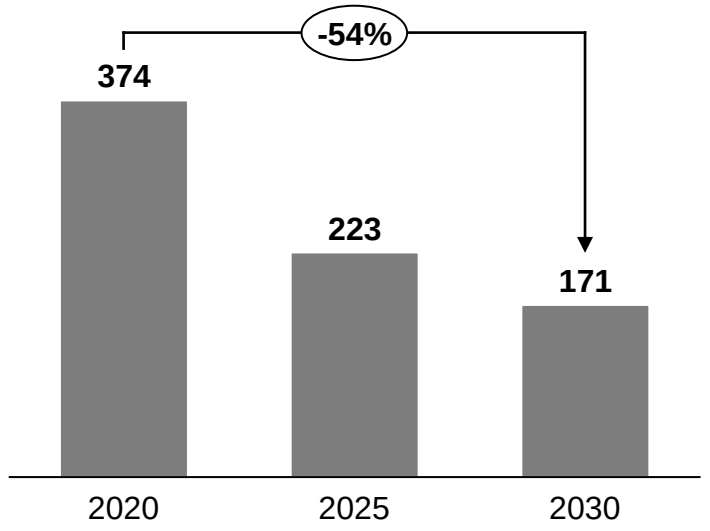
Estimated global electric heavy duty vehicle market size

Electric heavy duty vehicle demand[1] *[Thousands]*



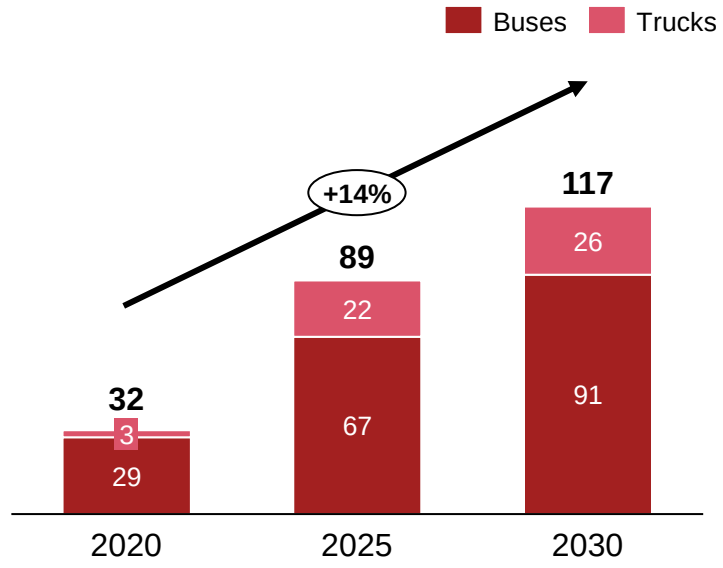
- Electric vehicles are anticipated to take **~20% of the total bus sales and ~3% of the total truck sales globally by 2030**
- **EV bus demand is expected to be 3.5x the EV truck demand by 2030**

Electric heavy duty vehicle cost[2] *[$ k]*



- **Decreasing cost of battery packs and rapid changes in powertrain technology** are the main reasons for the anticipated cost decrease
- **Electric heavy duty vehicles are anticipated to be cost competitive with ICE vehicles by** 2025 if anticipated cost reductions are realized

Annual market size *[$ Bn]*



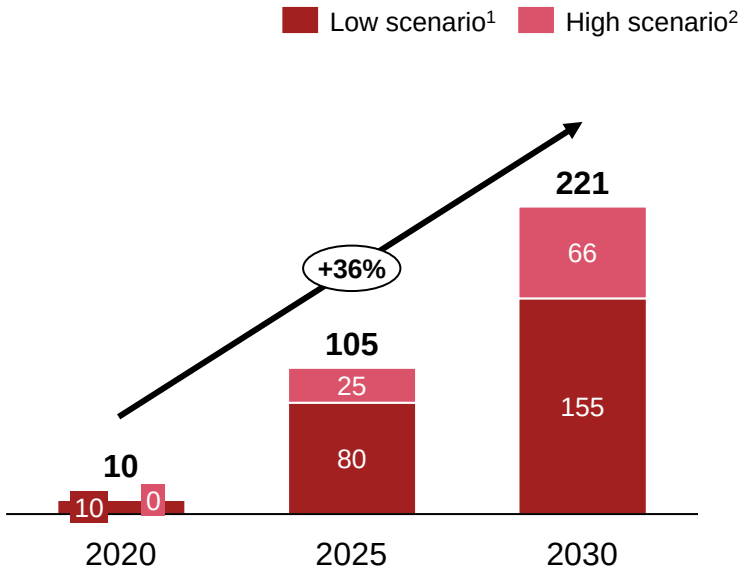
- The annual market size results from **multiplying the electric heavy duty vehicle demand by the average electric heavy duty vehicle cost**
- **The electric heavy duty vehicle market is expected to become a ~$120 Bn annual market by 2030**

1) Based on IEA STEPS scenario and only considering BEV's, 2) Based on NREL cost projections (low scenario) of class 8 long haul electric truck
Sources: IEA (2021), NREL (2021a), Strategy& analysis

The stationary storage systems market is expected to become a $30-45 Bn annual market by 2030

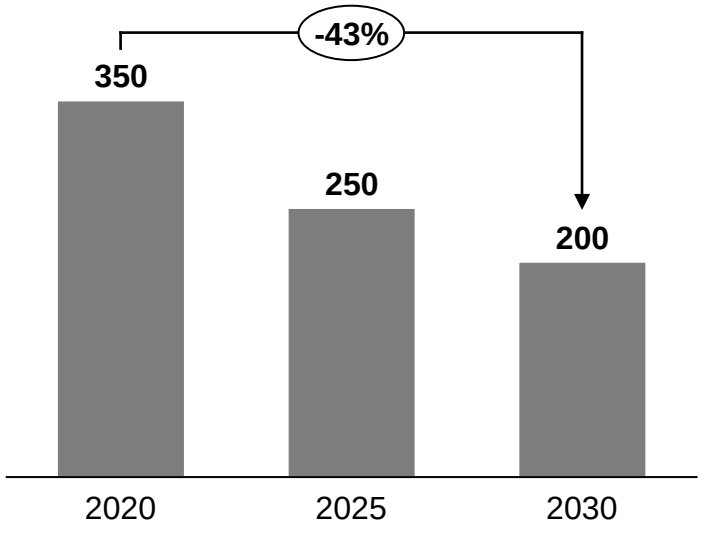
Estimated global stationary storage market size

Stationary storage demand *[GWh]*



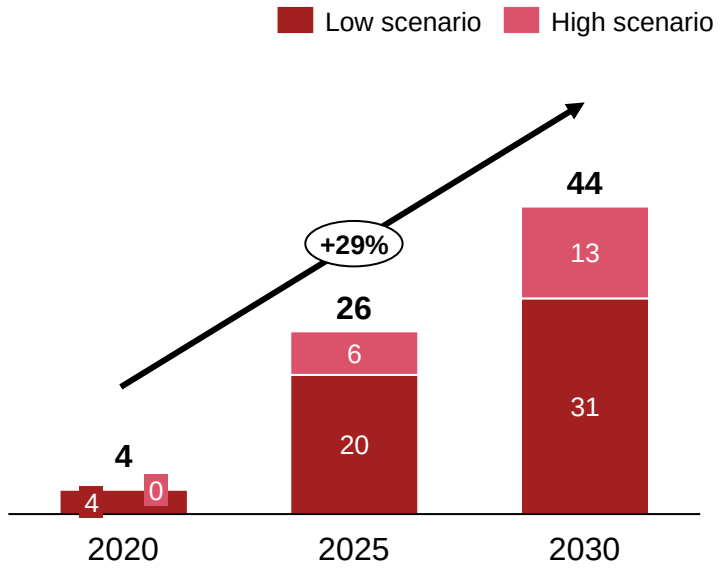
- **Increasing flexibility requirements,** on account of increasing share of RES and variability of demand, is the main driver for **stationary storage**
- **Storage duration requirements will shift from hours to days, weeks and months** which require new battery technological innovations

4-hour utility scale storage costs[3,4] *[$/kWh]*



- **Decreasing cost of battery packs and competition amongst major manufacturers** are the key reasons for the declining installed costs of utility scale storage
- **Co-locating storage with RES can further decrease costs by ~8-10%**

Annual market size *[$ Bn]*



- The annual market size results from **multiplying the stationary storage demand by installed costs**
- **The stationary storage market is expected to become a ~$40 Bn annual market by 2030**

1) Low scenario based on projections from BNEF, 2) High scenario based on projections from the World Economic Forum; 3) Stationary storage systems installed costs projections taken from NREL, 4) All stationary storage demand is assumed to be utility scale
Sources: BloombergNEF (2020a), WEF (2019), NREL (2021b), Strategy& analysis

Battery pack production has the maximum revenue pool in both electric vehicle and stationary storage value chain

Revenue pools across various value chains

Battery pack value chain[1]

	Raw materials supply	Cell component production	Battery cell production	Battery pack assembly	Re-usage and recycling
Revenue pool %	30 - 40%	5 – 10%	38 – 43%	15 – 20%	

Includes mining and refining

Re-use and recycling is a step after battery pack production and revenue pool estimation is detailed in the economic potential assessment section of related business opportunities

Electric vehicle value chain[2]

Other component manufacturing	Battery pack production	Power train production	Power electronics man.	Chassis assembly	Interior/exterior production	Vehicle assembly	Re-usage and recycling
10 – 15%	25 – 40%	3 – 5%	10 – 15%	6 – 10%	25 – 30%	6 – 10%	

Stationary storage value chain[3]

Battery pack production	Balance of system prod.	Power conversion system prod.	Energy management	Transformer prod.	System integration	EPC[4] services	Project development
25 – 40%	8 – 12%	11 – 14%	3 – 6%	4 – 8%	4 – 8%	4 – 8%	12 – 16%

Note: the revenue pool of the relevant activity applicable to the business opportunity is detailed in the economic potential assessment section

1) Based on estimates from NREL, WEF and Rystad, 2) Based on estimates from Financial Times and World Electric Vehicle Journal, 3) Based on estimates from World Bank, 4) Engineering, procurement and construction

Sources: NREL (2019), WEF (2019), Adrian König *et al* (2021), Financial Times (2020), Rystad, The World Bank (2020), Expert interviews, Strategy& analysis

The Dutch potential market share in 2030 is estimated using competitive scores, market share assumptions and the EU share of global market

Market share estimation methodology

			Battery pack production		Electric heavy duty vehicle		Stationary storage		
Dutch competitive score	**EU market share**	**Rest of world market share**	**EU share of global market (2030)**	**Effective global market share**	**EU share of global market (2030)**	**Effective global market share**	**EU share of global market (2030)**	**Effective global market share**	**Rationale**
< 2	**0 – 2.5%**	**0%**		**<1%**		**<0.5%**		**<1%**	Dutch companies have low competitive potential and will mainly supply the local market with limited opportunities regionally and globally
2 – 2.5	**1 – 10%**	**0 – 1.5%**		**<4%**		**<3%**		**<4%**	Dutch companies have a moderate competitive potential and are active in the regional landscape with limited exports globally
2.5 – 3	**5 – 15%**	**0.5 – 2%**	**15 – 25%[1]**	**1 – 5%**	**5 – 15%[2]**	**1 – 4%**	**20 – 30%[3]**	**1 – 6%**	Dutch companies have a moderate to good competitive potential and are well established in EU and some of non EU markets
3 – 3.5	**10 – 20%**	**1 – 2.5%**		**2 – 7%**		**1 – 5%**		**3 – 8%**	Dutch companies have good competitive potential with substantial market share in EU and also compete globally
>3.5	**>15%**	**>1.5%**		**>4%**		**>2%**		**>4%**	Dutch companies have substantial competitive potential and are recognized leaders in the global landscape

Based on phase 2 findings of the study

EU and ROW market share assumptions based on expert interviews and comparisons with similar industries

Battery pack, electric vehicle and stationary storage effective global market shares calculated by multiplying the EU and ROW market share assumptions with their respective 2030 global market shares

1) Based on data from EBA and SP Global; 2) Based on IEA data; 3) Based on data from US DOE, Global Data and Strategy& model
Sources: EBA (2020), SP Global (2021), IEA (2021), US DOE (2020), GlobalData (2021), Strategy& analysis

Determining economic potential - Subsections

- Framework overview
- **Economic potential assessment per business opportunity**
- Summary of Dutch economic potential

The Dutch economic potential for producing silicon anodes is estimated to be $ 0,1 – 20 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Production of silicon anodes

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
X	
Market share of packs with Si-anodes	**10 – 20 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**5 – 10 %**
X	
Share of specific value chain activity	**15 – 20 %**
4. Obtainable market share	X
Potential NL market share	**0,2 – 4 %**
=	
Economic potential NL	**$ 0,1 – 20 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- Market share of battery packs with silicon anodes is based on expert input and estimated market size for producing silicon anodes[3)]

- The production of silicon anodes belongs to the ‘production of cell component’ step in the value chain, accounting for 5 – 10% of the total revenue pool in the manufacturing process[4)]
- In the value step of ‘cell component production’ anodes, cathodes, electrolyte and separators are the main components. The production of anodes account for approximately 15 – 20% of the total share[5)]

- Estimated market share in the battery pack market based on the NL competitive score of 2,3[6)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) The Insights Partners (2020), expert input; 4) NREL (2019), WEF (2019); 5) Expert input; 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for selling/leasing patents related to new battery concepts is estimated to be $ 2 – 80 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Selling/ leasing of patents related to material science or production methodologies of new battery concepts

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
X	
Market share of new battery technologies	**10 - 20%**
3. Revenue pool	X
Revenue pool of specific value chain step	**45 – 50 %**
X	
Share of specific value chain activity	**4 – 10 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 2 – 80 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- Market share of new battery technologies is based on expert input and estimated demand for redox flow batteries[3)] and solid states batteries[4)], constituting 10 – 20 % of the total battery market

- The production of new battery concepts corresponds to the ‘production of cell component’ and ‘cell production’ steps in the value chain, collectively accounting for 45 – 50 % of the total revenue pool in the manufacturing process[5)]
- The contribution of R&D in the production process is estimated based on financials analysis[6)] and expert input and accounts for 4 – 10 %

- Estimated market share in the battery pack market based on the NL competitive score of 2,5[7)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) US DOE (2020); 4) The Faraday Institution (2020), expert input; 5) NREL (2019), WEF (2019); 6) LG Chem (2020), expert input; 7) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for polymeric battery components is estimated to be $ 0,1 – 5 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Producing materials for new battery electrodes and electrolytes (e.g. polymer concepts)

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total Li-ion battery pack market size	**$ 109k – 148k M**
X	
Market share of solid-state batteries	**5 – 10 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**5 – 10 %**
X	
Share of materials	**55 – 60 %**
X	
Share of polymers in materials	**7,5 – 10 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 0,1 – 5 M**

Rationale

- Lithium-ion battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted lithium-ion battery demand[1)] and battery pack prices[2)]
- The polymeric components are used in solid-state batteries, for which the relevant market is the forecasted share of the lithium-ion mobility battery market that solid-state could potentially acquire[3)]

- Polymeric battery components belong to the 'production of cell component' step in the value chain, accounting for 5 – 10% of the total revenue pool in the manufacturing process[4)]

- In cell production, materials account for 55 – 60 % of the total share[5)], polymers are estimated to make up for 7,5 – 10%[6)] - based on the assumption that liquid electrolyte will be replaced by composite solid state electrolyte (which a mixed polymeric ceramic structure)

- Estimated market share in the battery pack market based on the NL competitive score of 2,5[7)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) The Faraday Institution (2020), expert input; 4) NREL (2019), WEF (2019); 5) Rystad Energy (2021), Fabian Duffner *et al* (2021); 6) Yun Zheng *et al* (2020); 7) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing manufacturing equipment for lithium-ion batteries is estimated to be $ 5 – 100 M revenue annually

Economic potential of business opportunity

Business opportunity: Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries (e.g. deposition/ coating techniques)

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
3. Revenue pool	X
Revenue pool of specific value chain step	**45 – 50 %**
	X
Share of coating in cell manufacturing	**12 – 17 %**
	X
Share of machinery in cell manufacturing	**5 – 15 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
	=
Economic potential NL	**$ 5 – 100 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- The production of new battery concepts corresponds to the ‘production of cell component’ and ‘cell production’ steps in the value chain, collectively accounting for 45 – 50 % of the total revenue pool in the manufacturing process[3)]
- In the manufacturing process, coating accounts approximately 12 – 17 % of the share[4)]
- Machinery is estimated to contribute to 5 – 15 % of the total share in the ‘production of cell component’ and ‘cell production’ steps[5)]
- Estimated market share in the battery pack market based on the NL competitive score of 2,8[6)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) NREL (2019), WEF (2019); 4) Yangtao Liu *et al* (2021); 5) Rystad Energy (2021), Fabian Duffner *et al* (2021); 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing manufacturing equipment for new battery concepts is estimated to be $ 5 – 150 M revenue annually

Economic potential of business opportunity

Business opportunity: Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
X	
Market share of new technologies	**10 – 20 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**45 – 50 %**
X	
Share of machinery in cell manufacturing	**5 – 15 %**
4. Obtainable market share	X
Potential NL market share	**2 – 7 %**
=	
Economic potential NL	**$ 5 – 150 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- Market share of new battery technologies is based on expert input and estimated demand for redox flow batteries[3)] and solid states batteries[4)], constituting 10 – 20 % of the total battery market

- The production of new battery concepts corresponds to the ‘production of cell component’ and ‘cell production’ steps in the value chain, collectively accounting for 45 – 50 % of the total revenue pool in the manufacturing process[5)]
- Machinery costs is estimated to contribute to 5 – 15 % of the total share in the ‘production of cell component’ and ‘cell production’ steps[6)]

- Estimated market share in the battery pack market based on the NL competitive score of 3,2[7)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF(2020a); 2) BloombergNEF (2020b); 3) US DOE (2020); 4) The Faraday Institution (2020), expert input; 5) NREL (2019), WEF (2019); 6) Rystad Energy (2021), Fabian Duffner *et al* (2021); 7) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing BMS hardware components is estimated to be $ 30 – 340 M revenue annually

Economic potential of business opportunity

Business opportunity:
Production of hardware components (sensors/controllers) which go into a battery management system

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
3. Revenue pool	X
Revenue pool of specific value chain step	**55 – 60 %**
	X
Share of battery management system	**5 – 8 %**
	X
Share of hardware	**80 – 90 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
	=
Economic potential NL	**$ 30 – 340 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- Manufacturing battery cells includes both the ‘cell production’ and ‘pack assembly’ steps in the value chain, collectively accounting for 55 – 60 % of the total revenue pool in the manufacturing process[3)]
- The battery management accounts for approximately 5 – 8 % of the total battery share[4)]
- The vast majority of the battery management systems costs are related to hardware components, the software is generally developed inhouse by the companies that integrate the batteries into end-user application[4)]
- Estimated market share in the battery pack market based on the NL competitive score of 2,8[5)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) NREL (2019), WEF (2019); 4) Guenter Schneider *et al* (2021); 5) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for manufacturing testing equipment for cell production is estimated to be $ 0,5 – 50 M revenue annually

Economic potential of business opportunity

Business opportunity:
Manufacturing testing equipment required in the cell production process

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 109k – 148k M**
3. Revenue pool	X
Revenue pool of specific value chain step	**45 – 50 %**
	X
Share of machinery in cell manufacturing	**5 – 15 %**
	X
Share of testing equipment in machinery	**8 – 12 %**
4. Obtainable market share	X
Potential NL market share	**0,2 – 4 %**
	=
Economic potential NL	**$ 0,5 – 50 M**

Rationale

- Battery pack market size includes both the storage and mobility market – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]

- The production of new battery concepts corresponds to the ‘production of cell component’ and ‘cell production’ steps in the value chain, collectively accounting for 45 – 50 % of the total revenue pool in the manufacturing process[3)]
- Machinery is estimated to contribute to 5 – 15 % of the total share in the ‘production of cell component’ and ‘cell production’ steps[4)]
- The share of testing equipment out of machinery is approximately 8 – 12 %, for more complex battery concepts which require more cycles of charging/ discharging during the formation steps the share can increase[5)]

- Estimated market share in the battery pack market based on the NL competitive score of 2,2[6)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) NREL (2019), WEF (2019); 4) Rystad Energy (2021), Fabian Duffner *et al* (2021); 5) Expert input; 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for developing data-driven services for battery storage systems is estimated to be $ 2 – 120 M revenue annually

Economic potential of business opportunity

Business opportunity: Offer data-driven solutions as a service to owners and developers of storage systems (remote monitoring, forecasting, predictive maintenance, charge/discharge optimization)

Economic potential calculation (2030)

1. Value chain alignment	Stationary storage
2. Market size	
Total energy storage market size	**$ 31k – 44k M**
3. Revenue pool	X
Revenue pool of energy services	**3 – 7 %**
4. Obtainable market share	X
Potential NL market share	**0,2 – 4 %**
	=
Economic potential NL	**$ 2 – 120 M**

Rationale

- The energy storage market is estimated based on the forecasted battery storage demand[1)] and cost projections for utility scale battery storage[2)]
- The opportunity applies to the 'Energy management Services' step in the value chain – collectively accounting for 3 – 7 % of the total revenue pool[3)]
- Estimated market share in the stationary battery storage market based on the NL competitive score of 2,3[4)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) NREL (2021b); 3) The World Bank (2020); 4) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for developing separation techniques for recycling is estimated to be $ 2 – 40 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Developing recycling techniques related to the chemical separation of batteries

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total mobility battery pack market size	**$ 100k – 135k M**
X	
Available for recycling	**3 – 8 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**37 – 42 %**
X	
Share of specific value chain activity	**12 – 17 %**
4. Obtainable market share	X
Potential NL market share	**0,2 – 4 %**
=	
Economic potential NL	**$ 2 – 40 M**

Rationale

- Only the mobility battery pack market is considered as current EV batteries are expected to be the first wave of batteries to reach end-of-life – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- The amount of batteries available for recycling is based on projections of the number of batteries that become end-of-life as a share of the new battery pack market in the same year[3)]

- The opportunity applies to the ‘recycling’, ‘mining’ and ‘refining’ steps in the value chain – collectively accounting for 37 – 42 % of the total revenue pool in the manufacturing process[4)]
- The business opportunity combines R&D (selling/leasing patents related to materials science) and the production equipment. Within the three value-chain steps, material science R&D and equipment collectively account for 12 – 17 % of the total share[5)]

- Estimated market share in the battery pack market based on the NL competitive score of 2,5[6)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) IEA (2020); 4) NREL (2019), WEF (2019); 5) Rystad Energy (2021), Fabian Duffner *et al* (2021); 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for recycling/ dismantling end-of-life batteries is estimated to be $ 1 – 35 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Recycling/ dismantling end-of-life batteries

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total battery pack market size	**$ 100k – 135k M**
X	
Available for recycling	**3 – 8 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**2 – 6 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 1 – 35 M**

Rationale

- Only the mobility battery pack market is considered as current EV batteries are expected to be the first wave of batteries to reach end-of-life – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- The amount of batteries available for recycling is based on projections of the number of batteries that become end-of-life as a share of the new battery pack market in the same year[3)]

- The opportunity applies to the ‘recycling’ step in the value chain – accounting for 2 – 6 % respectively of the total revenue pool in the manufacturing process[4)]

- Estimated market share in the battery pack market based on the NL competitive score of 2,7[5)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) IEA (2020); 4) NREL (2019), WEF (2019); 5) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for the production of solid state batteries is estimated to be $ 40 – 480 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Production of solid state batteries

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total mobility battery pack market size	**$ 100k – 135k M**
X	
Market share of solid-state batteries	**5 – 10 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**63 – 68 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 40 – 480 M**

Rationale

- The battery pack market for mobility applications – it is estimated based on the forecasted battery demand[1)] and battery pack prices[2)]
- Market share of solid-state batteries is the forecasted share of the lithium-ion mobility battery market that solid-state could potentially acquire[3)]
- The production of solid-state batteries applies to the ‘production of cell component’, ‘cell production’ and ‘pack assembly’ steps in the value chain – collectively accounting for 63 – 68 % of the total revenue pool in the manufacturing process[4)]
- Estimated market share in the battery pack market based on the NL competitive score of 2,5[5)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) The Faraday Institution (2020), expert input; 4) NREL (2019), WEF (2019); 5) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing electric heavy duty vehicles is estimated to be $ 670 – 3.200 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Production of electric heavy duty commercial vehicles (buses, coaches)

Economic potential calculation (2030)

1. Value chain alignment	Electric vehicle
2. Market size	
Total electric heavy duty vehicle market	**$ 105k – 129k M**
3. Revenue pool	X
Revenue pool of specific value chain step	**44 – 49 %**
4. Obtainable market share	X
Potential NL market share	**1,5 – 5 %**
	=
Economic potential NL	**$ 670 – 3.200 M**

Rationale

- The electric commercial heavy duty vehicle market is estimated based on the forecasted vehicle demand[1)] and cost projections for heavy-duty vehicles[2)]
- The production of electric heavy duty commercial vehicles includes the ‘power train’, ‘e-drive and power electronics’, ‘chassis assembly’, ‘vehicle exterior’ and ‘vehicle assembly’ steps – collectively accounting 44 – 49 % of the total electric vehicle value chain[3)] (It is assumed that interior is supplied to the OEMs by a third-party manufacturer, and that interior accounts for 50% of the added value in the ‘vehicle interior and exterior’ step in the value chain)
- Estimated market share in the electric mobility market based on the NL competitive score of 3,2[4)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) IEA (2021); 2) NREL (2021a); 3) Adrian König *et al* (2021), Financial Times (2020); 4) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing commercial vehicle e-drive trains is estimated to be $ 340 – 1.800 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Production of e-drive trains for heavy duty vehicles

Economic potential calculation (2030)

1. Value chain alignment	Electric Vehicle
2. Market size	
Total electric commercial vehicle market	**$ 105k – 129k M**
3. Revenue pool	X
Revenue pool of specific value chain step	**22 – 27 %**
4. Obtainable market share	X
Potential NL market share	**1,5 – 5 %**
	=
Economic potential NL	**$ 340 – 1.800 M**

Rationale

- The electric heavy duty commercial vehicle market is estimated based on the forecasted vehicle demand[1)] and cost projections for heavy-duty vehicles[2)]
- The production of electric heavy duty commercial vehicles includes the ‘power train’, ‘e-drive and power electronics’ and ‘chassis assembly’ steps – collectively accounting for 22 – 27 % of the total electric vehicle value chain[3)]
- Estimated market share in the electric mobility market based on the NL competitive score of 3,0[4)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) IEA (2021); 2) NREL (2021a); 3) Adrian König *et al* (2021), Financial Times (2020); 4) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing membrane stacks for redox flow batteries is estimated to be $ 0,5 – 5 M revenue annually

Economic potential of business opportunity

Business opportunity:
Production of integrated membrane stacks to be used in redox flow batteries

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total storage battery pack market size	**$ 9k – 13k M**
X	
Market share of redox flow batteries	**5 – 10 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**63 – 68 %**
X	
Share of membrane stack in flow battery	**8 – 13 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 0,5 – 5 M**

Rationale

- The battery pack market for stationary storage applications is estimated based on the forecasted stationary storage battery demand[1)] and battery pack prices[2)]
- Market share of redox flow batteries is the forecasted share of the stationary storage battery market that redox flow batteries could potentially acquire[3)]

- The opportunity applies to the ‘production of cell component’, ‘cell production’ and ‘pack assembly’ steps in the value chain – collectively accounting for 63 – 68 % of the total revenue pool in the manufacturing process[4)]
- The integrated membrane stack accounts for approximately 8 – 13% of the total share of the redox flow battery[5)]

- Estimated market share in the battery pack market based on the NL competitive score of 2,5[6)]

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) BloombergNEF(2020b); 3) US DOE (2020); 4) NREL (2019), WEF (2019); 5) IRENA (2020), expert input; 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for producing utility scale batteries with longer discharge times is estimated to be $ 5 – 45 M revenue annually

Economic potential of business opportunity

Business opportunity:
Production of utility scale batteries with longer discharge times (redox flow, salt water, other technologies)

Economic potential calculation (2030)

1. Value chain alignment	Battery pack
2. Market size	
Total storage battery pack market size	**$ 9k – 13k M**
X	
Market share of redox flow batteries	**5 – 10 %**
3. Revenue pool	X
Revenue pool of specific value chain step	**63 – 68 %**
4. Obtainable market share	X
Potential NL market share	**1 – 5 %**
=	
Economic potential NL	**$ 5 – 45 M**

Rationale

- The battery pack market for stationary storage applications is estimated based on the forecasted stationary storage battery demand[1)] and battery pack prices[2)]
- The forecasted market share of redox flow batteries is assumed to be a proxy for the potential market for bulk batteries – of all concepts redox flow batteries are expected to be the first become commercially viable[3)]
- The opportunity applies to the ‘production of cell component’, ‘cell production’ and ‘pack assembly’ steps in the value chain – collectively accounting for 63 – 68 % of the total revenue pool in the manufacturing process[4)]
- Estimated market share in the battery pack market based on the NL competitive score of 2,7[5)]
- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF(2020a); 2) BloombergNEF (2020b); 3) US DOE (2020), expert input; 4) NREL (2019), WEF (2019); 5) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

The Dutch economic potential for integration of stationary storage into the grid is estimated to be $ 10 – 300 M revenue annually in 2030

Economic potential of business opportunity

Business opportunity:
Integration of stationary storage into the grid

Economic potential calculation (2030)

1. Value chain alignment	Stationary storage
2. Market size	
Total energy storage market size	**$ 31k – 44k M**
X	
EU share of the market	**20 – 30%**
3. Revenue pool	X
Revenue pool of development and EPC	**18 – 22 %**
4. Obtainable market share	X
Potential NL market share	**1 – 10 %**
=	
Economic potential NL	**$ 10 – 300 M**

Rationale

- The energy storage market is estimated based on the forecasted battery storage demand[1)] and cost projections for utility scale battery storage[2)]
- The stationary storage grid integration market is very regional in nature and hence on EU market is considered to estimate economic potential
- The EU share of the global storage market is based on assumed RES growth by country globally[3)]

- The opportunity applies to the 'EPC[4)] services' and 'project development' steps in the value chain – collectively accounting for 18 – 22 % of the total revenue pooled[5)]

- Estimated market share in the stationary battery storage market based on the NL competitive score of 2,5[6)] (only EU market share has been considered due to the regional nature of the business opportunity)

- The economic potential is the estimated annual added value in 2030 which the NL companies could potentially generate in the identified business opportunity

Sources; 1) WEF (2019), BloombergNEF (2020a); 2) NREL (2021b); 3) US DOE (2020), GlobalData (2021), Strategy& model; 4) Engineering, procurement, construction; 5) The World Bank (2020); 6) Market share calculation methodology is highlighted in the framework section; Strategy& analysis

Determining economic potential - Subsections

- Framework overview
- Economic potential assessment per business opportunity
- **Summary of Dutch economic potential**

The estimated Dutch economic potential in 2030 appears to be good for opportunities relating to equipment manufacturing and BMS systems

Overview of economic potential assessment (1/2)

Business opportunity	Average estimated annual economic potential (2030)	Rationale
1 **Production of silicon anodes**	**~ $ 10 M**	*Limited economic potential* - Only 10-20% of the lithium-ion batteries are expected to have silicon anodes in 2030 and the production of anodes is estimated to only contribute to 1-2% of the total revenue pool in battery pack manufacturing
2 **Selling/ leasing of patents related to material science or production methodologies of new battery concepts**	**~ $ 40 M**	*Moderate economic potential* - Battery production steps of the value chain are estimated to collectively account for 45-50% of the total revenue pools and R&D accounts for a significant 4-10% of that
3 **Producing materials for new battery electrodes and electrolytes** (e.g. polymer concepts)	**~ $ 5 M**	*Limited economic potential* - Polymer concepts apply to solid state battery concepts, which are estimated to account for only 5-10% of the battery demand in 2030, additionally polymer is a fraction of the total materials used in these concepts
4 **Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	**~ $ 50 M**	*Moderate economic potential* - Battery manufacturing is estimated to account for a substantial part of the total revenue pool (45-50%) with machinery accounting for 5-15% of it and coating processes are among the key drivers (12-17%) of machinery investments
5 **Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production**	**~ $ 80 M**	*Moderate economic potential* - New battery concepts are estimated to take 10-20% of total battery demand in 2030, cell component and cell production are a significant (45-50%) part of the revenue pool – equipment is 5-15% of total revenue pool in these steps
6 **Production of hardware components** (sensors/ controllers/ chip sets) **which go into a battery management system**	**~ $ 180 M**	*Good economic potential* - Battery management systems apply to the total battery pack market and within the battery manufacturing revenue pool, BMS accounts for 5-8%
7 **Manufacturing testing equipment required in the cell production process**	**~ $ 25 M**	*Limited economic potential* - Testing equipment is estimated to only be 8-12% of the total equipment required for cell production, which accounts for only 5-15% of the total revenue pool in the cell production process
8 **Offer data-driven solutions as a service to owners and developers of storage systems** (e.g. remote monitoring, forecasting, predictive maintenance etc.)	**~ $ 60 M**	*Moderate economic potential* – Data driven solutions are estimated to account for 3-7% of the total revenue pool in the stationary energy storage market

Strategy&

Note: LeydenJar, a Dutch scale-up involved in the production, selling/leasing patents and producing manufacturing equipment related to silicon anodes, estimates annual revenue in 2030 to be €1.2 B

In addition, the opportunities related to solid state batteries, electric heavy duty vehicles and stationary storage systems also stand out

Overview of business opportunity benchmark (2/2)

Business opportunity	Average estimated annual economic potential (2030)	Rationale
9 **Developing recycling techniques related to the chemical separation of batteries**	**~ $ 20 M**	*Limited economic potential* - Estimated recycling market in 2030 is only 3-8% of the battery pack demand that year, developing R&D and equipment only account for a limited fraction of the market
10 **Recycling/ dismantling of end-of-life mobility batteries**	**~ $ 20 M**	*Limited economic potential* - Estimated recycling market in 2030 is only 3-8% of the battery pack demand that year, the limited revenue pool of performing the recycling reduces the economic potential
11 **Production of solid sate batteries**	**~ $ 250 M**	*Good economic potential* - Solid state batteries are estimated to take 5-10% of the total mobility market, of which battery production is a significant share of the total revenue pool
12 **Production of electric heavy duty commercial vehicles** (buses, coaches)	**~ $ 1,950 M**	*Good economic potential* - The total electric heavy duty commercial vehicle market is substantial ($ 90k-120k M), of which vehicle production accounts for a significant share (44-49%) – strong positioning of NL results in relatively high market shares
13 **Production of e-drive train for heavy duty vehicles**	**~ $ 1,000 M**	*Good economic potential* - E-drive train production accounts for a significant share (22-27%) of the revenue pool across the electric vehicle value chain and is a subset of the previous opportunity
14 **Production of integrated membrane stacks to be used in redox flow batteries**	**~ $ 5 M**	*Limited economic potential* - Redox flow batteries are expected to take 5-10% of the battery storage market, the membrane stacks account for only 8-15% of the total costs
15 **Production of utility scale batteries with longer discharge times** (redox flow, salt water, other technologies)	**~ $ 25 M**	*Limited economic potential* - With 5-10% new battery technologies take a significant share of the total battery storage market
16 **Integration of stationary battery storage into the grid**	**~ $ 150 M**	*Good economic potential* - The revenue pool of grid integration compared to the total energy storage value chain is substantial (18-22%)

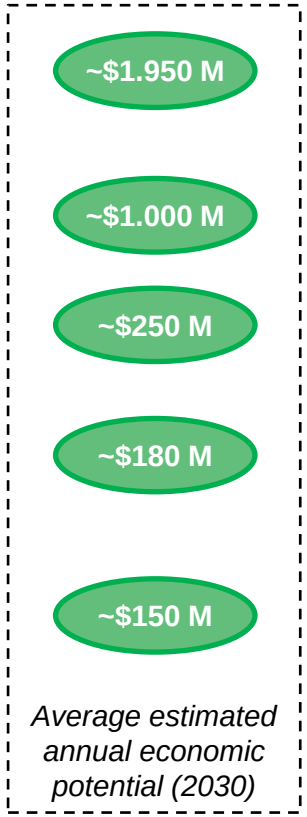
Note: Elestor, a Dutch scale-up developing and producing redox flow batteries, estimates annual revenue in 2026 to be in the range of €800-900 M

Production related opportunities appear to have the highest economic potential as they capture larger revenue pools in the battery value chain

Key findings of economic potential assessment

Promising business opportunities

1. **Production of electric heavy duty commercial vehicles** *(buses, trucks)*
2. **Production of electric drivetrains** (subset of electric heavy duty vehicle production)
3. **Production of solid state batteries**
4. **Production of hardware components** (sensors/ controllers/ chip sets) **which go into a battery management system**
5. **Integration of stationary battery storage into the grid**



For details on **calculation methodology and assumptions**, see pages 108-131

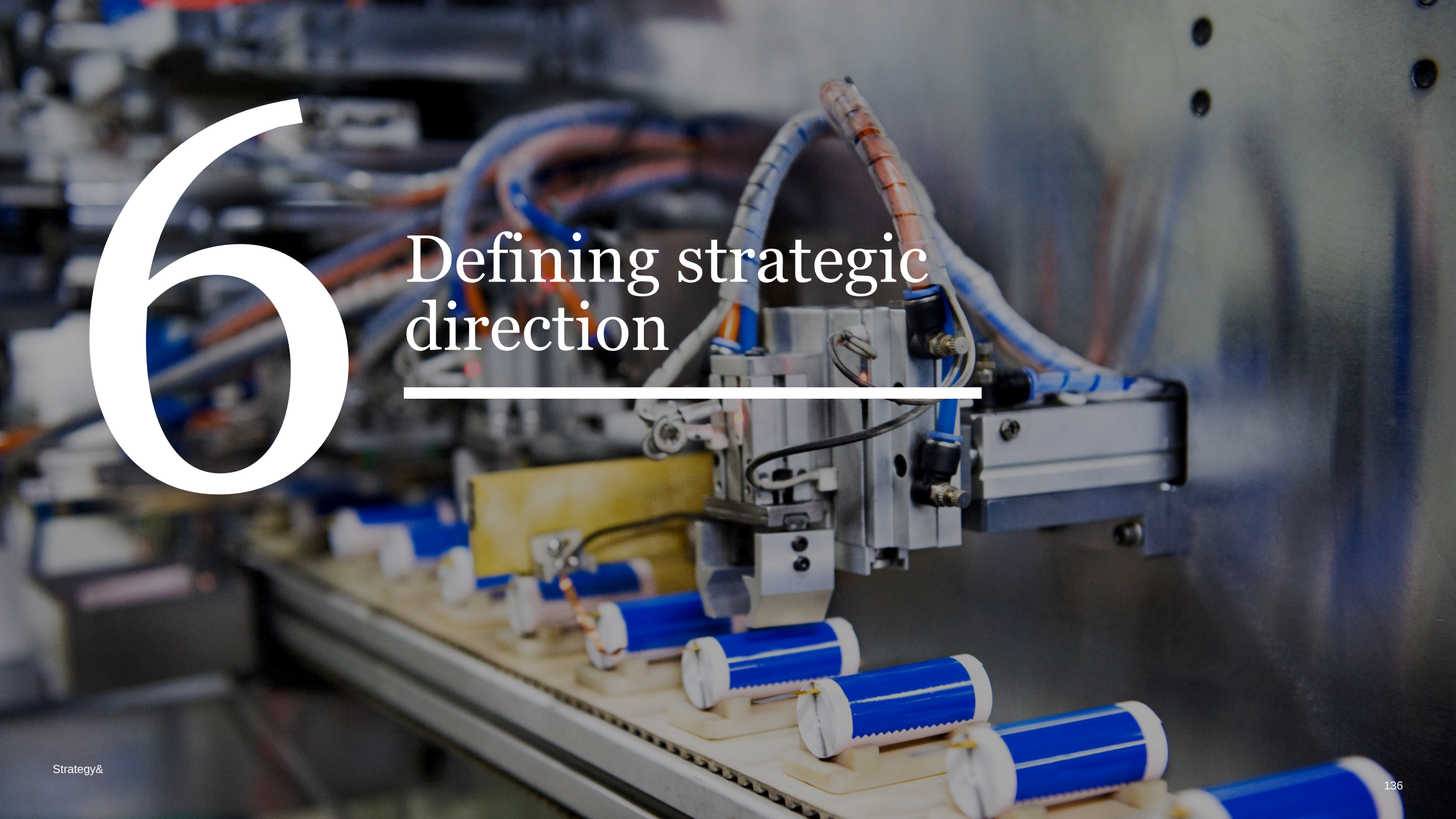
Key drivers for economic potential

Revenue pools

- Opportunities that span across multiple steps of the value chain yield higher economic potential – e.g. cell component production only accounts for 5-10%, where component production to pack assembly is 63-68%
- Within value chain steps, more specific activities result in lower economic potential – e.g. producing polymer materials relates to material costs within cell component production, and polymers are only a share of the total material costs

Market share

- Opportunities with a higher competitiveness score yield higher market share which contribute to economic potential – the average potential market share varies between 2-5%
- The size of the European market impacts the obtainable market share – e.g. on a global scale the European market for electric heavy duty mobility is smaller than the stationary energy storage systems market, which limits the global market share



6 Defining strategic direction

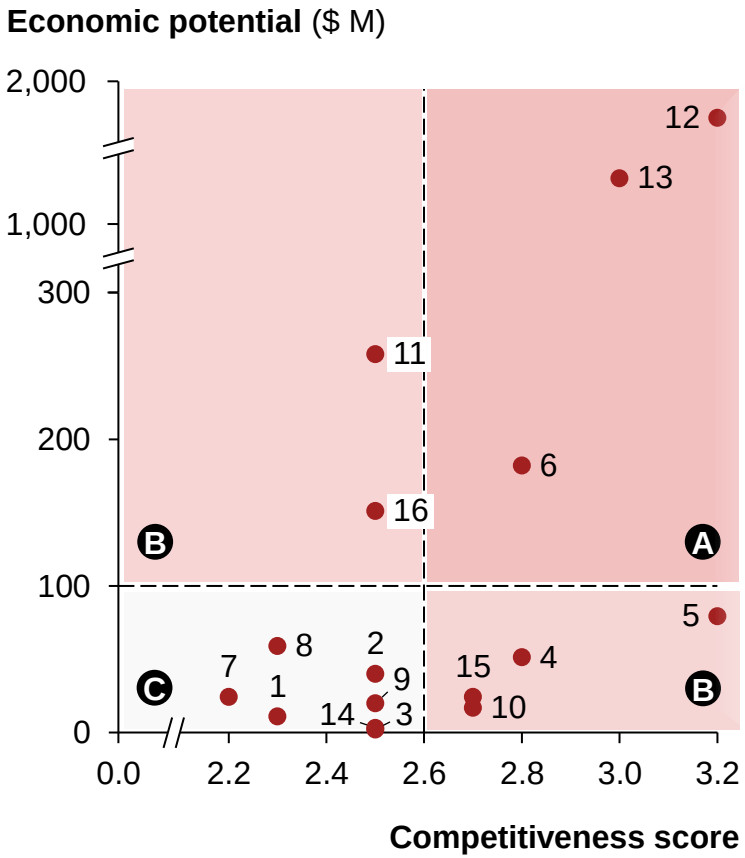
Combining the competitiveness and economic potential assessment yields three regions with distinct strategic characteristics

Combined assessment of competitiveness and economic potential (1/5)

Business opportunities

1. Production of silicon anodes
2. Patents for new battery concepts
3. Producing materials for new battery components
4. Production equipment for current battery technologies
5. Production equipment for new battery technologies
6. Production of battery management system hardware
7. Manufacturing of testing equipment
8. Data-driven solutions for battery storage
9. Chemical separation techniques for battery recycling
10. Recycling end-of-life mobility batteries
11. Production of solid-state batteries
12. Production of electric heavy duty commercial vehicles
13. Production of e-drive train for heavy duty vehicles
14. Integrated membrane stacks for redox flow battery
15. Production of bulk batteries
16. Integration of stationary storage into the grid

Competitiveness vs. economic potential



Strategic decisions based on identified regions

A – Double down

High economic potential and high competitiveness – Explore how NL could capitalize on strong competitive positioning

B – Grow

High economic potential and low competitiveness – Seek for ways to improve NL competitive position

OR

Low economic potential and high competitiveness – Explore possibility of increasing economic potential through backward or forward value chain integration

C – Incubate

Low economic potential and low competitiveness – Monitor potential of relevant opportunities, given the disruptive nature and development speed of the battery market

Opportunities surrounding heavy duty transport and BMS systems appear to be the most promising ones for NL to focus on

Combined assessment of competitiveness and economic potential (2/5)

Strategic decisions	Identified business opportunities	Rationale
Double Down *High economic potential and high competitiveness – Explore how NL could capitalize on strong competitive positioning*	**Production of electric heavy duty commercial vehicles (buses, coaches)**	Electrification of heavy duty transport is needed to meet the ambitious energy transition targets and Dutch companies like DAF and VDL are major players in the EU market for heavy duty transport
	Production of e-drive train	New business models are emerging with vehicle OEM's outsourcing specialized e-drive train manufacturing to third parties and Dutch players can utilize existing expertise to supply to vehicle OEM's globally
	Production of hardware components which go into a battery management system	The market for BMS systems is anticipated to increase significantly in line with battery demand and high potential exists for companies like NXP which already have a large global presence
Grow *High economic potential and low competitiveness – Seek for ways to improve NL competitive position* *OR* *Low economic potential and high competitiveness – Explore possibility of increasing economic potential through backward or forward value chain integration*	**Production of equipment for specific process steps in the manufacturing of current generation of lithium-ion batteries** (e.g. deposition/ coating techniques)	Rise of giga factories in EU will require a localized supply chain where companies like ASML can manufacture specialized equipment required for cell component production (e.g. deposition/ coating techniques)
	Production of equipment for the manufacturing of new battery technologies focusing on cell component and cell production	Though battery production has been commoditized in China, this has not been the case for specialized equipment manufacturing. New batteries will potentially require new equipment which can yield potential for Dutch manufacturers
	Production of solid sate batteries	Battery demand for mobility applications is anticipated to increase significantly with the uptake of EVs. Solid state shows promise and NL can capture a large value chain share if production is realized locally
	Integration of stationary battery storage into the grid	High renewable energy (RES) ambitions in EU will require stationary storage systems to integrate the renewable energy sources into the grid and since the ecosystem is very regional specific, Dutch companies can play a role if acted upon early
Incubate *Low economic potential and low competitiveness – Keep an eye out on future potential relevance of the opportunities*	**Multiple opportunities**	Opportunities like Redox-flow batteries, research into new battery technologies and recycling concepts show good potential due to market demand and presence of relevant startups and scaleups; future commercial attractiveness depends on how ecosystem evolves

Mapping opportunities to the overarching themes, identified in previous studies, shows battery packs as potentially the most promising theme

Combined assessment of competitiveness and economic potential (3/5)

Theme	Business opportunities	Competitiveness	Avg. estimated economic potential[1]	Key comments
New cells and materials	1 Production of silicon anodes 2 Patents for new battery concepts 3 Producing materials for new battery components 5 Production equipment for new battery technologies 11 Production of solid-state batteries	2,6	~$370 M	The opportunities focus on relatively small shares of manufacturing revenue pool and new battery technologies are expected to take only a minor share of the total battery market in 2030
Battery packs and systems	4 Production equipment for current battery technologies 12 Production of electric heavy duty commercial vehicles 13 Production of e-drive train for heavy duty vehicles	3,1	~$2.000 M	The production of electric commercial vehicles (including e-drive trains) covers a significant share of the manufacturing revenue pool and NL's strong position also increases the estimated economic potential
Recycling, second-use and reuse	9 Chemical separation techniques for battery recycling 10 Recycling end-of-life mobility batteries	2,6	~$40 M	The relatively small volume of end-of-life batteries available for recycling reduces the estimated economic potential
Grid support	14 Integrated membrane stacks for redox flow battery 15 Production of bulk batteries 16 Integration of stationary storage into the grid	2,5	~$180 M	The economic potential is driven by integration of stationary storage, which accounts for significant share of the stationary storage revenue pool
Safety	6 Production of battery management system hardware 7 Manufacturing of testing equipment 8 Data-driven solutions for battery storage	2,6	~$270 M	The production of battery management systems hardware applies to the whole battery market, yielding significant economic potential

1) Double counting of economic potential has been avoided in the broader themes

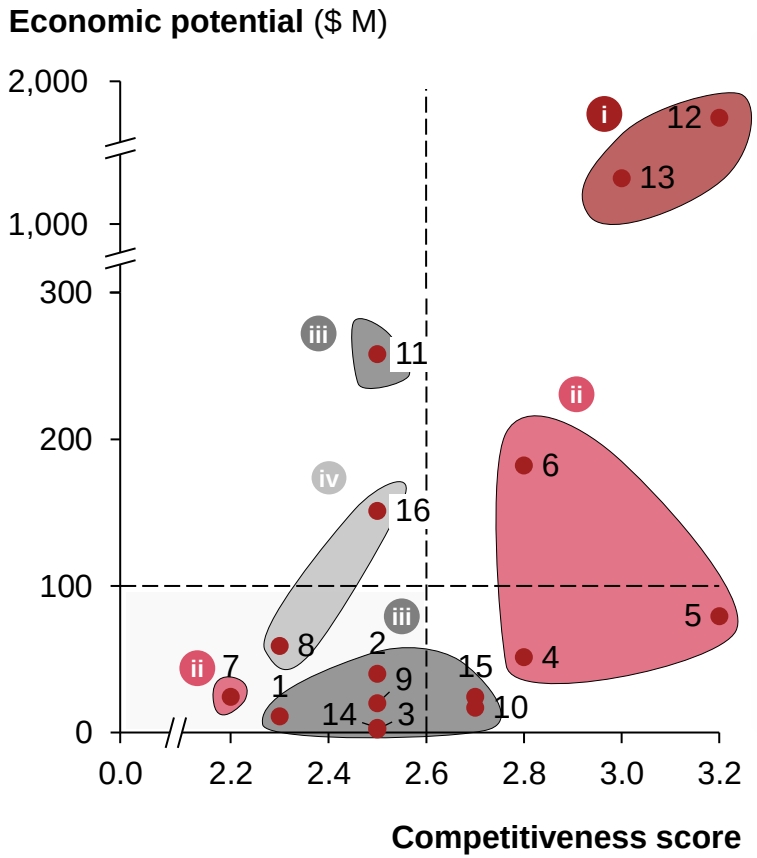
In addition, potential economies of scale and/ or skill can be identified by clustering the business opportunities into ecosystems

Combined assessment of competitiveness and economic potential (4/5)

Opportunity per ecosystem

- **i Electric heavy duty mobility**
  - 12 Production of electric heavy duty commercial vehicles
  - 13 Production of e-drive train for heavy duty vehicles
- **ii Equipment manufacturing**
  - 4 Production equipment for current battery technologies
  - 5 Production equipment for new battery technologies
  - 6 Production of battery management system hardware
  - 7 Manufacturing of testing equipment
- **iii New battery concepts**
  - 1 Production of silicon anodes
  - 2 Patents for new battery concepts
  - 3 Producing materials for new battery components
  - 9 Chemical separation techniques for battery recycling
  - 10 Recycling end-of-life mobility batteries
  - 11 Production of solid-state batteries
  - 14 Integrated membrane stacks for redox flow battery
  - 15 Production of bulk batteries
- **iv Stationary storage systems**
  - 8 Data-driven solutions for battery storage
  - 16 Integration of stationary storage into the grid

Competitiveness vs. economic potential



Potential ecosystem economies of scale/ skill

I – Electric heavy duty mobility
Through producing both electric drivetrains and heavy duty vehicles, NL could strength the competitive position and capitalize on the collective economic potential

II – Equipment manufacturing
NL could use its traditional manufacturing expertise to manufacture a range of equipment for current generation and new generation battery technologies – which all require high-tech equipment

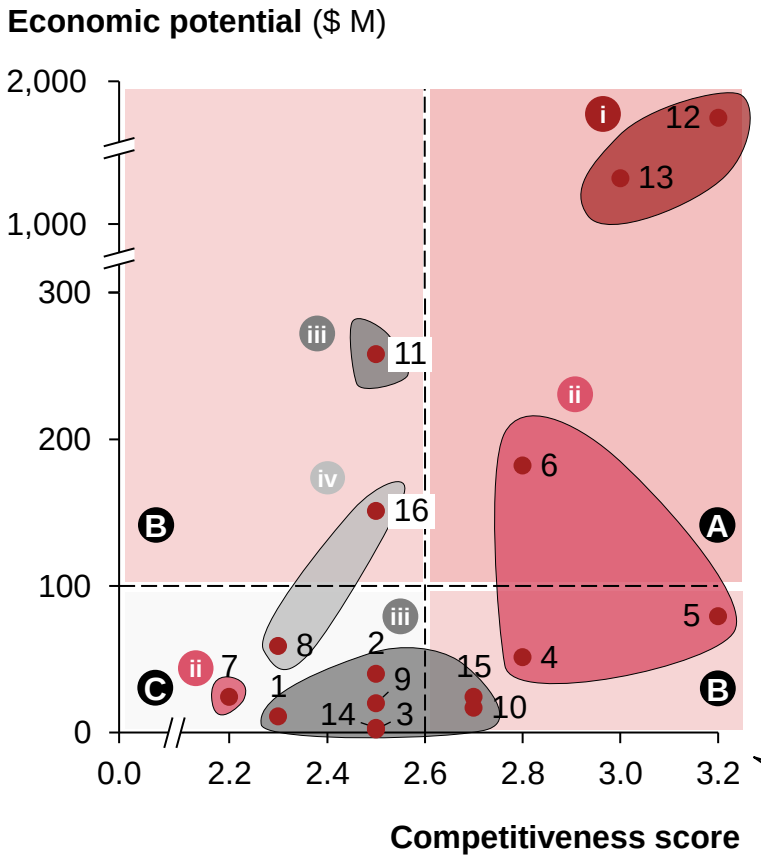
III – New battery concepts
NL could focus on research, developing and producing new battery technologies as well as recycling – all opportunities require significant R&D investments and close collaboration between research institutes and startups

IV – Stationary storage systems
Owing to the large amounts of RES development in EU, NL could spearhead the stationary storage growth in Europe

Clear strategic directions emerge when comparing the ecosystems against each other on competitiveness and economic potential

Combined assessment of competitiveness and economic potential (5/5)

Competitiveness vs. economic potential



Identified ecosystems

Ecosystem	Average competitiveness	Total economic potential, $ M	Strategic decision	Rationale
i **Electric heavy duty mobility**	3,1	~1.950	Double down	The ecosystem has the highest economic potential with already a strong presence of Dutch players competing in the regional and global space
ii **Equipment manufacturing**	2,9	~340	Grow	The ecosystem competitiveness is high due to the traditional Dutch capabilities in manufacturing and a sizeable portion of economic potential can be attained if the companies focus efforts towards batteries
iii **New battery concepts**	2,5	~330	Incubate	High level of collaboration is required between startups, universities and research institutes; high upside is possible if new technologies are commercialized
iv **Stationary storage systems**	2,4	~210	Incubate	Mainly a local and regional play but high upside is possible due to the projected increase in the share of intermittent RES in the energy mix

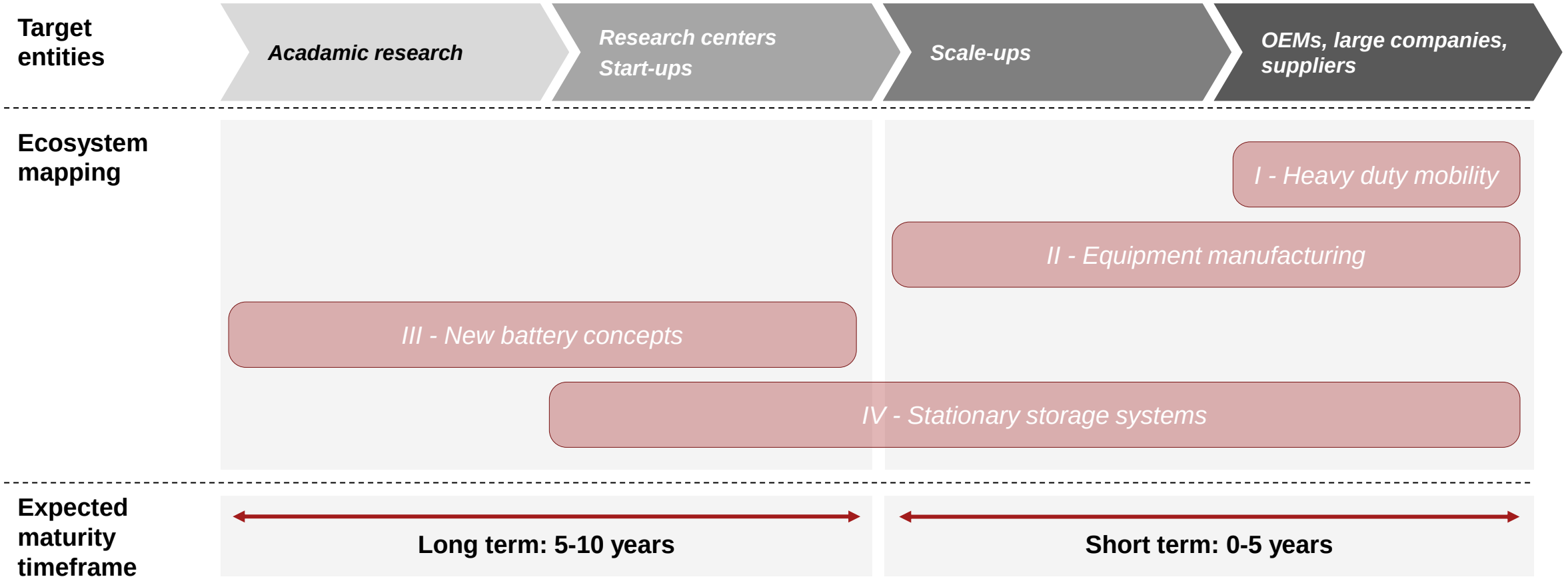
Strategic decisions based on identified regions
A – Double down **B – Grow** **C – Incubate**

Incubate

1) Double counting of economic potential has been avoided in the ecosystems

These ecosystems target different entities with different expected maturity timeframes

Ecosystem mapping to development funnel



In addition, the ecosystems have different challenges to overcome in order to achieve the strategic direction

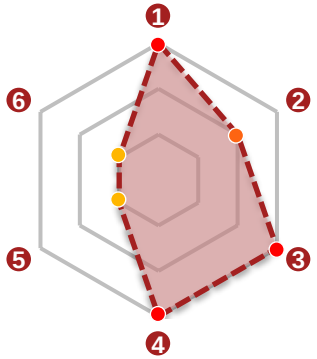
Challenges foreseen per ecosystem

Non-exhaustive

Challenges foreseen

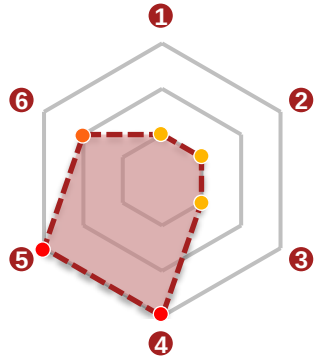
① Technology	Lack of a clear technology development path; it is unclear which technology can mature and become dominant in the market
② Costs	Ecosystems is insufficiently cost competitive compared to alternatives in the market
③ Legislation	Legislative environment is not conducive enough to stimulate faster uptake in the market
④ Competition	Strong competition from experienced and potent companies/ countries within the market
⑤ Commitment	Ecosystem focus is on current lucrative solutions, less effort on investing in growth of battery market
⑥ Capabilities	Lack of R&D focus, skilled workforce and technical knowhow to realize ecosystem growth

Ecosystem mapping



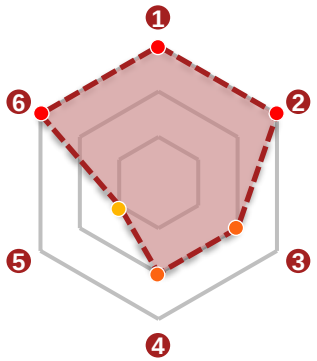
I – Electric heavy duty mobility

- **Technology** – Battery pack energy density needs to improve to facilitate long haul transport
- **Legislation** – Potential to increase incentives for cities and companies to become net-zero
- **Competition** – Germany, United States and South East Asia are well-positioned due to existing large manufacturers



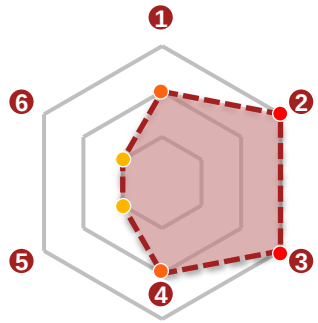
II – Equipment manufacturing

- **Competition** – Established manufacturers already exist supplying to current battery companies
- **Commitment** – Battery market is not sufficiently high on the agenda of existing high-tech companies
- **Capabilities** – Resources allocated to battery technology is limited compared to market



III - New battery concepts

- **Technology** – Uncertain which technology will become the main substitute for lithium-ion batteries
- **Costs** – Decreasing lithium-ion battery costs make it difficult for new technologies to compete
- **Capabilities** – Ecosystem of start-ups, scale-ups and research institutes is currently not sufficient to realize strong uptake



IV – Stationary battery storage

- **Cost** – Current high costs of utility scale storage prevent mass deployment to integrate RES
- **Legislation** – Unclarity around the role of stationary battery storage in the energy policy hinders deployment

Legend ● Minor challenge ● Moderate challenge ● Main challenge

! **Based on expert interviews and subjective assessment**

NL should aim to capitalize on its strong competitive positioning and establish a leading position in the heavy duty mobility ecosystem

Ecosystem deep dive – heavy duty mobility

Ecosystem characteristics

I – Heavy duty mobility

	Opportunity	Competitiveness	Economic potential, $M
12	Production of electric heavy duty commercial vehicles	3,2	~1950
13	Production of e-drives	3,0	~1000
	Average score[1] / total potential	**3,1**	**~1,950[2]**

Legend: *Promising opportunities*

Strategic direction

Overall strategic direction

Double down

"Enable Dutch companies to capitalize on strong competitive positioning"

Maturity time frame and development focus

- Focus on short term development (maturity time frame ~0-5 years)
- Target OEM's, suppliers, large companies
- Main challenges are technology, legislation and competition

Possible next steps to undertake

- Consider providing financial support that could enable OEMs and research institutes to improve on technology
- Explore legislation possibilities for stimulating electric vehicle adoption; e.g. zero emission zones in cities
- Review and potentially improve participation of Dutch OEMs in European tenders

Sample of companies/ institutions active **Non-exhaustive**

- VDL Bus and Coach
- DuraPower
- Ebusco
- Daf

1) The average competitiveness score is a weighted average of the benchmarking scores and the estimated economic potential; 2) The sum does not reflect the addition of individual opportunities as double counting has been avoided

NL should aim to increase economic potential in equipment manufacturing by shifting the focus of existing players towards batteries

Ecosystem deep dive – equipment manufacturing

Ecosystem characteristics

II – Equipment manufacturing

	Opportunity	Competitiveness	Economic potential, $M
4	Production equipment for current battery technologies	2,8	~50
5	Production equipment for new battery technologies	3,2	~80
6	Production of battery management system hardware	2,8	~180
7	Manufacturing of testing equipment	2,2	~25
	Average score[1] / total potential	**2,8**	**~340**

Legend: *Promising opportunities*

Strategic direction

Overall strategic direction

Grow

"Explore possibility of increasing economic potential through shifting focus of existing players on batteries"

Maturity time frame and development focus

- Focus on short term development (maturity time frame ~0-5 years)
- Target scale-ups, OEM's, suppliers and large companies
- Main challenges are competition, commitment and capabilities

Possible next steps to undertake

- Advocate building of regional supply chains for the upcoming EU Gigafactories
- Engage current active companies to showcase future battery potential with an aim to incentivize a dedicated focus on battery technology
- Review strength and weaknesses of current ecosystem to identify existing capability gaps and enact policies to fill them

Sample of companies/ institutions active **Non-exhaustive**

ASM	ASM	DEMCON	Demcon
delftIMP	DelftIMP	NTS	NTS
AMADA	Amada Miyachi	NXP	NXP
boschman	Boschman Technology	ELEO	Eleo

1) The average competitiveness score is a weighted average of the benchmarking scores and the estimated economic potential

NL should aim to increase ecosystem readiness in new battery concepts to capture economic potential once commercialization happens

Ecosystem deep dive – new battery concepts

Ecosystem characteristics

III – New battery concepts

	Opportunity	Competitiveness	Economic potential, $M
1	Production of silicon anodes	2,3	~10
2	Patents for new battery concepts	2,5	~40
3	Producing materials for new battery components	2,5	~5
9	Chemical separation techniques for battery recycling	2,5	~20
10	Recycling end-of-life mobility batteries	2,7	~20
11	Production of solid-state batteries	2,5	~260
14	Integrated membrane stacks for redox flow battery	2,5	~5
15	Production of bulk batteries	2,5	~25
	Average score[1] / total potential	**2,5**	**~330[2]**

Legend: *Promising opportunities*

1) The average competitiveness score is a weighted average of the benchmarking scores and the estimated economic potential; 2) The sum does not reflect the addition of individual opportunities as double counting has been avoided

Strategic direction

Overall strategic direction

Incubate

"Increase ecosystem readiness to capture the economic potential once the technologies are commercialized"

Maturity time frame and development focus

- Focus on long term development (maturity time frame ~5-10 years)
- Target academic research, patents, start-ups
- Main challenges are technology, costs and capabilities

Possible next steps to undertake

- Stimulate faster technology development by promoting collaboration within the ecosystem, e.g. intensify information sharing between universities and companies
- Explore possibilities for reducing the financial barriers for developing new battery concepts
- Review strength and weaknesses of current ecosystem to identify existing capability gaps and enact policies to fill them

Sample of companies/ institutions active **Non-exhaustive**

- LeydenJar Technologies
- E-magy
- Magento Special Anodes
- Elestor
- LionVolt
- Delft IMP
- Nouryon
- Brightlands
- Redox Storage Solutions

NL should increase ecosystem readiness in stationary storage to capture the projected economic potential from integrating RES in the energy mix

Ecosystem deep dive – stationary storage systems

Ecosystem characteristics

IV – Stationary storage systems

	Opportunity	Competitiveness	Economic potential, $M
8	Data-driven solutions for battery storage	2,3	~60
16	Integration of stationary storage into the grid	2,5	~150
	Average score[1] / total potential	**2,4**	**~210**

Legend: *Promising opportunities*

Strategic direction

Overall strategic direction

Incubate

"Increase ecosystem readiness to integrate the projected increase in the share of intermittent RES in the energy mix"

Maturity time frame and development focus

- Focus on medium term development (maturity time frame ~0-7.5 years)
- Target start-ups, patents, scale-ups, OEM's, suppliers, large companies
- Main challenges are costs and legislation

Possible next steps to undertake

- Use legislative mechanisms to incentivize project developers to co-locate RES and storage to realize cost synergies
- Consider providing financial support to stimulate deployment till cost parity is achieved
- Highlight the role of stationary storage in managing flexibility in the grid by connecting with TSO's and utility companies

Sample of companies/ institutions active **Non-exhaustive**

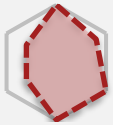
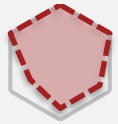
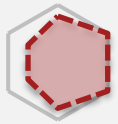
- Alfen
- Dexter
- Scholt Energy
- Gigastorage
- Vanadis Power
- Hanzenet

1) The average competitiveness score is a weighted average of the benchmarking scores and the estimated economic potential

A variety of possible next steps exist that can contribute to overcoming the ecosystem challenges

Summary of strategic direction

Non-exhaustive

Ecosystem	*I - Electric heavy duty mobility*	*II - Equipment manufacturing*	*III - New battery concepts*	*IV - Stationary storage systems*
Overall strategic direction	**"Double down"**	**"Grow"**	**"Incubate"**	**"Incubate"**
Expected time to maturity	Short term: 0-5 years	Short term: 0-5 years	Long term: 5-10 years	Medium term: 0-7.5 years
Target entities	OEM's, suppliers, large companies	Scale-ups, OEM's, suppliers, large companies	Academia, start-ups, research centers	Start-ups, academia, scale-ups, OEM's, suppliers, large companies
Challenges foreseen	 • Technology • Legislation • Competition	 • Competition • Commitment • Capabilities	 • Technology • Costs • Capabilities	 • Costs • Legislation
Possible next steps	• **Consider providing financial support** that could enable OEMs and research institutes to improve on technology • **Explore legislation possibilities for stimulating electric vehicle adoption**; e.g. zero emission zones in cities • **Review and potentially improve participation of Dutch OEMs** in European tenders	• **Advocate building of regional supply chains** for the upcoming European Gigafactories • **Engage active companies to focus on battery technologies** by showcasing future battery potential • **Stimulate research at R&D centers** of corporates through financial support	• **Stimulate faster technology development** by promoting collaboration within the ecosystem, e.g. intensify information sharing between universities and companies • **Explore possibilities for reducing the financial barriers** for developing new battery concepts • **Attract top talent** with strong credentials in battery research	• **Use legislative mechanisms to incentivize project developers** to co-locate RES and storage to realize cost synergies • **Consider providing financial support** to stimulate deployment till cost parity is achieved • **Highlight the role of stationary storage** in managing flexibility in the grid by connecting with TSO's and utility companies

7 Appendices

Abbreviations

Abb.	Definition
BMS	Battery Management System
BNEF	Bloomberg New Energy Finance
CBS	Statistics Netherlands
EBA	European Battery Elliance
EPC	Engineering, Procurement and Construction
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
EZK	Ministry of Economic Affairs and Climate Policy
FTE	Full Time Employee
GDP	Gross Domestic Product
IEA	International Energy Agency
IP	Intellectual Property
IPCEI	Important Projects of Common European Interest
IRENA	International Renewable Energy Agency
Li-ion	Lithium-ion
NiMH	Nickle-Metal Hydride
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer

Abb.	Definition
PV	Photovoltaic
R&D	Research and Development
RES	Renewable Energy Source
RFP	Request for Proposal
RUG	Univeristy of Groningen
Si	Silicon
SSB	Solid State Battery
TRL	Technology Readiness Level
TSO	Transmission System Operator
TU Delft	Delft Univeristy of Technology
UU	Utrecht University
WEF	World Economic Forum
WIPO	World Intellectual Property Organization
avg.	Average
e.g.	exempli gratia (for example)
n.a.	Not applicable
vs.	versus

Abbreviations

Unit	Definition
Bn	Billion
GWh	Gigawatt-hour
h	Hour
k	Thousand
kg	Kilogram
M	Million
min	Minute
Nr	Number
TWh	Terrawatt-hour
W	Watt
Wh	Watt-hour

Countries			
AT	Austria	CN	China
AU	Australia	CY	Cyprus
BE	Belgium	CZ	Czechia
BG	Bulgaria	DE	Germany
CA	Canada	DK	Denmark

Countries (continued)			
EE	Estonia	LT	Lithuania
ES	Spain	LU	Luxembourg
EU27	European Union	LV	Latvia
FI	Finland	MT	Alta
FR	France	NL	The Netherlands
GB	Great Britain	PL	Poland
GR	Greece	RO	Romania
HR	Croatia	RS	Serbia
HU	Hungary	SE	Sweden
IE	Ireland	SI	Slovenia
IN	India	SK	Slovakia
IT	Italy	TR	Turkey
JP	Japan	UA	Ukraine
KR	South Korea	US	United States

Interview list

Location	Organization	Role
Germany	Lithium Technology Corp	Former Chief Technology Officer
The Netherlands	VDL Enabling Technologies Group	Director Business Development
The Netherlands	Rijksuniversiteit Groningen	Chair of Materials Chemistry
Singapore	Malvern Panalytical	Segment Manager Advanced Materials
The Netherlands	NXP Semiconductors	Executive Director
The Netherlands	DNV	Senior Consultant Energy Systems
The Netherlands	Leiden University	Associate professor Institute of Environmental Sciences
The Netherlands	WMC Energy	Head of Battery Materials & Asset Development
The Netherlands	LionVolt	Chief Technology Officer
The Netherlands	Scholt Energy	Business Manager
The Netherlands	TNO	Director of Science Circular Economy & Environment
The Netherlands	Elestor	Chief Executive Officer
The Netherlands	Auto Recycling Nederland	Manager Batteries and Quality Assurance
The Netherlands	TU Eindhoven	Assistant Professor Membrane Materials and Processes
United States	Sila Nanotechnologies Inc. and others	Industry Advisor
United States	Element 3 Battery Venture LLC	Owner & Principal
Germany	P3 Group	Global Advisor, Partner

References (1/2)

Reference	Author	Title	Year	Type source
Adrian König *et al* (2021)	World Electric Vehicle Journal	An Overview of Parameter and Cost for Battery Electric Vehicles	2021	Article
BloombergNEF (2020a)	Bloomberg New Energy Finance	Electric Vehicle Outlook 2020	2020	Document
BloombergNEF(2020b)	Bloomberg New Energy Finance	Battery Pack Prices Cited Below $100/kWh for the First Time in 2030, While Market Average Sits at $137/kWh	2020	Website
CBS (2017)	CBS	High-tech industry exports almost €22 bn in goods	2017	Website
CWTS (2021)	Leiden University	CWTS Leiden Ranking	2021	Dataset
EBA (2020)	European Battery Alliance	Battery industry development: Europe is gaining momentum	2020	Website
EBA (2021)	European Battery Alliance	European Battery Alliance Network	2021	Dataset
Enerdata (2021)	Enerdata	The European Battery Alliance	2021	Website
European Commission (2020a)	Joint Research Center (European Commission)	Batteries - Technology Development Report 2020	2020	Document
European Commission (2020b)	European Commission	Strategic Research Agenda for batteries 2020	2020	Document
European Commission (2021)	European Commission	Study on energy subsidies and other government interventions in the European Union	2021	Document
Fabian Duffner *et al* (2021)	International Journal of Production Economics	Large-scale automotive battery cell manufacturing: Analyzing strategic and operational effects on manufacturing costs	2021	Article
Factiva (2021)	Dow Jones	Digital databse of global news and company data	2021	Dataset
Financial Times (2020)	Financial Times	Electric car costs to remain higher than traditional engines	2020	Website
GlobalData (2021)	GlobalData	Databse GlobalData	2021	Dataset
Guenter Schneider *et al* (2021)	Atlantis Highlights in Engineering	Electricity Storage With a Solid Bed High Temperature Thermal Energy Storage System (HTTES)	2021	Article
IEA (2020)	International Energy Agency	ETP Clean Energy Technology Guide	2020	Document
IEA (2020)	International Energy Agency	Global EV Outlook 2020	2020	Document
IEA (2021)	International Energy Agency	Global EV Data Explorer	2021	Website
IRENA (2020)	International Renewable Energy Agency	Green Hydrogen Cost Reduction – Scaling up electrolysers	2020	Document
Jianmin Ma *et al* (2021)	Journal of Applied Physics	The 2021 battery technology roadmap	2021	Article

References (2/2)

Reference	Author	Title	Year	Type source
LG Chem (2020)	LG Chem	3Q 2020 Business Results & Outlook	2020	Document
NREL (2019)	National Renewable Energy Laboratory	Battery Recycling Supply Chain Analysis	2019	Document
NREL (2021a)	National Renewable Energy Laboratory	Spatial and Temporal Analysis of the Total Costs of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks	2021	Document
NREL (2021b)	National Renewable Energy Laboratory	Cost Projections for Utility-Scale Battery Storage: 2021 Update	2021	Document
Orbis (2021)	Bureau Van Dijk	Company and other entity database	2021	Dataset
Rystad Energy (2021)	Rystad Energy	Batteries – Electrifying everything?	2021	Document
Scimago (2020)	Scimago	Journal and Country Rank	2020	Dataset
SP Global (2021)	SP Global	Top electric vehicle markets dominate lithium-ion battery capacity growth	2021	Website
The Faraday Institution (2020)	The Faraday Institution	Solid-State Batteries: The Technology of the 2030s but the Research Challenge of the 2020s	2020	Website
The Insights Partners (2020)	The Insights Partners	Silicon Anode Battery Market to 2027	2020	Website
The World Bank (2020)	The World Bank	Economic Analysis of Battery Energy Storage Systems	2020	Document
The World Bank (a)	The World Bank	High-technology exports (% of manufactured exports)	2019	Dataset
The World Bank (b)	The World Bank	Research and development expenditure (% of GDP)	2018	Dataset
TNO (2021)	TNO	Electricity as energy carrier	2021	Website
US DOE (2020)	U.S. Department of Energy	Energy Storage Grand Challenge: Energy Storage Market Report	2020	Document
WEF (2019)	World Economic Forum	A Vision for a Sustainable Battery Value Chain in 2030	2019	Document
WIPO (2021)	World Intellectual Property Organization	IP Statistics Data Center Database	2021	Dataset
Yangtao Liu *et al* (2021)	iScience	Current and future lithium-ion battery manufacturing	2021	Article
Yun Zheng *et al* (2020)	The Chemical Reviews	A review of composite solid-state electrolytes for lithium batteries: Fundamentals, key materials and advanced structures	2020	Article

The assumptions used in the steps of the economic potential estimation are based on consolidation of a variety of sources

Source overview of economic potential estimation (1/2)

Calculation step	Substep	References	Type of source
1 Value chain	Battery pack value chain	Rystad Energy (2021)	Document
	Battery pack value chain	NREL (2019)	Document
	Battery pack value chain	WEF (2019)	Document
	Electric heavy duty mobility value chain	Financial Times (2020)	Website
	Stationary storage value chain	The World Bank (2020)	Document
2 Global market size	Battery pack demand	WEF (2019), BloombergNEF (2020a)	Document, Document
	Battery pack price	BloombergNEF(2020b)	Website
	Electric commercial vehicle demand	IEA (2021)	Website
	Electric commercial vehicle price	NREL (2021a)	Document
	Energy storage demand	WEF (2019), BloombergNEF (2020a)	Document, Document
	Energy storage price	NREL (2021b)	Document
	Solid state battery demand	The Faraday Institution (2020), expert input	Website, interview
	Redox flow battery demand	US DOE (2020)	Document
	Silicon anodes demand	The Insights Partners (2020), expert input	Website, interview
	Batteries available for recycling	IEA (2020)	Document

The assumptions used in the steps of the economic potential estimation are based on consolidation of a variety of sources

Source overview of economic potential estimation (2/2)

Calculation step	Substep	References	Type of source
3 Revenue pools	Battery pack value chain revenue pool	NREL (2019), WEF (2019)	Document, Document
	Electric mobility value chain revenue pool	Adrian König *et al* (2021), Financial Times (2020)	Article, Website
	Energy storage value chain revenue pool	The World Bank (2020)	Document
	Materials and machinery revenue pool	Rystad Energy (2021), Fabian Duffner *et al* (2021)	Document, Article
	Polymer component revenue pool	Yun Zheng *et a*l (2020)	Article
	R&D revenue pool	LG Chem (2020), expert input	Document, interview
	Battery management system revenue pool	Guenter Schneider *et al* (2021)	Article
	Test equipment revenue pool	Expert input	Interview
	Membrane stack revenue pool	IRENA (2020), expert input	Document, interview
4 Market shares	EU share of battery pack production market	EBA (2020), SP Global (2021)	Website, Website
	EU share of electric heavy duty mobility market	IEA (2021)	Website
	EU share of stationary storage market	US DOE (2020), GlobalData (2021), Strategy& model	Document, Dataset

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