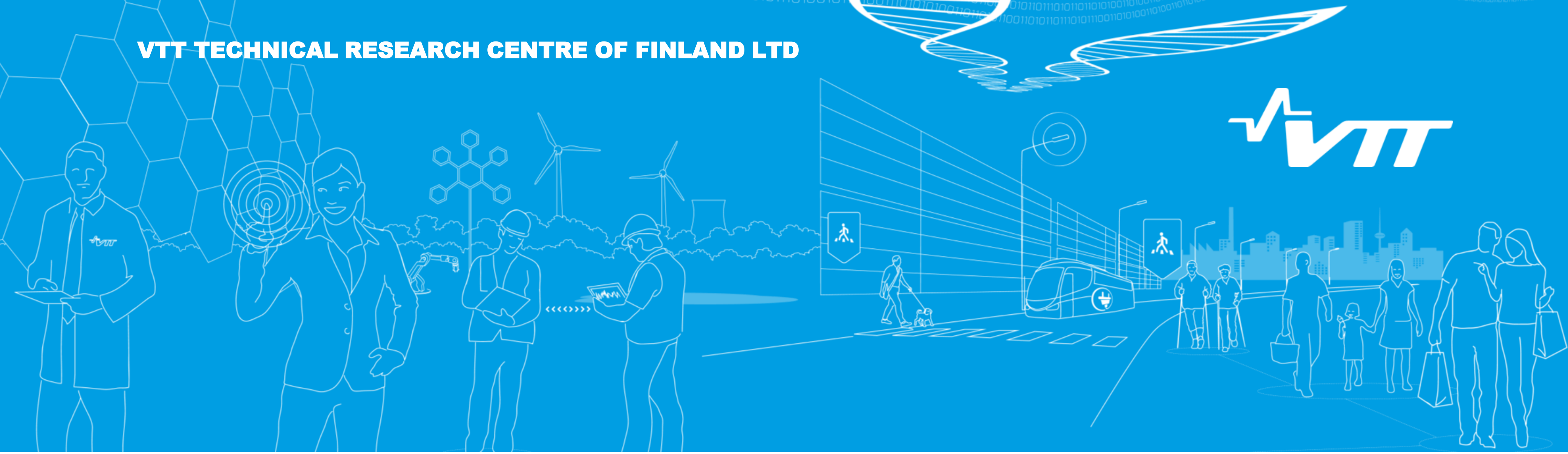


New Energy Ecosystem

Ville Erkkilä

General status of battery storages globally

- 2016:
  - 50 % growth of new storage, mostly batteries
  - Utility-scale energy storage grew to over 500 MW
  - 90 % of installed capacity Li-ion
  - 1 GW of new capacity was announced

- To keep up with the climate targets, 21 GW needed by 2025

- Energy storage Li-ion $20 billion/year market by 2040
  - Small-scale energy storages in homes and offices with PV will account for 57 % of installed capacity by 2040

Battery storage verticals

- Upstream: raw materials
  - Critical materials for Li-ion batteries
    - Cobalt, natural graphite, silicon metal
    - China is dominating global production of natural graphite and silicon metal, increasing control of cobalt production

Battery storage verticals

Raw materials	Main global producers (average 2010-2014)	Main importers to the EU (average 2010-2014)	Sources of EU supply (average 2010-2014)	Import reliance rate	Substitution index	End-of-life recycling input rate
Cobalt	Democratic Republic of Congo (64 %) China (5 %) Canada (5 %)	Russia (91 %) Democratic Republic of Congo (7 %)	Finland (66 %) Russia (31 %)	32 %	1.0/1.0	0 %
Natural graphite	China (69 %) India (12 %) Brazil (8 %)	China (63 %) Brazil (13 %) Norway (7 %)	China (63 %) Brazil (13 %) Norway (7 %) EU (<1 %)	99 %	0.95/0.97	3 %
Silicon metal	China (61 %) Brazil (9 %) Norway (7 %) United States (6 %) France (5 %)	Norway (35 %) Brazil (18 %) China (18 %)	Norway (23 %) France (19 %) Brazil (12 %) China (12 %) Spain (9 %) Germany (5 %)	64 %	0.99/0.99	0 %

Battery storage verticals

- Upstream: raw materials
  - Cobalt: market forecast until 2020 indicates a small surplus
  - Natural graphite: large surplus in 2020 (over 10%)
  - Silicon metal: market balance in 2020

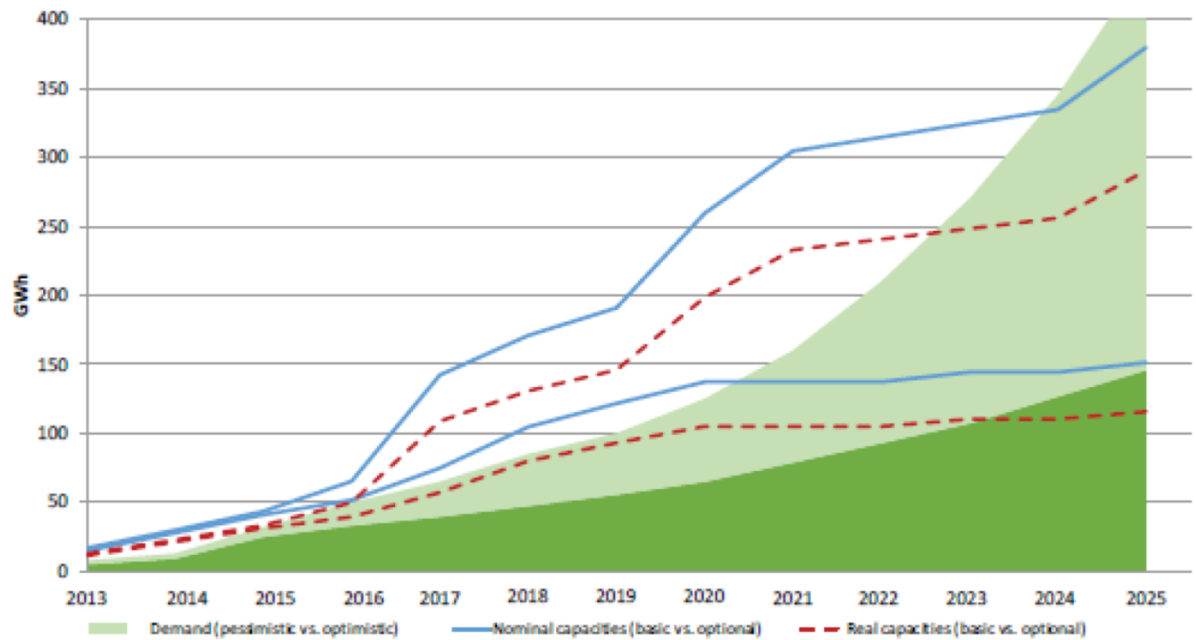
  - Lithium: 75 000 tonnes 2016; 600 000 tonnes 2025

Battery storage verticals

- Midstream: components
  - 2015: most of Li-ion materials manufactured in Asia
    - 85 % of cathode materials
    - 97 % of anode materials
    - 84 % separators
    - 64 % electrolytes

Battery storage verticals

- Midstream: components
  - 2016: 80 GWh of Li-ion cells manufactured
    - 88 % of the manufacturing in China, Japan, and Korea
  - Production capacity growth:
    - 2015: 70 GWh
    - 2016: 150 GWh
    - 2020: 260 GWh
    - 2025: 550 GWh
  - Global demand is expected to exceed capacity in 2022-2023

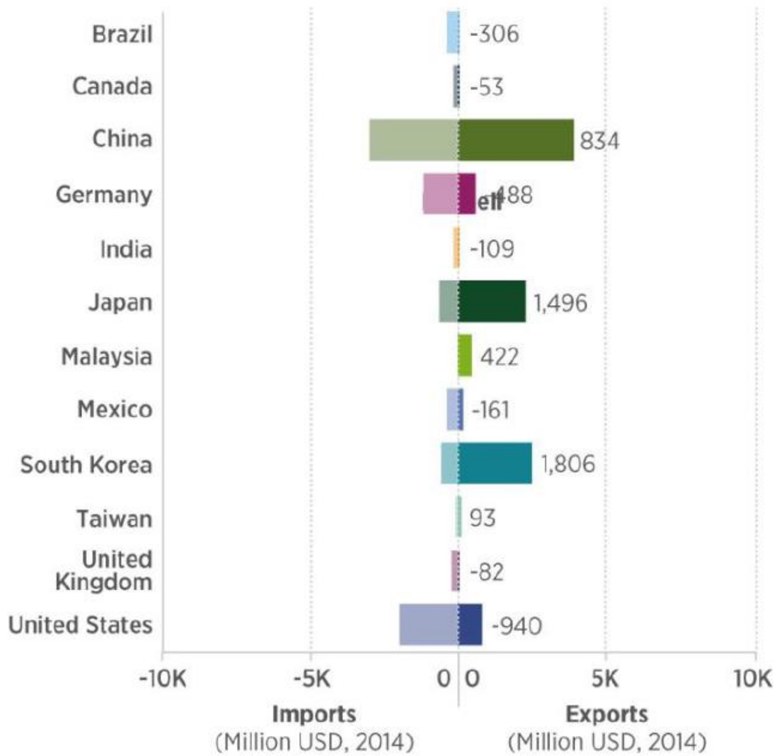


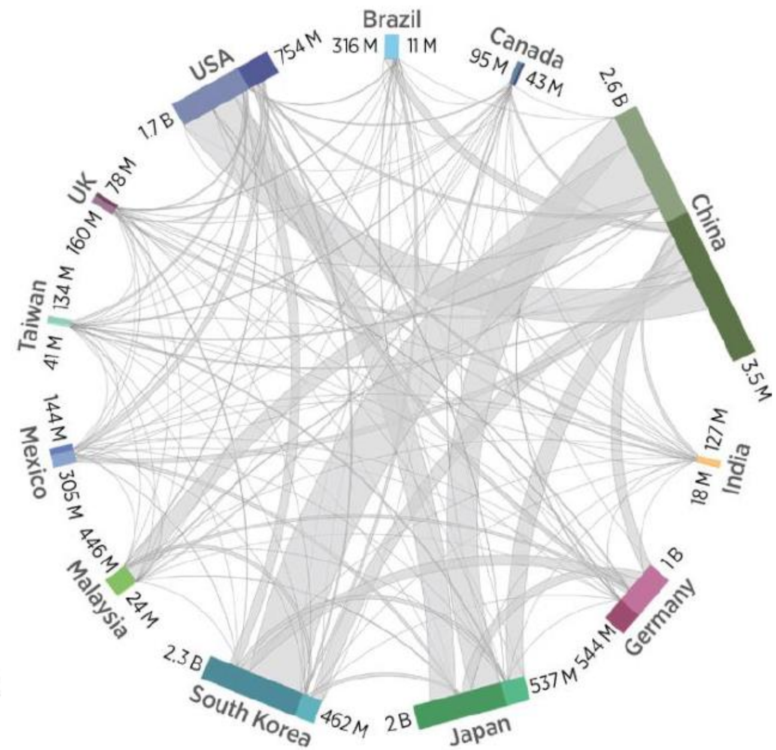
Battery storage verticals

- Midstream: components
  - 26 planned gigafactories totalling 344.5 GWh
    - China 49 %, 169 GWh
    - EU 23 %, 78.5 GWh
    - US 15 %, 53 GWh
    - Thailand, 50 GWh by 2020
    - Australia, 16 GWh
    - India, no specifications

Battery storage verticals

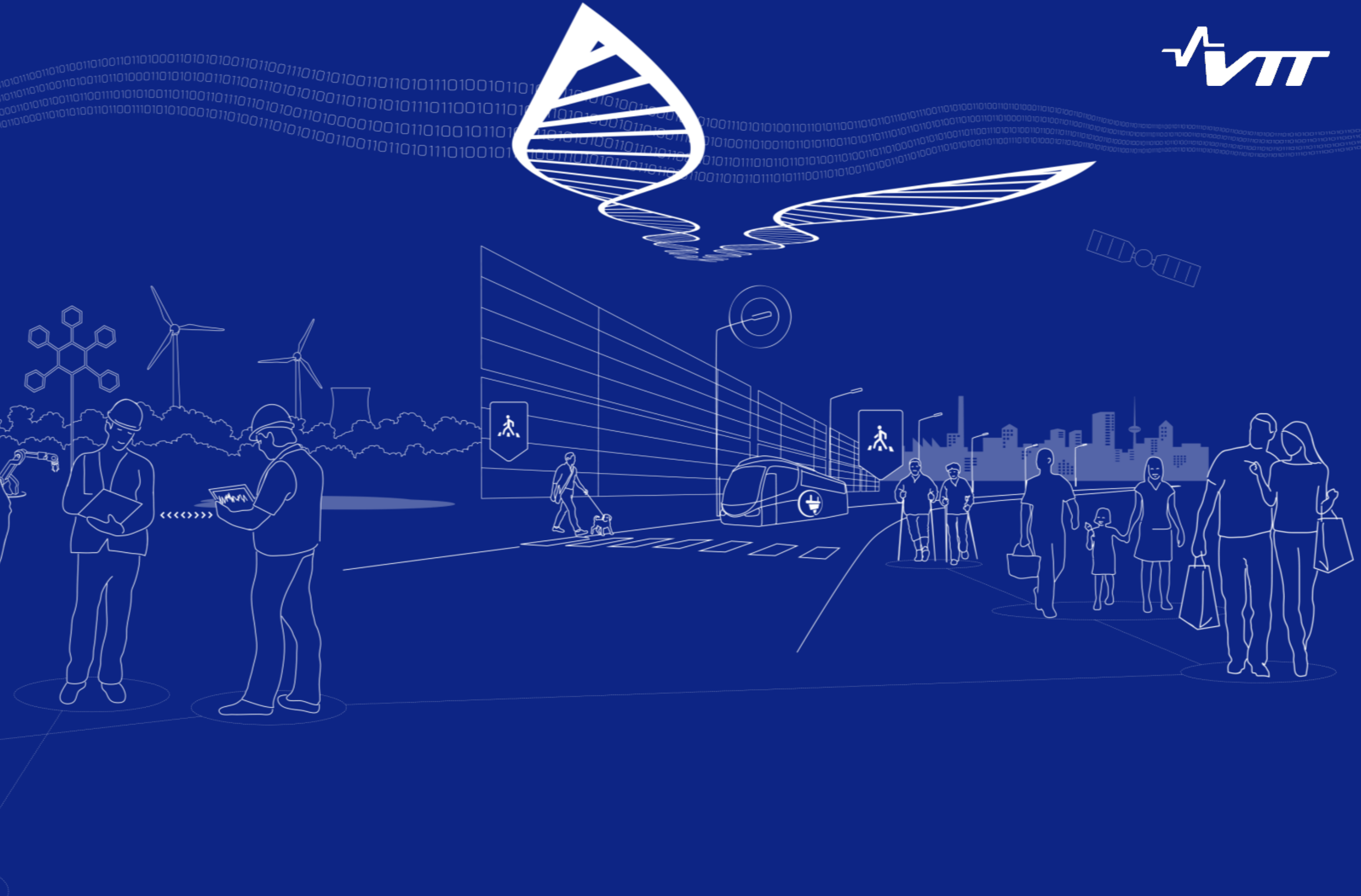
- Midstream: components

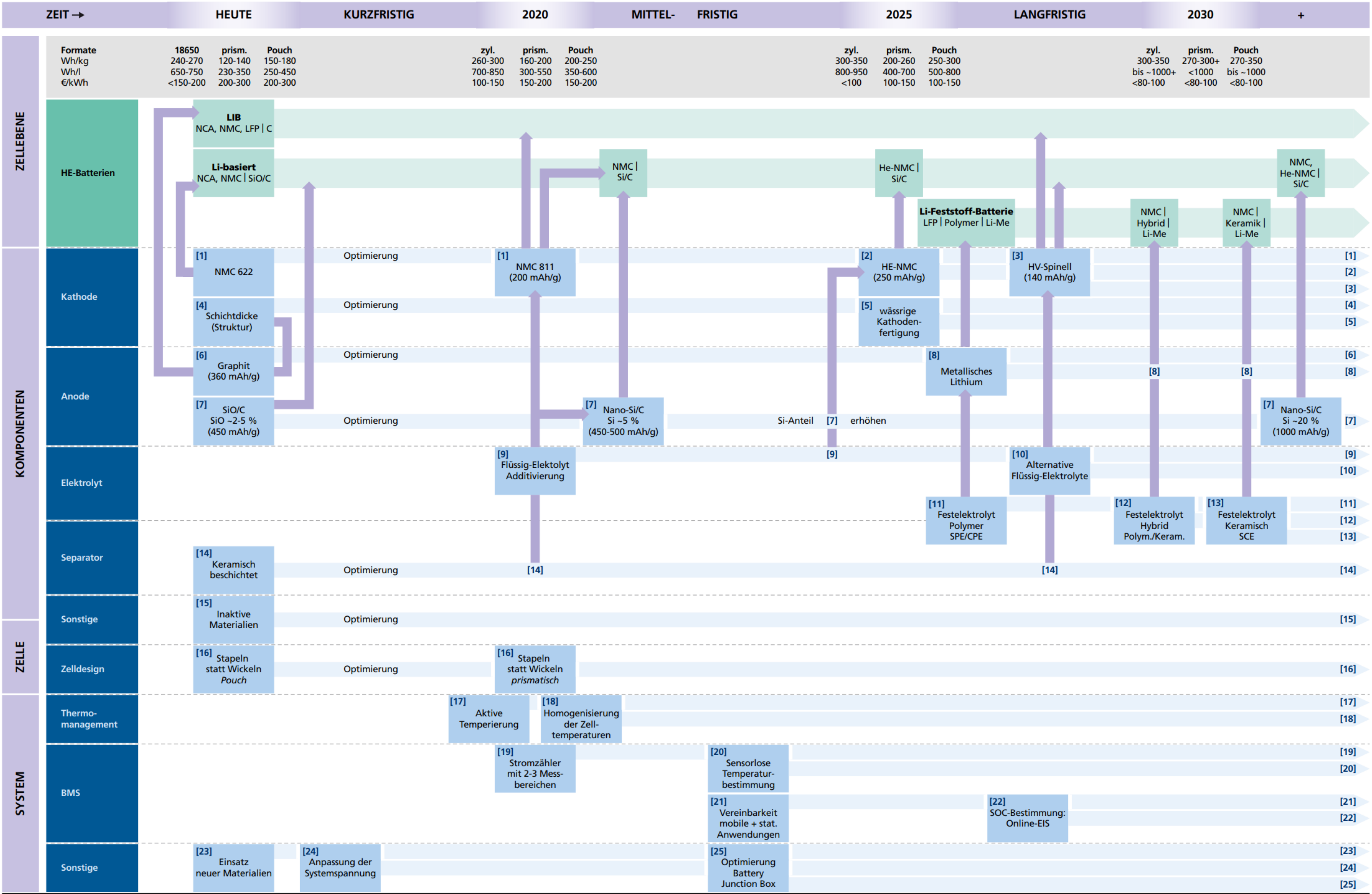




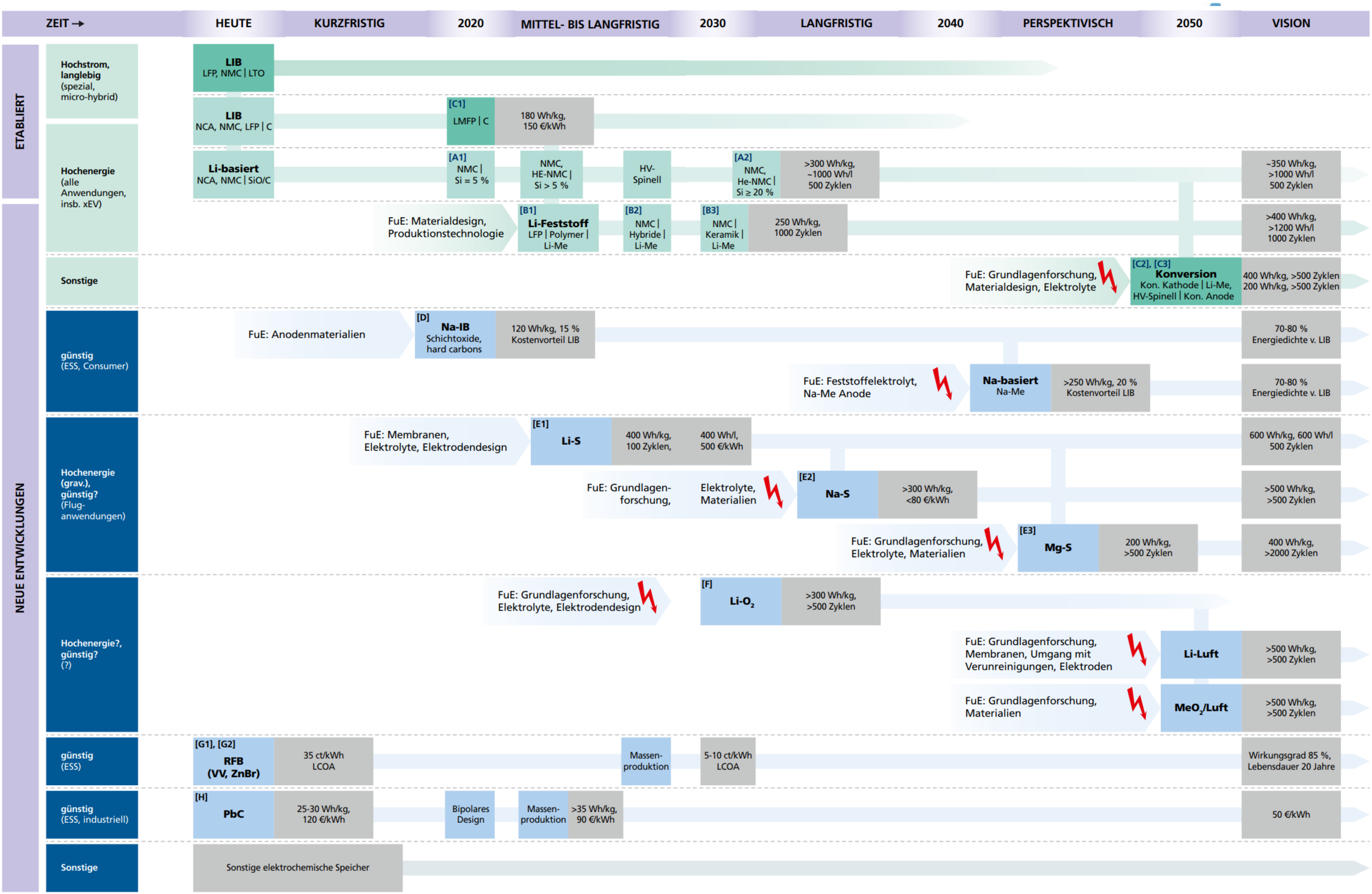
Battery storage verticals

- Midstream: components
  - Ongoing and announced production plans:
    - LG Chem, 2 GWh by 2018
    - Samsung SDI, 2.5 GWh by 2018
    - Northvolt, 32 GWh by 2024
    - TerraE, 34 GWh by 2028
    - SERI, 200 MWh by 2018
    - SK Innovation
    - Tesla
    - Monbat

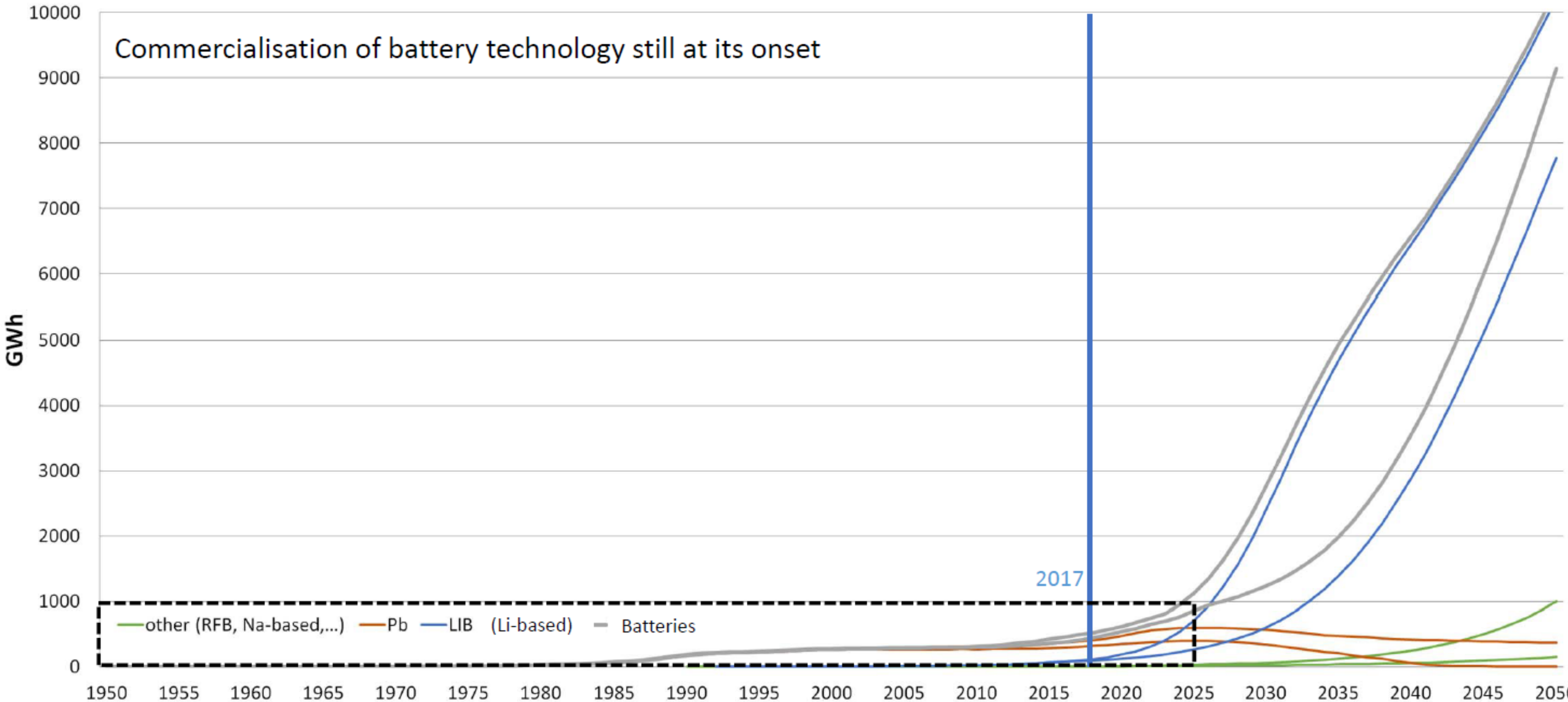




ZEIT →
HEUTE
KURZFRISTIG
2020
MITTEL-
FRISTIG
2025
LANGFRISTIG
2030
+
ZELLEBENE
KOMPONENTEN
ZELLE
SYSTEM
Formate
Wh/kg
Wh/l
€/kWh
18650
240-270
650-750
<150-200
prism.
120-140
230-350
200-300
Pouch
150-180
250-450
200-300
zyl.
260-300
700-850
100-150
prism.
160-200
300-550
150-200
Pouch
200-250
350-600
150-200
zyl.
300-350
800-950
<100
prism.
200-260
400-700
100-150
Pouch
250-300
500-800
100-150
zyl.
300-350
bis ~1000+
<80-100
prism.
270-300+
<1000
<80-100
Pouch
270-350
bis ~1000
<80-100
HE-Batterien
LIB
NCA, NMC, LFP | C
Li-basiert
NCA, NMC | SiO/C
NMC | Si/C
He-NMC | Si/C
Li-Feststoff-Batterie
LFP | Polymer | Li-Me
NMC | Hybrid | Li-Me
NMC | Keramik | Li-Me
NMC, He-NMC | Si/C
Kathode
[1] NMC 622
Optimierung
[1] NMC 811 (200 mAh/g)
[2] HE-NMC (250 mAh/g)
[3] HV-Spinell (140 mAh/g)
[4] Schichtdicke (Struktur)
Optimierung
[5] wässrige Kathoden-fertigung
Anode
[6] Graphit (360 mAh/g)
Optimierung
[8] Metallisches Lithium
[7] SiO/C SiO ~2-5 % (450 mAh/g)
Optimierung
[7] Nano-Si/C Si ~5 % (450-500 mAh/g)
Si-Anteil [7] erhöhen
[7] Nano-Si/C Si ~20 % (1000 mAh/g)
Elektrolyt
[9] Flüssig-Elektolyt Additivierung
[9]
[10] Alternative Flüssig-Elektrolyte
[11] Festelektrolyt Polymer SPE/CPE
[12] Festelektrolyt Hybrid Polym./Keram.
[13] Festelektrolyt Keramisch SCE
Separator
[14] Keramisch beschichtet
Optimierung
[14]
[14]
Sonstige
[15] Inaktive Materialien
Optimierung
Zelldesign
[16] Stapeln statt Wickeln *Pouch*
Optimierung
[16] Stapeln statt Wickeln *prismatisch*
Thermo-management
[17] Aktive Temperierung
[18] Homogenisierung der Zell-temperaturen
BMS
[19] Stromzähler mit 2-3 Mess-bereichen
[20] Sensorlose Temperatur-bestimmung
[21] Vereinbarkeit mobile + stat. Anwendungen
[22] SOC-Bestimmung: Online-EIS
Sonstige
[23] Einsatz neuer Materialien
[24] Anpassung der Systemspannung
[25] Optimierung Battery Junction Box
[1] [2] [3] [4] [5] [6] [8] [7] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25]


ZEIT →
HEUTE
KURZFRISTIG
2020
MITTEL- BIS LANGFRISTIG
2030
LANGFRISTIG
2040
PERSPEKTIVISCH
2050
VISION
ETABLIERT
NEUE ENTWICKLUNGEN
Hochstrom, langlebig (spezial, micro-hybrid)
Hochenergie (alle Anwendungen, insb. xEV)
Sonstige
günstig (ESS, Consumer)
Hochenergie (grav.), günstig? (Flug-anwendungen)
Hochenergie?, günstig? (?)
günstig (ESS)
günstig (ESS, industriell)
Sonstige
LIB LFP, NMC | LTO
LIB NCA, NMC, LFP | C
[C1] LMFP | C
180 Wh/kg, 150 €/kWh
Li-basiert NCA, NMC | SiO/C
[A1] NMC | Si = 5 %
NMC, HE-NMC | Si > 5 %
HV-Spinell
[A2] NMC, He-NMC | Si ≥ 20 %
>300 Wh/kg, ~1000 Wh/l 500 Zyklen
~350 Wh/kg, >1000 Wh/l 500 Zyklen
FuE: Materialdesign, Produktionstechnologie
[B1] Li-Feststoff LFP | Polymer | Li-Me
[B2] NMC | Hybride | Li-Me
[B3] NMC | Keramik | Li-Me
250 Wh/kg, 1000 Zyklen
>400 Wh/kg, >1200 Wh/l 1000 Zyklen
FuE: Grundlagenforschung, Materialdesign, Elektrolyte
[C2], [C3] Konversion Kon. Kathode | Li-Me, HV-Spinell | Kon. Anode
400 Wh/kg, >500 Zyklen 200 Wh/kg, >500 Zyklen
FuE: Anodenmaterialien
[D] Na-IB Schichtoxide, hard carbons
120 Wh/kg, 15 % Kostenvorteil LIB
70-80 % Energiedichte v. LIB
FuE: Feststoffelektrolyt, Na-Me Anode
Na-basiert Na-Me
>250 Wh/kg, 20 % Kostenvorteil LIB
70-80 % Energiedichte v. LIB
FuE: Membranen, Elektrolyte, Elektrodendesign
[E1] Li-S
400 Wh/kg, 100 Zyklen,
400 Wh/l, 500 €/kWh
600 Wh/kg, 600 Wh/l 500 Zyklen
FuE: Grundlagen-forschung, Elektrolyte, Materialien
[E2] Na-S
>300 Wh/kg, <80 €/kWh
>500 Wh/kg, >500 Zyklen
FuE: Grundlagenforschung, Elektrolyte, Materialien
[E3] Mg-S
200 Wh/kg, >500 Zyklen
400 Wh/kg, >2000 Zyklen
FuE: Grundlagenforschung, Elektrolyte, Elektrodendesign
[F] Li-O$_2$
>300 Wh/kg, >500 Zyklen
FuE: Grundlagenforschung, Membranen, Umgang mit Verunreinigungen, Elektroden
Li-Luft
>500 Wh/kg, >500 Zyklen
FuE: Grundlagenforschung, Materialien
MeO$_x$/Luft
>500 Wh/kg, >500 Zyklen
[G1], [G2] RFB (VV, ZnBr)
35 ct/kWh LCOA
Massen-produktion
5-10 ct/kWh LCOA
Wirkungsgrad 85 %, Lebensdauer 20 Jahre
[H] PbC
25-30 Wh/kg, 120 €/kWh
Bipolares Design
Massen-produktion
>35 Wh/kg, 90 €/kWh
50 €/kWh
Sonstige elektrochemische Speicher

Historical development of the global battery demand and future scenarios (1950-2050)



Source: Thielmann et al. 2017: Energy Storage Roadmap (update 2017) - Highenergy batteries 2030+ and prospects for future battery technologies, Fraunhofer ISI 2017.

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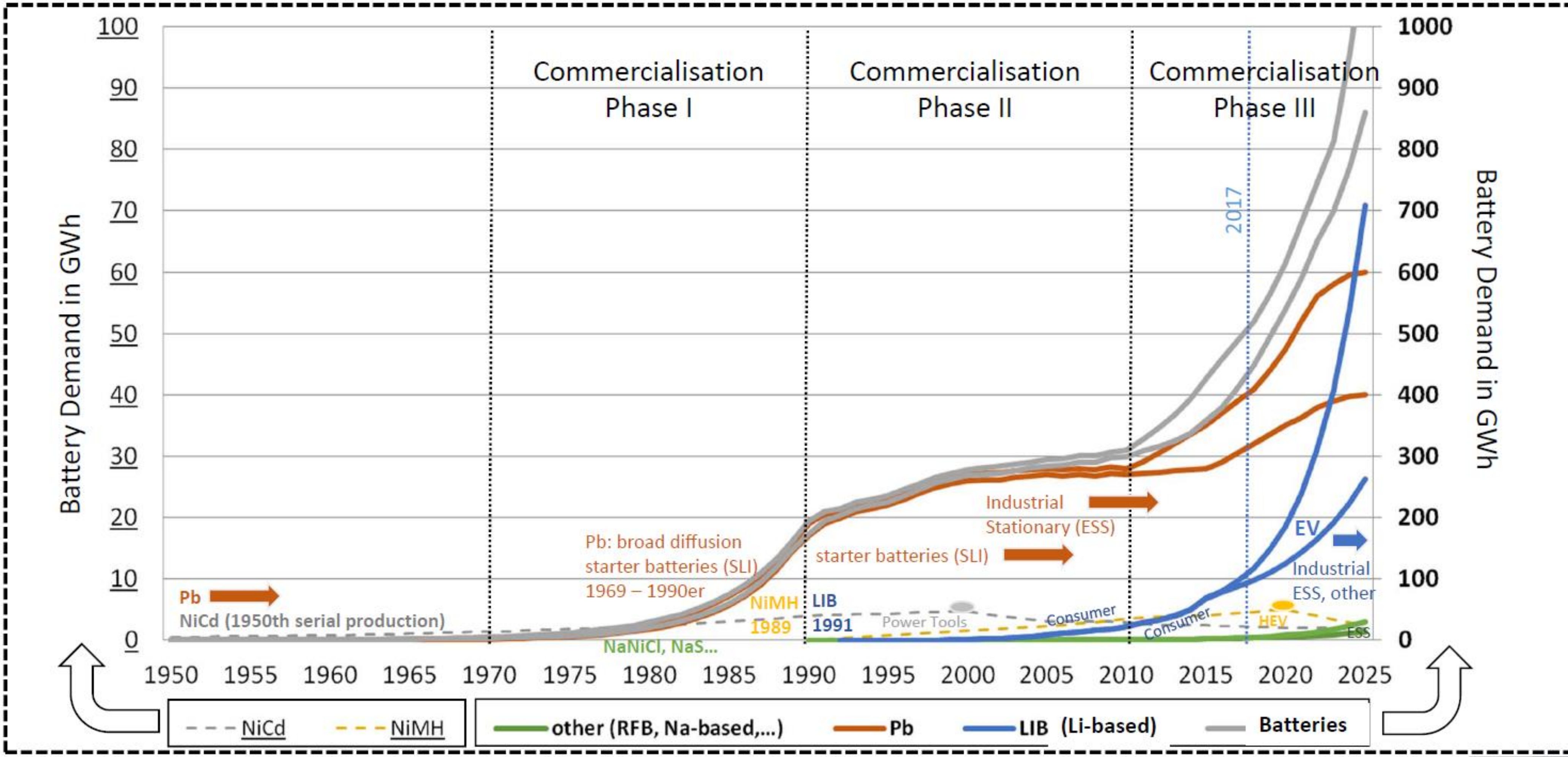
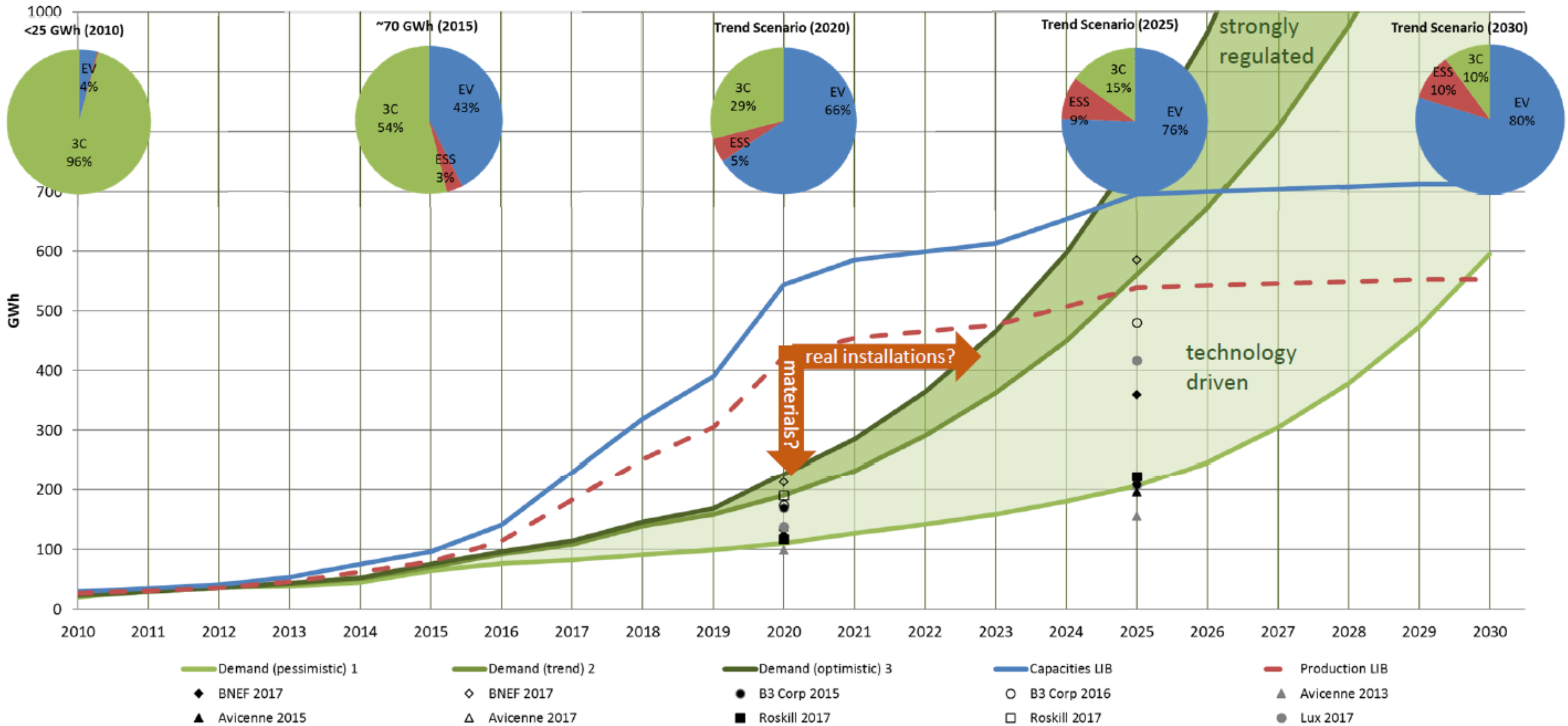
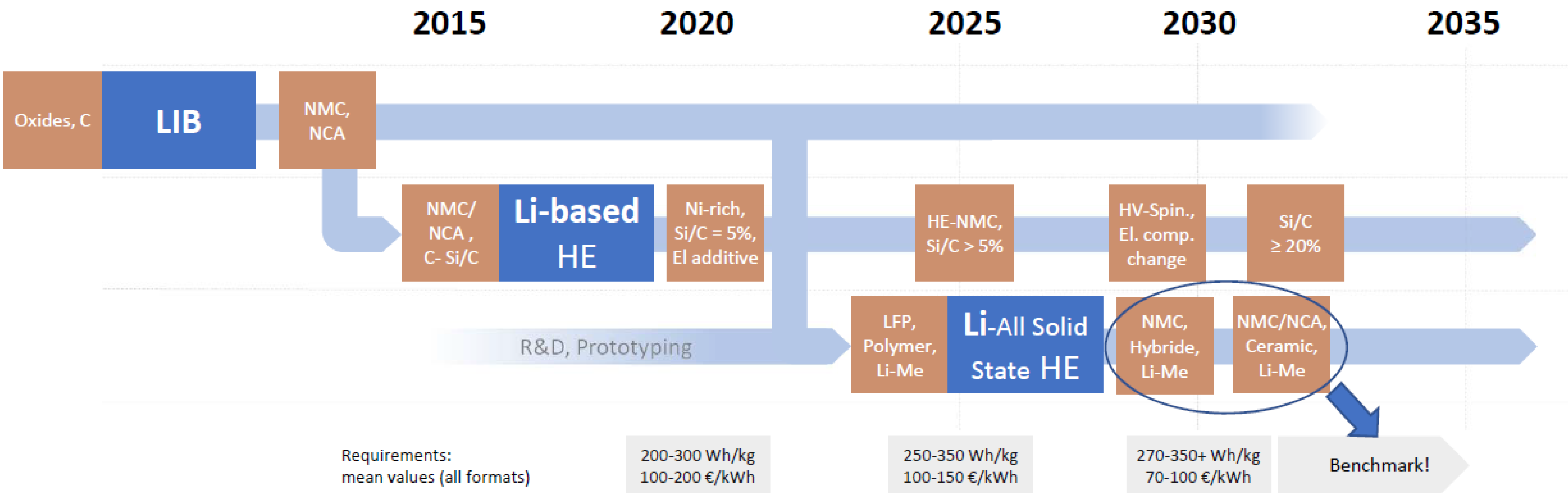


Global demand vs. production capacities for LIB cells 2010-2030

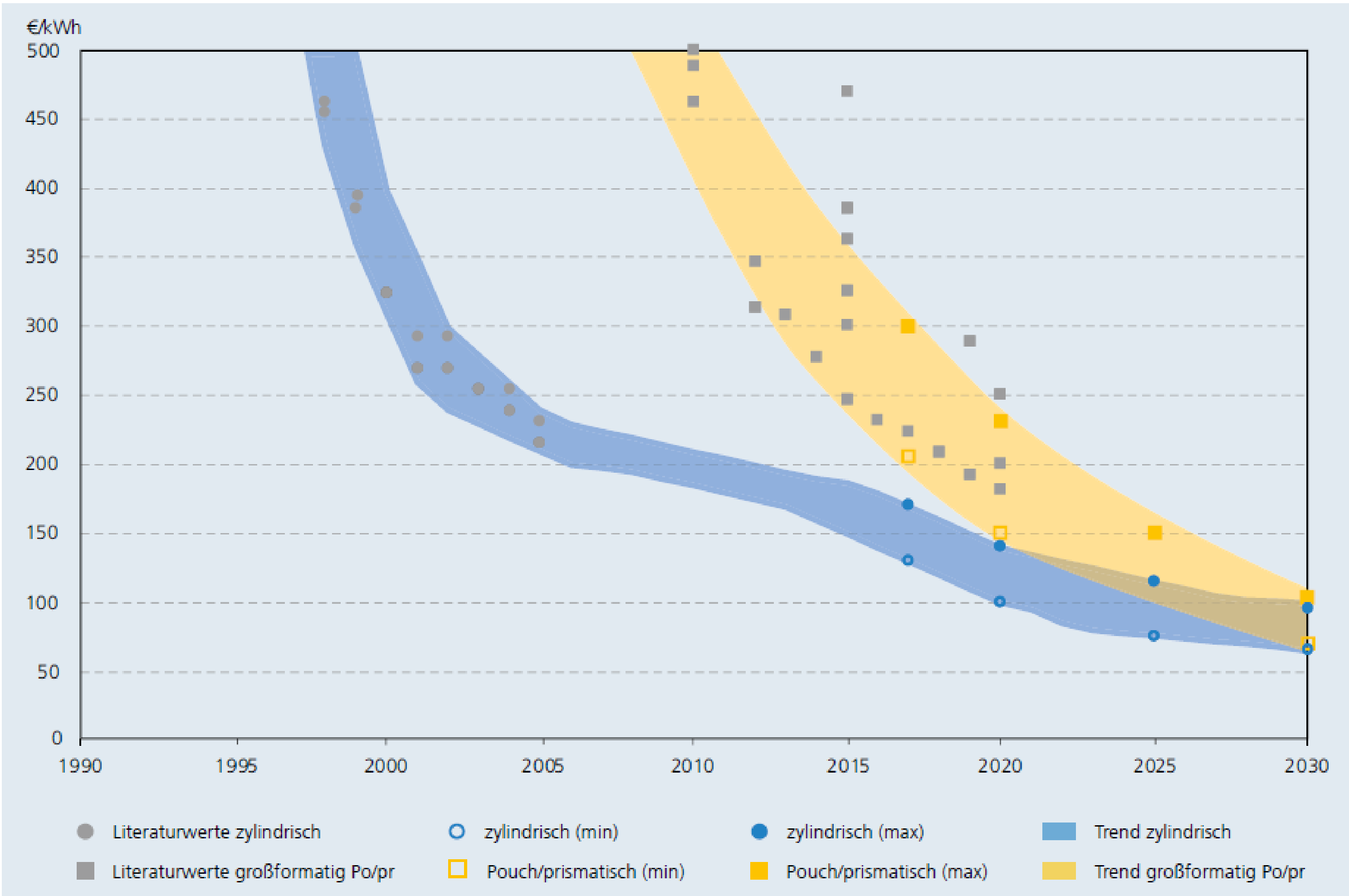


Source: Thielmann et al. 2017: Energy Storage Roadmap (update 2017) - Highenergy batteries 2030+ and prospects for future battery technologies, Fraunhofer ISI 2017.

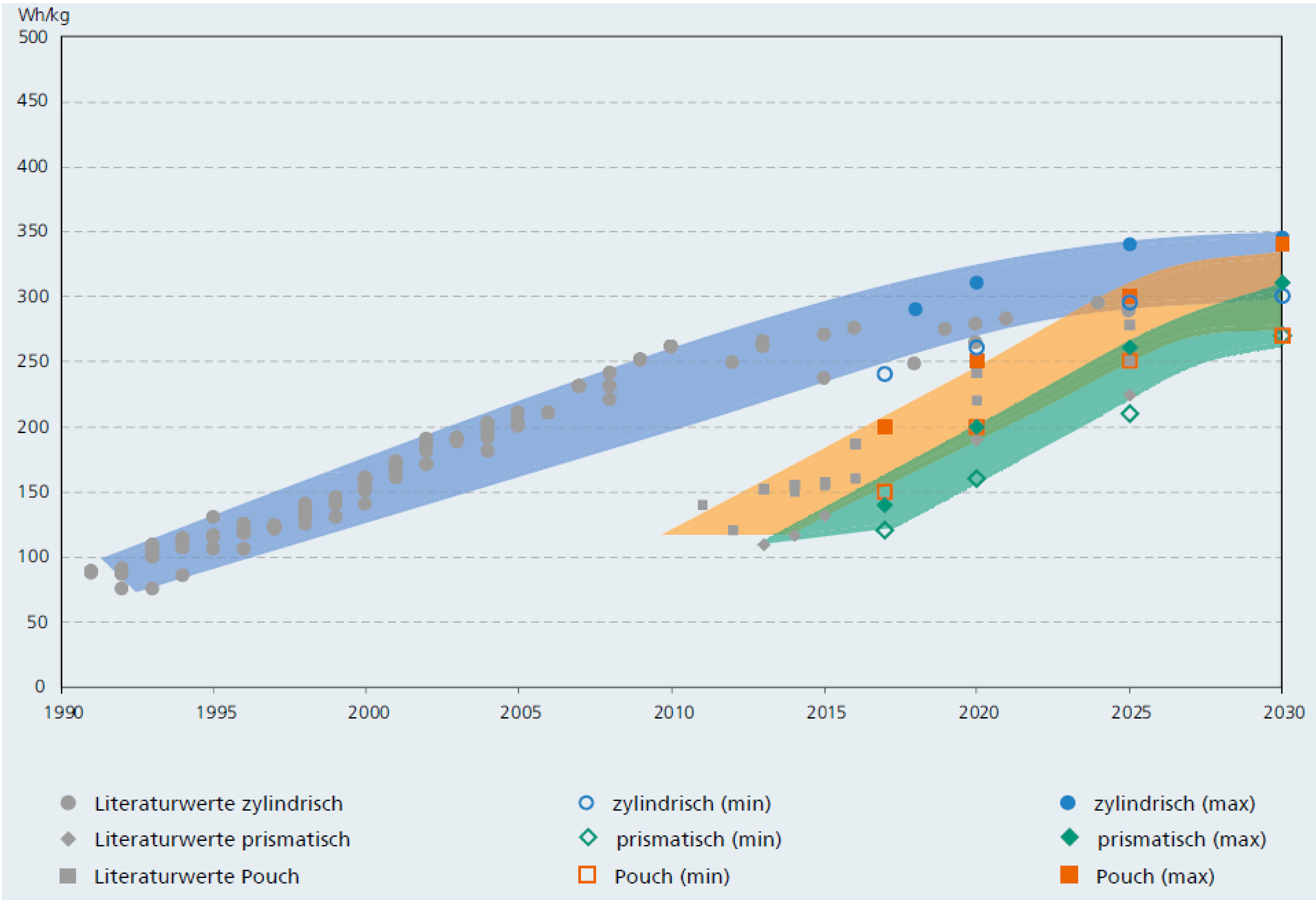
Li-based high-energy automotive battery roadmap towards HE-NMC based LIB



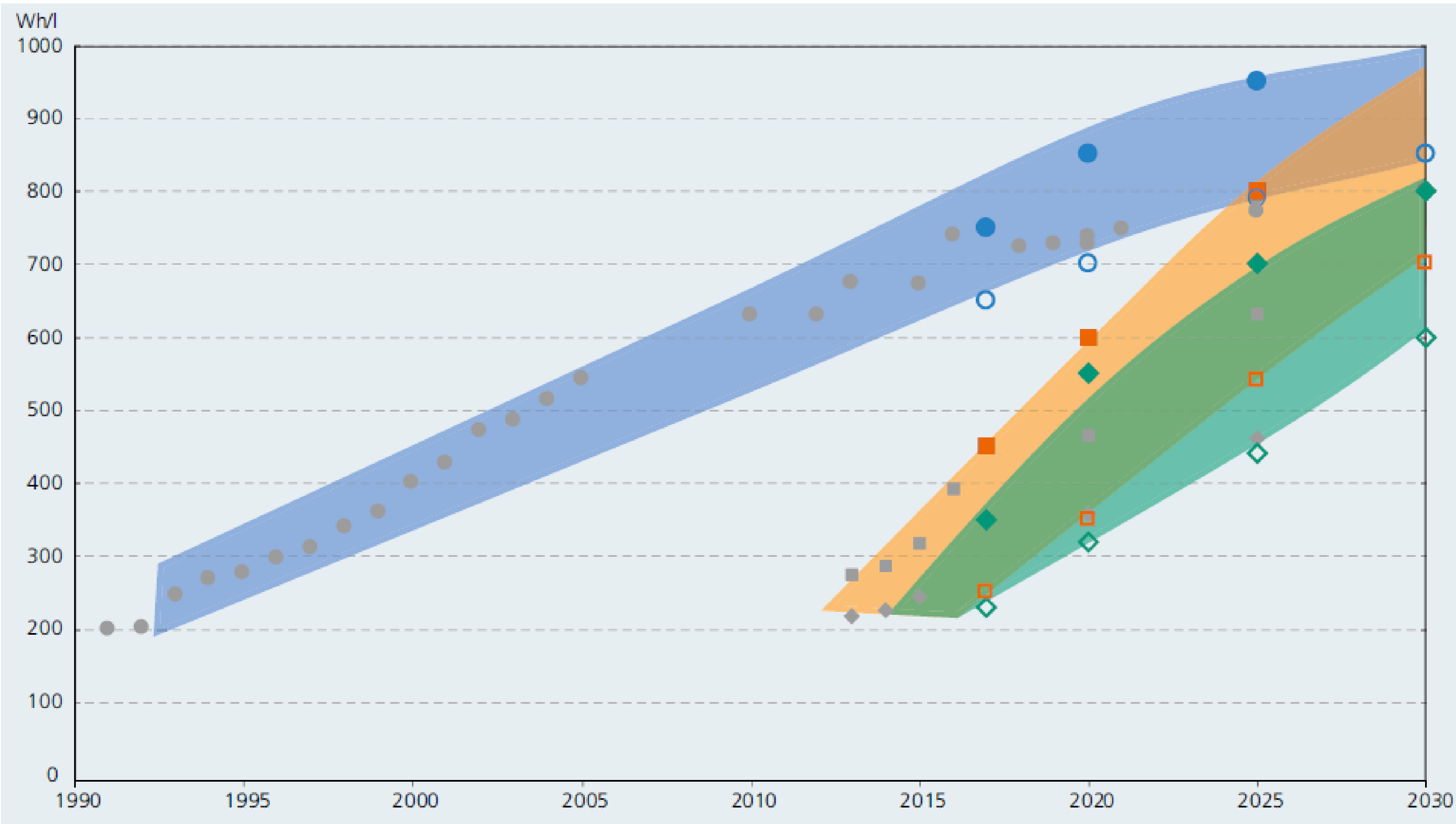
Development of LIB cells costs by cell format



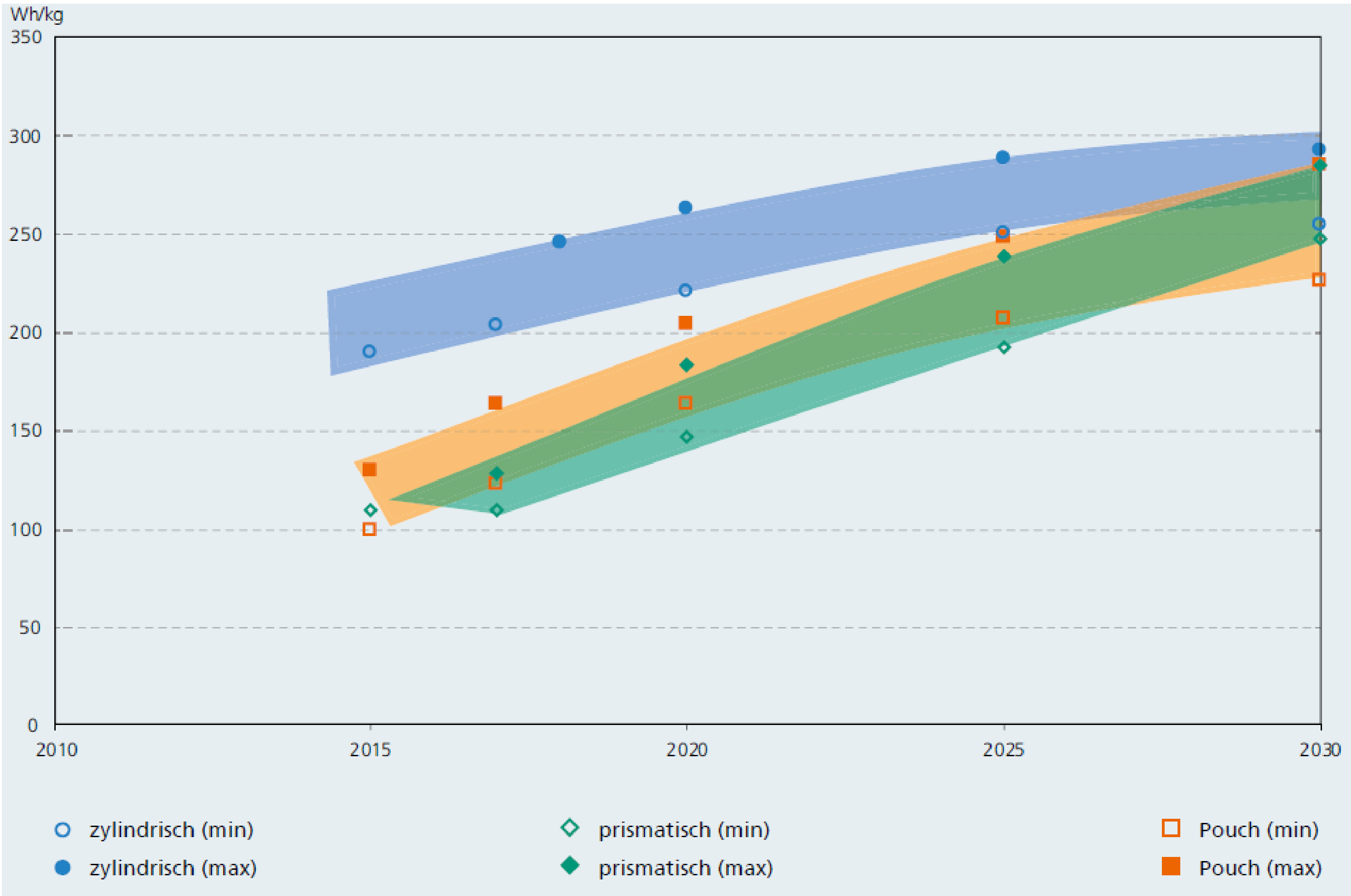
Development of gravimetric energy density for LIB cells by cell format



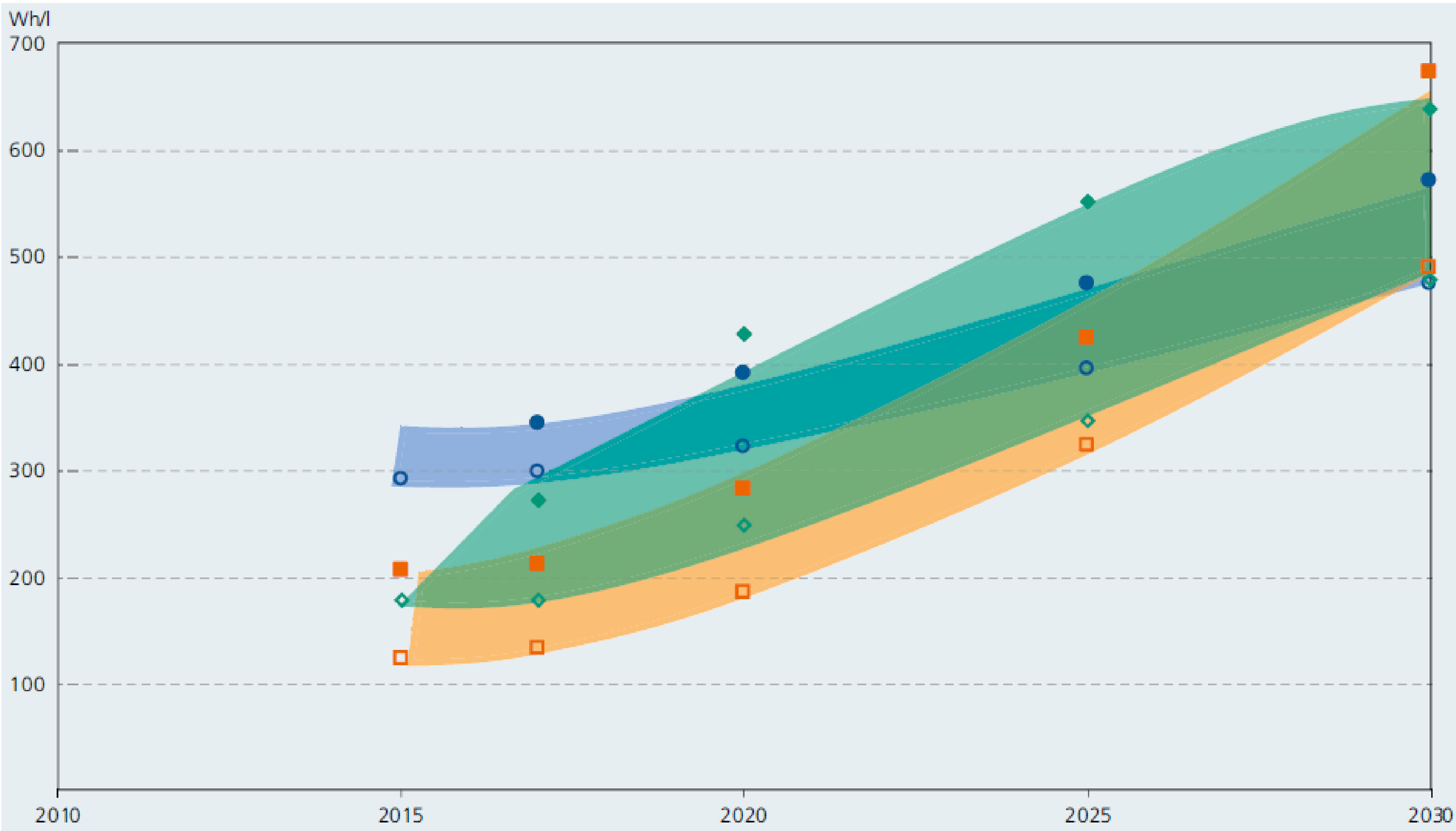
Development of volumetric energy density for LIB cells by cell format



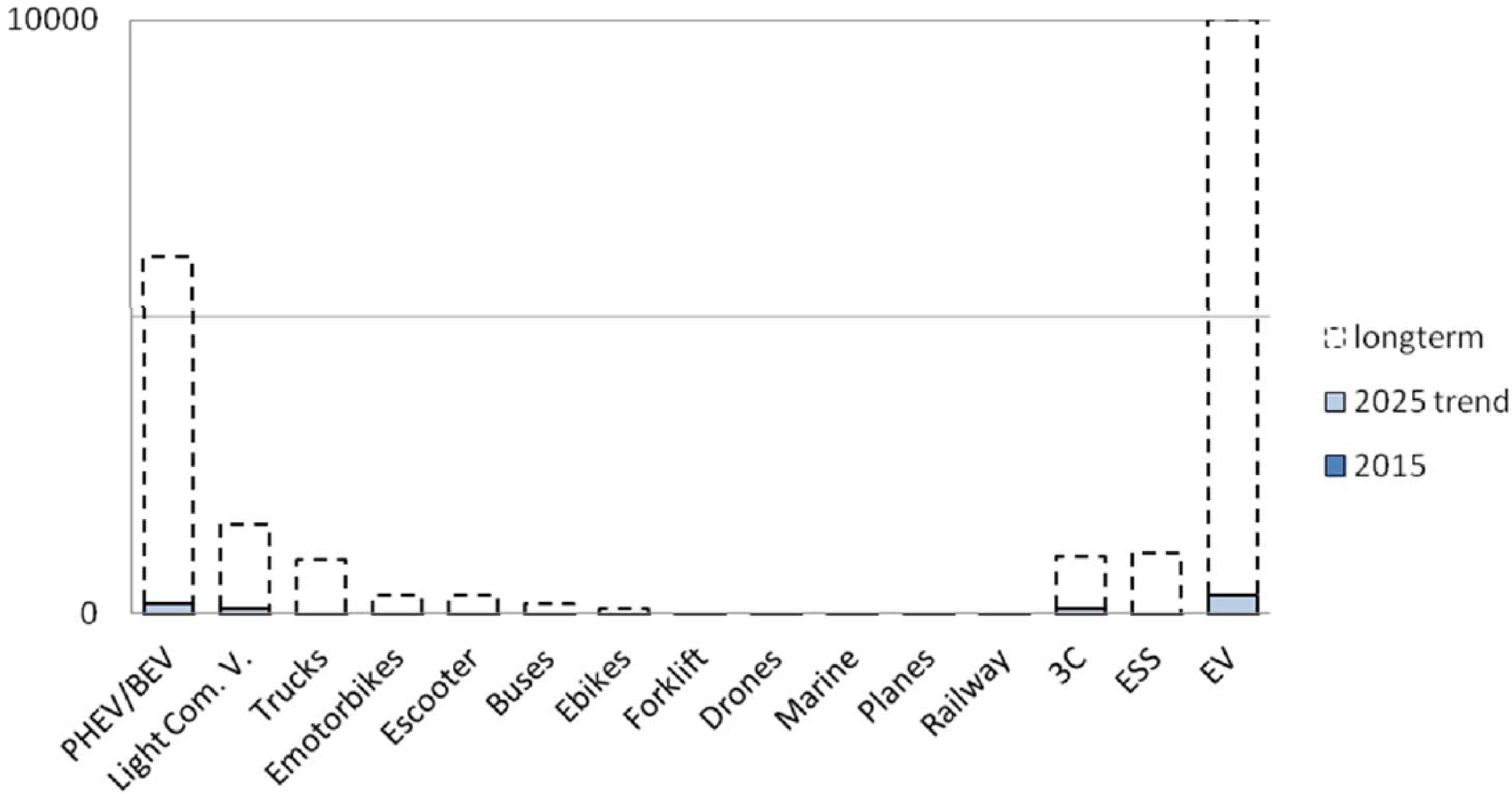
Development of gravimetric energy density for LIB modules by cell format



Development of volumetric energy density for LIB modules by cell format



Global LIB demand and future potential demand by applications and segments (GWh)



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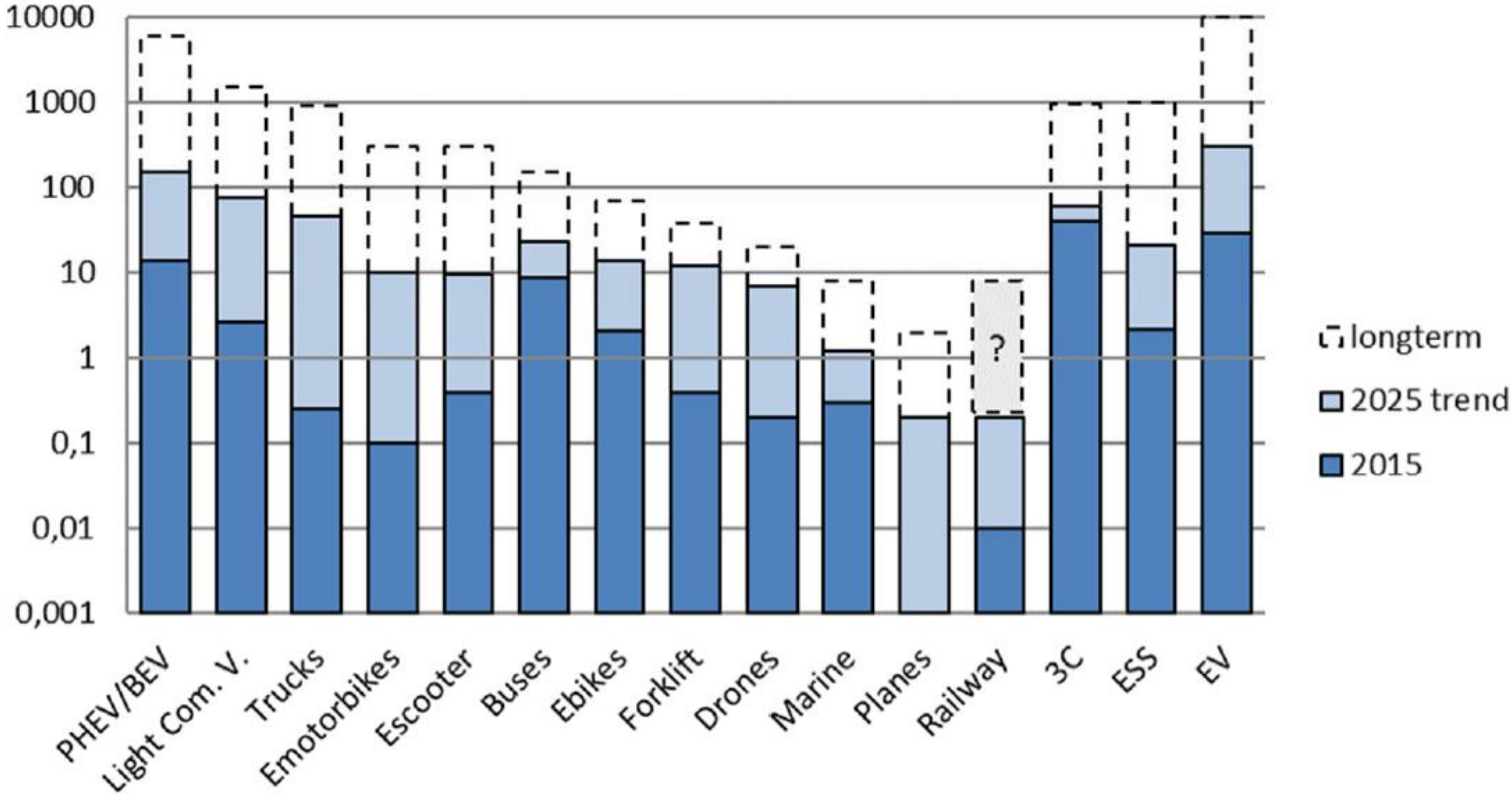
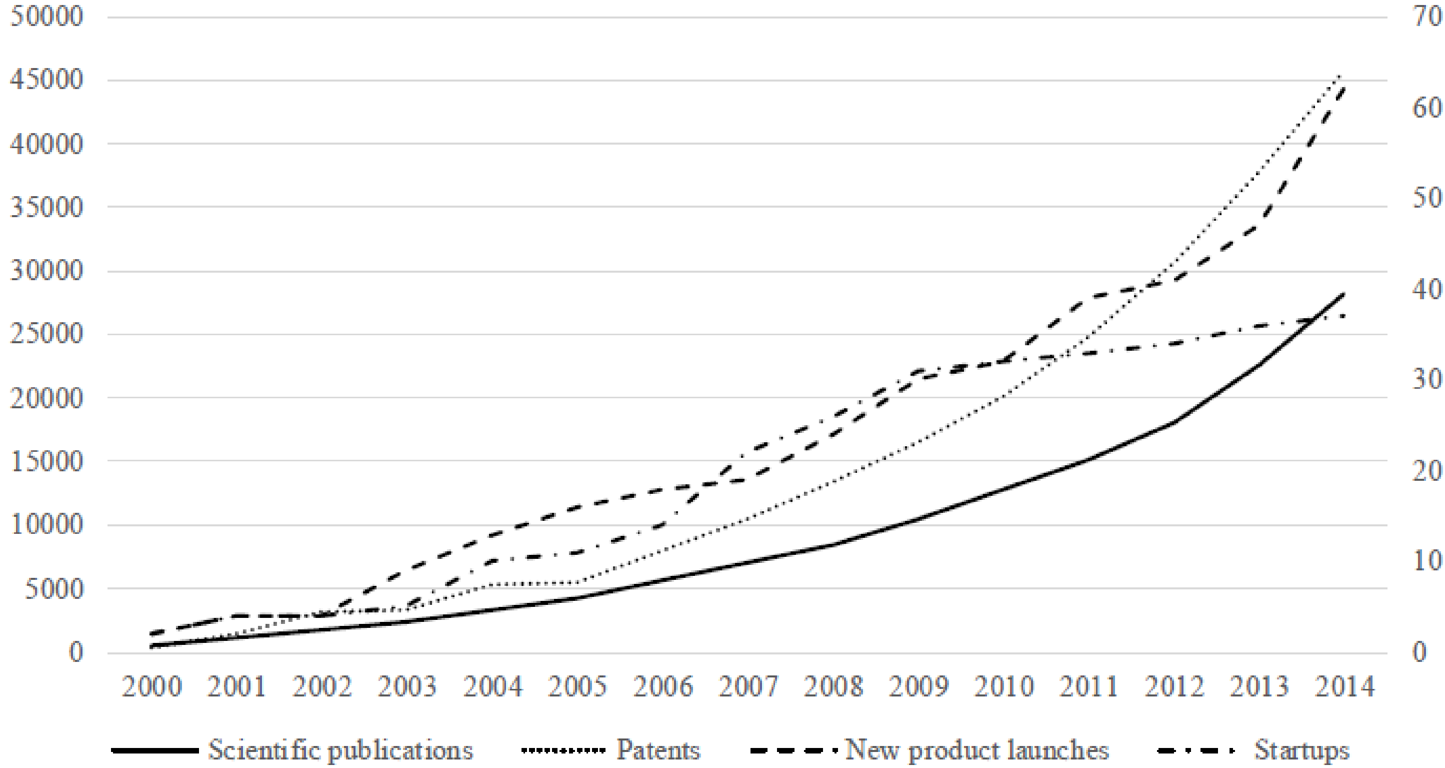


Li-ion battery technology R&D landscape



- More patents than scientific publications

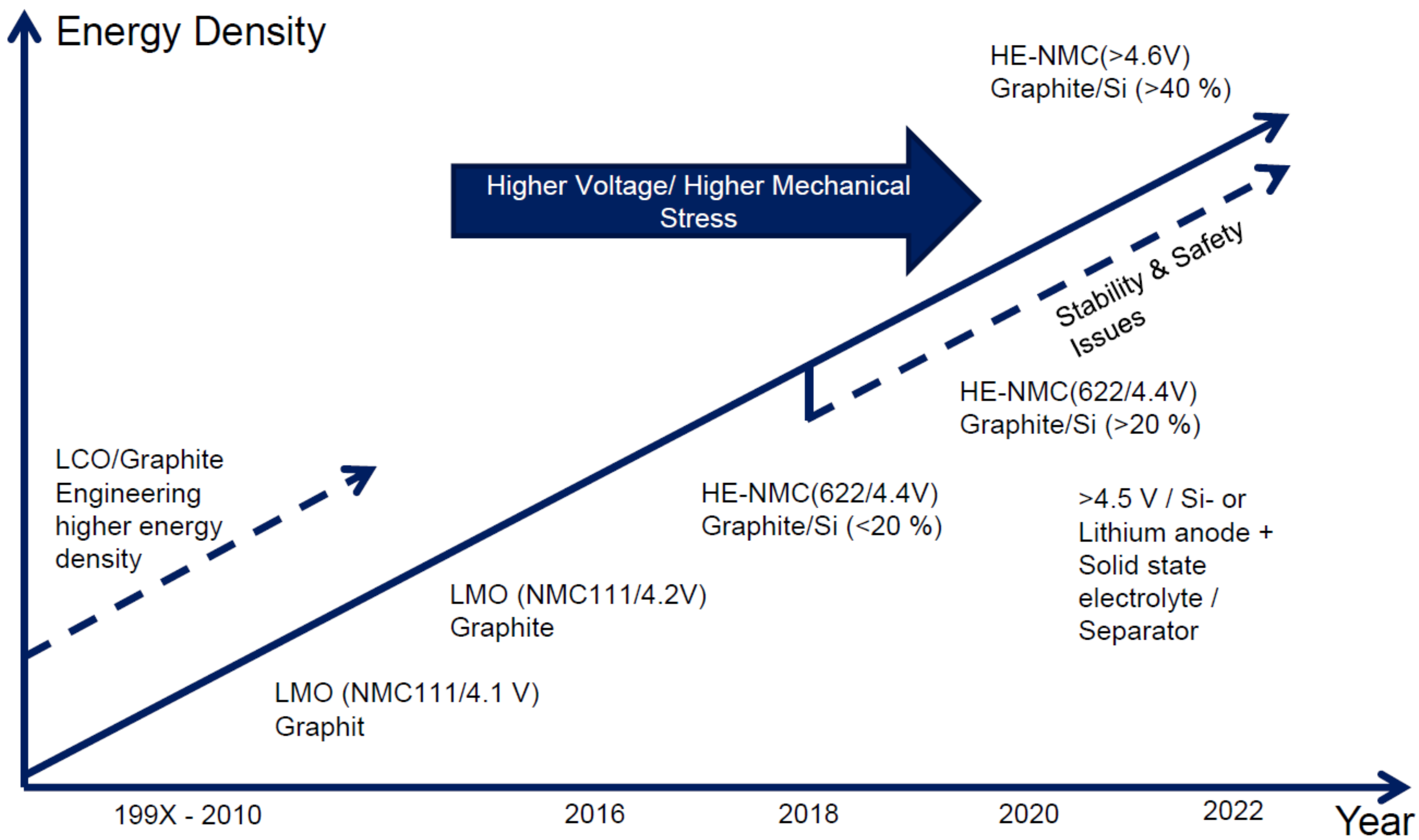
Upscaling of ”breakthrough technologies”

- 1 GWh production/year: 1-3 B€ investment
- 2-3 years from decision to turn key (experienced and established producer) / 3-4 years for new players
- New materials for breakthrough technologies: add minimum another year for scale up
- Adoption of automotive OEMs: new technology must prove itself in non-automotive applications - > minimum 4 years to series production

- -> 8+ years from prototype cells into car

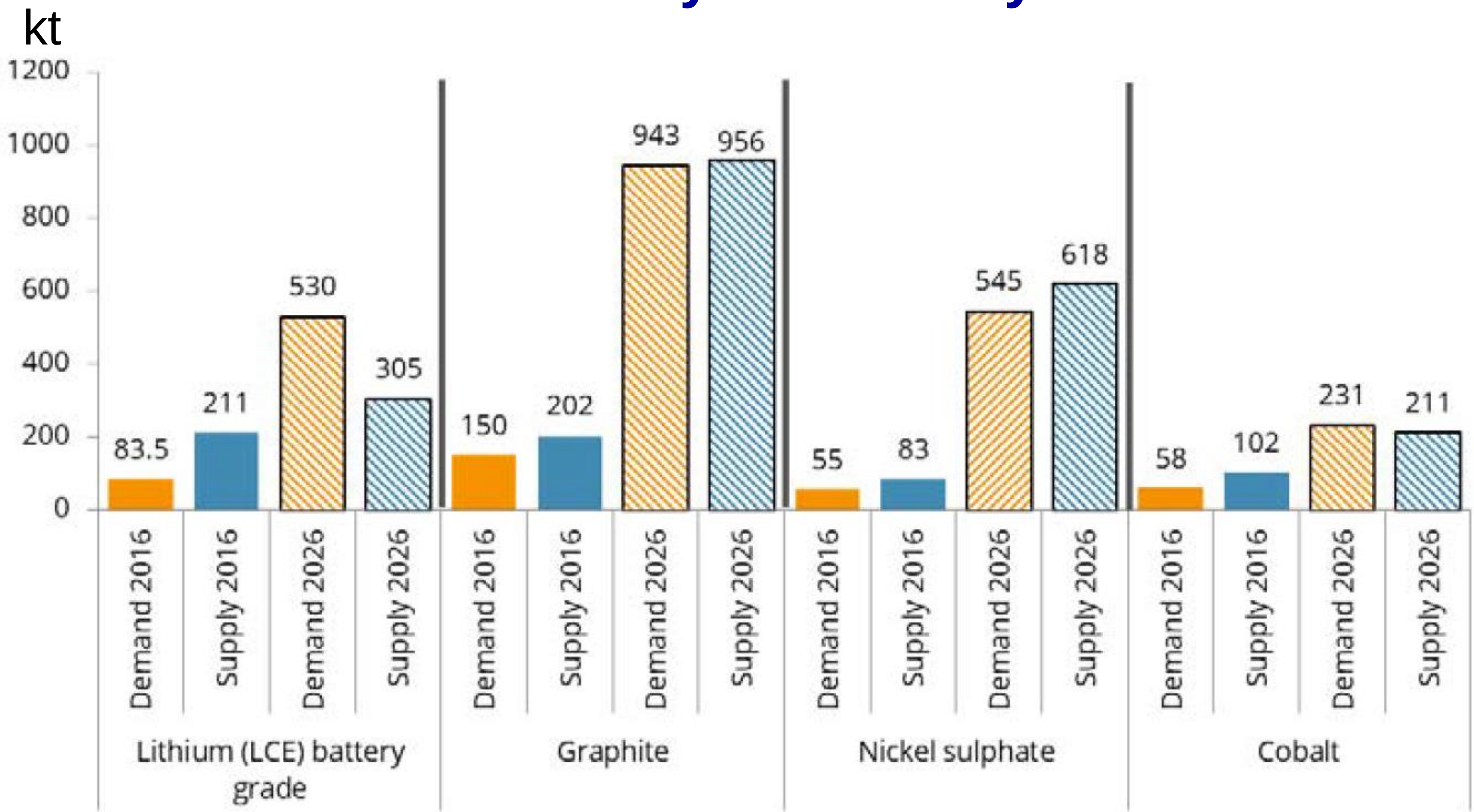
Source: Julich AABC

Technology development



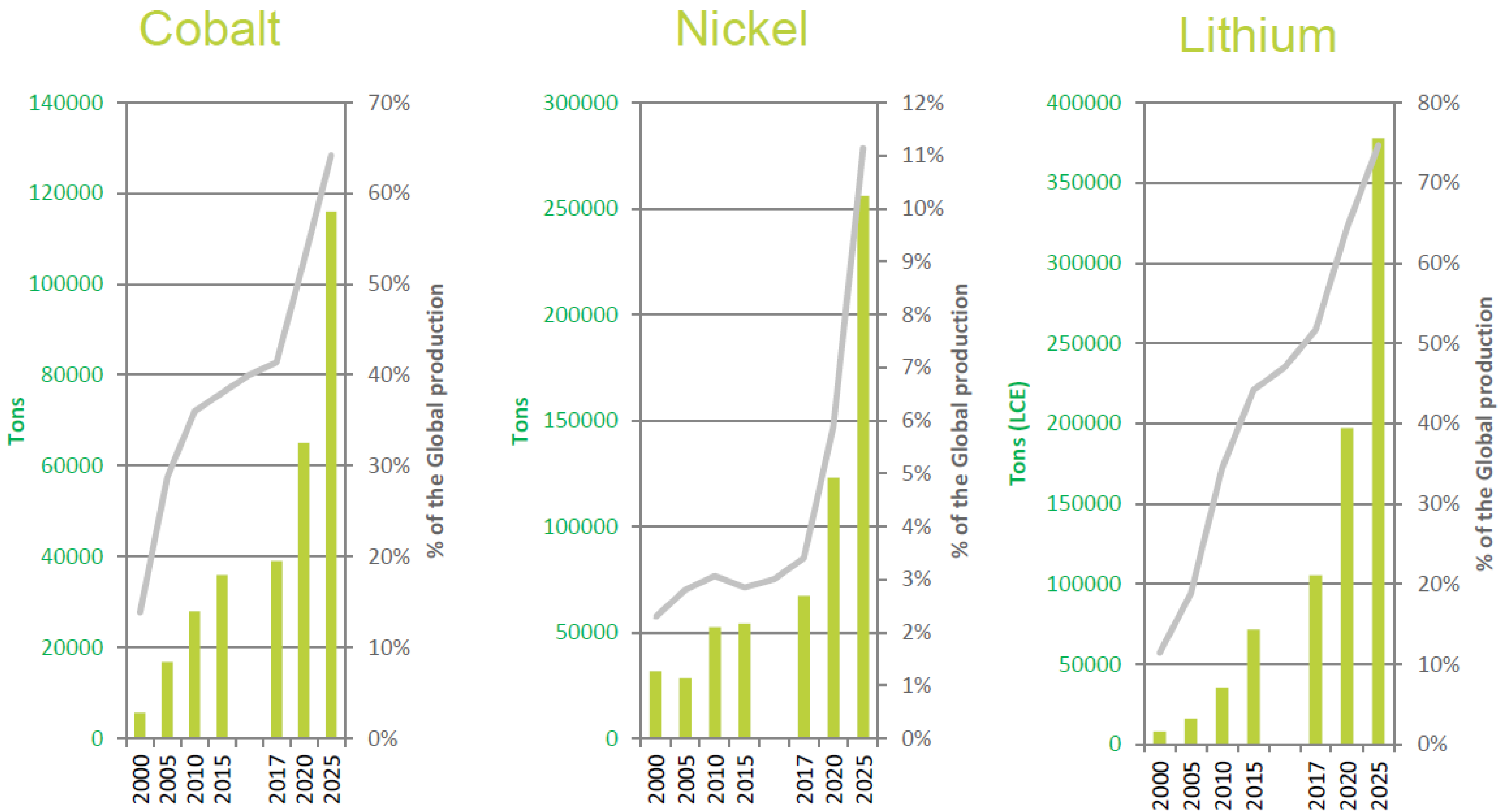
Source: Julich AABC

Demand for batteries by commodity



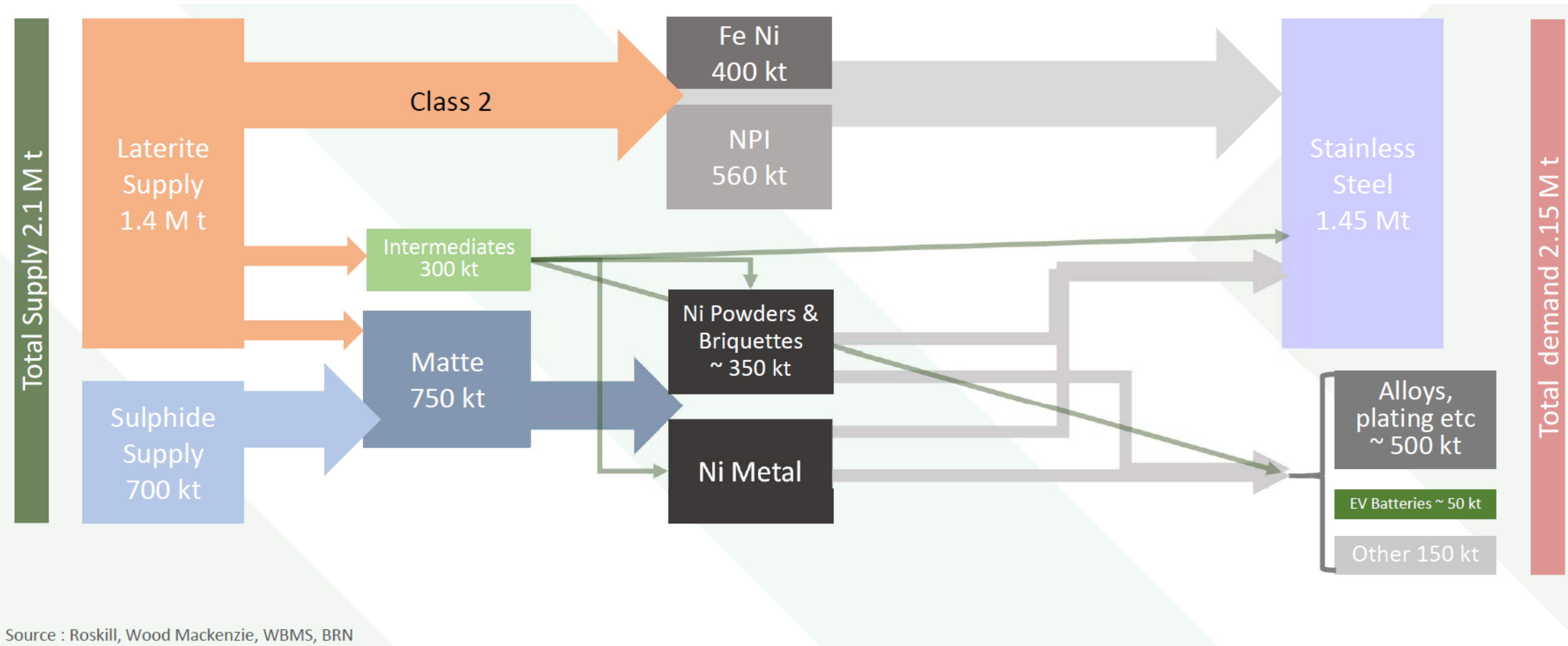
Source: Roskill

Metal needs for batteries will increase

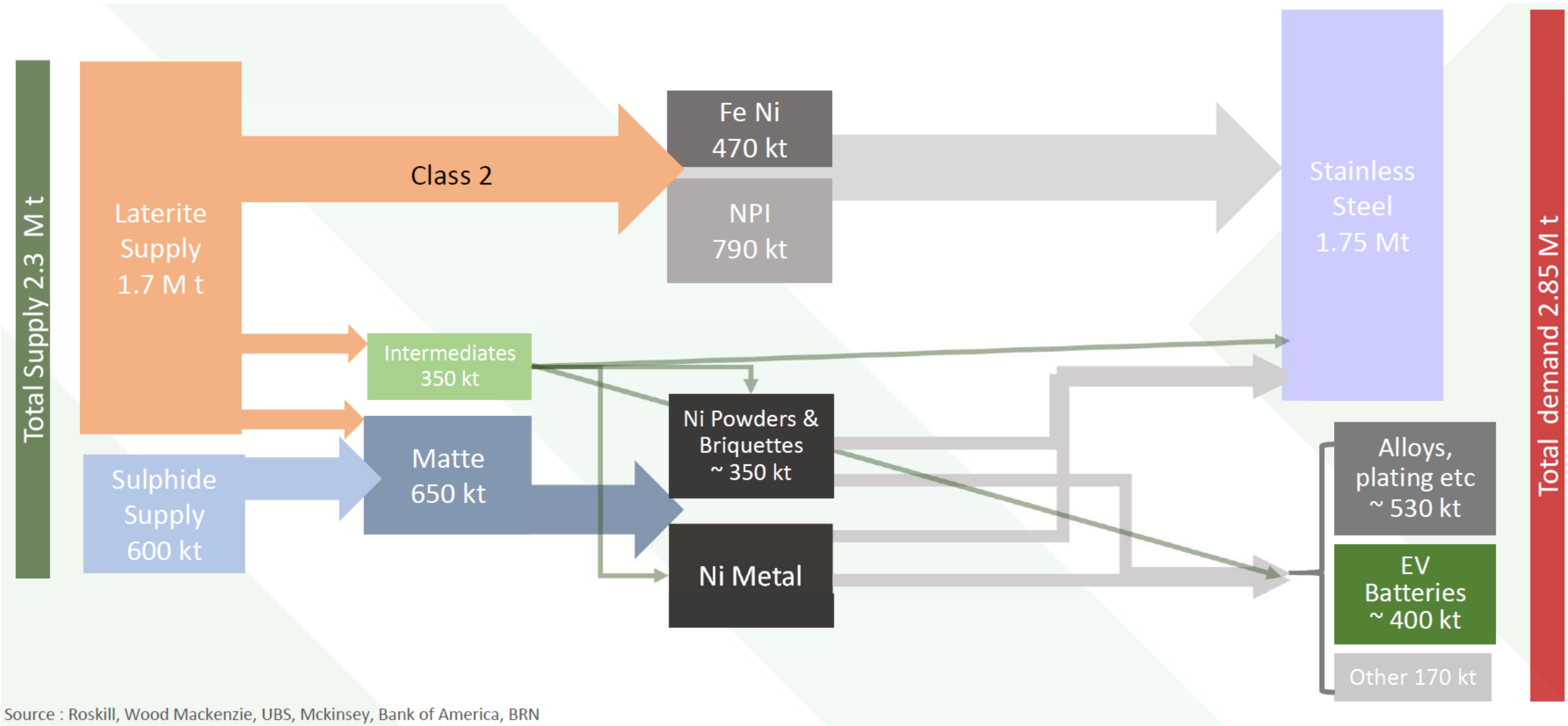


Source: Avicenne Energy

Nickel market supply chain - today

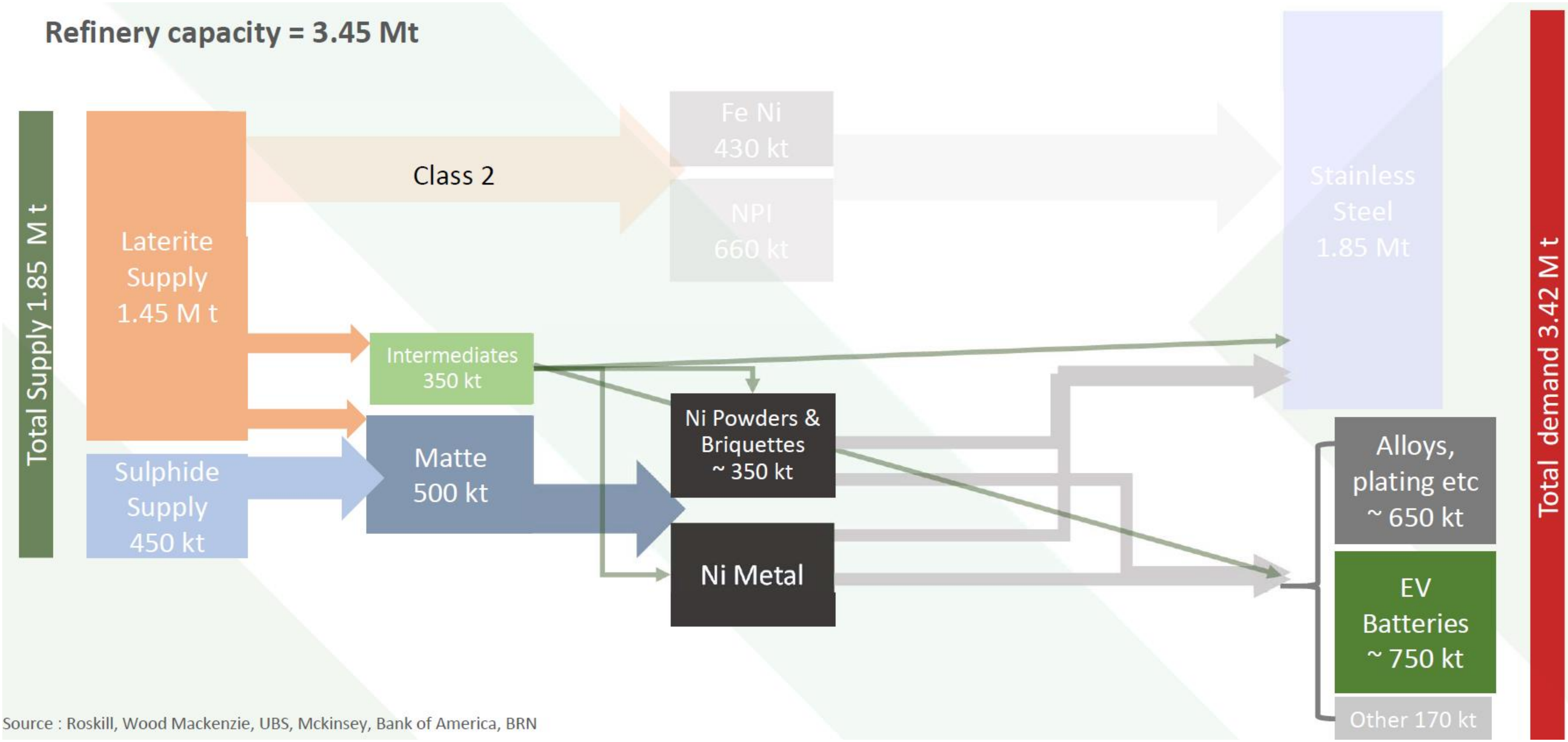


Nickel market supply chain - 2025

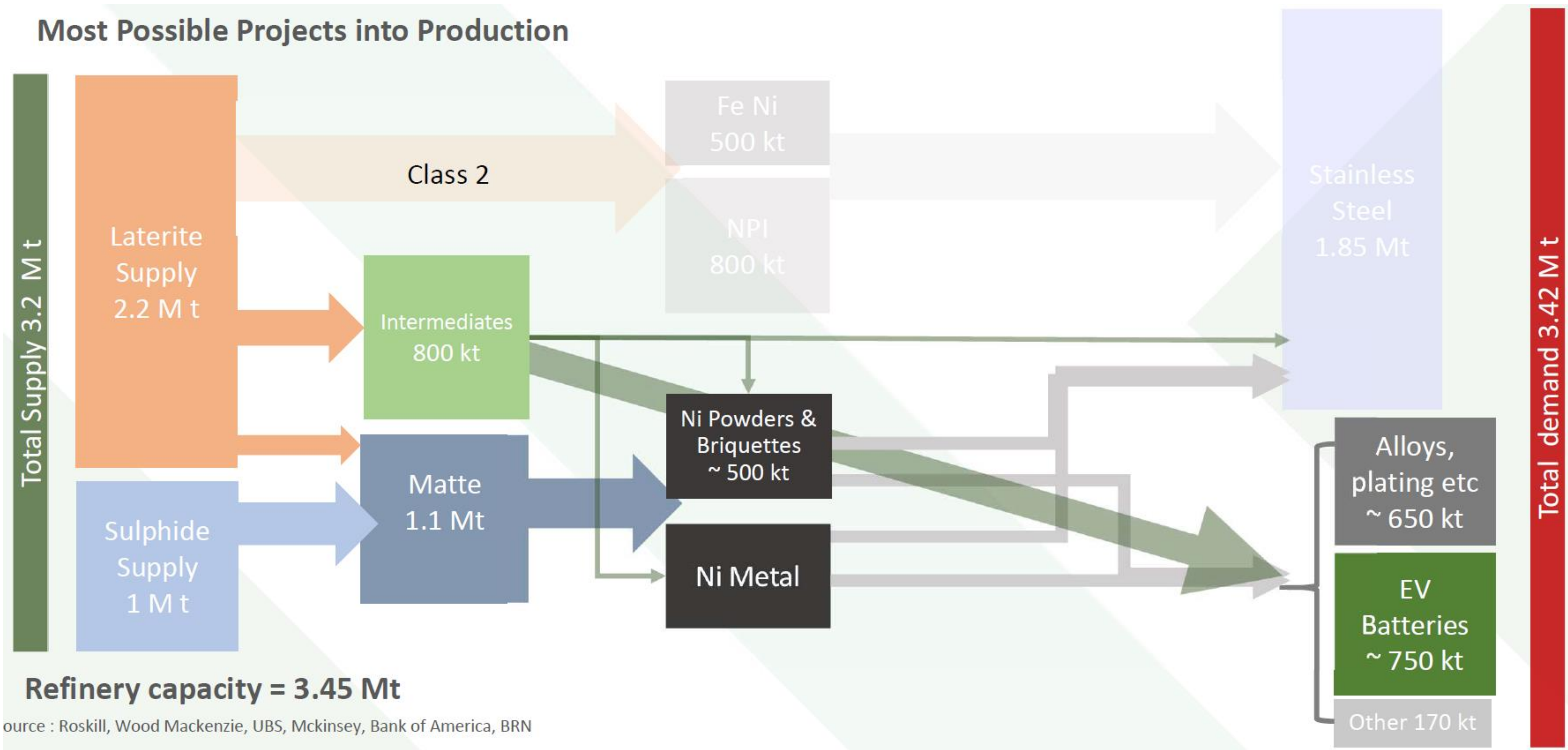


Source : Roskill, Wood Mackenzie, UBS, Mckinsey, Bank of America, BRN

Nickel market supply chain - 2030

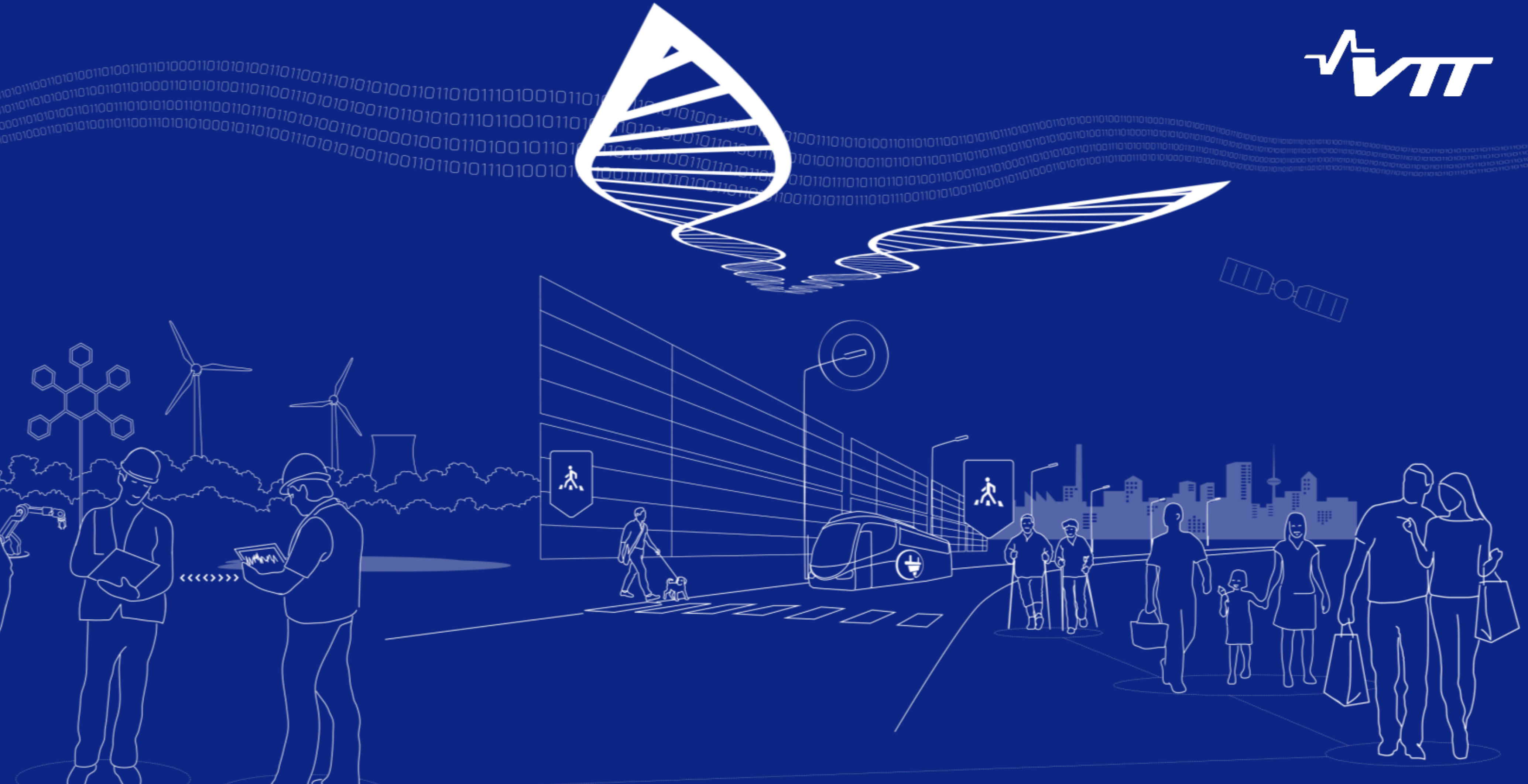


Nickel market supply chain - 2030



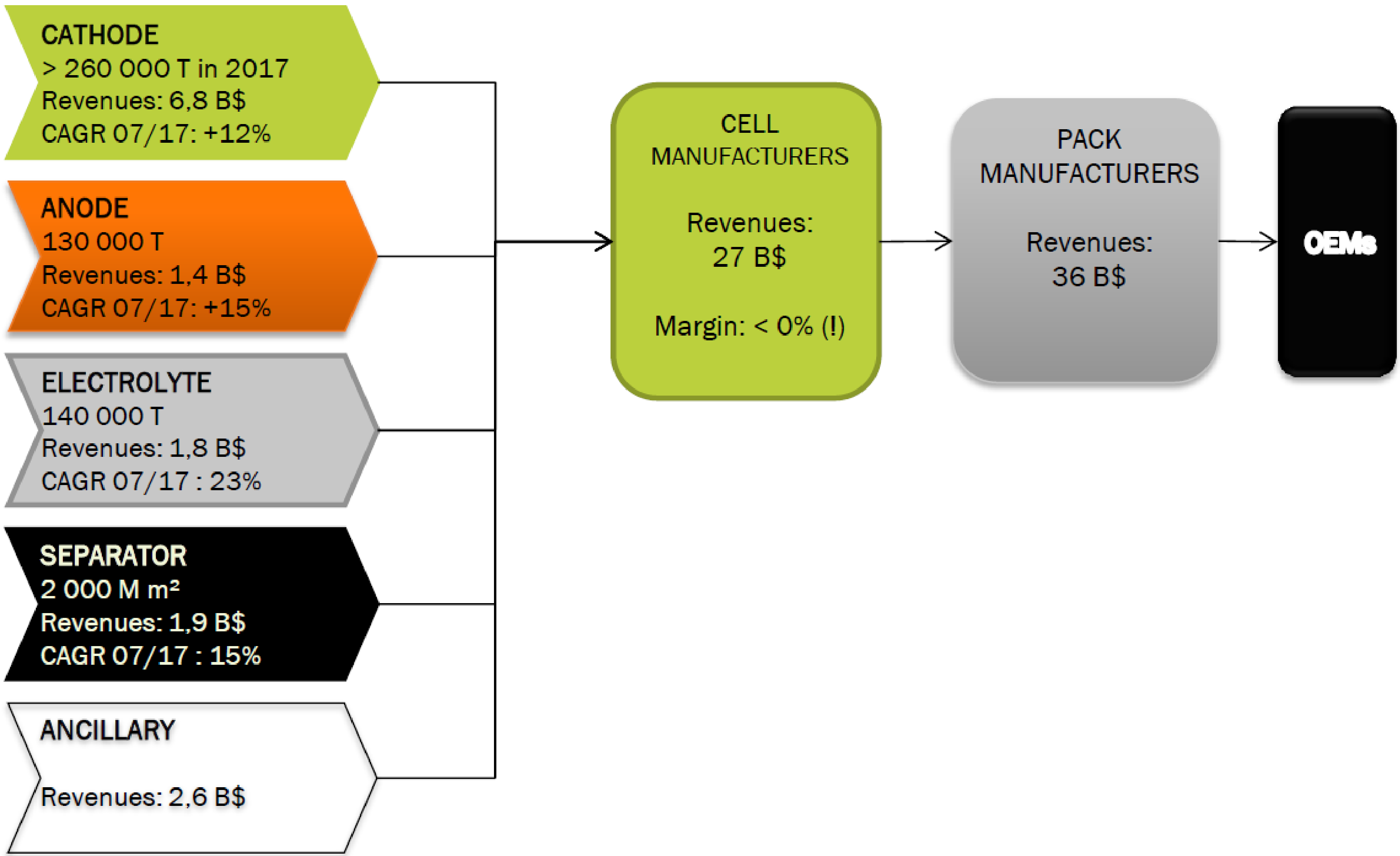
Downstream processing adds value

Source: Neometals



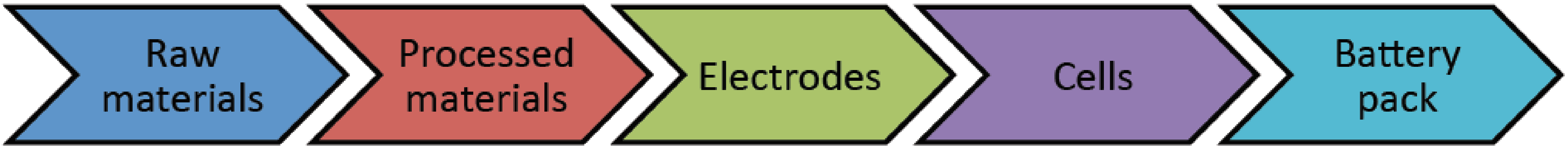
Value chains

Li-ion value chain – market demand



Source: Avicenne Energy

Automotive LIB manufacturing value chain



Raw materials

- Basic input materials (e.g. lithium, nickel, cobalt, graphite, etc.).

Processed materials

- Purified input materials ready for transformation into cell components.
- Processed materials are considered Critical to Quality (CTQ), meaning the materials' purity greatly influences overall cell performance and production yields.

Electrodes

- Cathode and anode materials.
- CTQ, cathode materials quality especially contributes to cell capacity and overall performance.

Cells

- Fundamental functional, charge-retaining battery unit comprised of cathode, anode, separator, electrolyte, and housing.
- CTQ.

Battery pack

- Full battery pack comprised of multiple cells, controls, thermal management, and physical protection.

Source: CEMAC

Automotive LIB manufacturing value chain

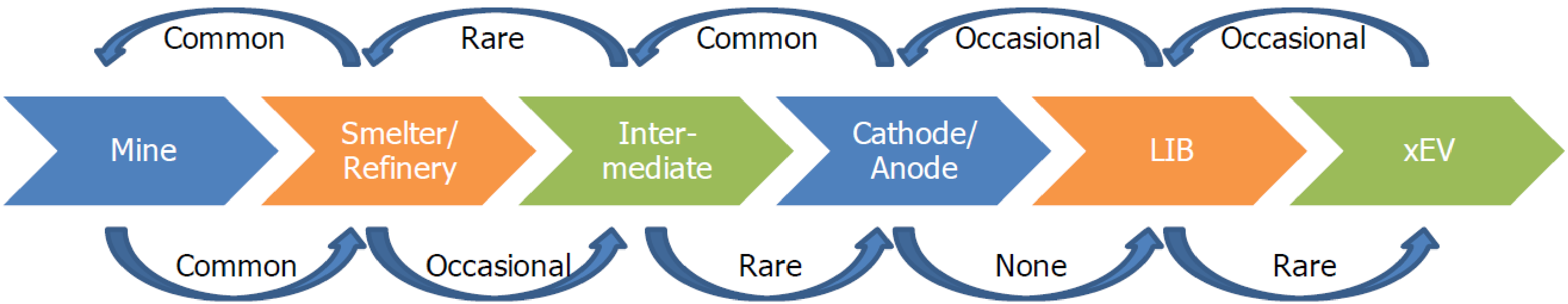
2014 Best-in-Class PHEV LIB Value Chain ($US/kWh)

	Raw Materials	Processed Materials	Electrodes	Cells	Battery Pack	TOTAL
VALUE		$168	$28	$146* (cum. $342*)	$229	$571
SHARE		29%	5%	26%	40%	100%
CURRENTLY SHIPPED	Globally	Globally	Regionally	Globally	Locally	
SUCCESS FACTORS	• **Indigenous resources** • Low export restrictions or limitations	• **Critical to quality** • **Demand assurance** • **Cost of capital** • **Production cost inputs:** e.g. regulatory, energy.	• **Critical to quality** • **Processing know-how**: e.g. coating thickness uniformity, solvent & moisture content.	• **Critical to quality** • **Processing know-how**: e.g. stack uniformity, drying, formation, electrolyte additive	• **End-product knowledge and integration know-how** • **Proximity to customers**: shipping costs, exchange of technical specifications	

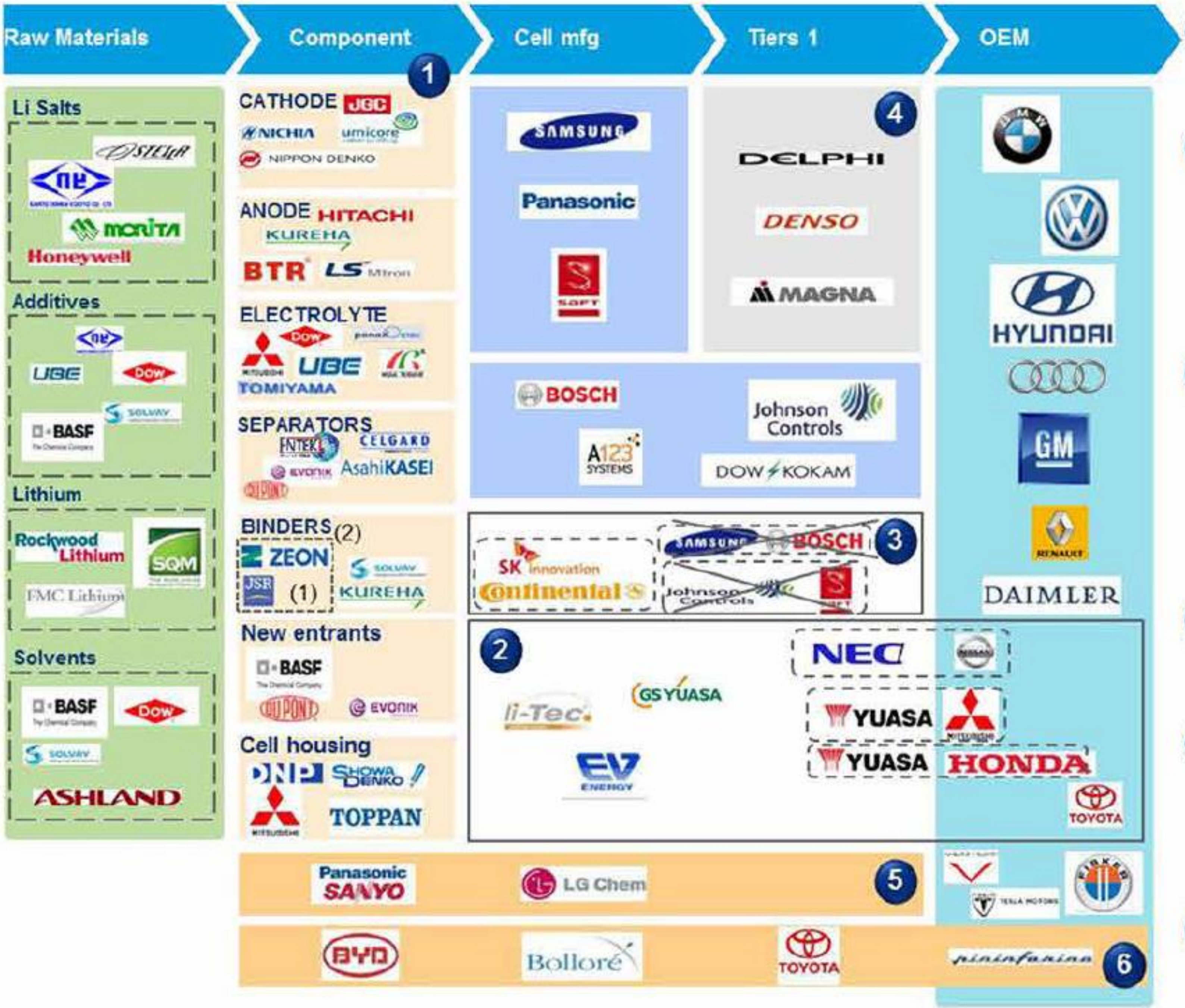
* Ex factory gate – shipping from Asia to the west coast of the United States adds approximately $7/kWh

Source: CEMAC

Automotive LIB manufacturing value chain



Source: Roskill



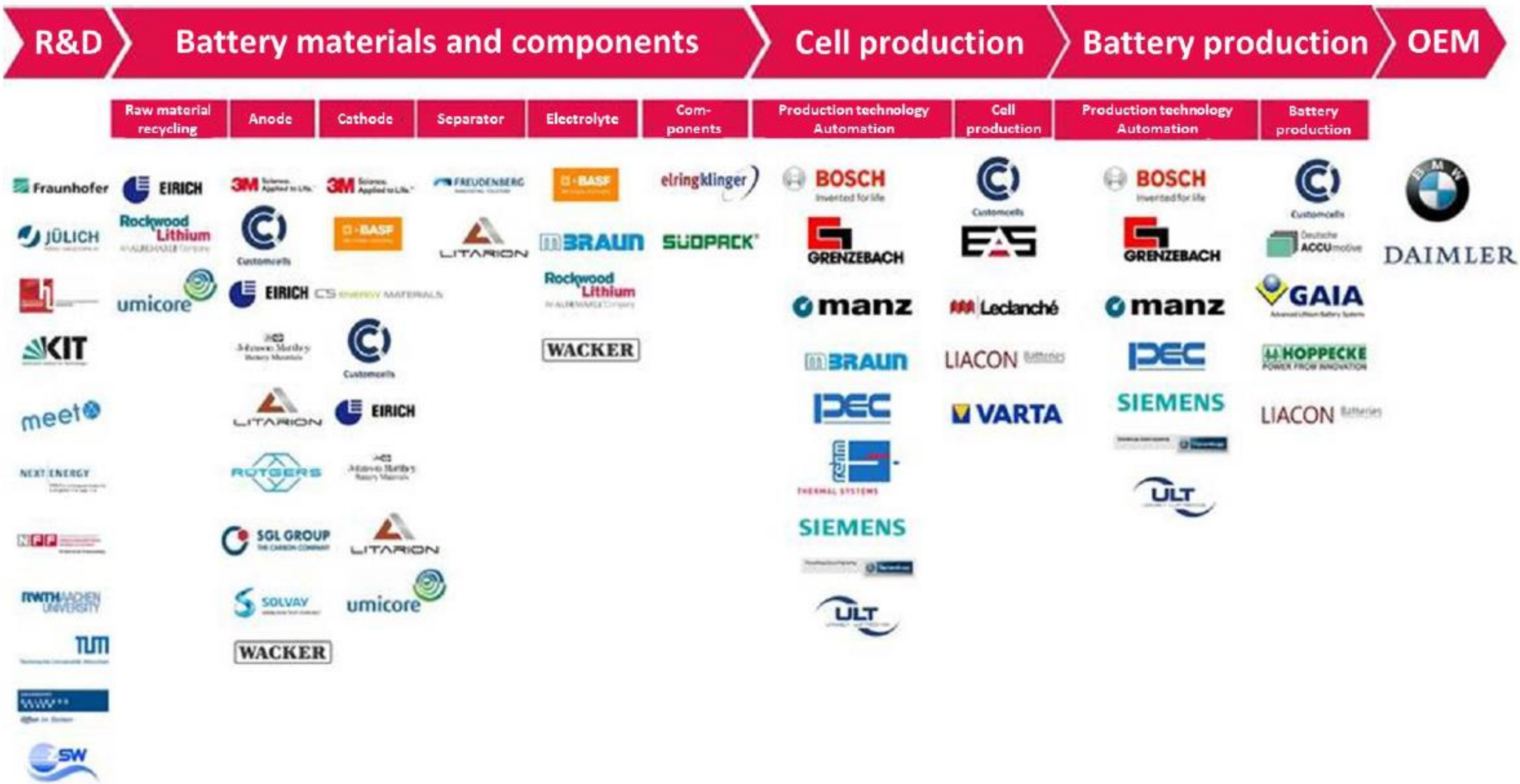
Comments

1. The largest share of the value (40%) comes from cell components
2. Cell manufacturers & OEM alliance may be the winning model but comes with high risk if the wrong cell manufacturer is selected
3. Tiers 1- cell manufacturers alliance: most of them disappear (eg. Saft-Johnson Controls, Bosch-Samsung, Enerdel-Delphi…)
4. Tiers 1- OEM alliance on Battery are not successful
5. Panasonic and LG Chem, cell manufacturers develop raw -material in-house and make the pack integration for OEM
6. On a different scale, Toyota, BYD or BOLLORE are fully integrate

Production of components	Production of cells	Production of modules	Production of packs	Vehicle integration
Samsung SDI		BMW		
BYD				
A123 Systems*				Chevrolet Spark**
LG Chem		Chevrolet Volt		
Li-Tec - Smart (Tochter: Daimler)		Accumotive - Smart (Tochter: Daimler)		Daimler
Panasonic – B-Klasse				Daimler
LG Chem				Ford
Lithium Energy Japan (Joint Venture: MMC, Mitsubishi, GS Yuasa)				Mitsubishi
AESC (Joint Venture: Nissan, NEC)				Nissan
LG Chem - ZOE, Twizy				Renault
AESC - Fluence, Kangoo				Renault
Primearth EV Energy (Joint Venture: Toyota & Panasonic)				Toyota
Sanyo		VW Group		

Source: MFiVE

Actors of LIB value chain in Germany



Source: KLIB

Actors of LIB value chain in Finland

R&D	Mining	Metal refining	Battery materials	Cell manufacturing	Module/pack manufacturing	OEM	2nd life/ recycling
VTT	Mondo Minerals	Outotec	Beneq	European Batteries	VISEDO Electricity in Motion.	Linkker Future Moves	AKKUSER
Aalto-yliopisto	FINNCOBALT	BOLIDEN	Picodeon	broadbit	valmet automotive	KALMAR	KUUSAKOSKI RECYCLING
LUT Lappeenranta University of Technology	FENNOSCANDIAN RESOURCES	NORNICKEL				Rocla	Akkukierrätys Pb Oy
UNIVERSITY OF OULU	KELIBER	Freeport Cobalt				SANDVIK	URecycle®
UNIVERSITY OF EASTERN FINLAND	Terrafame					normet	
AKKURATE						AVANT	
						ABB	
						WÄRTSILÄ	
						KONE	
						KONECRANES	

CRM value chain analysis

Value-Chain Structure

Production → Adv. mat. manufacturing → Components → Battery cells & stacks → Battery system → Recycling

	Cobalt	REE	Graphite	Cathode	Anode	NiMH	Li-ion	Recycling
Europe	umicore; xstrata	Entry in Europe of REEs in alloys form		ARKEMA			small co. : Saft (FR), Gaia (DE), Evonik (DE), ECC Repenning (DE), Leclanche (CH)	umicore; Other small co. : Batrec (CH), Recupyl (FR), Akkuser (FI) Accurec (DE)
North America	OMG; Cobalt			New unit (2013) BASF				TOXCO
Asia	47 % Cobalt supply	Chinese domination	BTR; Hitachi Chemical; 日本カーボン株式会社 Nippon Carbon Co., Ltd.; 75 % market share	Umicore Korea : N°1 worldwide; umicore; NICHIA; KUREHA	BTR; Hitachi Chemical; LS Mtron; 日本カーボン株式会社 Nippon Carbon Co., Ltd.; 90 % market share	GOLD PEAK; EV ENERGY; 80 % market share; Panasonic SANYO	SONY; LG; Panasonic SANYO; SAMSUNG SDI; 85% market share	JX Nippon Mining & Metals; SONY; SUMITOMO METALS; DOWA; GS YUASA

Production / Adv. mat. manufacturing:
- 1 EU leading Cobalt supplier (Umicore)
- Domination of Asia (for REE & graphite)

Components:
- No EU leading cathode supplier
- Domination of Asia (for NiMH & Li-ion)

Battery cells & stacks / Battery system:
- Domination of Asia for NiMH and Li-ion manufacturing
- Some EU "niche" leaders like Saft

Recycling:
- 1 leading European company, among several US and Asian companies

Source: CRM_InnoNet

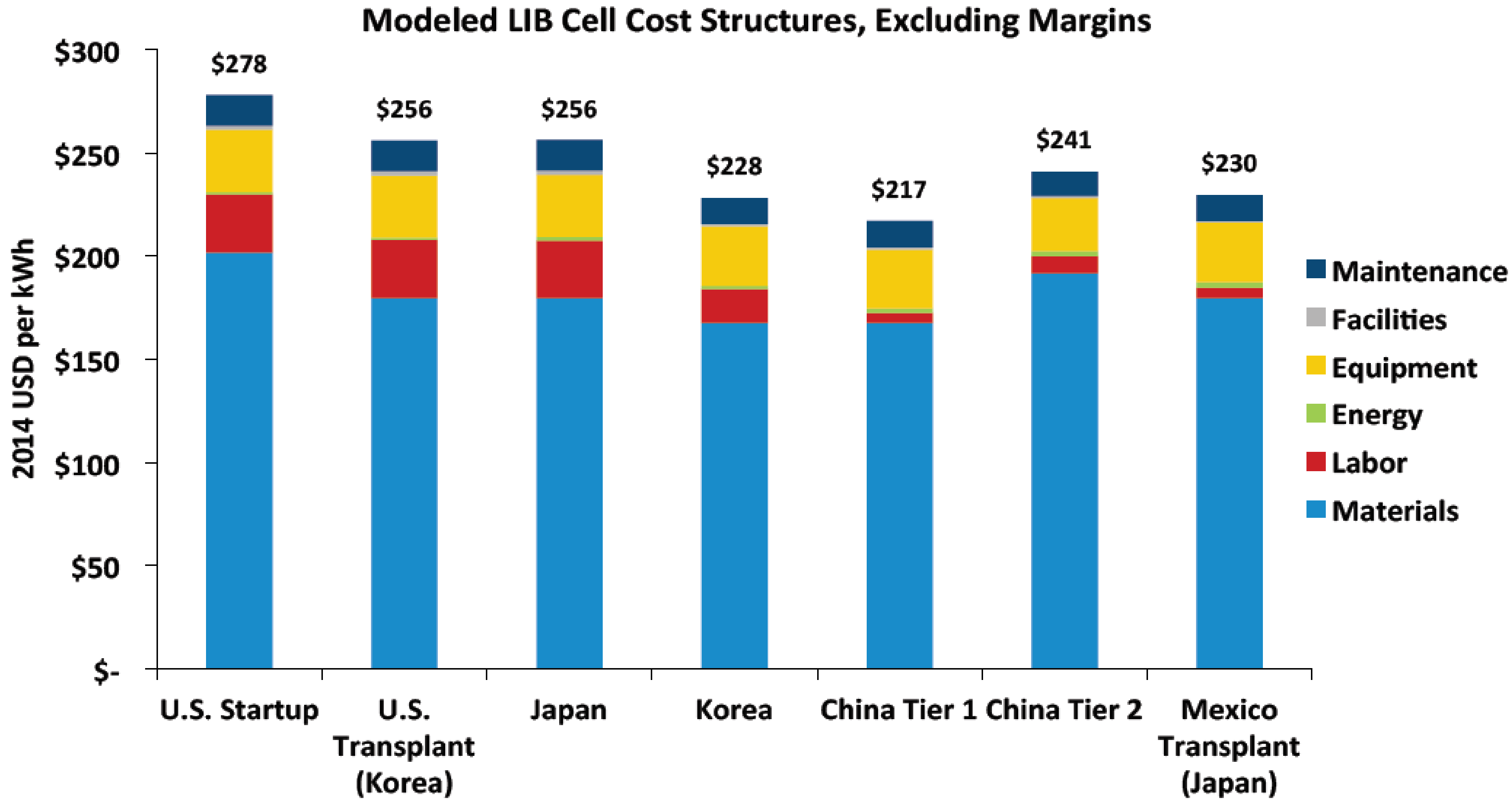
European Battery Alliance

Raw materials	Active Materials	Battery Cells and Battery Packs		Applications		Recycling/2nd life
				E-mobility / ESS / Ind. applications		
EIT Raw Materials	Nanomakers	Litarion GmbH	Akasol	VOLKSWAGEN	ENEL	Umicore
Leading Edge Materials	Blue Solutions (Bolloré)	Saft	E4V	FIAT	TERNA	Veolia
Outotec	BASF	Varta	Continental	RENAULT	EDF	Solvay
EUROMINES	Arkema	Leclanché	LION E-Mobility	Jaguar-Landrover	cyberGRID GmbH	EBRA
Eramet	NXP Semiconductors	EAS Batteries	BMZ - Batteriemontagezentrum	BMW	Atlas Copco	SUEZ
Boliden	SGL Carbon SE	Terra E	Sonnen GmbH	PSA Groupe	Manz	
Terrafame	BELENOS	Liacon	EoCell Inc	NISSAN (FR)	Elring-Klinger	
Rio Tinto	CEFIC	Northvolt	HE3DA	VOLVO	Stihl	
Magnis/ Allocate	Heraeus	CustomCells		Husqvarna	Vattenfall	
	Nanomakers	KLIB		Daimler	Total	

Research and associations active in all parts of the value chain

Fraunhofer, CEA, ENEA, T&E, EASE, EUROBAT, EMIRI, ANIE, Ångström Advanced Battery Centre, RECHARGE, Akkurate OY, CEPS, SET PLAN TWG 7

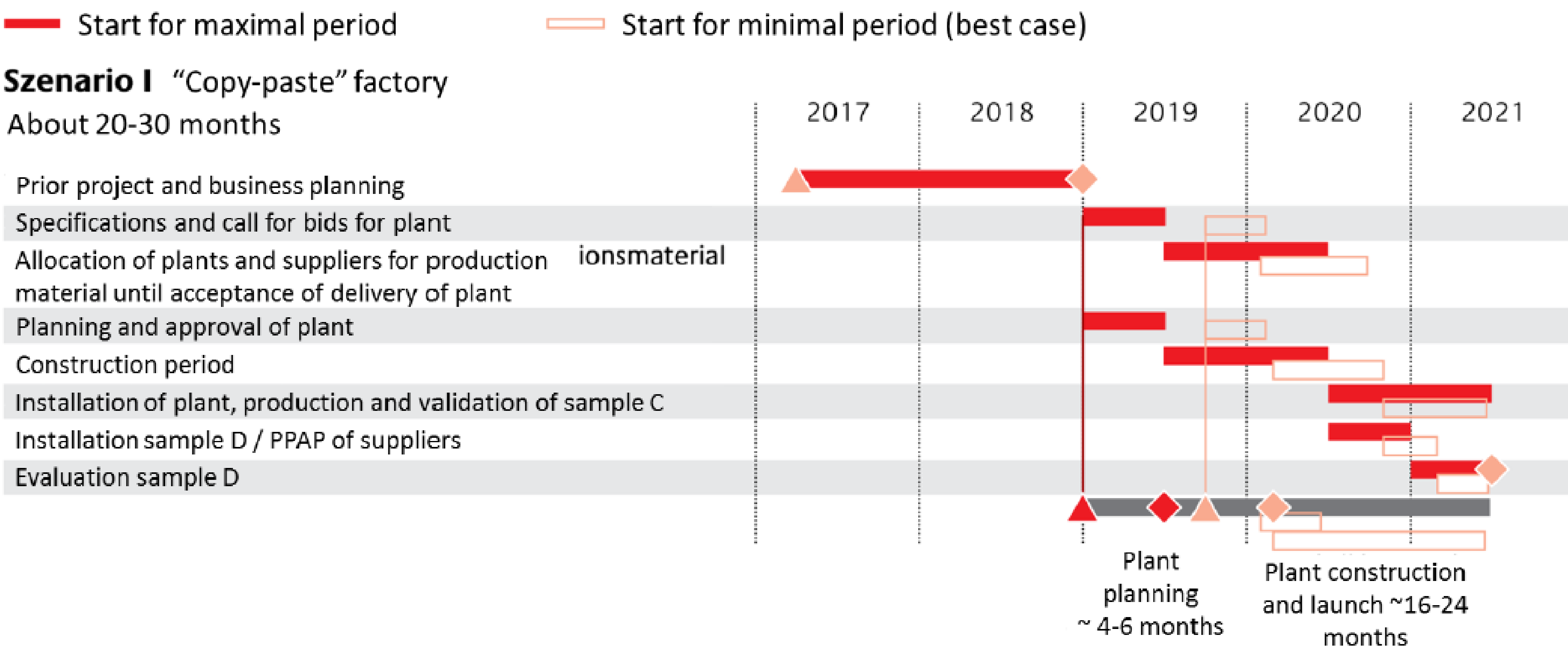
Regional comparison of cell manufacturing costs



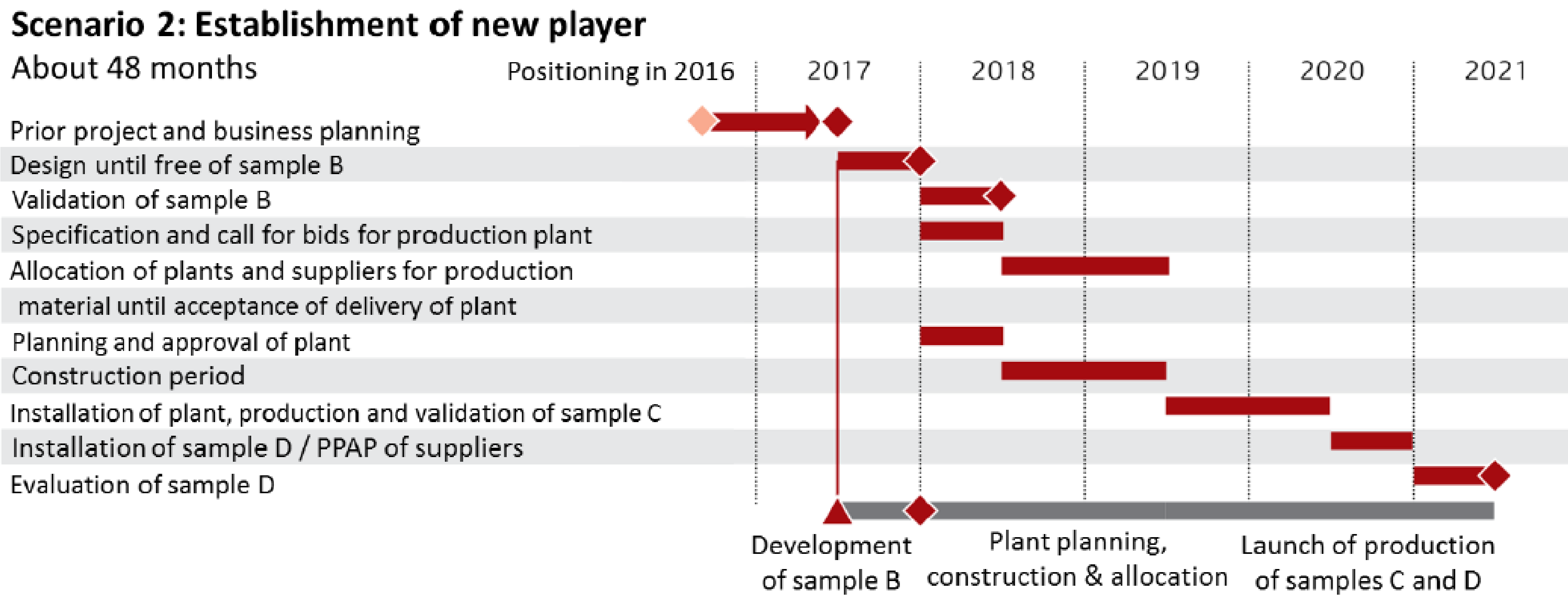
- Materials and labor constitute the key cost differences across countries
- Labor costs are driven by location, whereas materials costs are driven by country and company characteristics

Source: CEMAC

LIB cell manufacturing



LIB cell manufacturing



Source: NPE UAG 2.2 M. Weiss, members, 2015

LIB value creation

- Three major value creation steps:
  - Cell manufacturing
  - Module manufacturing
  - Pack manufacturing and vehicle integration
- Further important steps:
  - Production of processed materials
  - Manufacturing of electrodes
  - Manufacturing of machineries for LIB production plants
- Two additional steps:
  - Second life of LIB as part of the renewable energy system
  - Recycling of raw materials of LIB at their end-of-life

Criteria for selection of LIB cell manufacturing site

- Access to raw materials (graphite, lithium, cobalt, nickel, manganese).
- Proximity to machinery suppliers.
- Existing clusters of battery and materials manufacturers.
- Protection of intellectual property, including process innovations.
- Energy cost and environmental legislation.
- Logistical risks and proximity to end-markets.
- Supply chain optimization e.g. degree of vertical integration.
- Access to talented workforce, especially in RD&D.
- Labor cost of RD&D staff and of skilled factory staff.
- Competitive edge of incumbents that can not be caught up anymore.
- Sunk cost of factories that would produce old technologies if new cell technologies were produced by the new factory.
- Discounts provided to regional customers or members of the regional cluster but not to foreign customers.
- Opportunity to generate lead markets or at least export markets.
- Policy and regulatory context.
- Ease-of-doing-business-considerations.
- Brand and reputation.

Key players

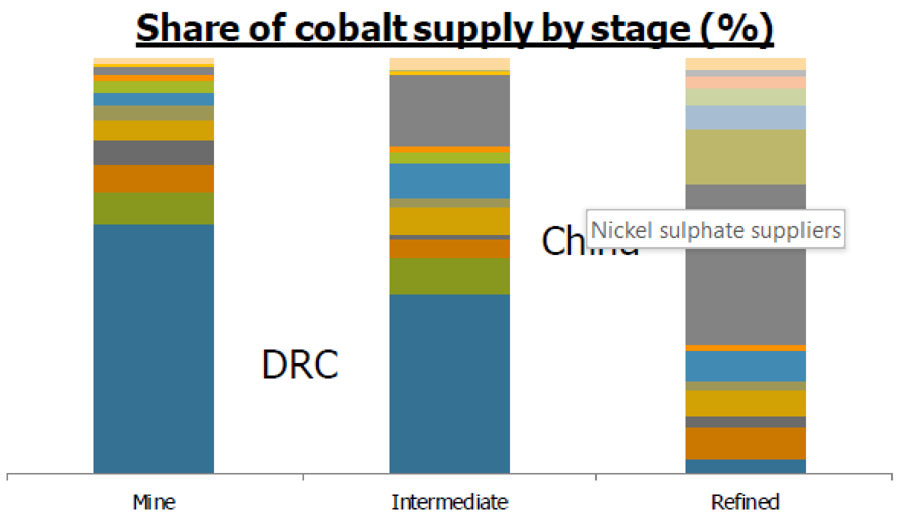
Lithium suppliers

- Mined product
  - Talison 31 % (AU)
  - SQM 22 % (Chile)
  - Albemarle 17 % (USA)
  - FMC 9 % (USA)
  - Orocobre 5 % (AU)
  - Galaxy 3 % (AU)
  - Neometals 1 % (AU)
  - China mineral 5 %
  - China brine 2 %
  - Other mineral 5 %
- Converted minerals
  - Tianqi 43 % (China)
  - Ganfeng 17 % (China)
  - Zhonge 13 % (China)
  - Ruifu 11 % (China)
  - General Li 9 % (China)
  - Sichuan Ni&Co 7 % (China)
  - China 100 %
- Refined products
  - SQM 23 % (Chile)
  - Albemarle 17 % (USA)
  - Tianqi 13 % (China)
  - FMC 10 % (USA)
  - Technical minerals 8 %
  - Orocobre 6 % (AU)
  - Ganfeng Li 5 % (China)
  - Sichuan Ni&Co 5 % (China)
  - Ruifu 4 % (China)
  - Zhonge 4 % (China)
  - General Li 3 % (China)
  - China brine 2 %

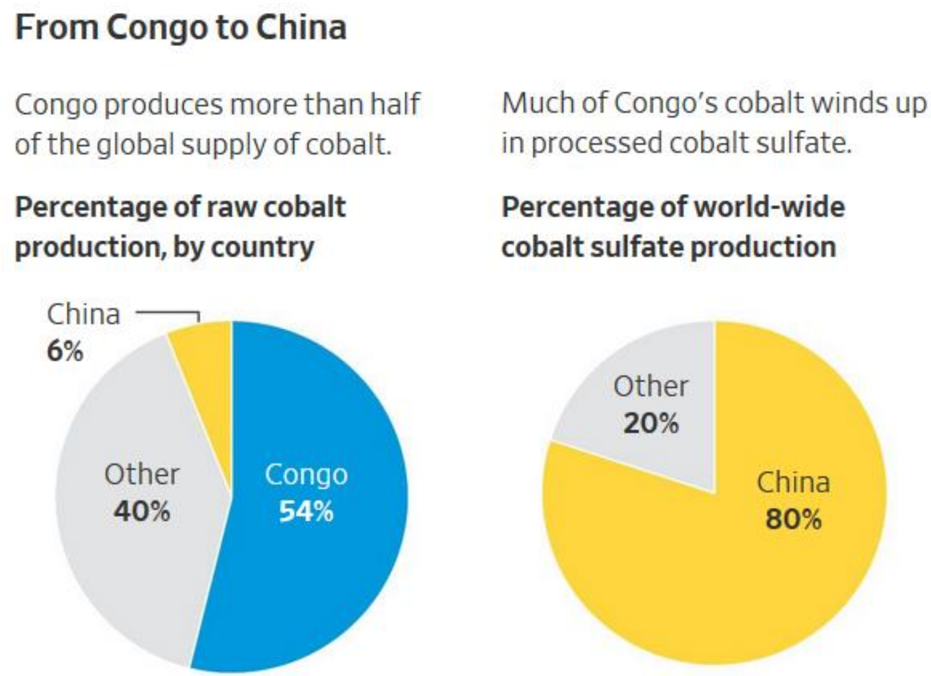
Nickel sulphate suppliers

- Sumitomo 18 % (Japan)
- Jilin Jien 13 % (China)
- Jinchuan 11 % (China)
- Norilsk Nickel 8 % (Russia)
- Umicore 6 % (Belgium)
- Others 23 %
- Others China 21 %

Cobalt suppliers



Source: Roskill



For batteries:
-China 80 %
-Finland (Freeport) 20 %

Source: WSJ

Cobalt suppliers

- 77 % of refined cobalt produced in China (67 % in 2012)
- CRU: soon 90 %

Cobalt mine in Congo

Cobalt miners in Congo produce 14 % of the output

Cathode materials – LCO suppliers

- L&F 16 % (Korea)
- Umicore 15 % (Belgium)
- Pulead 12 % (China)
- B&M 12 % (China)
- ShanShan 10 % (China)
- Easpring 9 % (China)
- Reshine 9 % (China)
- Nichia 8 % (Japan)
- Xianmen Tungsten 7 % (China)
- Others 2 % (China)

- China 61 %

Cathode materials – NMC suppliers

- Umicore 18 % (Belgium)
- Internal 12 % (LG Chem, Samsung SDI, etc.)
- ShanShan 12 % (China)
- Xianmen Tungsten 10 % (China)
- L&F 9 % (Korea)
- Nichia 9 % (Japan)
- Easpring 8 % (China)
- Jinhe 7 % (China)
- Tianjiao 6 % (China)
- Kelong 2 % (China)
- Dahua 2 % (China)
- Pulead 1 % (China)
- Others 4 % (China)

- China 52 %

Cathode materials – NCA suppliers

- Sumitomo 73 % (Japan)
- Toda Kogyo 10 % (Japan)
- Ecopro 5 % (Korea)
- Nihon Kagaku Sangyo 5 % (Japan)
- Kelong 5 % (China)
- Others 2 % (China)

- Japan 88 %

Cathode materials – LFP suppliers

- Internal 27 % (BYD, Hefei, Huanyu, LG, A123, Hi Power)
- Pulead 13 % (China)
- BYD 8 % (China)
- Zhuoneng 6 % (China
- STL 5 % (China)
- Johnson Matthey 4 % (UK)
- Alees 3 % (Taiwan)
- Kelong 2 % (China)
- Tatung 1 % (Taiwan)
- Others 28 % (China)

- China 92 %

Anode materials – natural graphite suppliers

- Shenzhen BTR 40 % (China)
- Mitsubishi 15 % (Japan)
- Hitachi 10 % (Japan)
- Shinzoom 9 % (China)
- Posco Chemtech 4 % (Korea)
- Nippon Carbon 4 % (Japan)
- Sinuo 3 % (China)
- Others 10 %

- China 70 %

Anode materials – artificial graphite suppliers

- ShanShan 21 % (China)
- Sinuo 20 % (China)
- BTR 16 % (China)
- Zichen 15 % (China)
- Hitachi 7 % (Japan)
- JFE 5 % (Japan)
- Mitsubishi 4 % (Japan)
- Shinzoom 4 % (China)
- Showa Denko 2 % (Japan)
- Others 6 % (China)

- China 82 %

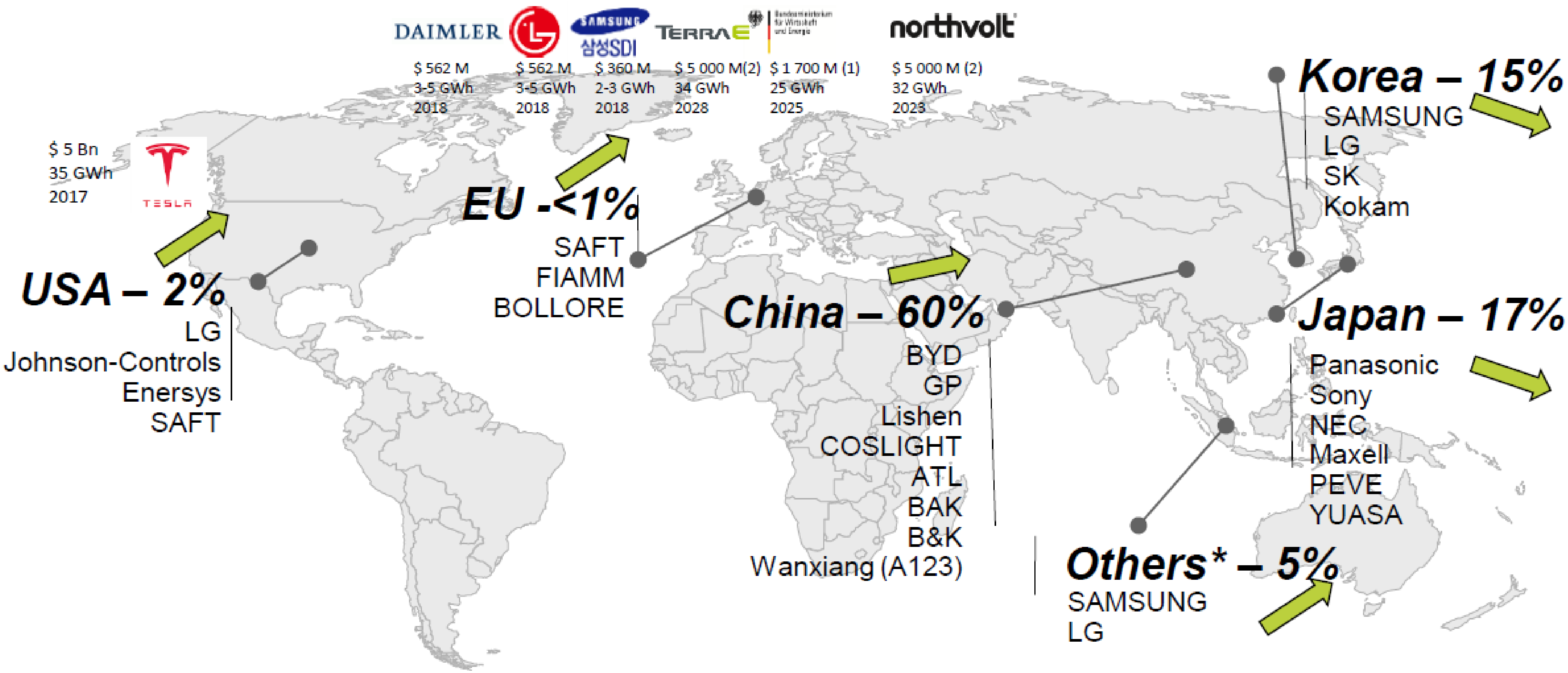
LIB separator suppliers

- Asahi 17 % (Japan)
- Toray 15 % (Korea)
- SK Innovation 9 % (Korea)
- Celgard 8% (Asahi subsidiary)
- Sumitomo 6 % (Japan)
- Ube 6 % (Japan)
- W-Scope 6 % (Japan)
- Jinhui 4 % (China)
- Entek 4 % (USA)
- Senior 3 % (China)
- Green 3 %
- Others 19 %

LIB electrolyte suppliers

- Zhangjiagang Guotai-Huarong 15 % (China)
- Capchem 14 % (China)
- Mitsubishi 12 % (Japan)
- In-house 9 %
- Panax-Etec 8 % (Korea)
- ShanShan 8 % (China)
- Jinniu 8 % (China)
- Tinci 6 % (China)
- Soulbrain 5 % (Korea)
- Ube 4 % (Japan)
- Mitsui 3 % (Japan)
- Tomiyama 3 % (Japan)
- Others 5 %

Li-ion cell production



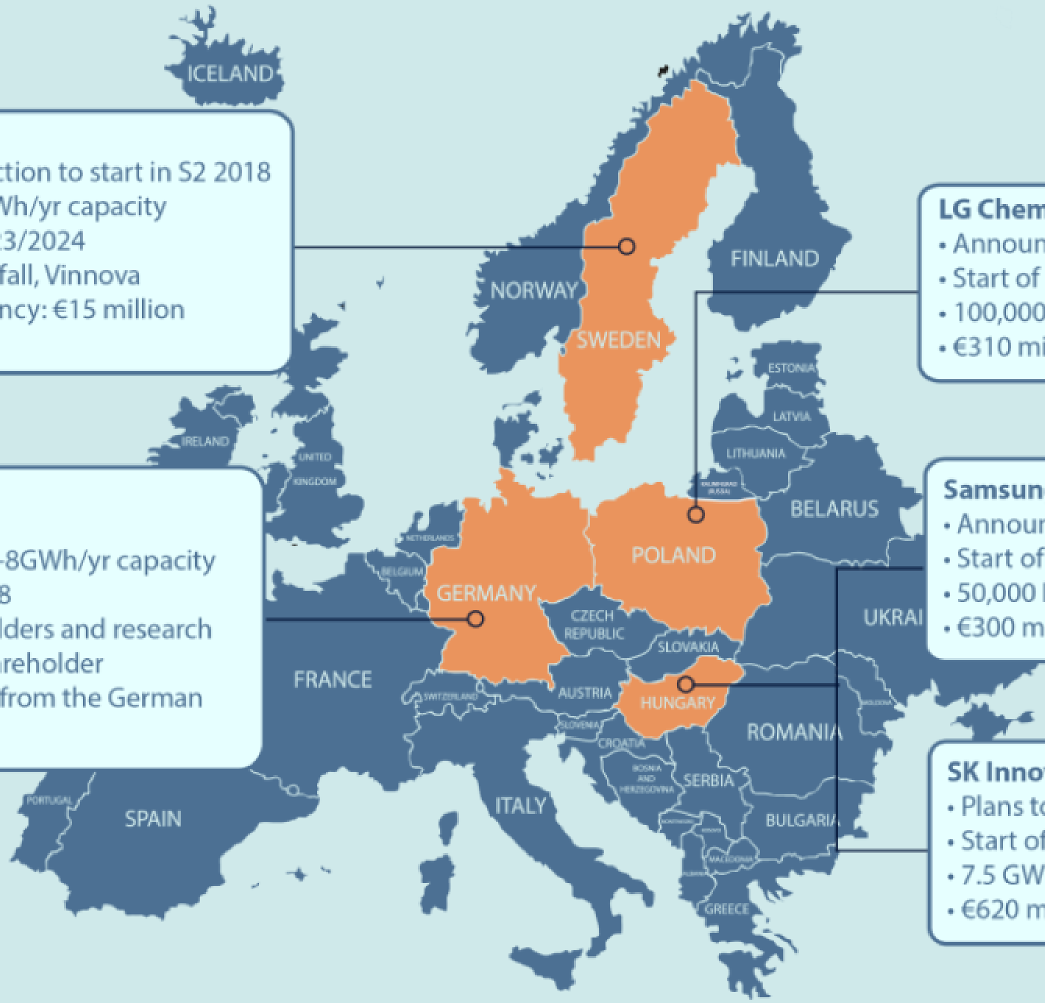
Source: Avicenne Energy

* Others: Malaysia mainly
(1) Government subsidies only
(2) Avicenne estimation

Gigafactory projects in the European Union (as of 20 February 2018)

NORTHVOLT
- Announced in spring 2017, construction to start in S2 2018
- Demo line ready mid-2019 with 8GWh/yr capacity
- 32GWh/yr production target for 2023/2024
- Investors: InnoEnergy, Stena, Vattenfall, Vinnova
- Grant from the Swedish Energy Agency: €15 million
- EIB loan: €52.2 million

TERRA-E
- Announced in spring 2017
- Start of operation in Q4 2019 with 6-8GWh/yr capacity
- 34GWh/yr production target by 2028
- Consortium of 17 industrial stakeholders and research institutes, with BMZ as the main shareholder
- Benefiting from a €5.2 million grant from the German Ministry of Education



LG Chem Wroclaw factory
- Announced in 2016
- Start of operation in Q4 2018
- 100,000 EV batteries (4GWh/yr) production target
- €310 million to be invested up to 2020

Samsung SDI Göd factory
- Announced in 2016
- Start of operation in Q2 2018
- 50,000 EV batteries (2GWh/yr) production target
- €300 million investment

SK Innovation Komárom factory
- Plans to break ground in February 2018
- Start of production in early 2020
- 7.5 GWh/yr production target
- €620 million to be invested

Source : Carole Mathieu, "The EU Battery Alliance: Can Europe Avoid Technological Dependence?", Édito Énergie, Ifri, February 2018.