Green Transport Delta

Electrification

Battery Recycling in The Netherlands?

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GTD-E Final Projectday 2024, Born

TNO innovation for life

BRAINPORT DEVELOPMENT
economische ontwikkelingsmaatschappij

rai AUTOMOTIVE INDUSTRY NL

Battery Competence Center

Battery recycling: So many initiatives!

Press Release

Growth area of battery recycling: Aurubis starts test operation in new pilot plant in Hamburg

Hamburg | Friday, March 18, 2022

15. MARCH 2022

Saubermacher sets new standards in recycling

TES starts large facility in Rotterdam to recycle batteries from electric vehicles

05 July 2021

Jan 31, 2022 - 02:03 pm

Li-Cycle announces two new recycling plants

Mar 17, 2022 - 01:53 pm

Eramet & Suez to build battery recycling plant in France

Neometals Battery Recycling JV, Primobius, has Officially Opened its 10tpd Commercial Lithium-ion Battery Recycling Plant in Hilchenbach, Germany

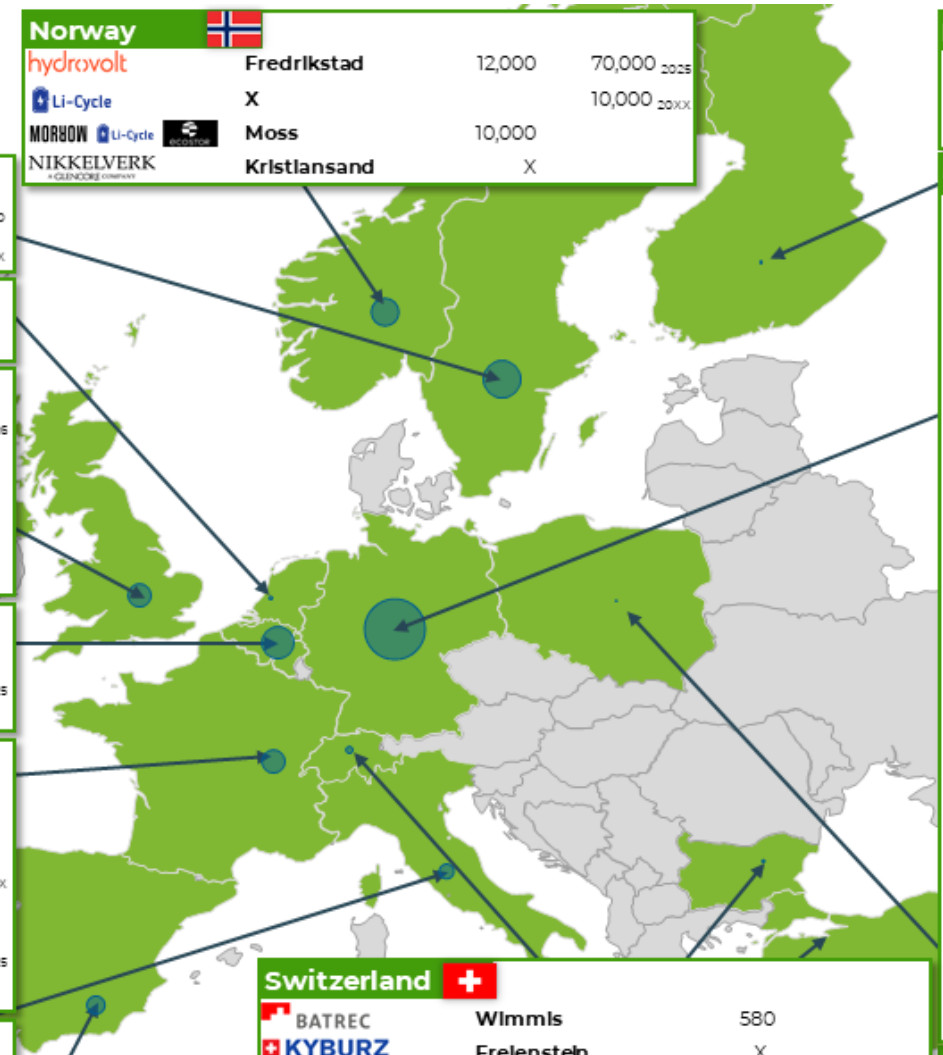
Europe's largest electric vehicle battery recycling plant begins operations

May 15, 2022

As commercial recycling operations start at Hydrovolt in Norway, joint venture partners look towards European expansion.

LIB recycling projects EU: May 2024

Published by: BATTERY-NEWS.DE



Sweden

northvolt	Skellefteå		125,000 2030
STENA	Halmstad	10,000	20,000 20XX

Netherlands

TES	Rotterdam	10,000	

Great Britain

Altilium Metals	Teesside		50,000 2026
Altilium Metals	Devon	100	
Veolia	Minworth	5,000	
ecobat	Darlaston	20,000	
Recover	Newport	X	
Recyclus Group	Wolverhampton	3,800	

Belgium

umicore	Hoboken	7,000	
Aurubis	Olen	X	100,000 2025
ABEE	Dour	20,000	

France

Veolia	Dieuze	X	
Veolia	Amneville	7,000	
SNAM	Saint Quentin	1,000	5,000 20XX
Li-Cycle	Harnes	10,000	
Suez / Eramet	Dunkirk		50,000 2025
TES	Grenoble	X	

Italy

Li-Cycle / Glencore	Portovesme		50,000 20XX

Spain

endesa	Cubillos del Sil		8,000 20XX
SungEel HiTech	Navarra		10,000 2025
Recypilas	Erandio	X	
ENU	Alicante		45,000 20XX

Norway

hydrovolt	Fredrikstad	12,000	70,000 2025
Li-Cycle	X		10,000 20XX
Morrow / Li-Cycle / Ecostor	Moss	10,000	
Nikkelverk / Glencore	Kristiansand	X	

Switzerland

BATREC	Wimmis	580
KYBURZ	Frelenstein	X
libREC	Biberist	10,000

Turkey

Exitcom	Kocaeli	10,000

Bulgaria

Altilium Metals	Medet	8,000

Based on official announcements, Recycling until black mass or metal precursor
All values in tons/year

Finland

fortum	Harjavalta	X	
fortum	Ikaalinen		5,000 20XX
Nivala	Nivala	800	3,000 20XX

Germany

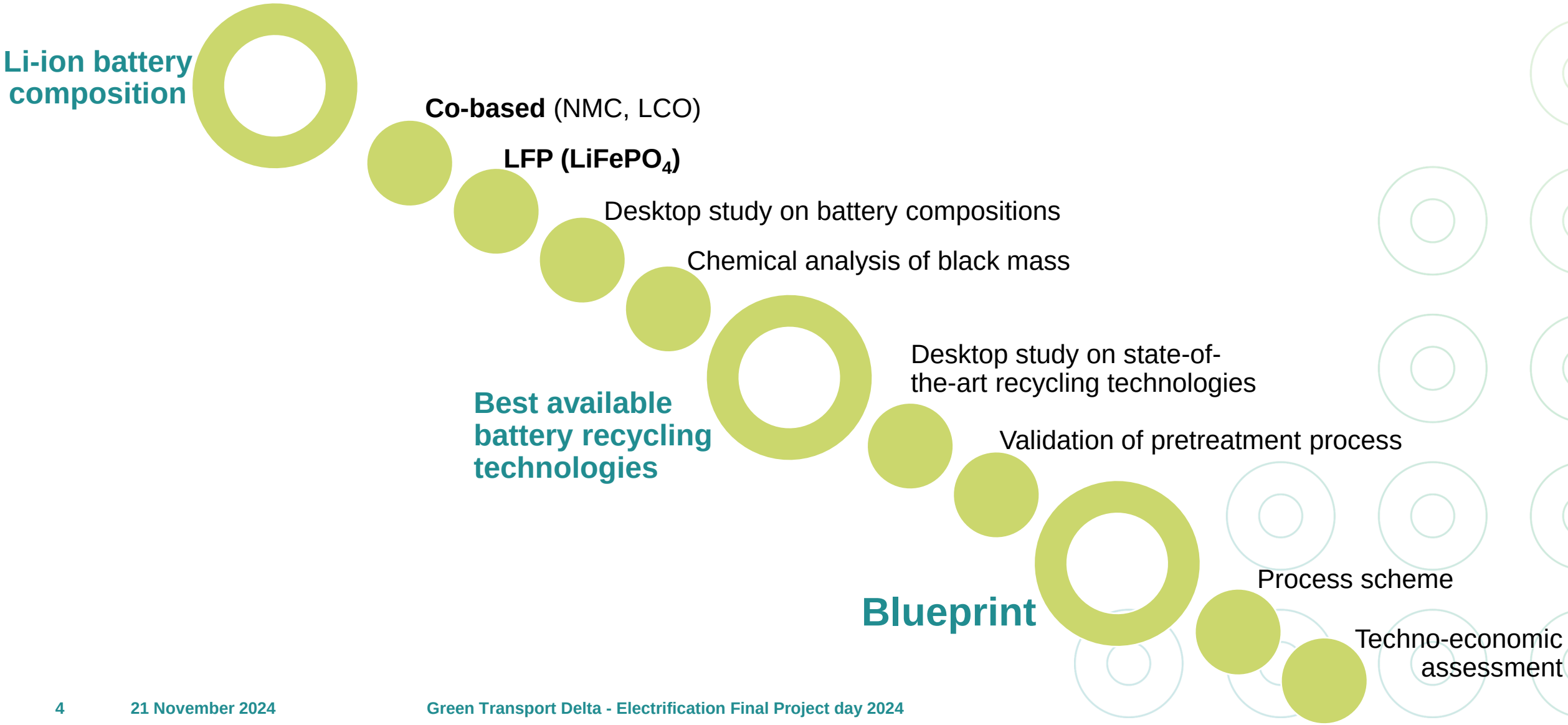
ACCUREC	Krefeld	4,000	
KYBURZ	Chemnitz	200	2,000 2025
Aurubis	Hamburg	X	
BASF	Schwarzheide		
Duesenfeld	Wendeburg	3,000	
ecobat	Hettstedt	20,000	
ERLOS	Zwickau	3,500	
Mercedes-Benz	Kuppenheim	2,500	
SungEel HiTech	Gera-Cetzschwitz		
Redwood Materials	Bremerhaven	10,000	
Roth International	Wernberg-Köblitz	9,000	
CYLIB	Aachen	120	7,500 2026
tozero	München		90,000 2027
Li-Cycle	Magdeburg	10,000	30,000 20XX
Walch	Baudenbach	X	
Primobius	Hilchenbach	20,000	
northvolt	Heide		X 20XX
Nickelhütte Aue	Aue	7,000	10,000 20XX
fortum	Kirchardt	3,000	
RE.LION.BAT.	Meppen	20,000	
Pure Battery	Hagen	2,500	15,000 20XX

Poland

SungEel HiTech	Bukowice	X	
Royal Bees	Legnica	3,600	
elementa	Zawiercie	X	

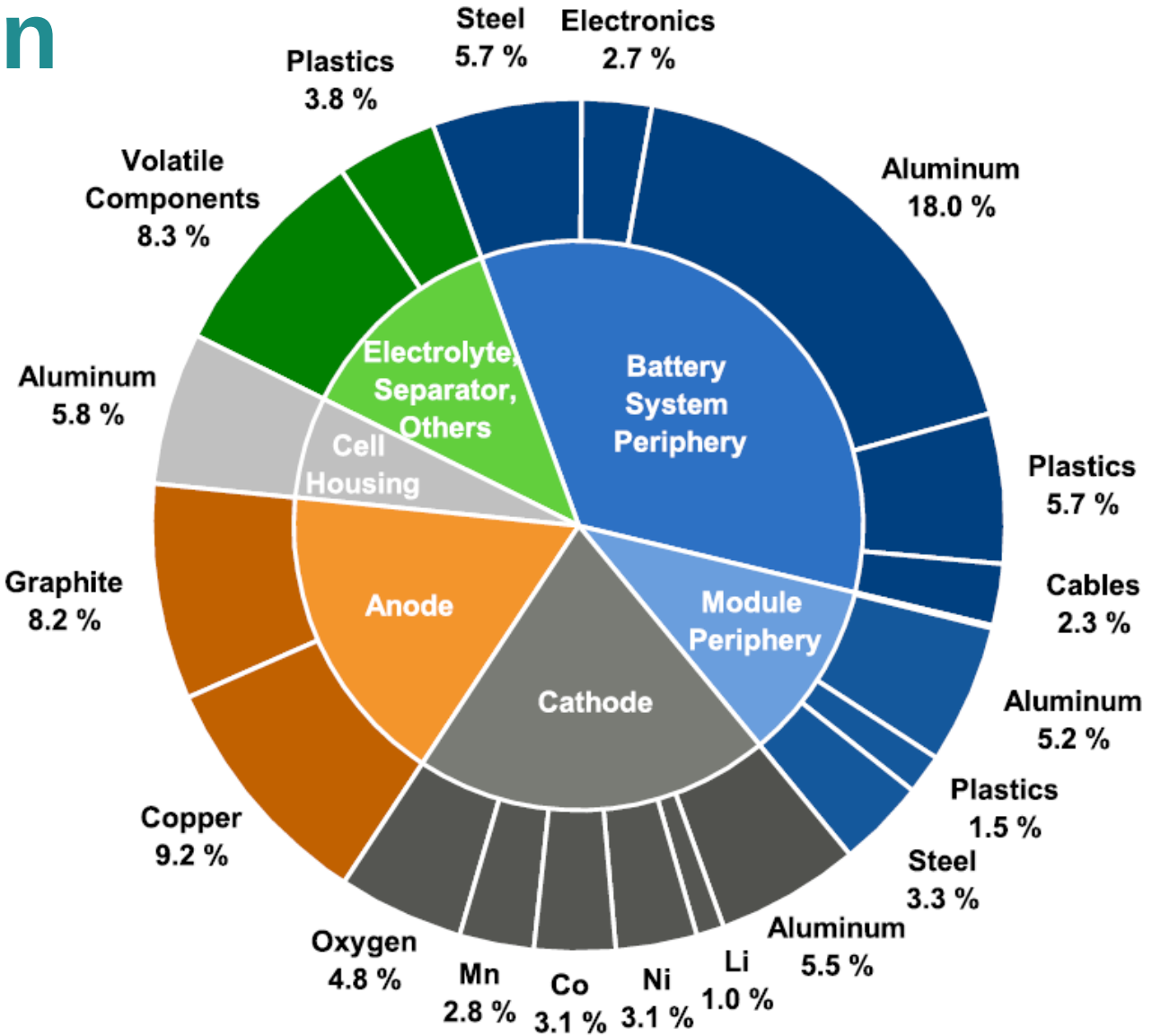
Authors: Natalia Soldan & Dr, Heiner Heimes (PEM RWTH Aachen University)

Battery recycling in context



Battery Composition

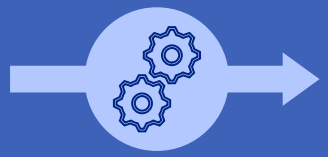
Generic composition Li-ion
NMC111 chemistry



Diekmann et al., 2017

Scope – recycling technologies

Pre-treatment



Large impact on input materials and further processing

Pyrometallurgy

\+ Flexible

– High-energetic process

– Low and limited recovery, merely Ni and Co

– High emissions

Hydrometallurgy

+/- Specific to battery type, limited flexibility

\+ Lower environmental impact

\+ Selective dissolution and extraction

\+ High recovery rates

Direct recycling

– Specific to battery type, no flexibility

\+ Low environmental impact

– Lower quality metal oxides → lower battery performance

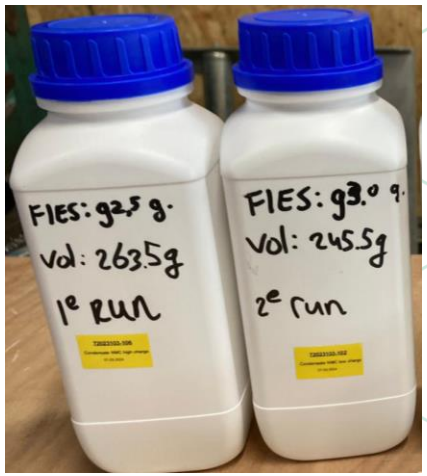
Pretreatment

- Sub-contractor Future Recycling Technologies (FRT)
- Shredding charged batteries, 50 kg/h scale
- Benchmark process:
  25 kg charged NMC in casing batteries

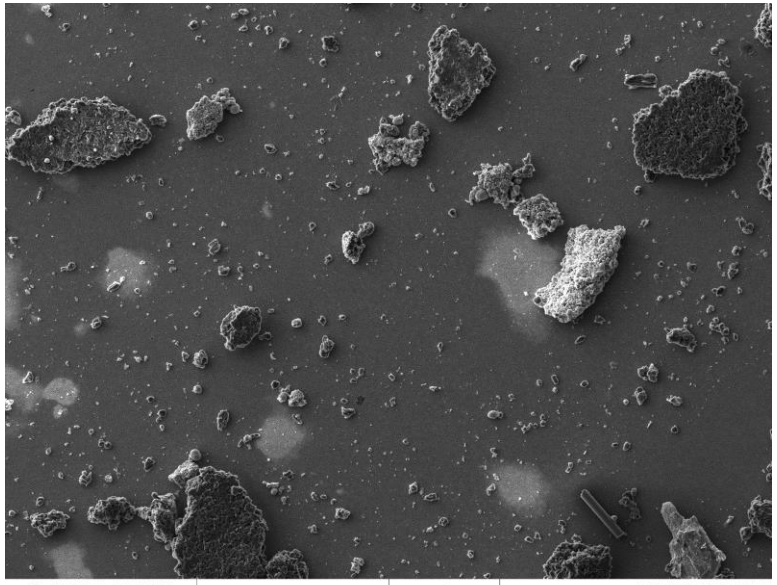
Input batteries

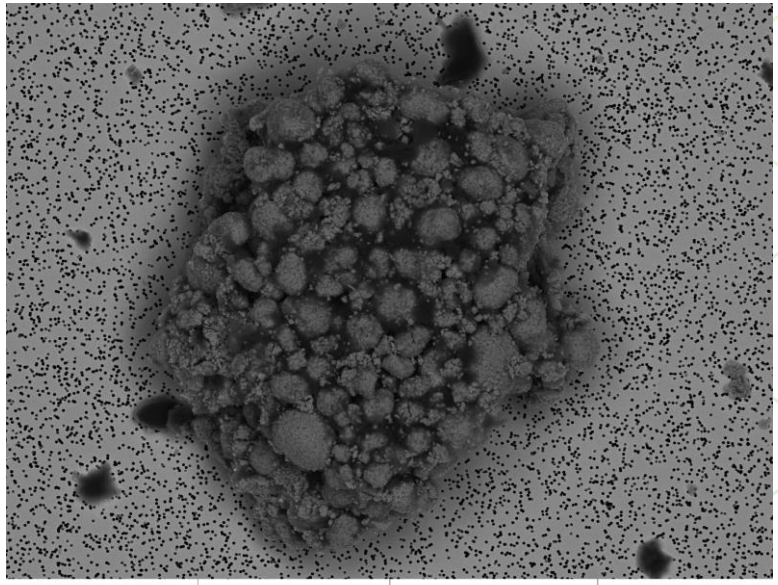
Shredding and separation

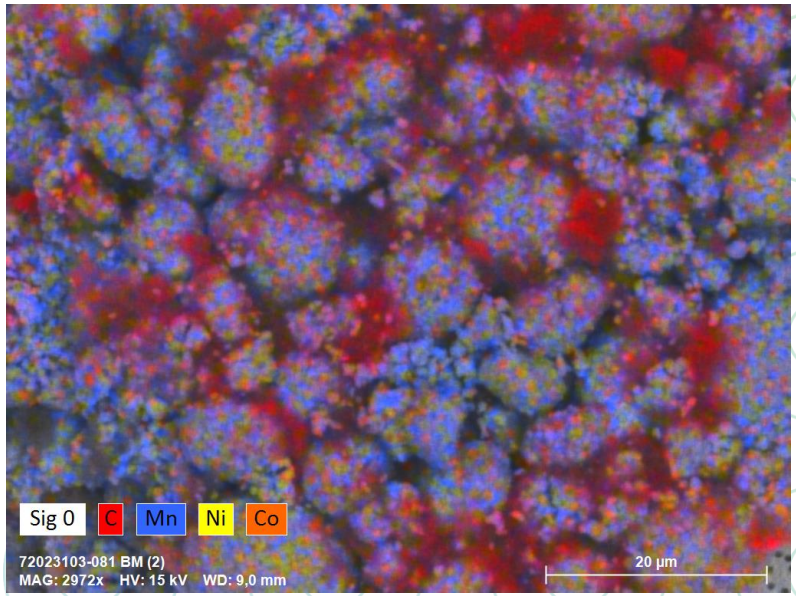
Output materials



Materials are displayed today, come and have a look!







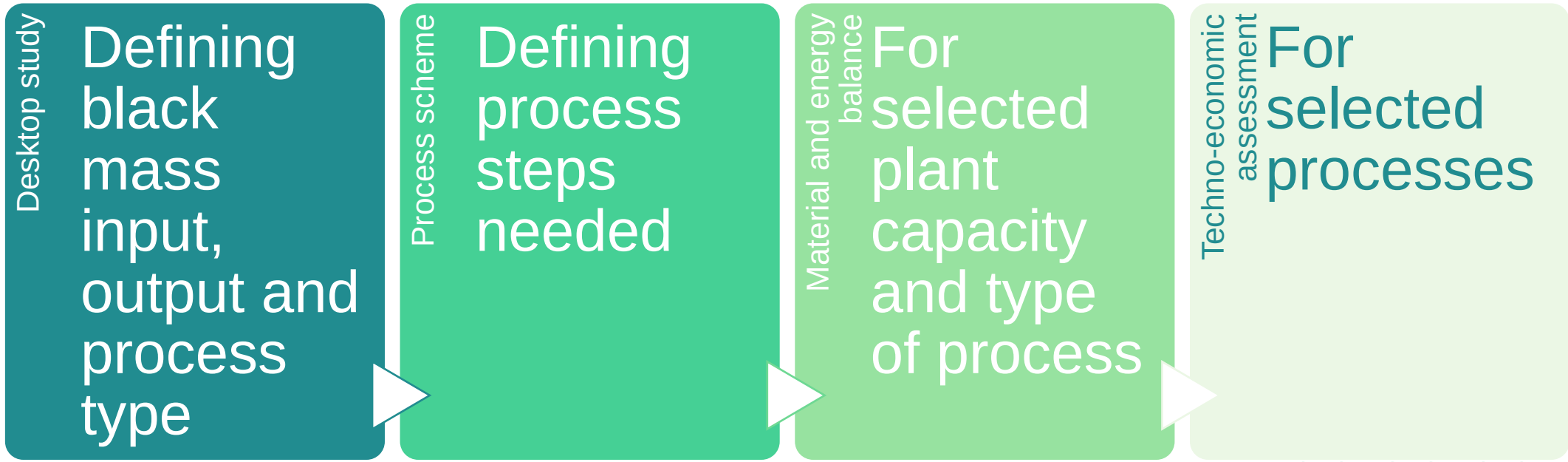
Materials are displayed today, come and have a look!

Results

Validation and optimization of battery pre-treatment process: shredding of batteries and separation of materials

- Good mass balance: 97 – 99 % of input mass accounted for
- Black mass recovery efficiency: <50% cathode active materials recovered in black mass
  - separation coarse materials to be improved
- Electrolyte removal efficient for NMC and NCA, not so much for LFP
  - high boiling point
  - more electrolyte present (up to 30% instead of ca. 10% for Co-batteries)
  - bigger packs shredded
- Suggestions for optimization
  - better separation of electrolyte
  - optimize sieve size

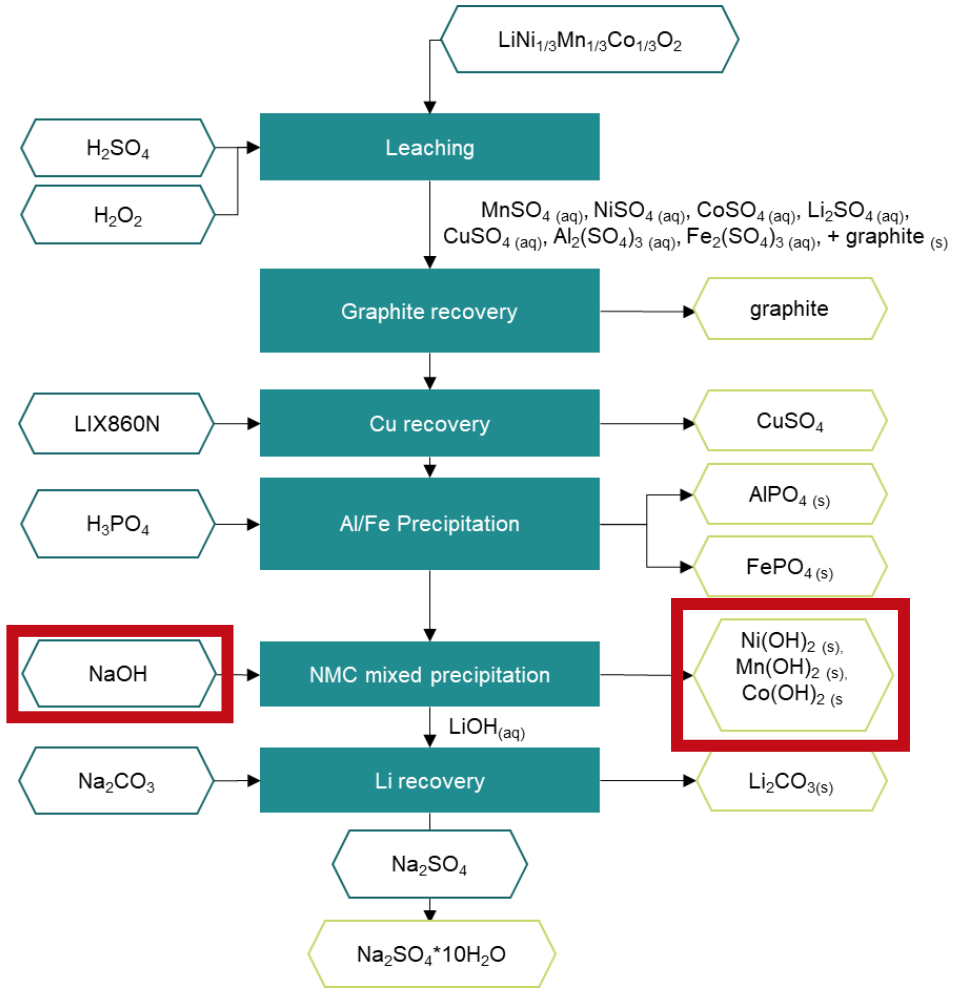
Approach to a blueprint

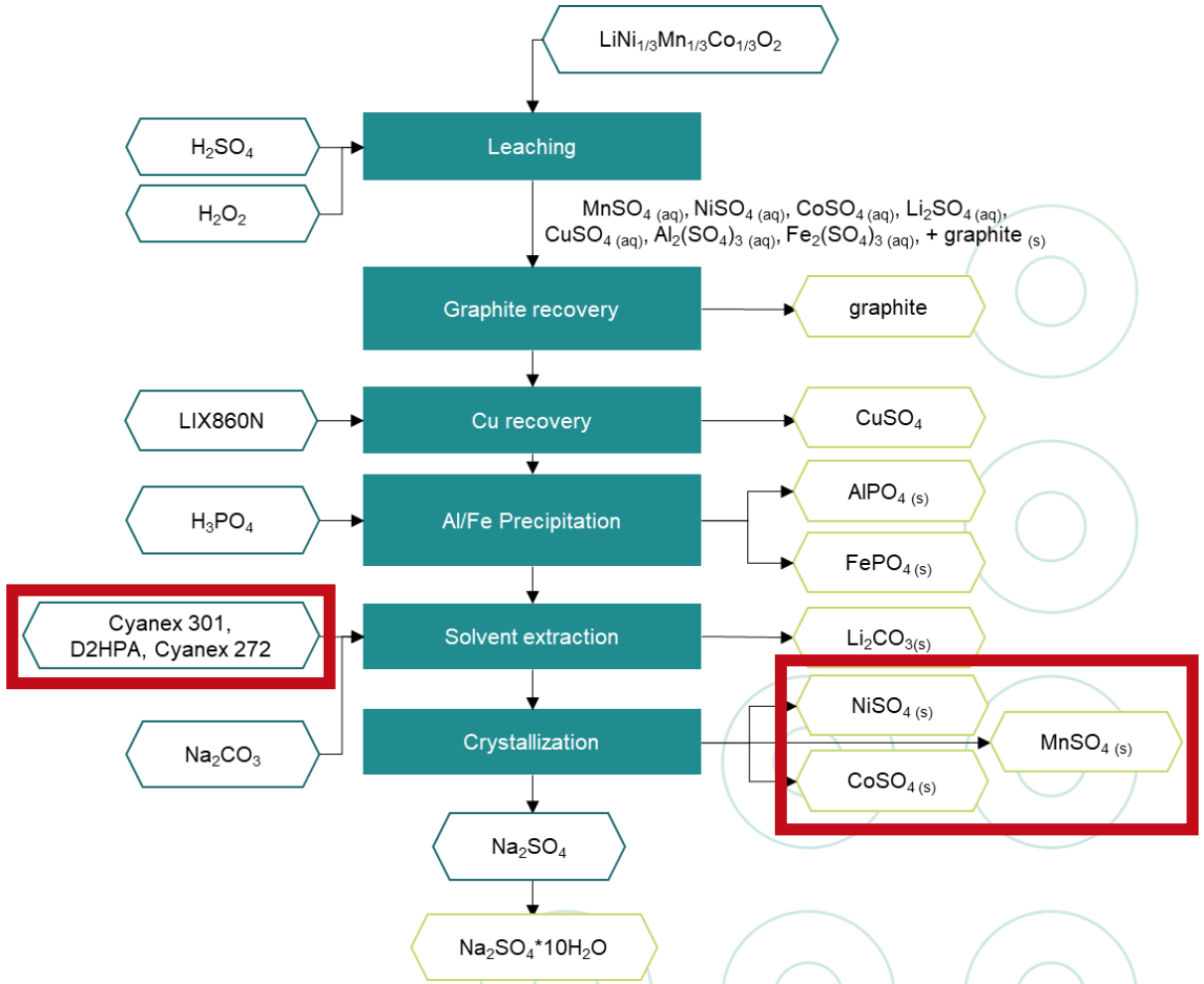


Some assessment administration

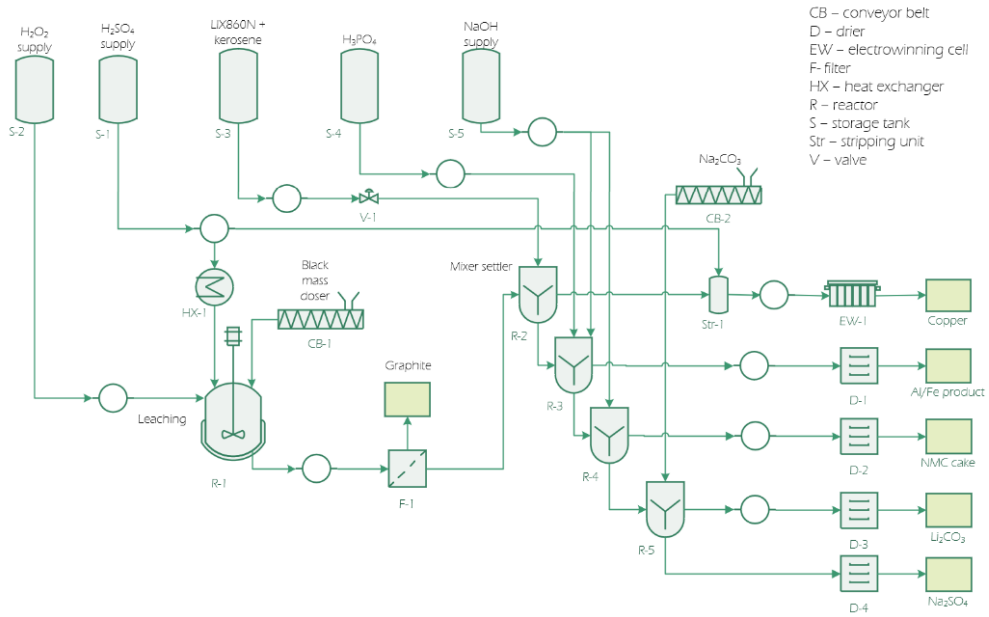
- Process capacity: 6 kt black mass per year
- Operational hours: 8000
- In scope:
  - chemical processing of black mass (leaching, recovery of CAM and non-CAM materials)
- Out of scope:
  - pretreatment of batteries
  - waste water treatment
  - recovery of solvents
  - additional refining processes

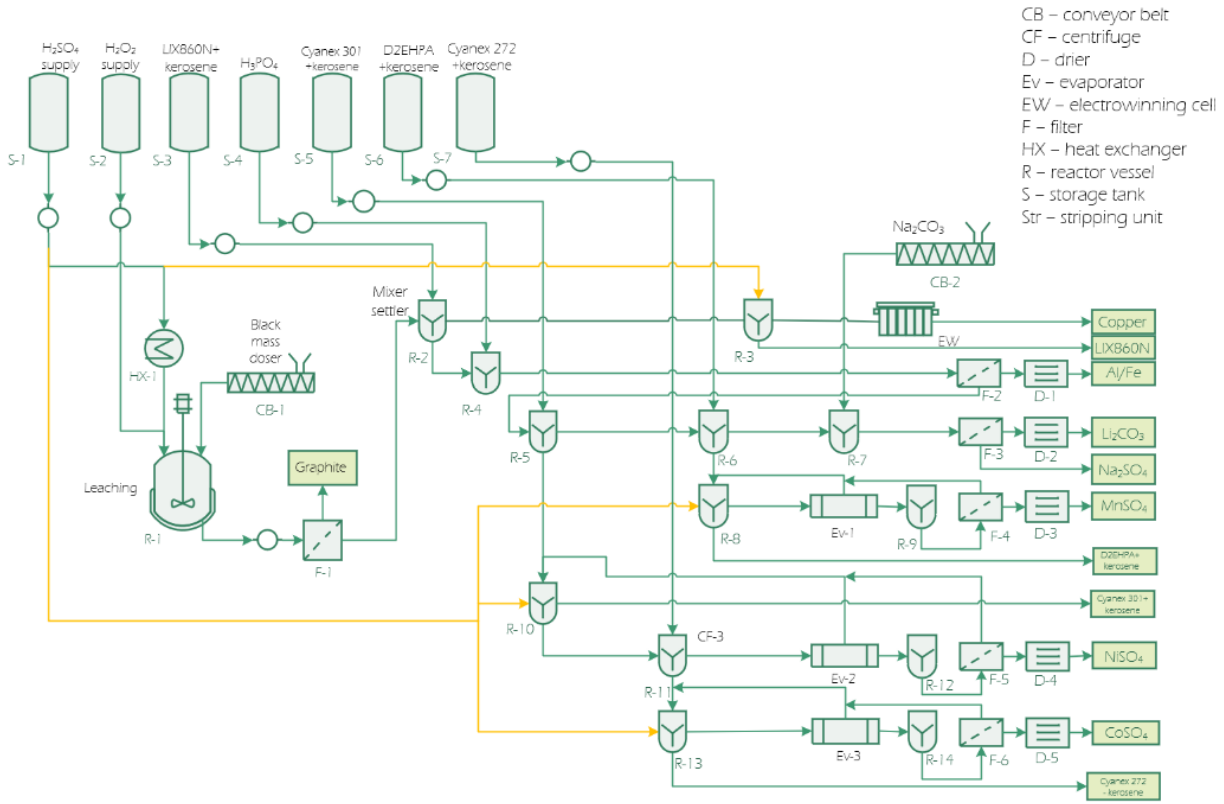
Two processes: similar at first sight…





… but it’s all in the details

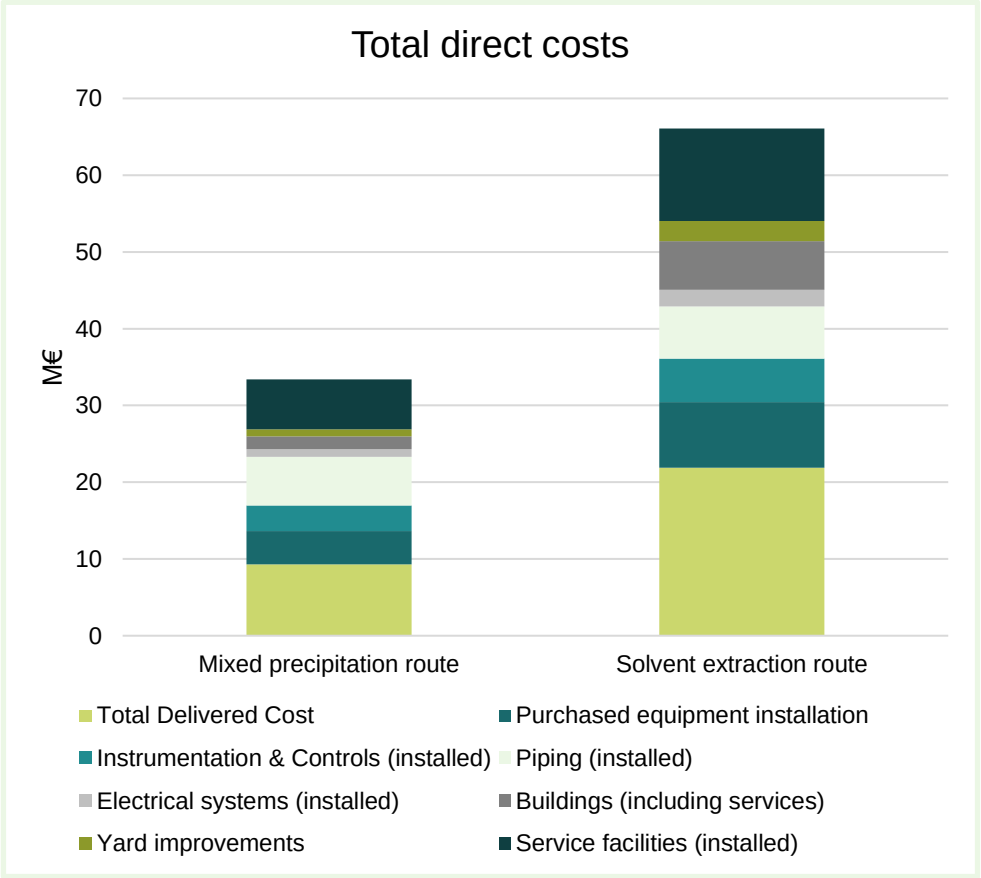




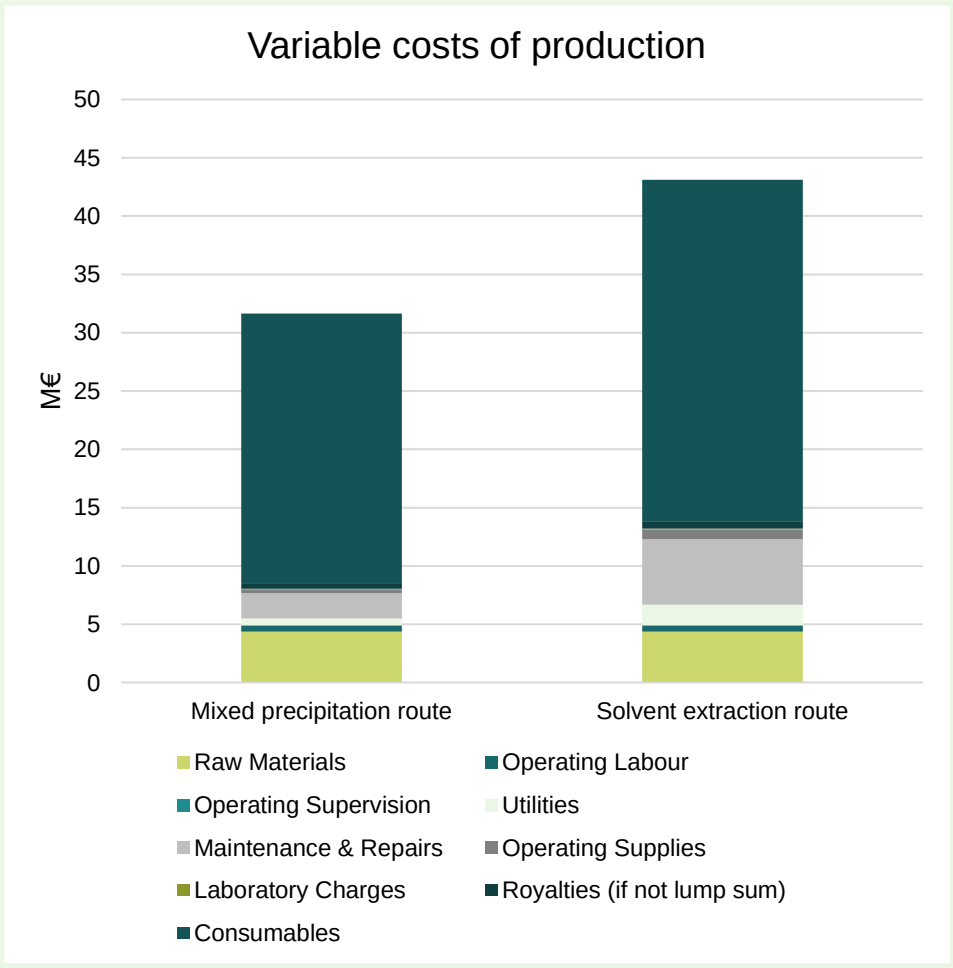
Investments for SX-process significantly higher than for MP-process

Recovery of graphite, aluminium, iron and copper equal for both processes

→ Additional costs all due to SX-process steps and additional recovery and drying equipment



Impact on operational costs is limited



Recovery of graphite, aluminium, iron and copper equal for both processes

Efficient recovery of SX-solvents results in limited additional cost for consumable

→ Separation processes and separate recovery of Co, Ni and Mn requires significant more energy:

Type	Mixed precipitation	Solvent extraction
	Power [kW/kg feed]	
Heating	3.52	23.17
Cooling	2.15	22.55
Electricity	0.16	1.15

Conclusions

- TEA shows significant differences in investments and utility requirements: balancing act of investment and operational costs vs. product quality
- Current TEA does not include waste treatment, while costs relating to consumables and utilities are already relatively high
- Opportunities for development of innovative technologies:
  - processes operating at room temperature
  - regeneration of consumables
  - electrification where possible

TNO innovation for life

All reports available on TNO.nl

Thank you for your attention

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