Kemian osaaminen vihreän siirtymän ja kiertotalouden vauhdittajana

(TIA) Professori Ulla Lassi

Oulun yliopisto, Kokkolan yliopistokeskus Chydenius

7.10.2023

UNIVERSITY OF OULU

Battery chemistry research since 2007

Sustainable Chemistry Research Unit

Prof. Ulla Lassi, head of the Unit

FACTS (2021):

Staff: 53
3 Full professor, 5 adj. prof., 17 post docs
Degrees: 15-20 M.Sc., 3 Ph.D.
14 public research projects (BF, AF, EU funded)
Over 40 international publications, 3 pending patents
Close company collaboration
Disciplines in material chemistry, physical chemistry and chemical engineering

RESEARCH FOCUS AREAS IN APPLIED CHEMISTRY (Scientific results during past years)

I.	Lithium-ion battery chemicals Metals recovery, leaching, and co-precipitation	(5 PhD, 6 PhD students, 20 M.Sc., publ.,)
II.	New inorganic water treatment chemicals	(6 PhD, 6 PhD students, 10 M.Sc., 30 publ)
III.	Inorganic catalysts in biomass conversion	(5 PhD, 4 PhD students, 6 M.Sc., 15 publ.)
IV.	Carbon materials as catalysts and energy storage	(3 PhD, 3 M.Sc., 20 publ.)

www.oulu.fi/sustainablechemistry

Research unit of Sustainable chemistry

FACTS (2022):

Staff: 54

4 professors, 7 senior researchers, 17 post docs

Degrees: 15-20 M.Sc., 3 Ph.D.

14 public research projects (BF, AF, EU funded)

Over 60 international publications

5 pending patents/invention disclosures

Close company collaboration

Kokkola Industrial Park (KIP), www.kip.fi, the largest hub of inorganic chemical industry in Northern Europe. Close research collaboration with the university.

www.oulu.fi/sustainablechemistry

Vihreä siirtymä

BIOPOLTTOAINEET FOSSIILISTEN POLTTONESTEIDEN KORVAAJINA (biobensiini, biodiesel, uusiutuva diesel)

KAASUAUTOT (maakaasu, biokaasu)

©Keliber Oy

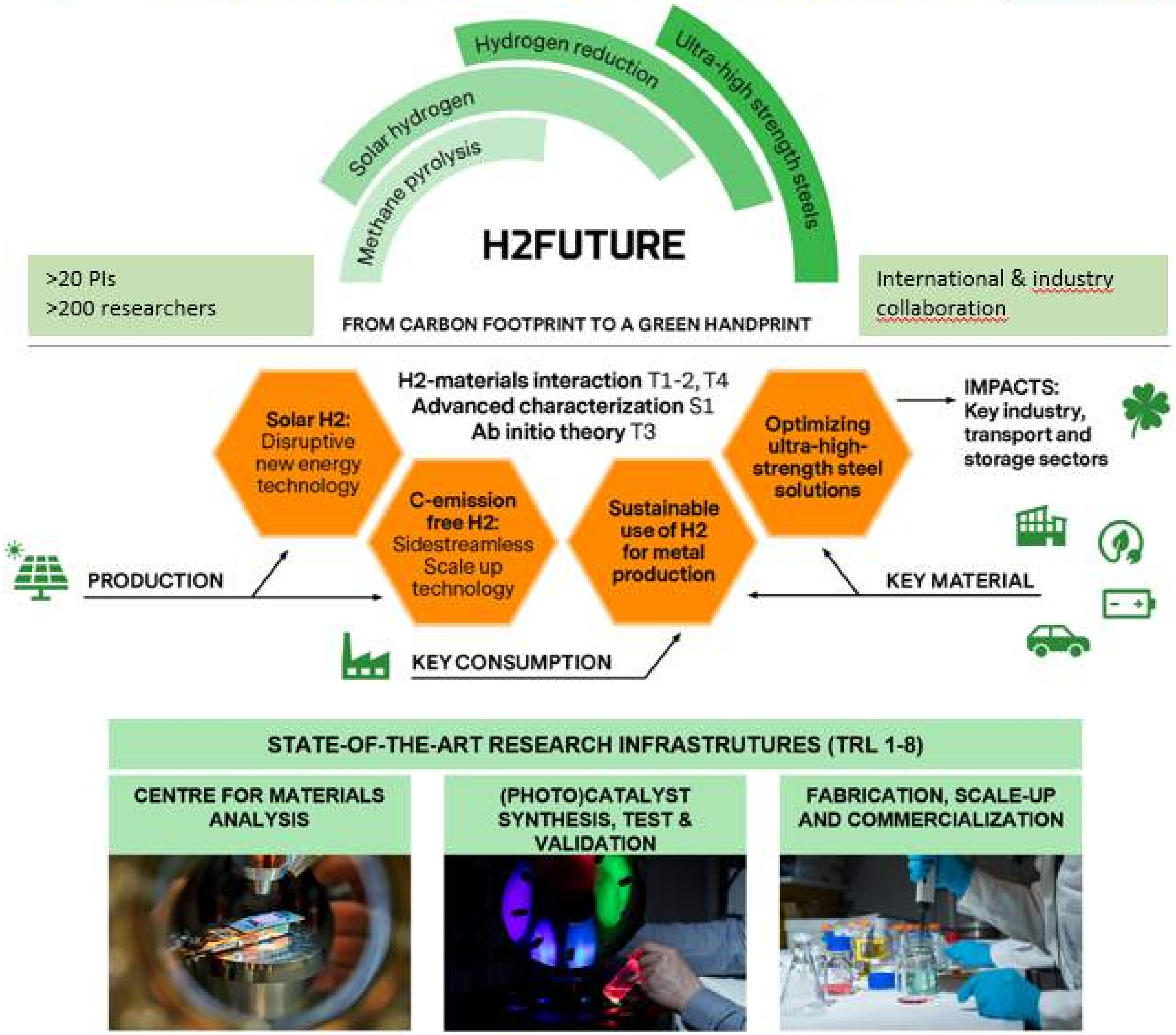
HYBRIDIAJONEUVOT (kaksi vaihtoehtoista energialähdettä)

POLTTOKENNOLLA VARUSTETUT VETYAUTOT

LITIUMIONIAKULLA VARUSTETUT SÄHKÖAUTOT

Vetytalous osana vihreää siirtymää

H2FUTURE - Multidisciplinary Research and Education as a Foundation of the Green Transition



- National profilation project **H2FUTURE** 2023-2028
- CO_2 free and energy efficient H2 production methods: ***solar H2 and (bio)methane pyrolysis***
- Energy materials research: electroceramics
- Solar panels and nanocoatings
- Coordination of Hydrogen Research Forum Finland (9 research organization members): Research based view on hydrogen transition
- **National graduate school on H2 transition under construction**
- I4WORLD EU-Horizon MSCA docotoral program focusing on UN SDG themes
- Offering courses on energy technology and systems, **minor** on sustainable development
- Open university and continuous learning, **education on H2 transition** (FiTech) and UNIC collaboration

I4WORLD UNIVERSITY OF OULU
Co-funded by the European Union
erc
BUSINESS FINLAND
SUOMEN AKATEMIA

Hydrogen roadmap – Sustainable chemistry

2008-2015

FT synthesis
Catalytic conversion of biomass-derived synthesis gas to olefins/FT diesel

Collaboration with LTU & NTNU

PhD thesis Romar 2015
PhD thesis Tuomikoski 2014

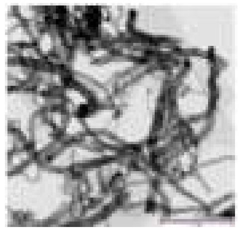
2015-2021

Methane pyrolysis to hydrogen and carbon

Carbon applications (activated carbon, carbon foams, carbon catalysis)

Carbon use in batteries

Hydrogen reduction (with MET)

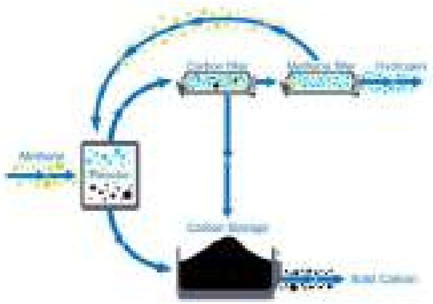


PhD thesis Bergna 2019
PhD thesis Kupila 2021
PhD thesis Varila 2020

2022-

Improved material efficiency for **methane pyrolysis** (use of secondary materials)

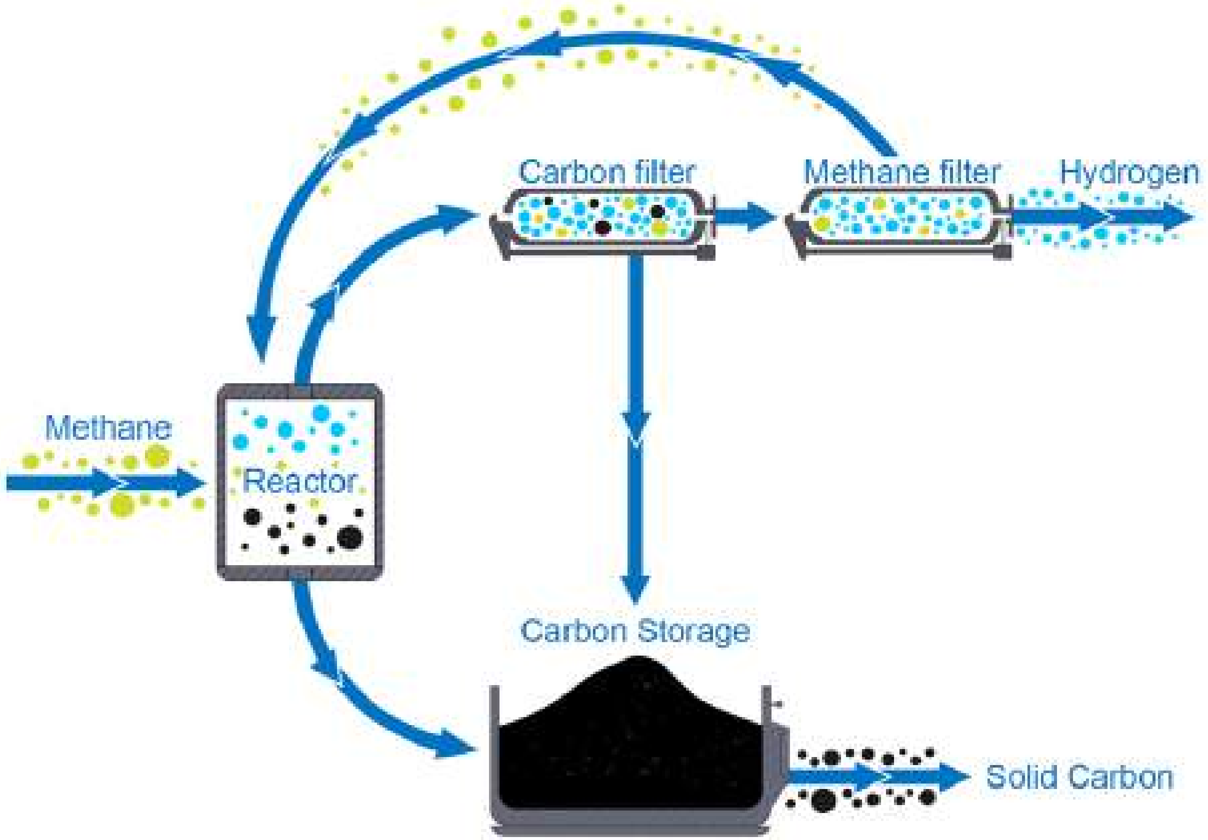
Hydrogen reduction in metallurgical industry (with MET)



Katalyyttinen metaanipyrolyysi

(Bio)methane pyrolysis (in the presence of catalyst)

TRL3 -> TRL7



Several innovations behind this:

1) Use of CO_2/CO free technology
2) Catalyst
3) Reactor set-up
4) Solid carbon for energy storage applications

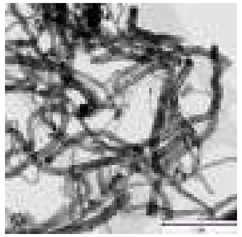
hycamite

Sustainable Carbon as a secondary product supplementing the sales

PRODUCTS

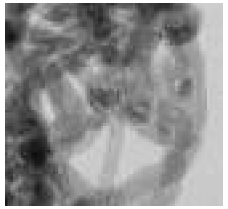
- Carbon nanotubes (CNT)
- Carbon nanofibers (CNF)
- Amorphous carbon → activated carbon
- Graphite

CNT, CNF



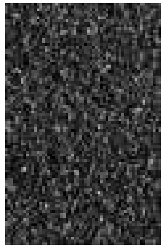
- Battery industry
- Electric vehicles (supercapacitors)
- Catalysts

Graphite



- Battery industry
- Lightweight materials for automotive and aerospace industry

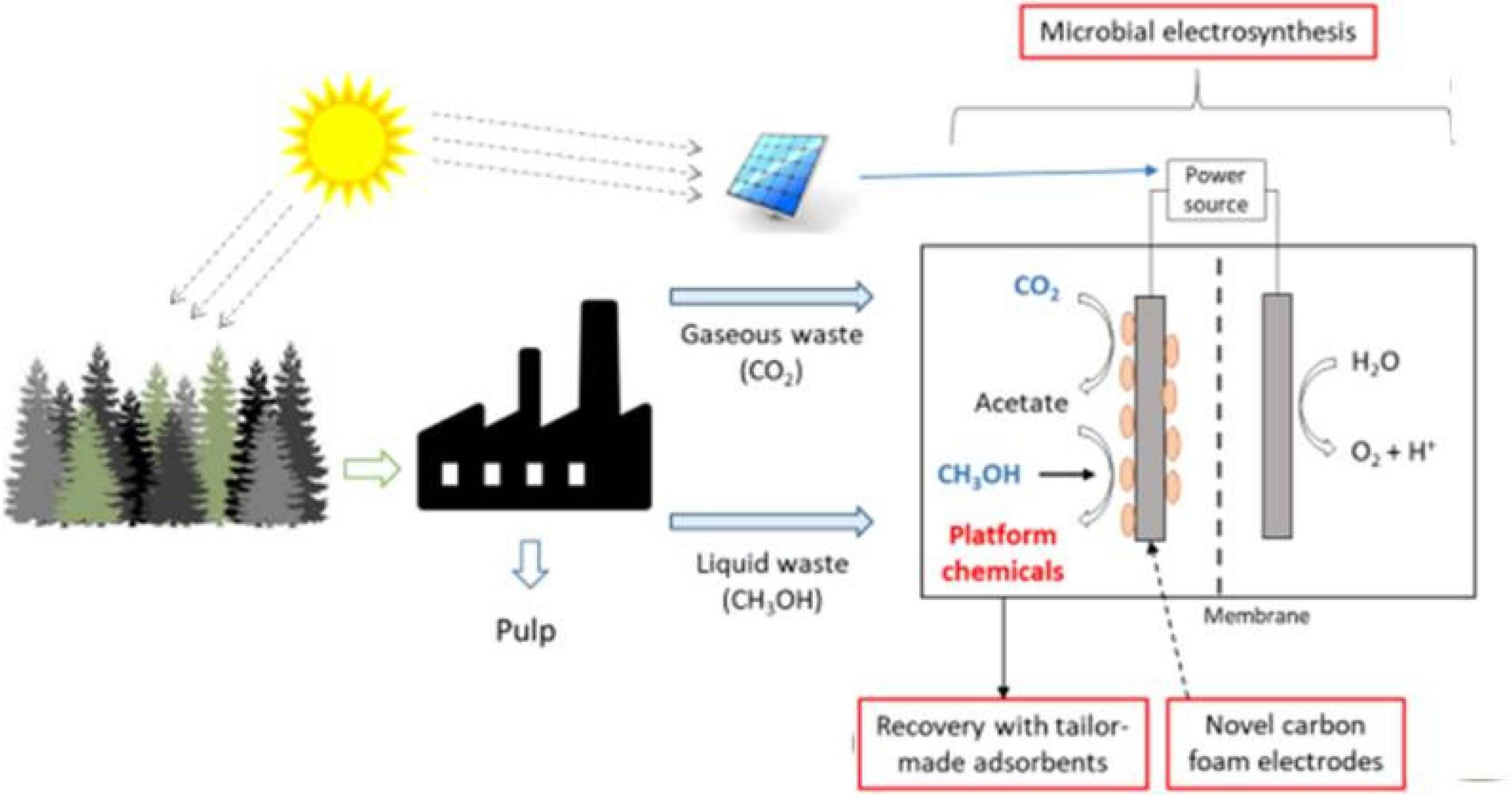
Activated carbon



- Water treatment
- Pharmaceutical purification
- Industrial applications

hycamite

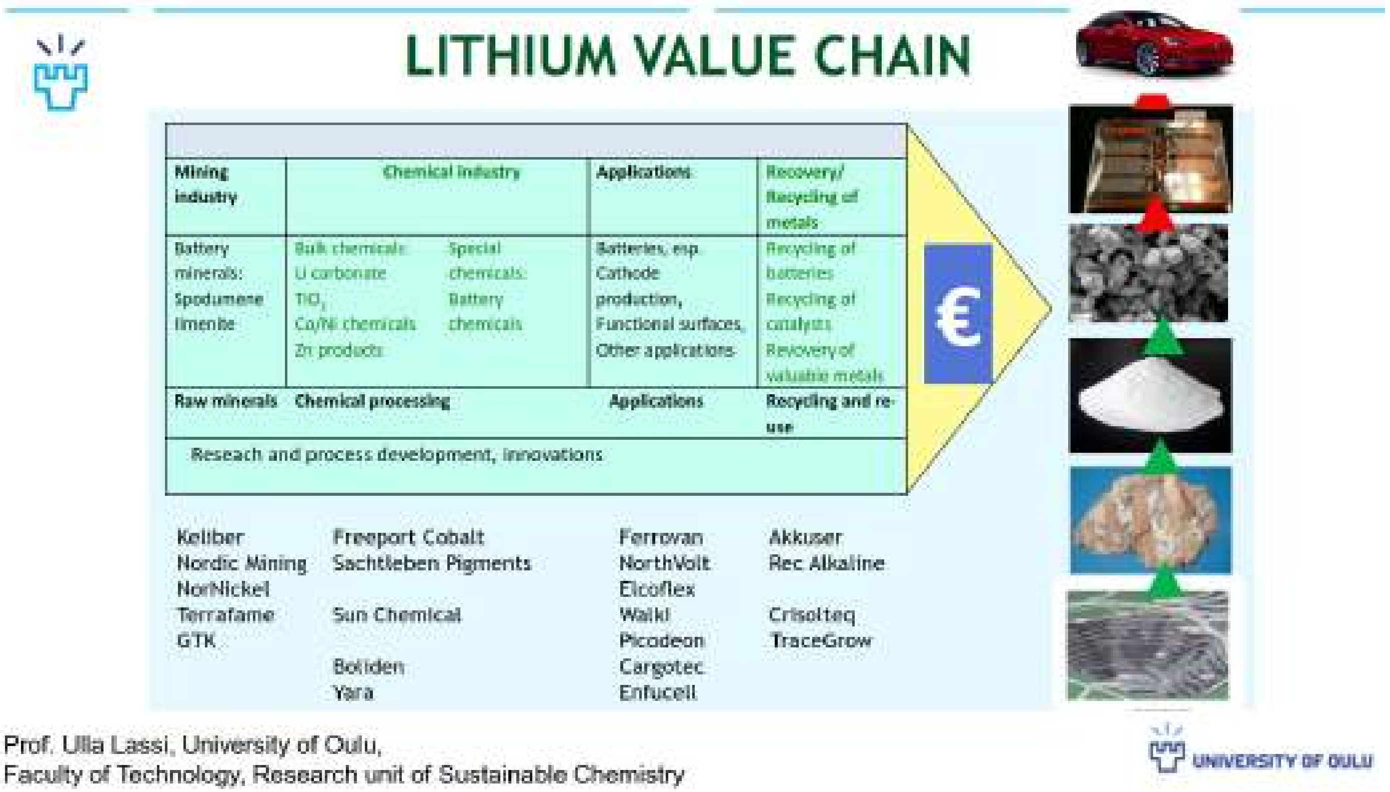
General project idea of CO_2MetMes

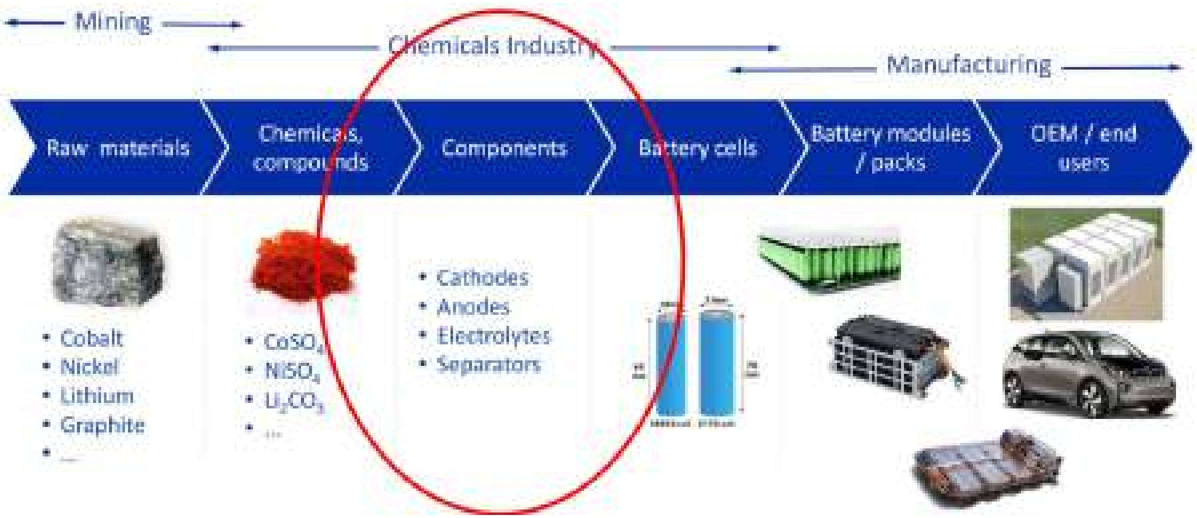


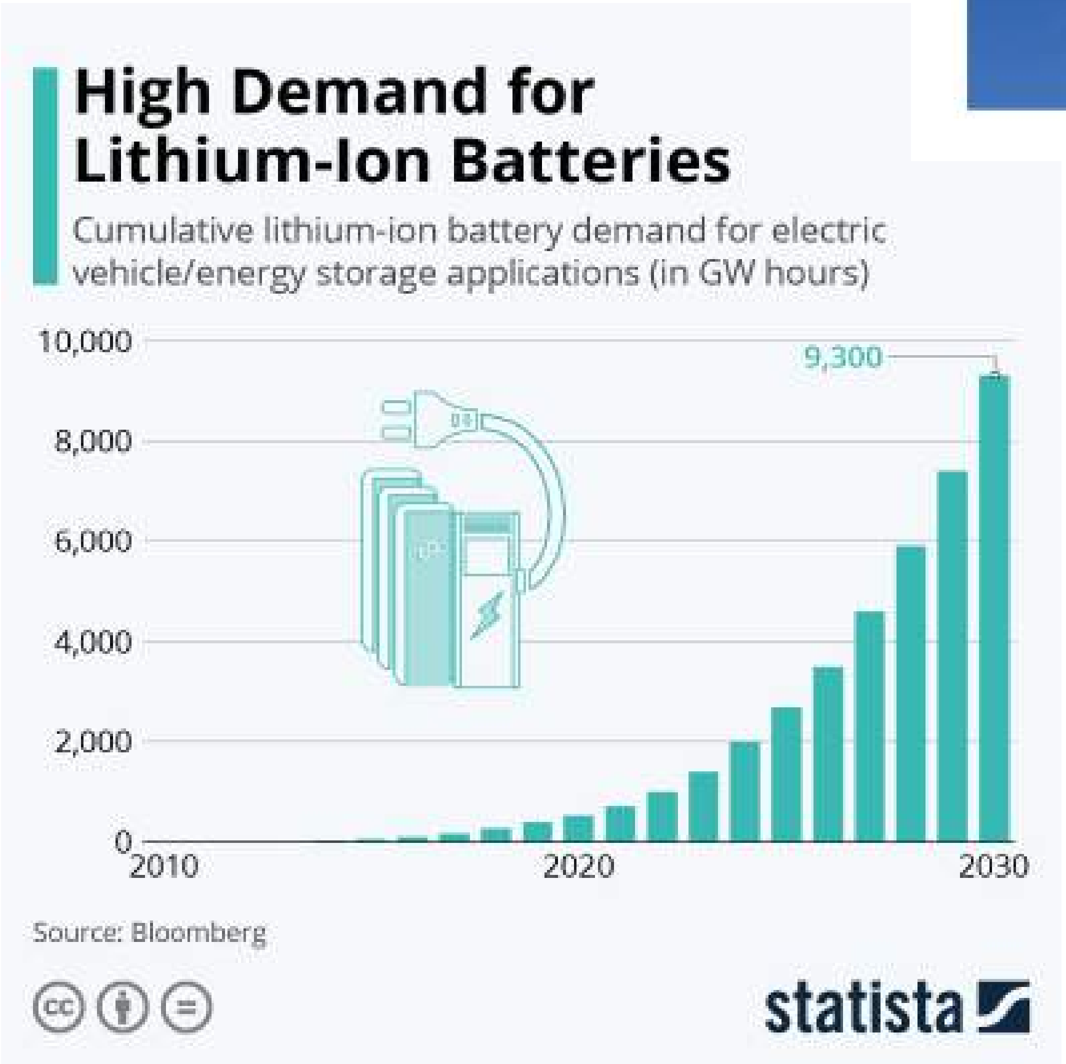
Main aim: Establish a bioelectrochemical technology for the conversion of CO_2 and methanol into platform chemicals. The integration of novel side stream based carbon catalysts and inline product extraction will enable high production rates of fatty acids.

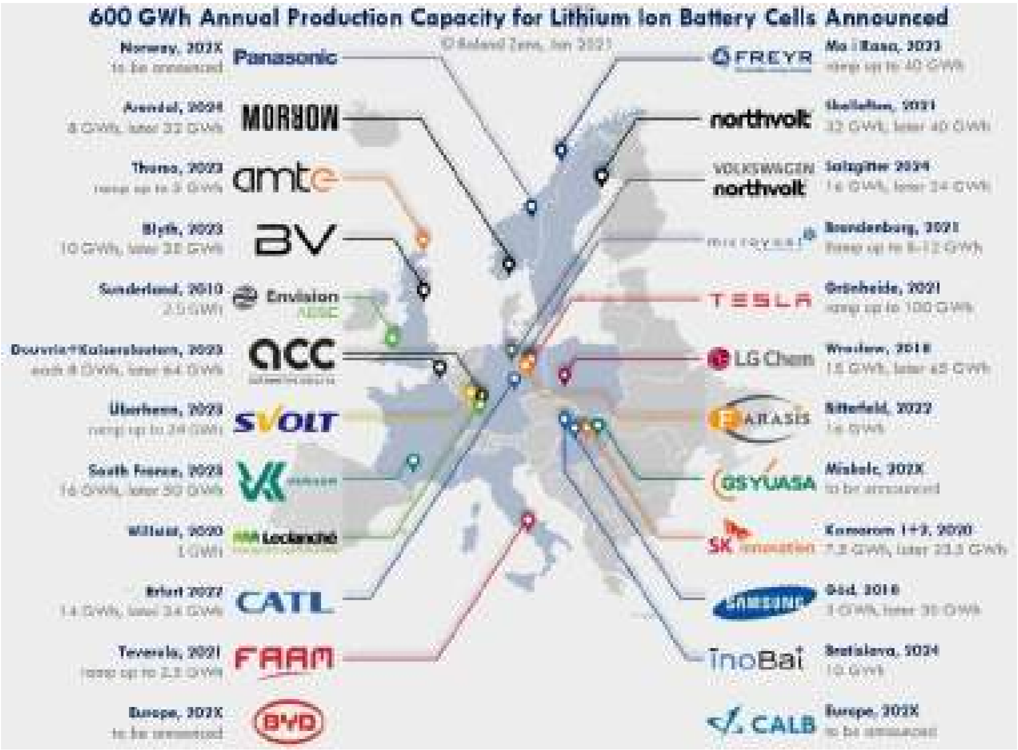
Energianvarastointi (akut) osana vihreää siirtymää

Akkuarvoketju





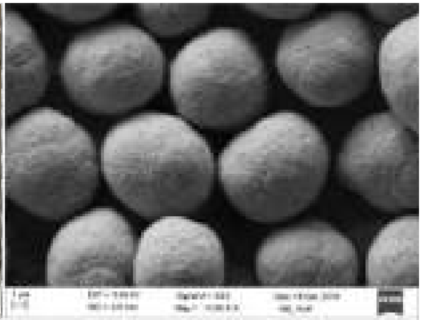




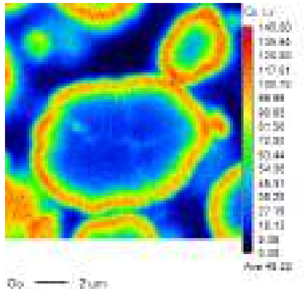
https://www.orovel.net/insights/li-on-battery-gigafactories-in-europe-june-2021

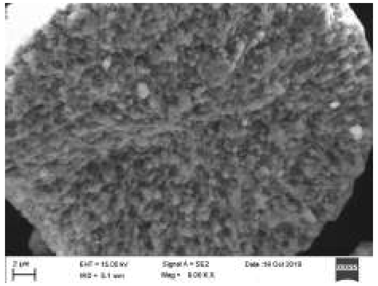
Overview of research competence and activities in the field of batteries (University of Oulu)

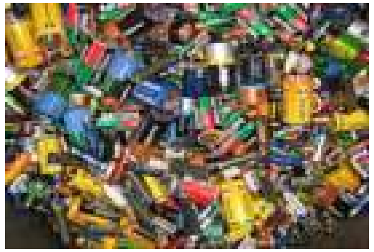
Co-precipitation of high-nickel precursors or lithium-rich cathodes



Improved characterization tools for solid precursors and electrodes

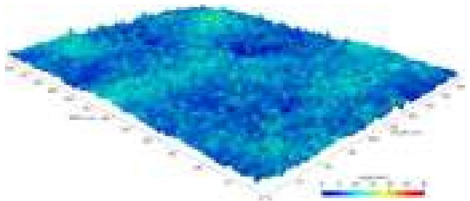






Improved lithiation processes for high-nickel NMCs, precursor effect on lithiation, role of washing, wet/dry lithiation

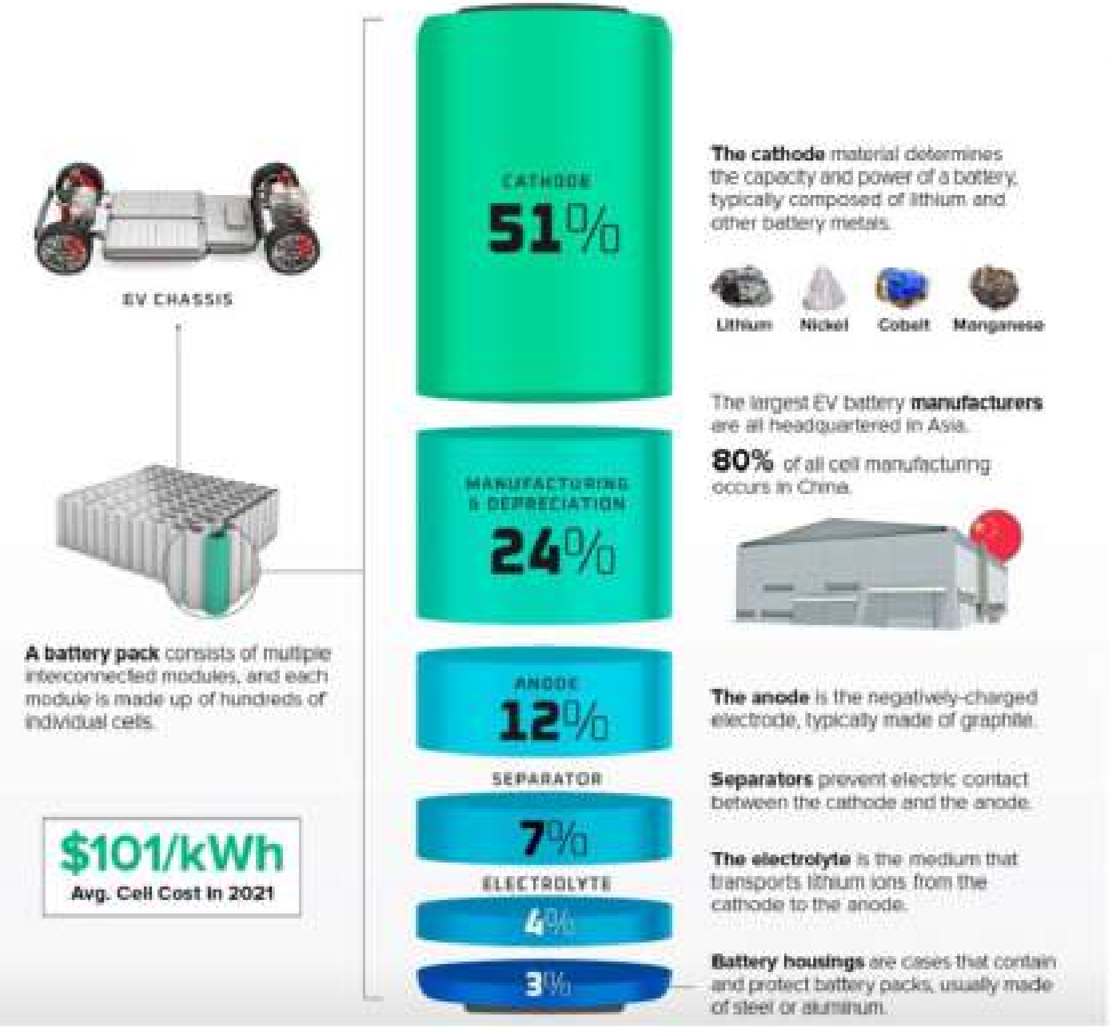
Use of secondary material flows in co-precipitation, role of impurities, reuse of sodium sulphate

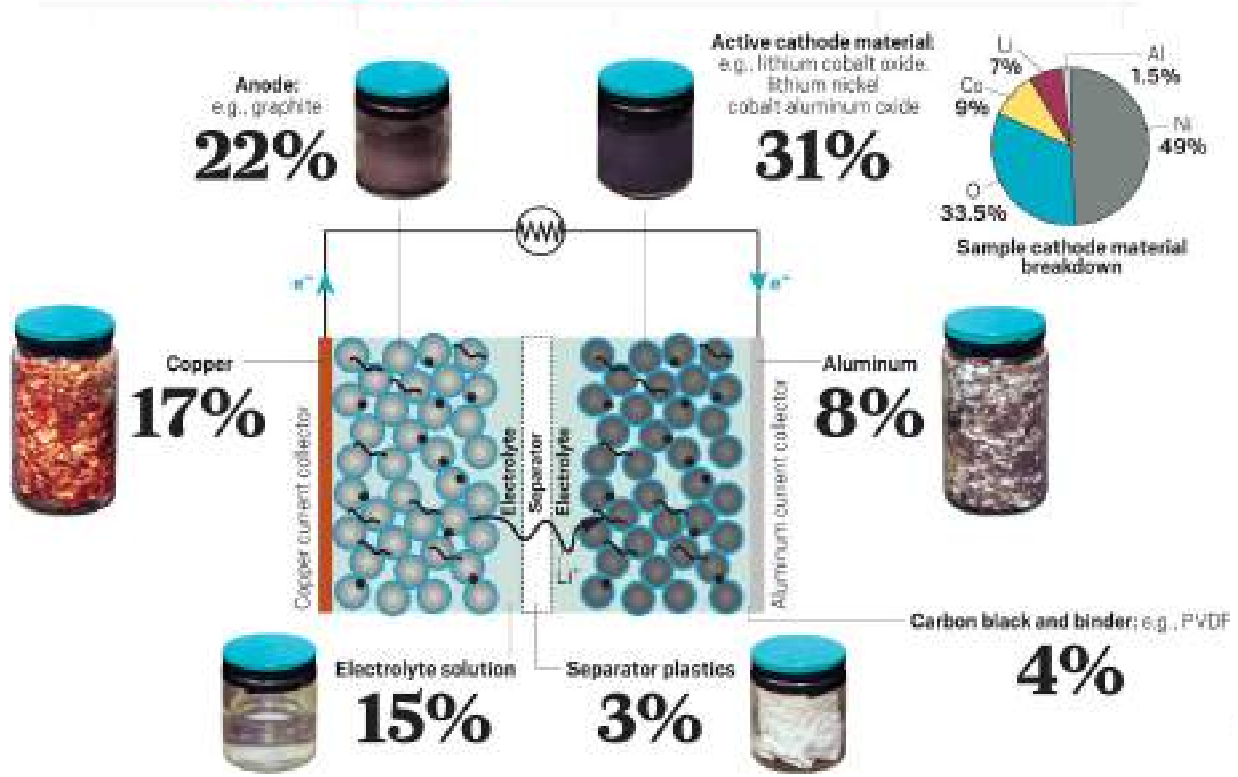


Sustainable pouch cell assembling
-new approaches to material-efficient coating
-use of greener solvents, additives and binders

Cathode materials - overview

Cathode	$LiNi_{0.5}Mn_{1.5}O_4$	$LiCoO_2$	$LiMn_2O_4$	$LiFePO_4$	$LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$
Energy Density (Wh kg^{-1})	650	518	400	495	576
Discharge Voltage (V)	4.7	3.7	3.9	3.4	3.7
Specific capacity (mAh g^{-1})	138	140	100	145	155





https://elements.visualcapitalist.com/

Kiertotalous osana vihreää siirtymää

ALKALIPARISTOJEN KIERRÄTYS – TEOLLINEN PROSESSI

https://www.paristokierratys.fi/blog/2021/01/20/kaytetyista-paristoista-kierratettiin-luomuviljelyyn-sopiva-lannoite/

Business Finland – ADCHEM 2016-2018

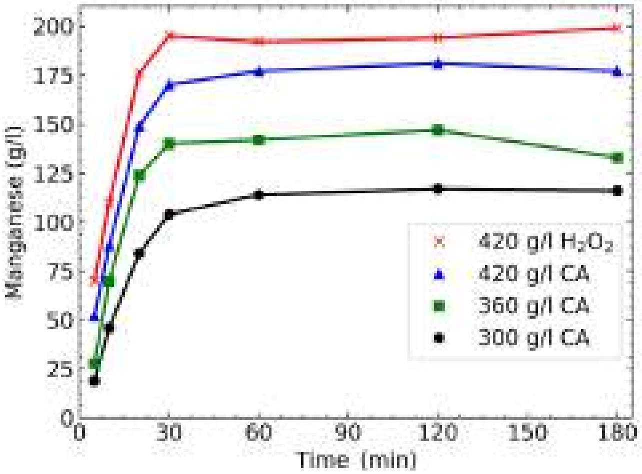
http://www.tracegrow.com/en/welcome

TEOLLISEN SIVUTUOTTEEN HYÖDYNTÄMINEN AKKUKEMIKAALEIKSI

RESEARCH UNIT OF SUSTAINABLE CHEMISTRY
UNIVERSITY OF OULU



Effect of S/L on manganese concentration at 60 °C.



Kauppinen, T; Vielma, T; Salminen, J; Lassi, U (2020) ChemEngineering 4 (2), 40. https://doi.org/10.3390/chemengineering4020040

https://www.boliden.com/sustainability/case-studies/purification-of-manganese-from-anode-sludge-at-kokkola

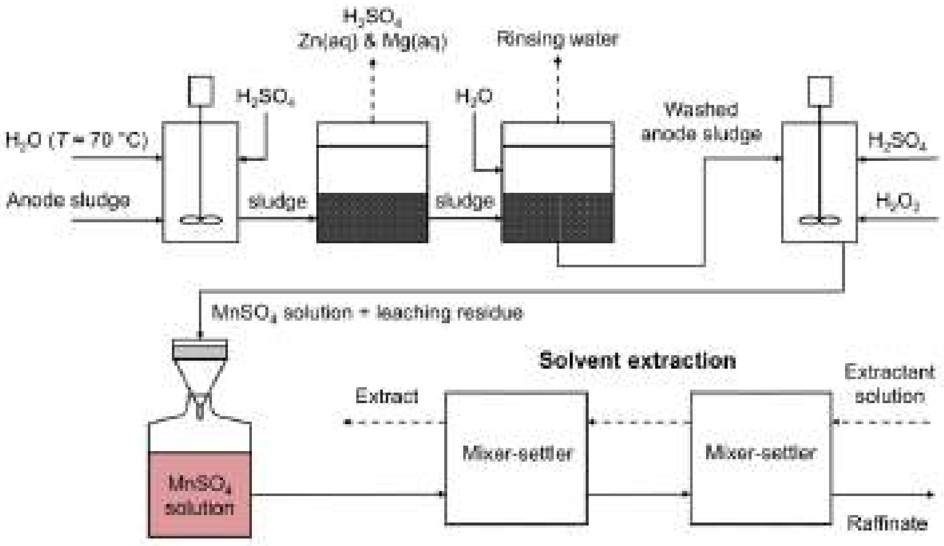
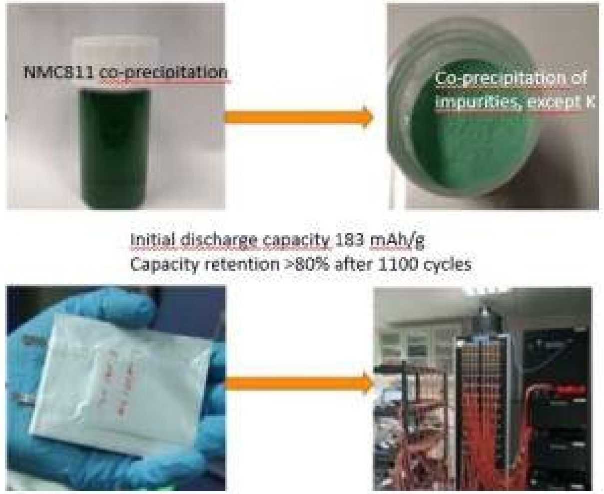


Fig. 1. Schematics showing the processing of the anode sludge in this study.

Jantunen, N.; Kauppinen, T; Salminen, J; Virolainen S; Lassi, U; Sainio T (2021) Minerals Engineering 173, 107200.



*T. Kauppinen, P. Laine, J. Välikangas, Dr. P. Tynjälä, Dr. T. Hu, Dr. J. Salminen, Prof. U. Lassi**

1 – 11

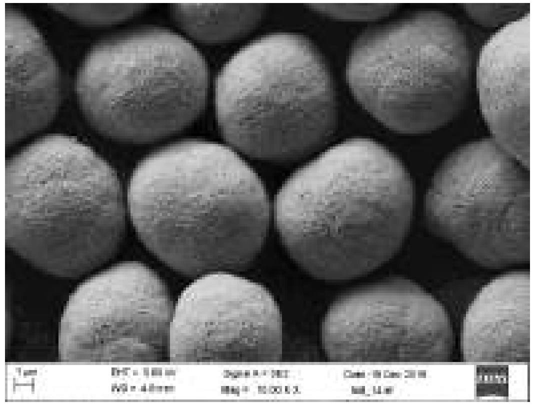
Co-precipitation of NCM 811 Using Recycled and Purified Manganese: Effect of Impurities on the Battery Cell Performance

Ovatko akut vihreää teknologiaa?

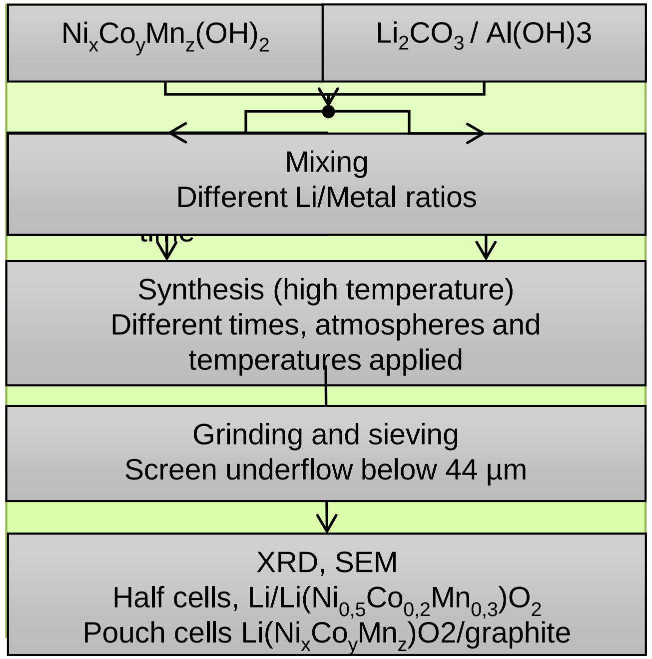
RESEARCH OF NCM CATHODE MATERIALS

Lithium mixed metal oxides $Li(Ni_xCo_yMe_{1-x-y})O_2$

360/40 mAh pouch cells

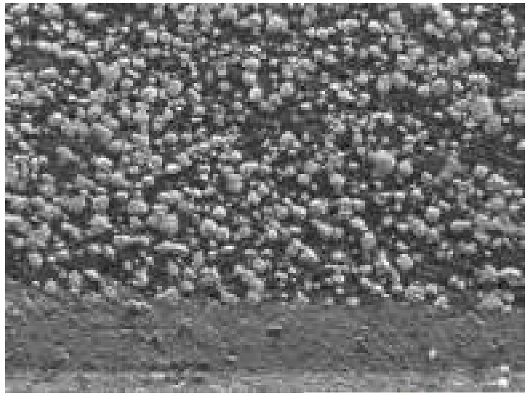


Co-precipitation



Solid-state synthesis of $Li(Ni_xCo_yMe_{1-x-y})O_2$ or lithium-rich compounds

Lithiation



Cell assembling

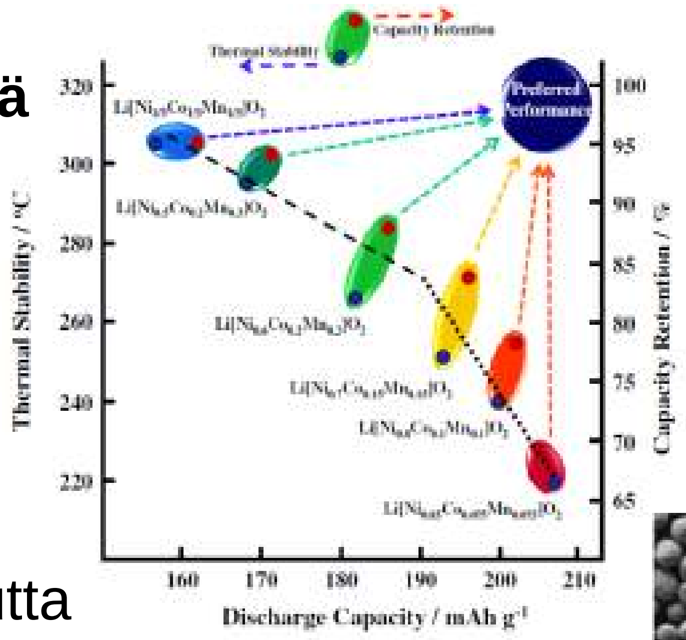
Researchers Pekka Tynjälä, Tao Hu, Marianna Hietaniemi, Yan Lin, Petteri Laine, Juho Välikangas, Eva Bozo, Toni Kauppinen, Palanivel Molayian, Immo Kervinen, Eeki Airola et al.

RESEARCH UNIT OF SUSTAINABLE CHEMISTRY

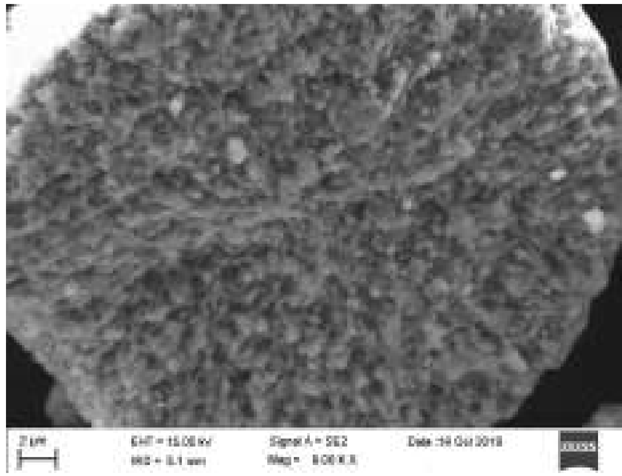
UNIVERSITY OF OULU

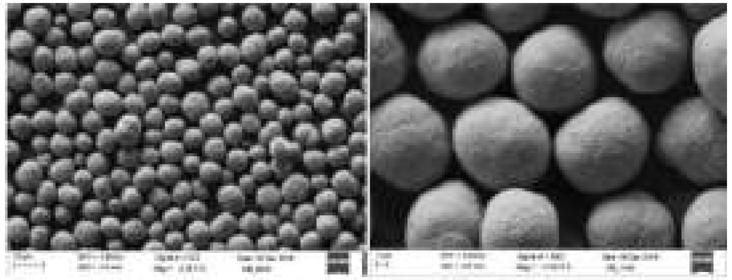
Kuinka parantaa kestävyyttä akkukemikaalien valmistuksessa?

- **Vähennetään riippuvuutta kriittisistä raaka-aineista (Co, grafiitti)**
- **Ratkaistaan haasteet liittyen muodostuvan nasun käsittelyyn**
- Parannetaan partikkelien morfologiaa (tehokkaampi litioituminen)
- Lisätään kierrätysraaka-aineiden osuutta



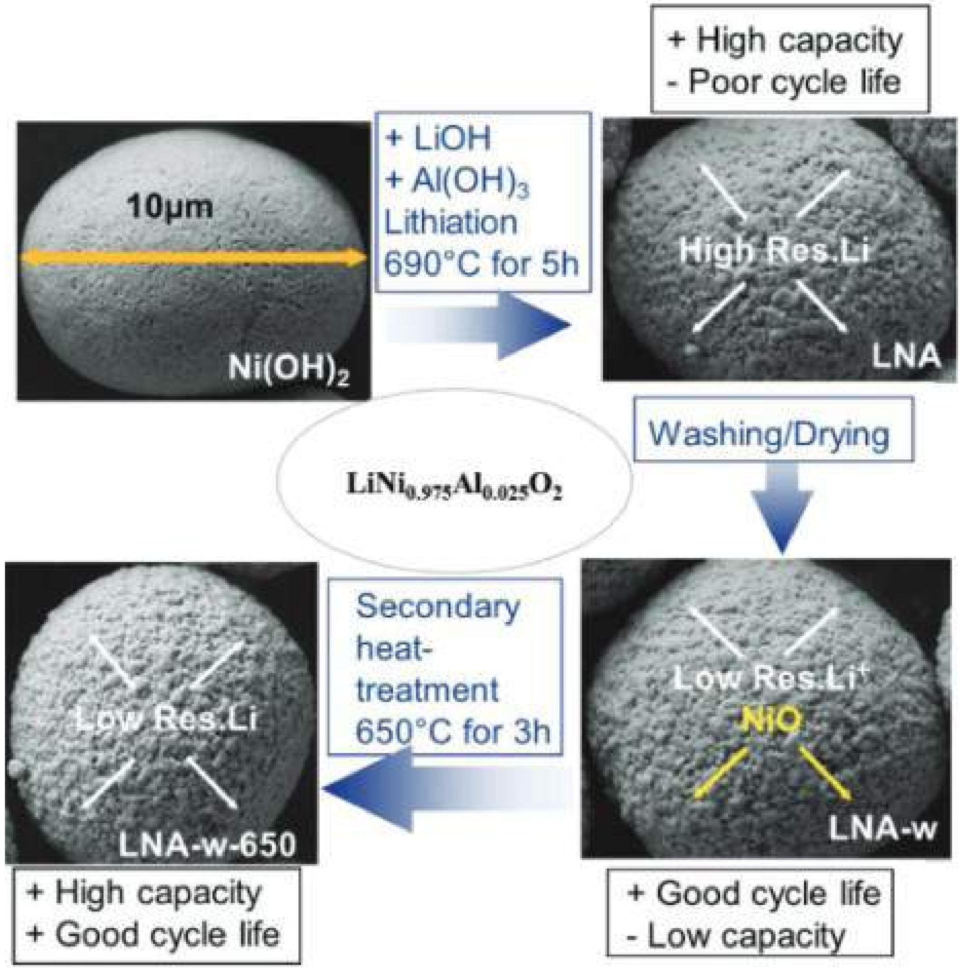
Noh *et al.* J. Power Sources. 233. 2013. 121-130





U Lassi, P Tynjälä, T Kauppinen (2022) Industrial solution for sodium sulphate, patent application
T Tuovinen, P Tynjälä, T Vielma, U Lassi (2021) Utilization of waste sodium sulfate from battery chemical production in neutral electrolytic pickling, Journal of Cleaner Production 324, 129237

LN(M)O -katodi



Cathode	$LiNi_{0.5}Mn_{1.5}O_4$	$LiCoO_2$	$LiMn_2O_4$	$LiFePO_4$	$LiCo_{1/3}Ni_{1/3}Mn_{1/3}O_2$
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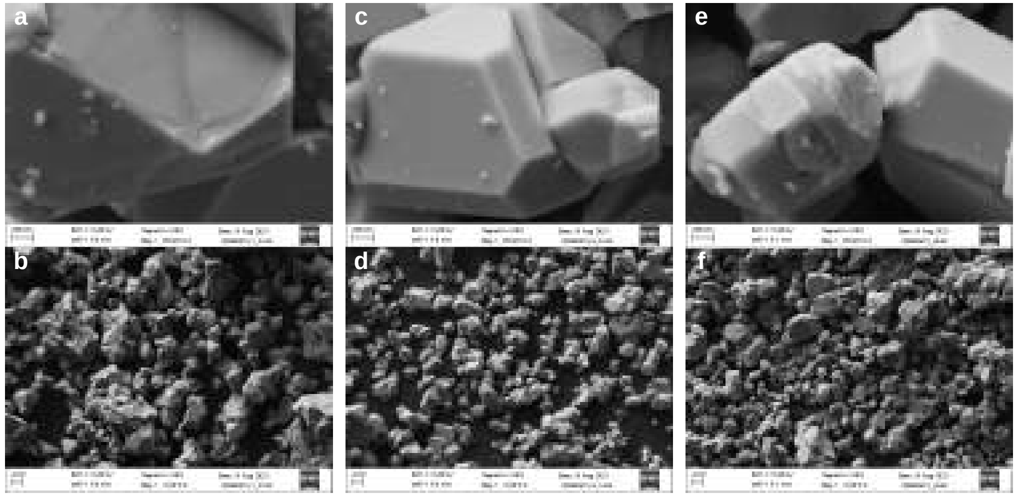
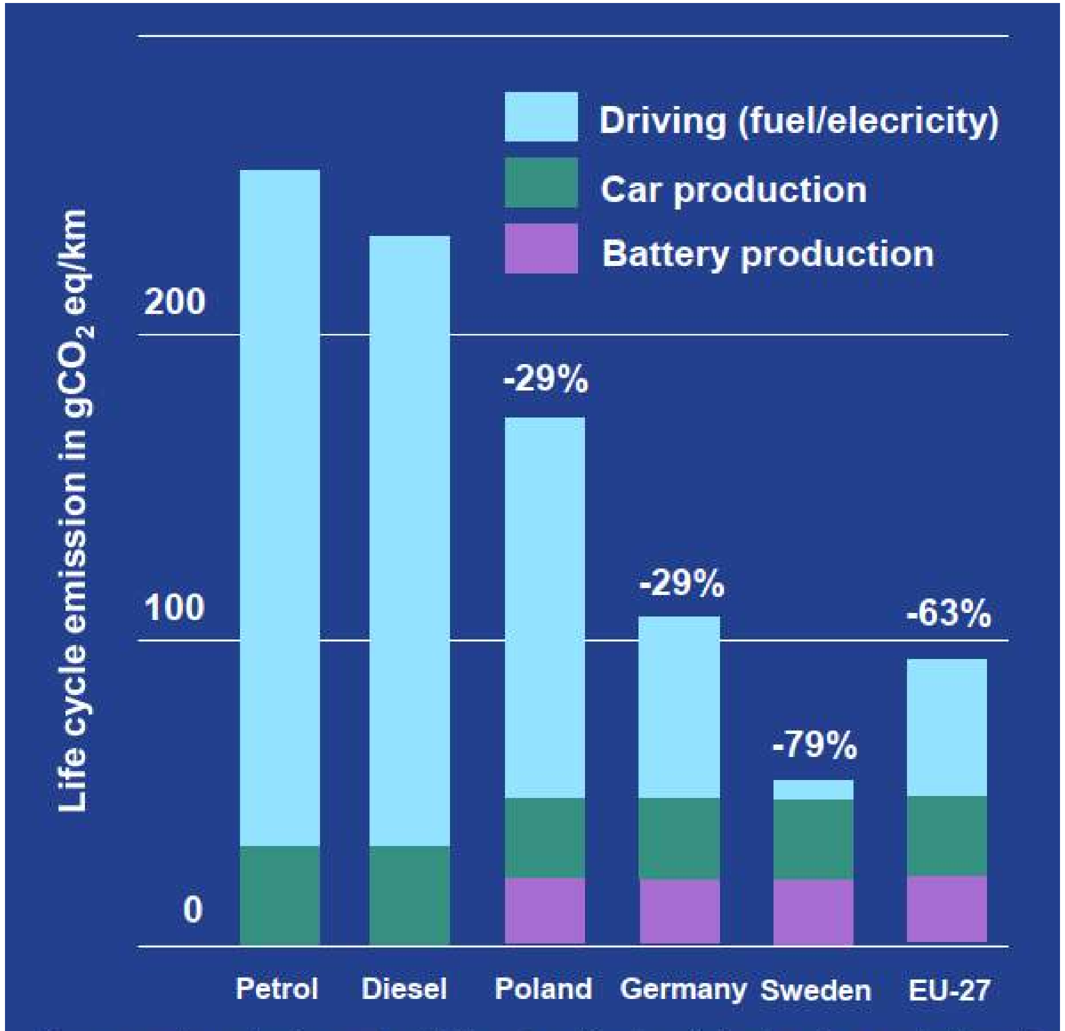
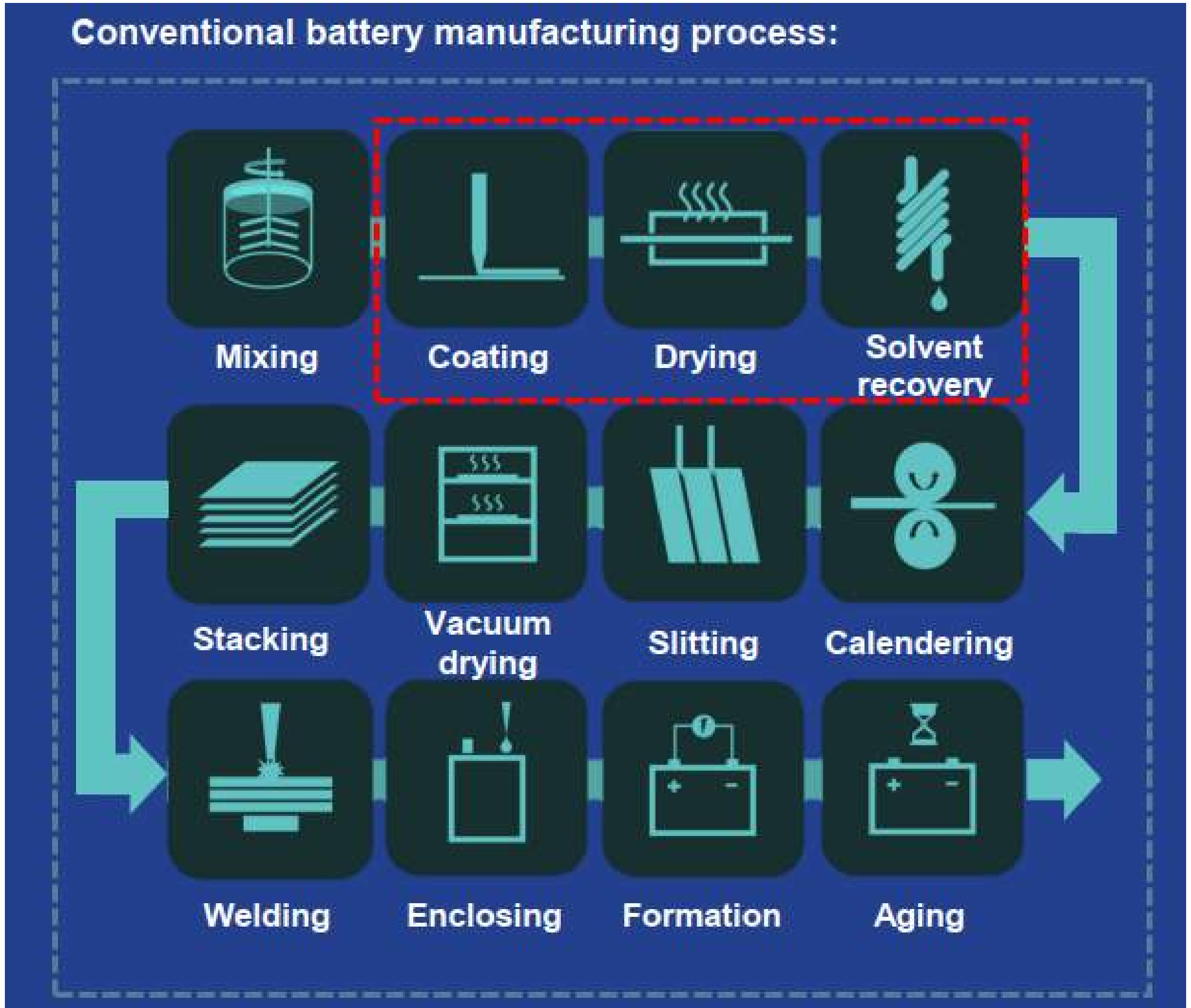


Yan, Lin:,Välikangas, Juho; Tynjälä, Pekka; Hu, Tao; Lassi, Ulla (2022) Synthesis of high-voltage LNMO for LIBs, manuscript.

Kestävyys akkukennojen valmistuksessa

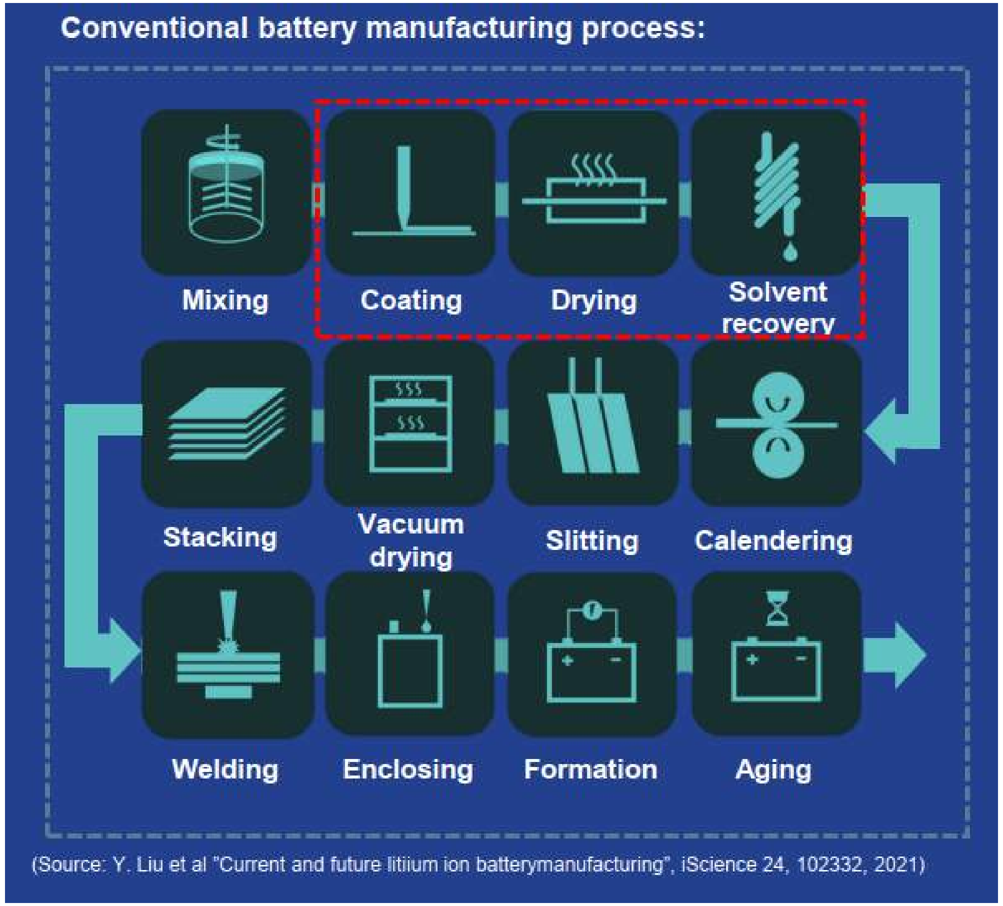


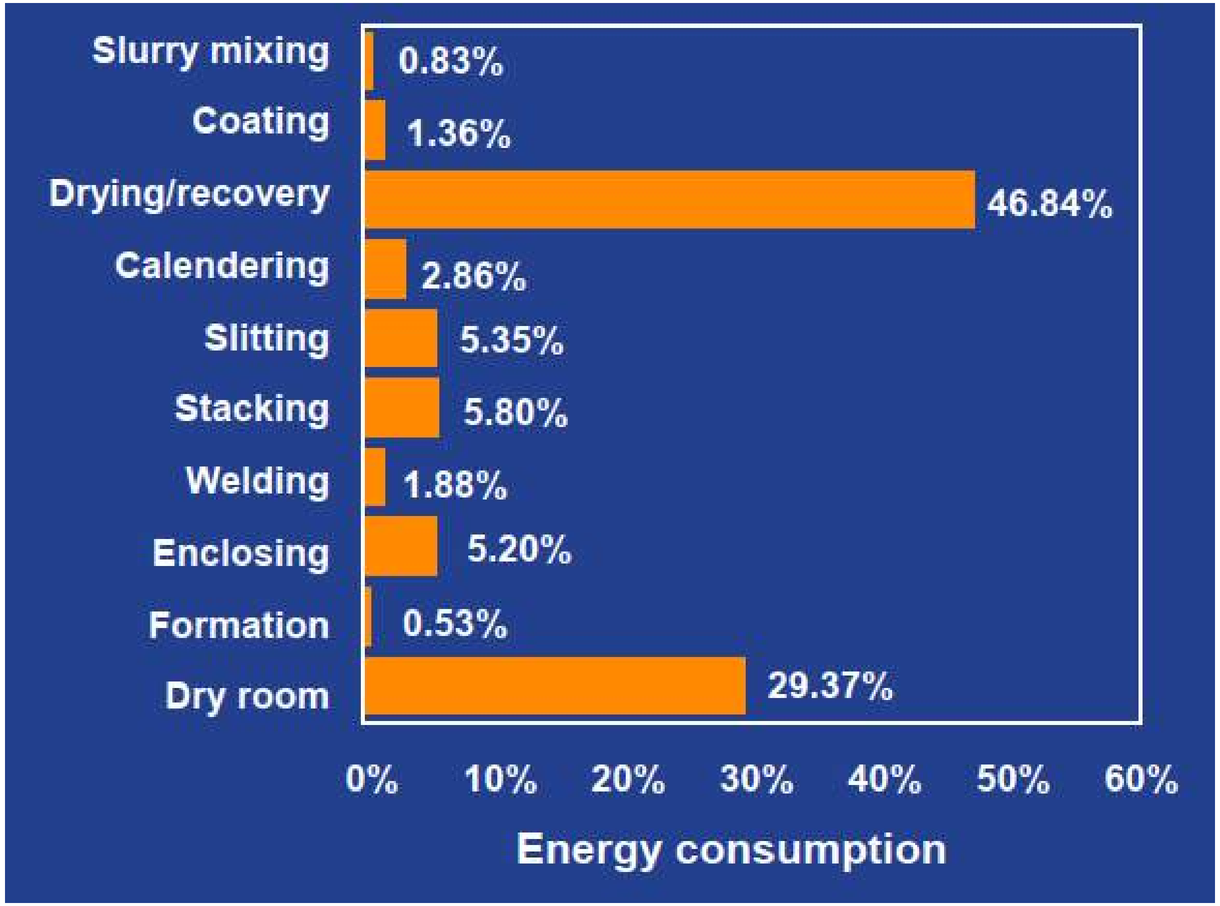
(Source: www.transportenvironment.org/challenges/cars/lifecycle-emissions/how-clean-are-electric-cars/)



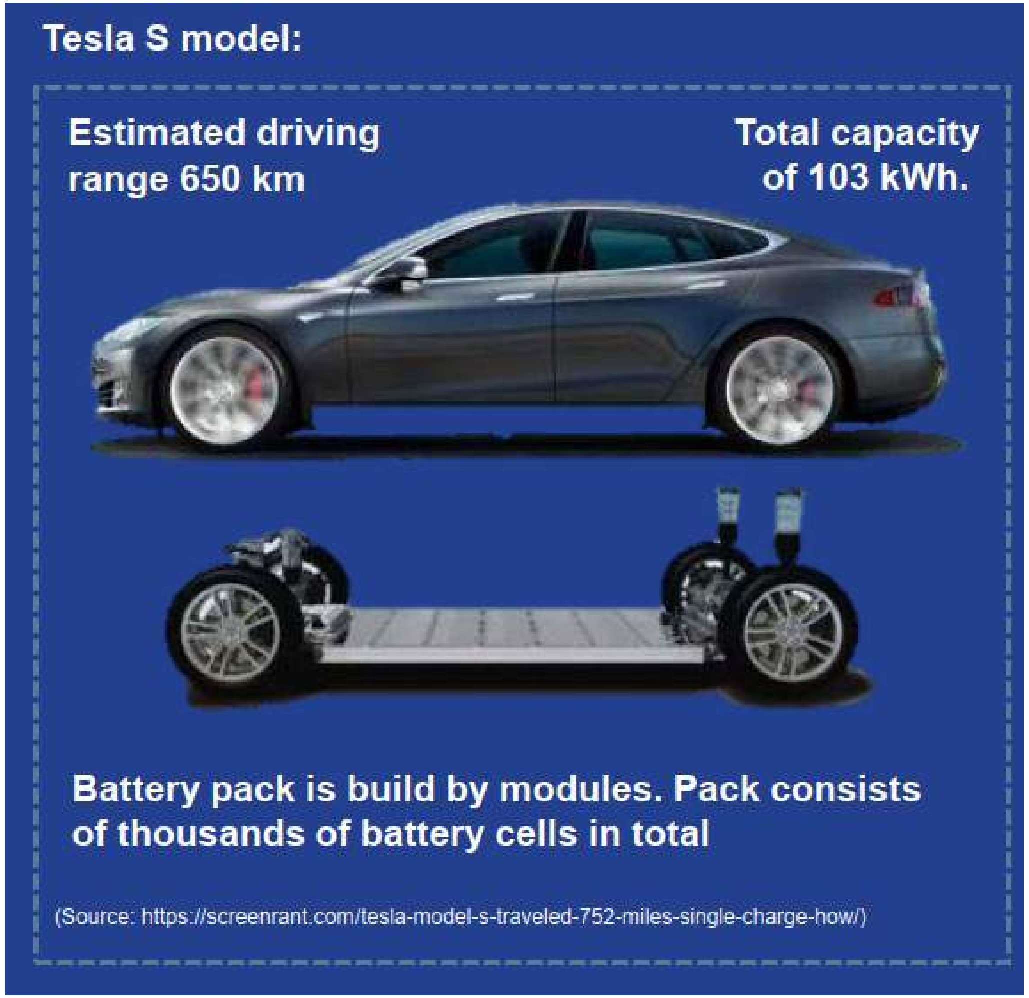
(Source: Y. Liu et al "Current and future litiium ion batterymanufacturing", iScience 24, 102332, 2021)

Energiatarve akkukennojen valmistuksessa





Mitä tämä tarkoittaa (Tesla S)?



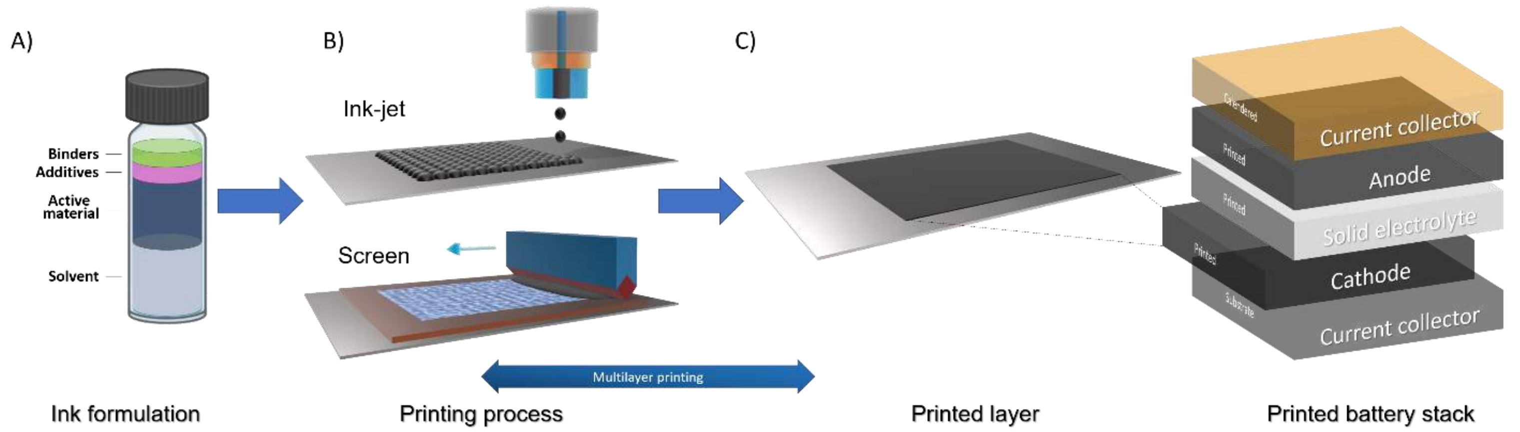
- Akkukapasiteetti 103 kWh
- Tähän kennostoon tarvitaan

noin 100 litraa liuotinta

- Liuotin (tyypillisesti NMP) on toksista ja se tulee ottaa talteenottaa
- Energian tarve tähän 5-6.5 MWh
- Voisiko tämän tehdä paremmin?

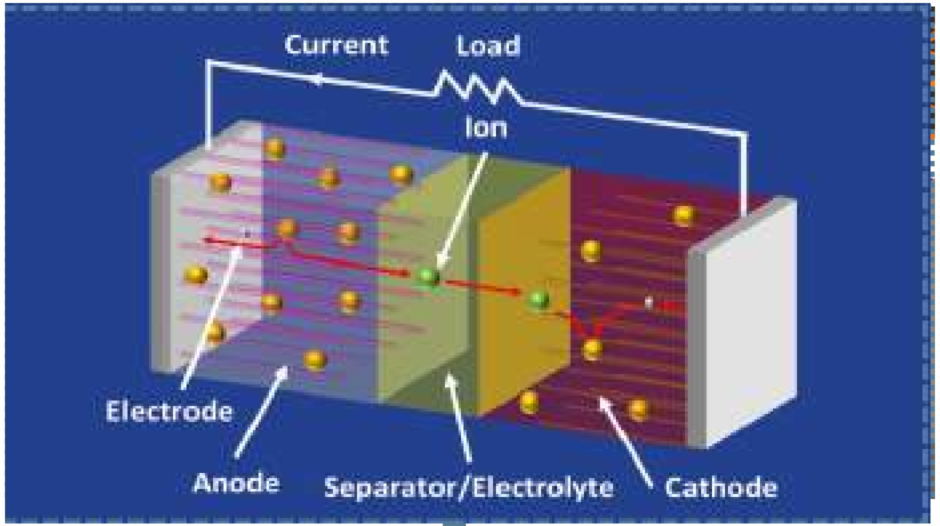
Miten viedään kestävyys osaksi kennonvalmistusta?

- Korvataan haitallisia liuottimia, tarvitaan vähemmän kuivausenergiaa kennon valmistuksessa
- Korvataan halogeeniyhdisteitä (sideaineet, elektrolyyttisuola)
- Käytetään painotekniikkaa valmistuksessa

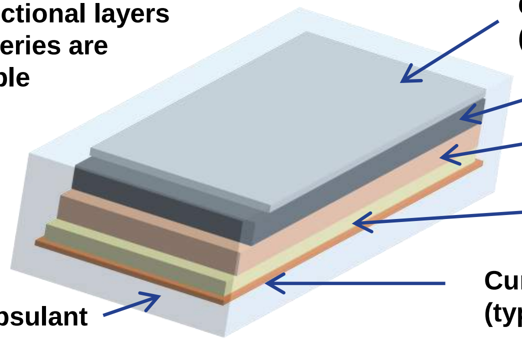


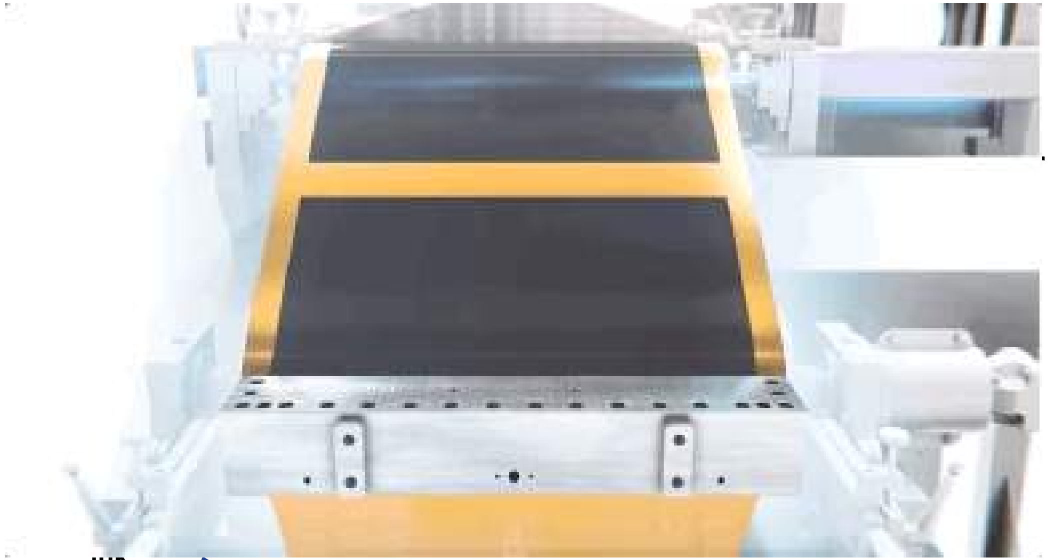
Sliz, Molayian, Fabritius, Lassi (2022) Printed electronics to accelerate solid-state battery development, https://doi.org/10.1088/2632-959X/ac5d8e

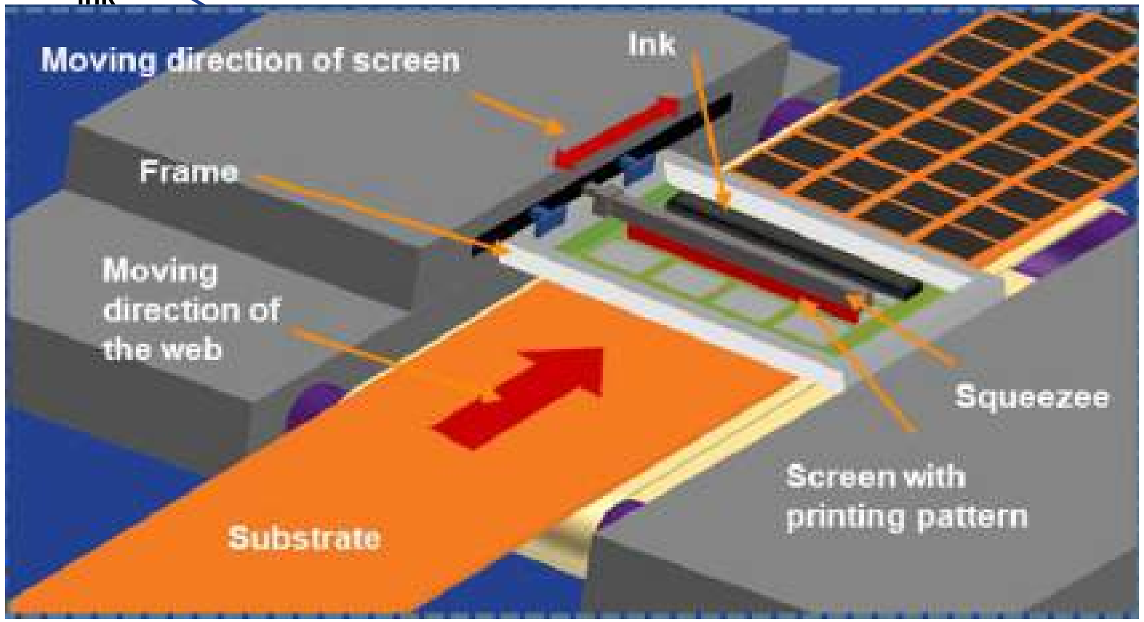
Kennon valmistus R2R



Repeatition of the process

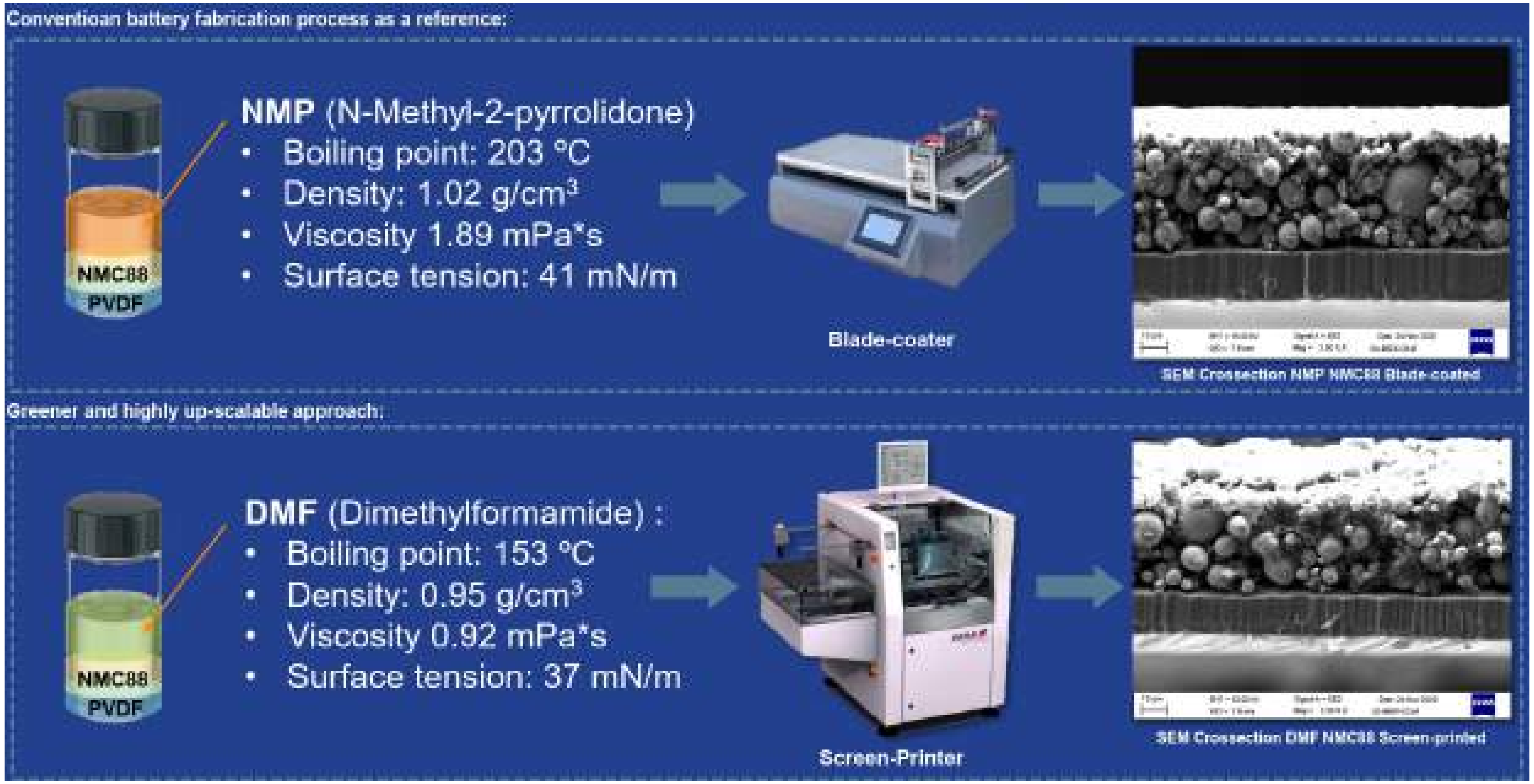






R2R Printing is energy and material efficient approach for high volume production

Eroon toksisista liuottimista…



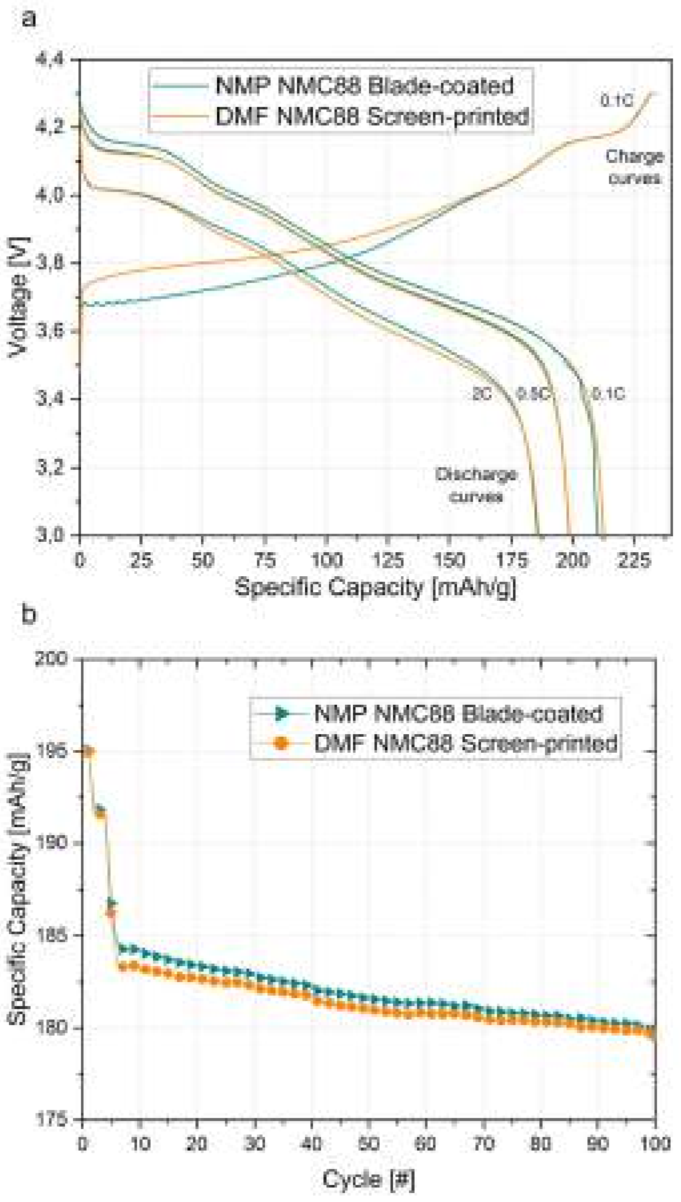


Figure 5. Electrical analysis of the fabricated batteries. a) Specific capacity vs voltage at various charge-discharge current (0.1C, 0.5C, 2C) for differently fabricated cathodes. b) Specific capacity during charging-discharging (1C/1C) process for differently fabricated cathodes.

Sliz, R., Valikangas, J., Silva Santos, H., ...Lassi, U., Fabritius, T. (2022) Suitable cathode NMP replacement for efficient sustainable printed Li-ion batteries, ACS Applied Energy Materials 5(4), pp. 4047–4058, https://doi.org/10.1021/acsaem.1c02923

Tulevaisuuden akkukemiat

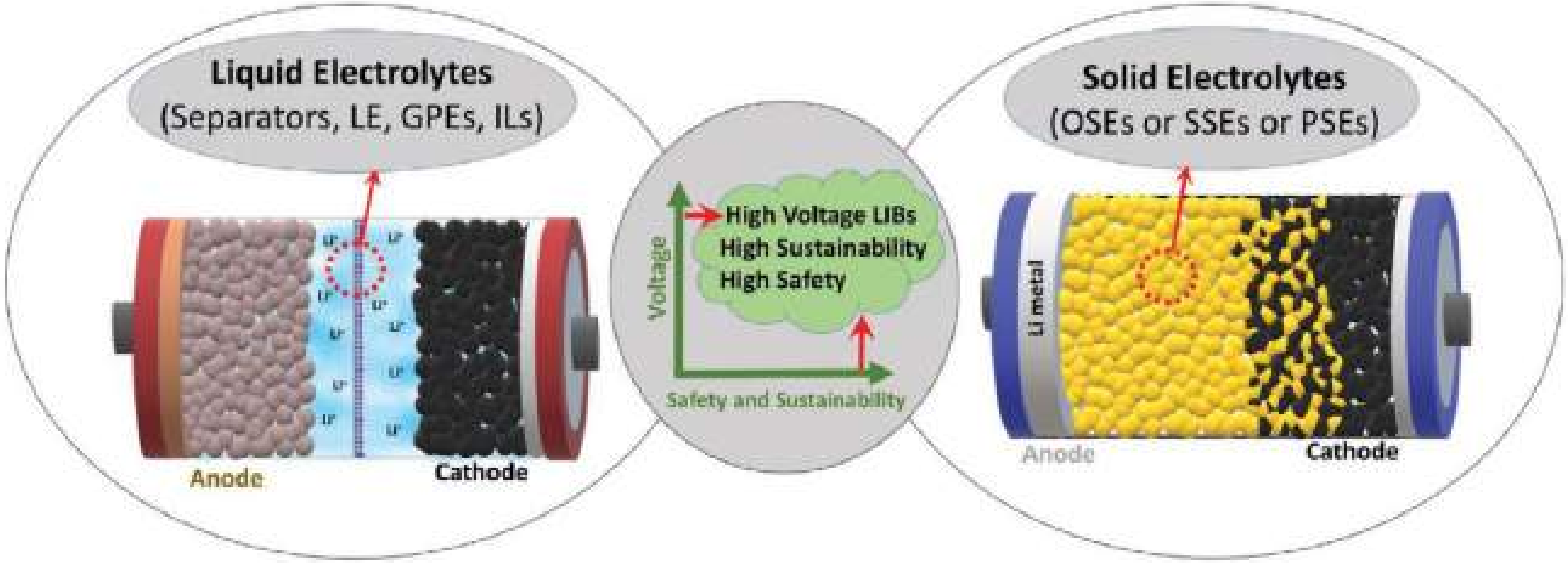


Figure 1. Schematic summarizes the strategies to improve the electrolyte region for HV-LIBs applications. The abbreviations are defined as follows: liquid electrolytes (LEs), gel polymer electrolytes (GPEs), ionic liquids (ILs), ceramic oxide solid electrolytes (OSEs), sulfide solid electrolytes (SSEs), and polymer solid electrolytes (PSEs).

Cavers, H., Molayian, P., Abdollahifar, M., Lassi, U., Kwade, A. (2022) Perspectives on Improving the Safety and Sustainability of High Voltage Lithium-Ion Batteries Through the Electrolyte and Separator Region, Advanced Energy Materials, 10.1002/aenm.202200147

Kiitos mielenkiinnostanne!

RESEARCH UNIT OF SUSTAINABLE CHEMISTRY
UNIVERSITY OF OULU

Prof. Ulla Lassi. University of Oulu
Kokkola University Consortium Chydenius
eMail: ulla.lassi@oulu.fi.
tel: +358 400 294 090

Prof. Tapio Fabritius
Asst Prof Rafal Sliz
Dr., Ass prof Pekka Tynjälä
Dr. Ass prof Tao Hu
Dr. Palanivel Molayian
Researchers Juho Välikangas, Marianna Hietaniemi, Petteri Laine, Yan Lin, etc.

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