



CHEMICAL PROCESS COMPETENCE NEEDS FOR THE GREEN TRANSITION AND 2050

*An introduction for NTNU Chemical Department's 75 year anniversary
By Erik Sauar*

October 2024

A short personal background

- Master in Chemical Eng., NTH, 1994 (Chemical Engineering/Physical Chemistry/Thermodynamics)
- Master in Anthropology, UNIT, 1996 (Democracy and human rights among kurds and turks in Turkey)
- Dr. techn. Physical Chem., NTNU 1998 (Non-equil. thermodynamics for energy efficient process design)

- Left Norsk Hydro 1998 unless they wanted to develop solar technology.
- Co-founded the **solar** company REC in '97/00 - grew 100% per yr for 10 years. CTO 2000-2013 growing from 0 to about 200 FTE in R&D. Solar module cost cut by about 75%.

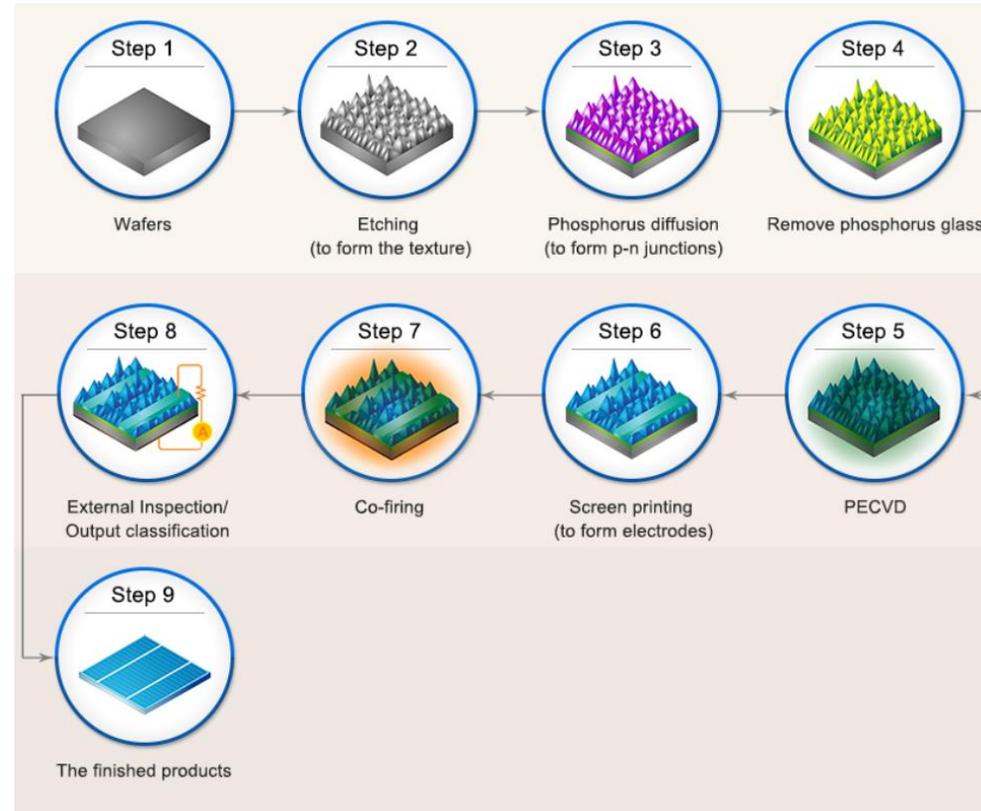
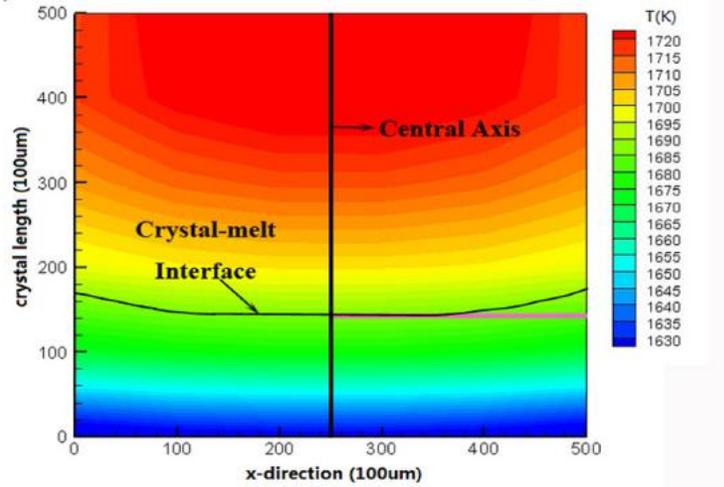
- Involved in several solar, technology and battery start-ups since 2013.
 - New metal paste for solar cells, Solar-as-a-service in rural Pakistan, floating solar, 3D printing of Titanium parts for airplanes, hydroponic production of vegetables etc.

- Co-founder and CEO of Cenate, developing **silicon anodes** for EV batteries since 2017.
- Board Director at Umoe (Bioenergy and hydrogen/biogas tanks)
- Board Director in Norway's Research Council for the portfolio on «energy, transport and low emissions»
- Chair of Board at Miljøstiftelsen Zero, Differ and Sunphase (storing energy in phase change materials)

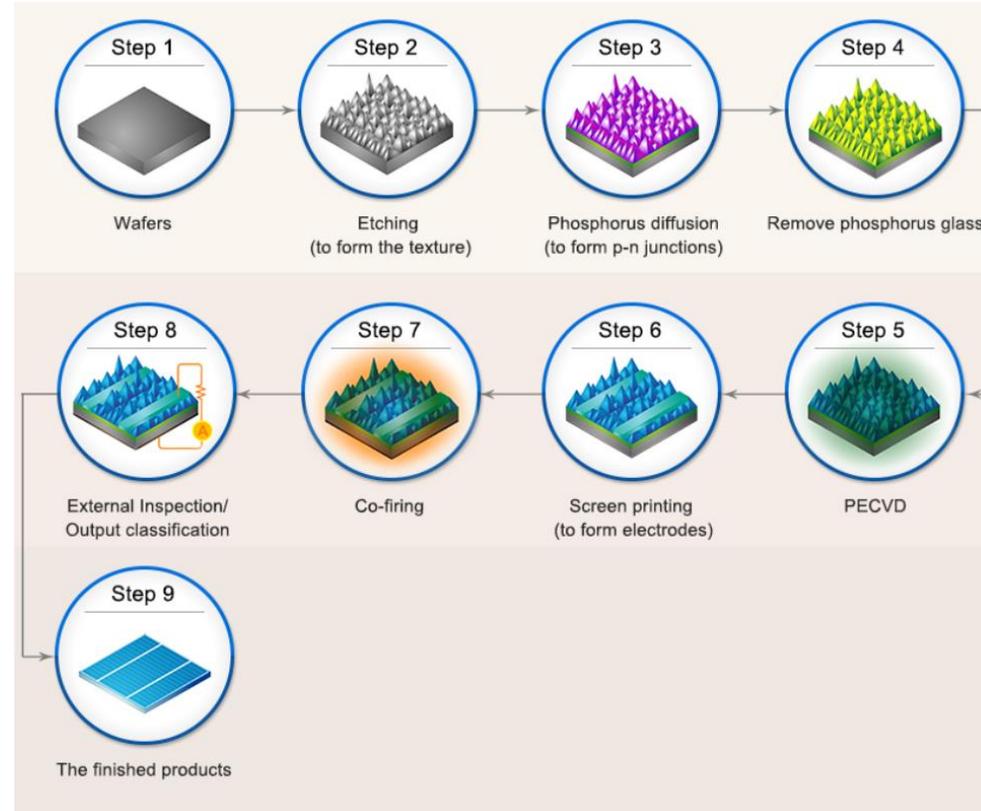
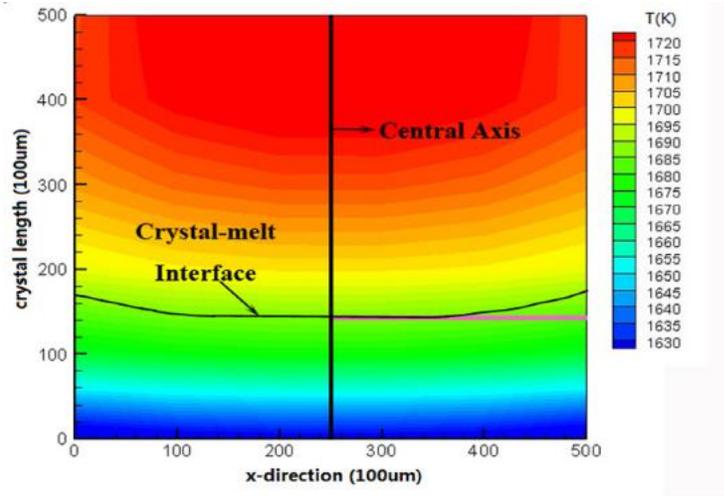
How was I - in 1998 prepared for solar – without having had any classes in solar ?



How was I - in 1998 prepared for solar – without having had any classes in solar ?



How was I - in 1998 prepared for solar – without having had any classes in solar ?

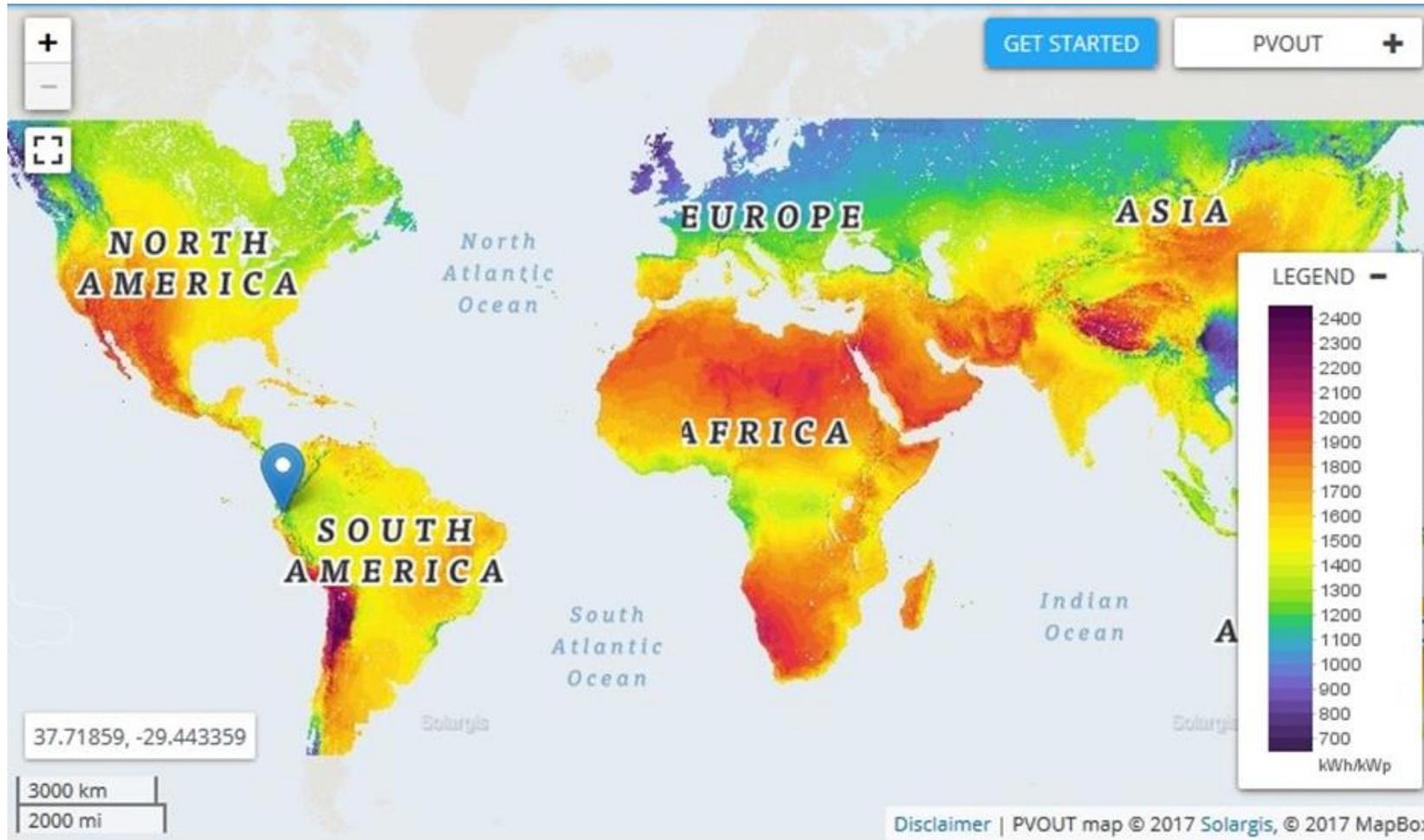


.... I believe I have used every course I have taken while in solar – with a small question on organic chemistry.

What was particularly useful ?

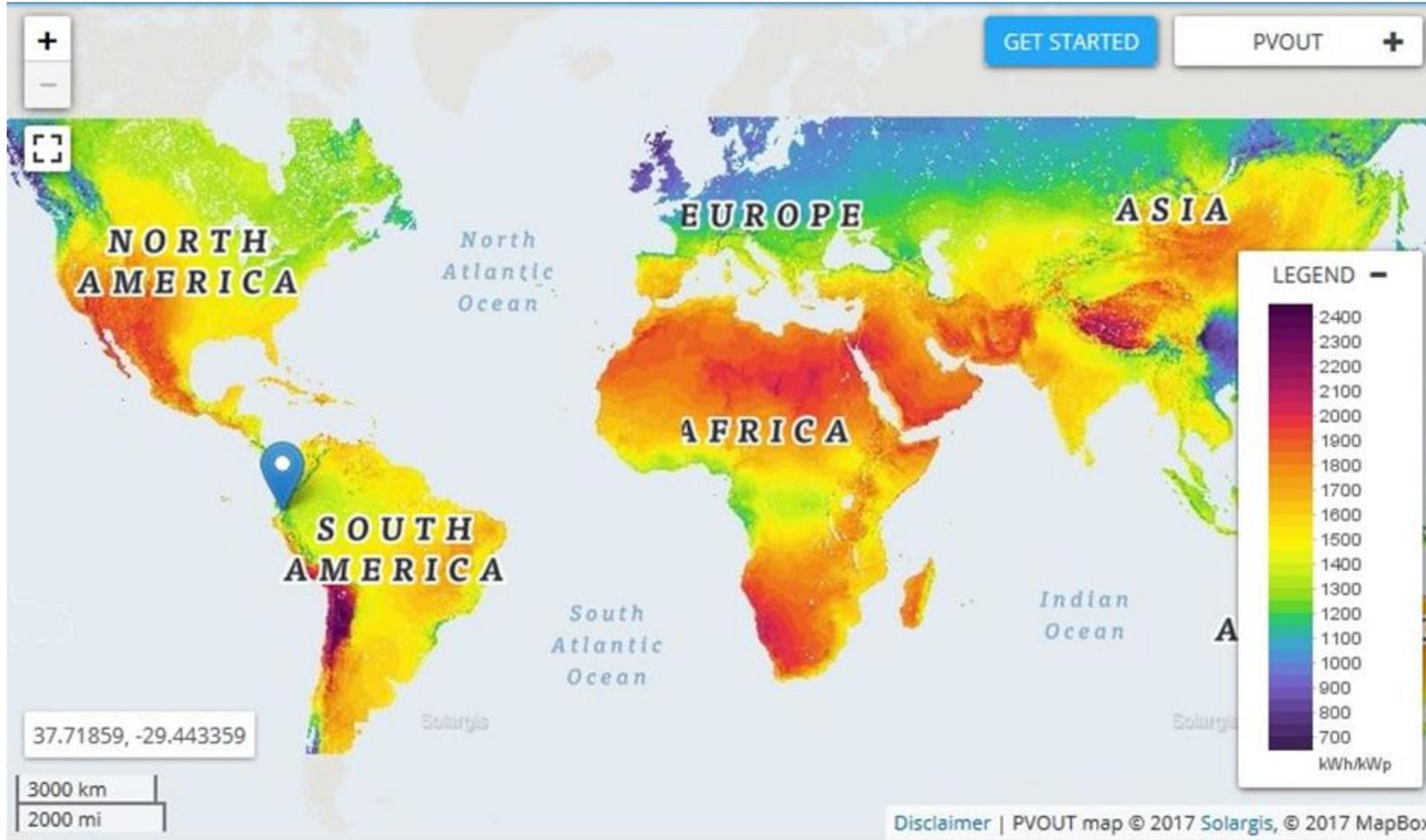
- The base courses in thermodynamics, chemical engineering and fluid mechanics, etc.
- Understanding and using statistics to separate valid from non-valid conclusions
(Out of 50 researchers at Herøya, nobody understood that they had to use a Student-T distribution.)
- Understanding error sources in own and other people's work
- The ability to zoom in and out – (i.e. also look at and analyse the complete system (or value chain) from a cost and efficiency perspective)
- Being able to collaborate with others and stimulate a positive, motivated atmosphere

Most people live in the sunbelt – where solar power is the lowest cost electricity – by far!



PV electricity in these areas is cheaper than all electricity options in Norway @ 20-30 øre/kWh

Most people live in the sunbelt – where solar power is the lowest cost electricity – by far!



In countries with sunshine also in the winter season, PV and batteries can deliver baseload electricity at 40 øre /kWh.

→ *Energy intensive industries will be drawn towards the sunny parts of the world.*

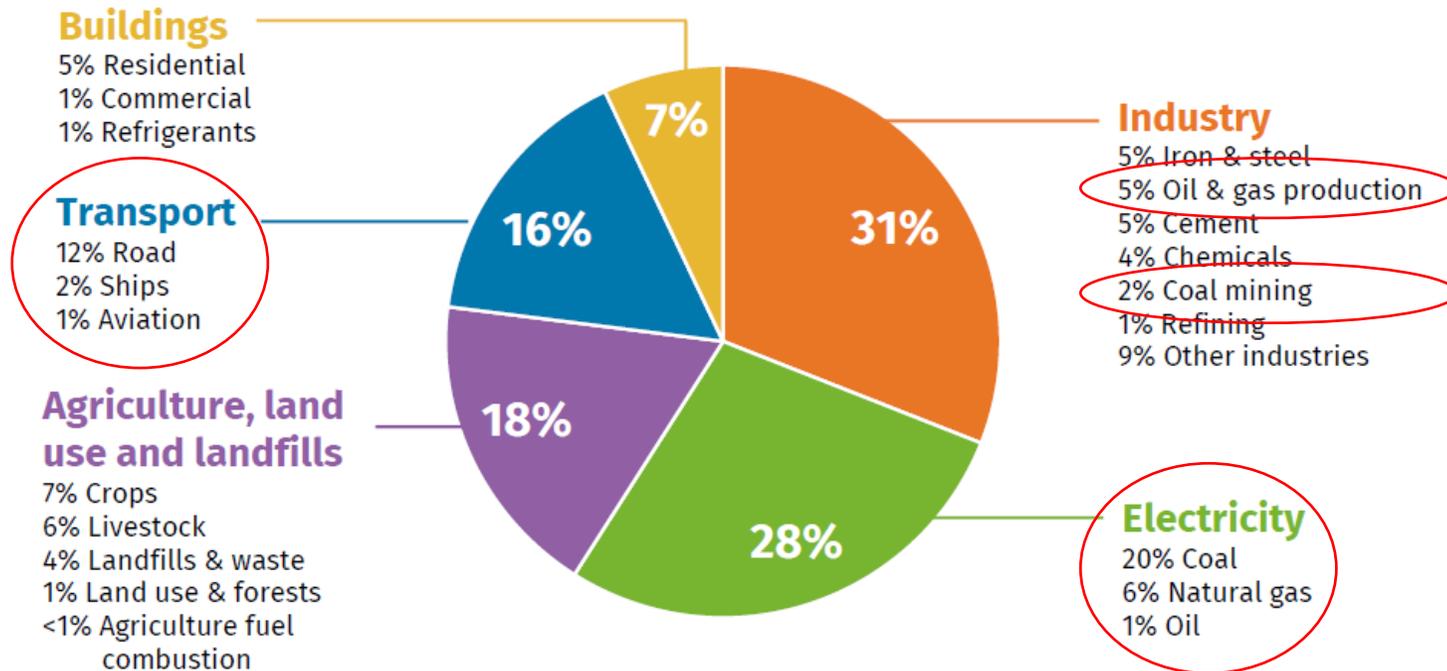
→ **Batteries, battery materials and battery applications will become huge industries (decarbonizing both the land transport and power sector)**

Batteries key to cut emissions in 3 out of 4 large CO2 emitting sectors globally !

FIGURE 6

Global emissions by sector

Percent share of 2020 net GHG emissions



Source: Rhodium Group

Cenate develops and produces silicon based nano composite for EV++ batteries



Has developed **world leading and patent pending silicon-based materials** to replace graphite in **lithium-ion batteries**, mainly for the rapidly growing EV battery market.

Building on Norway's **strong silicon industry competence**, being a spin-off company from Dynatec (Norwegian equipment producer, with co-founders from REC and IFE (Norwegian Inst. for Energy Technology)).

Research at Forskningsparken, Oslo, Norway. **Pilot plant built** in Tomter, 35 min. south of Oslo.

Record high energy density – efficient, climate friendly production

Record high energy density – record low Li/cathode cost:

- Each kg of Cenate's products **replaces 5-6 kg of graphite**.
- World leading first cycle **lithium efficiency** among silicon anode competitors. Thereby less of the costly Lithium and/or a thinner (and lower cost) cathode can be applied.

Cost effective production process:

- Cenate is producing its drop-in replacement materials in a unique and highly efficient way.
- The result is low capex needs, much lower energy consumption, and low emissions.

CO₂ footprint:

- Our simplified production process requires significantly **lower energy use** than the competitors.
- Cenate's potential for **recycling** of our material will further add to the low CO₂ footprint.



Record high energy density – efficient, climate friendly production

Record high energy density – record low Li/cathode cost:

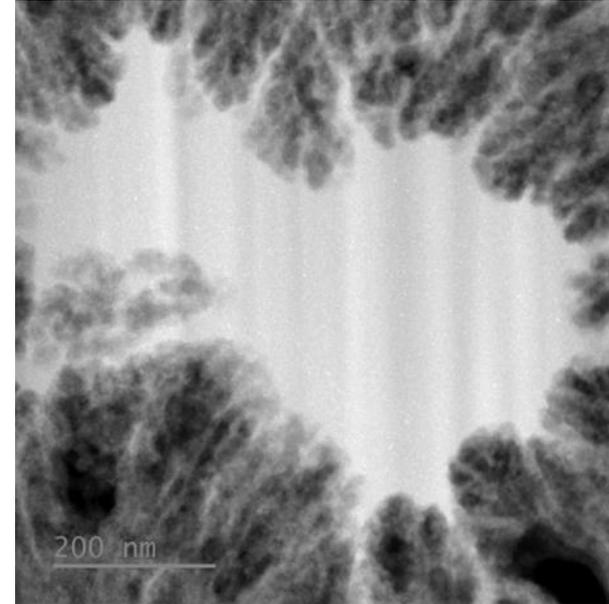
- Each kg of Cenate's products **replaces 5-7 kg of graphite**.
- World leading first cycle **lithium efficiency** among silicon anode competitors. Thereby less of the costly Lithium and/or a thinner (and lower cost) cathode can be applied.

Cost effective production process:

- Cenate is producing its drop-in replacement materials in a unique and highly efficient way.
- The result is low capex needs, much lower energy consumption, and low emissions.

CO₂ footprint:

- Our simplified production process requires significantly **lower energy use** than the competitors.
- Cenate's potential for **recycling** of our material will further add to the low CO₂ footprint.



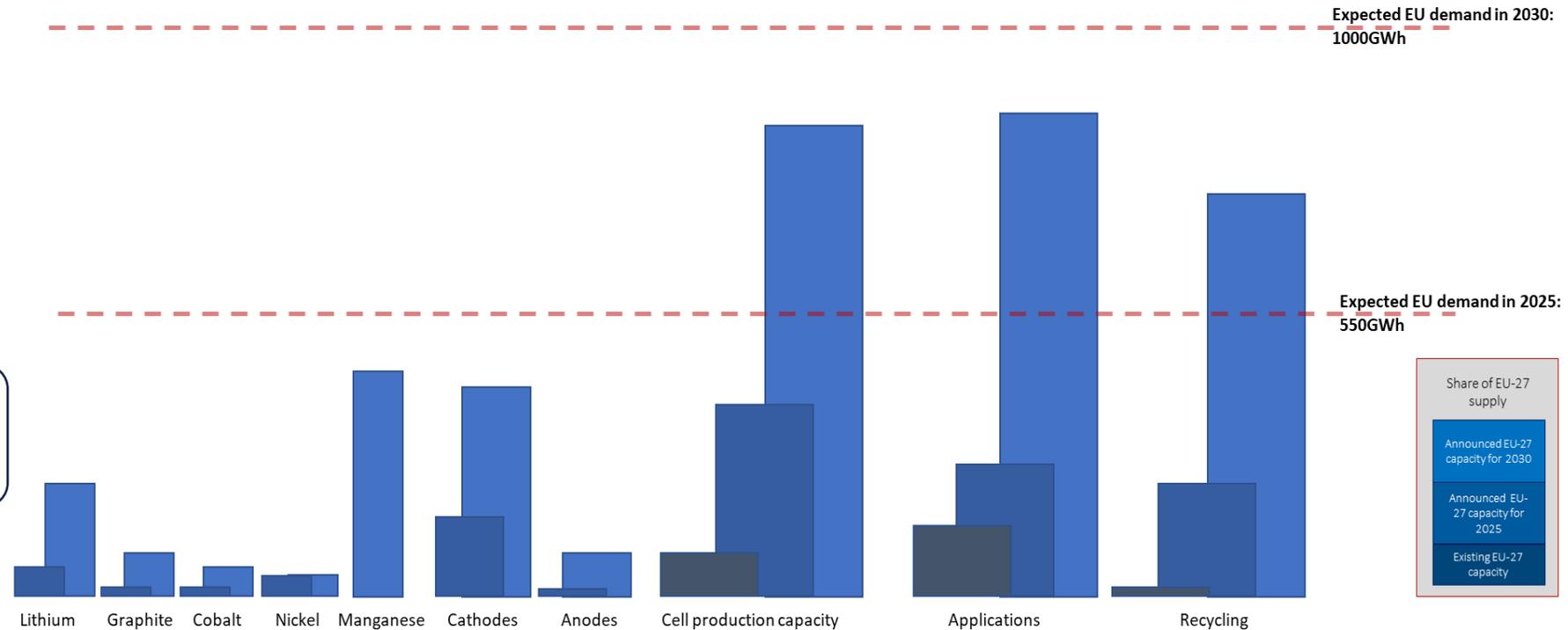
The main problem we have solved is reducing the magnitude of the Onsager relations $L_{ij} = L_{ji}$ (or nearly blocked co-diffusion)

The main tools have been/are: Inorganic chemistry, physical chemistry, electrochemistry, fluid mech, organic chemistry, physics and statistics

There will be MULTIPLE, large battery related materials industries



Analysis of demand-supply gaps along the battery value (2022)



Phosphate should also have been on the list

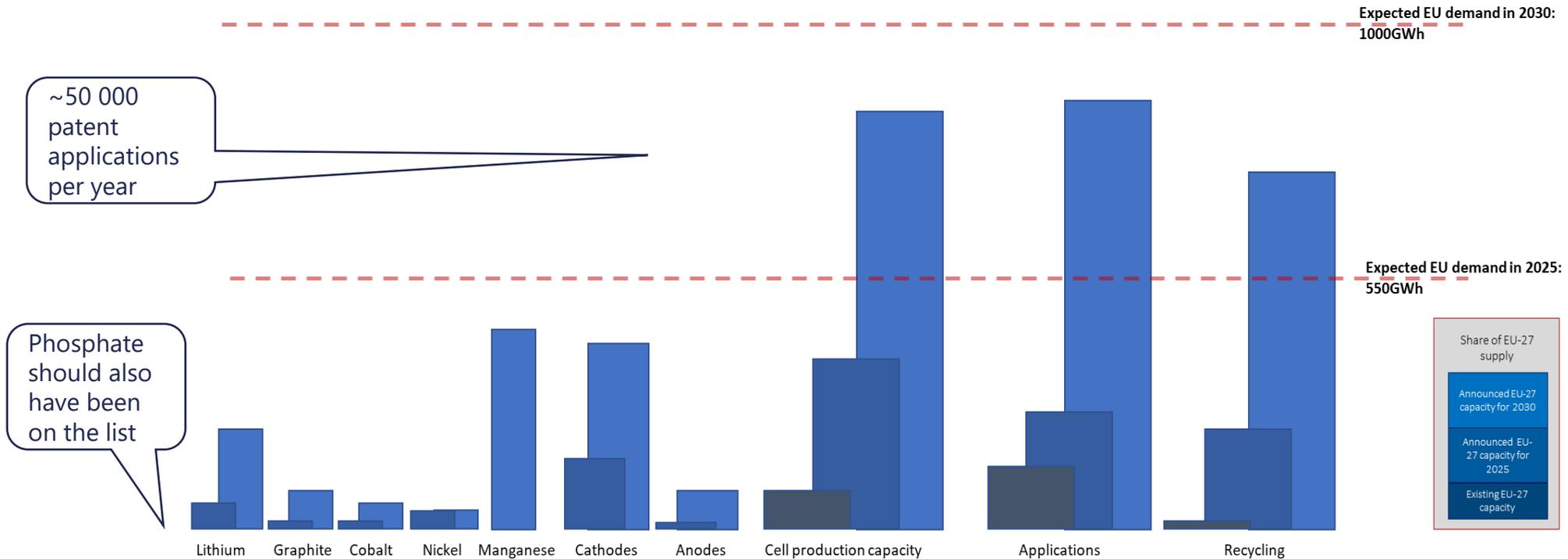
Share of EU-27 supply

- Announced EU-27 capacity for 2030
- Announced EU-27 capacity for 2025
- Existing EU-27 capacity

There will be MULTIPLE, large battery related materials industries



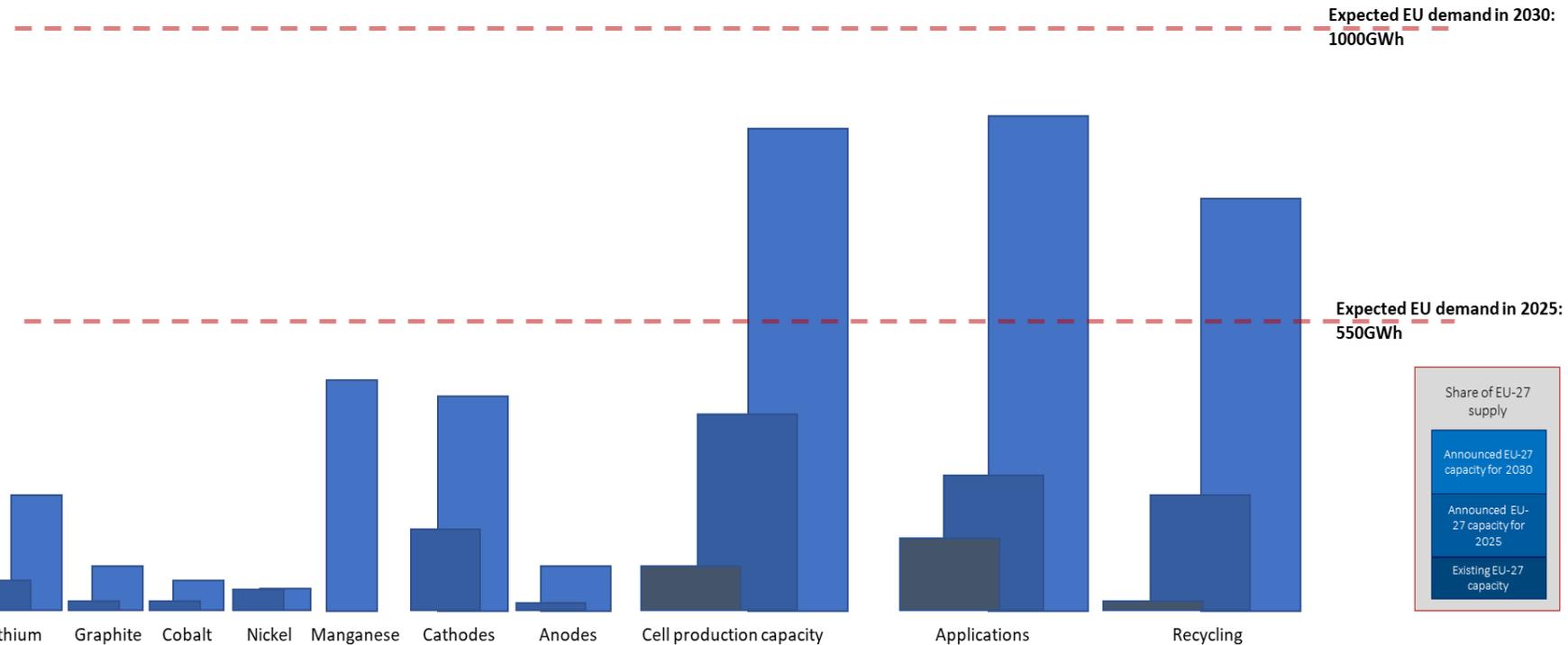
Analysis of demand-supply gaps along the battery value (2022)



There will be MULTIPLE, large battery related materials industries



Analysis of demand-supply gaps along the battery value (2022)



Phosphate should also have been on the list

A China attack on Taiwan is considered 50% probable => huge challenges, needs & opportunities

Where are the big green opportunities for chemists and chemical engineers ?

- Batteries will directly replace oil for land transport and the majority of coal/gas for power plants
 - Electro chemistry, electro chemistry, electro chemistry, lean manufacturing and statistical process control
 - Organic chemistry, inorganic chemistry, materials and all the regular chemical engineering courses
- Green metals (probably covered by Håvard) need to be made with new processes
 - Including more and new metal mining and new extraction/separation processes
- A series of materials/products will need to be made with new carbon neutral processes or replaced by other products:
 - concrete
 - road materials
 - construction materials
 - fertilizers
 - proteins (to replace imported soya as animal and fish fodder)
 - aviation and marine fuels (incl hydrogen and ammonia)
- Recycling of all kinds of materials (will often include a lot of separation processes)
 - Clothes, metals, plastics, battery materials
- All kinds of carbon capture and storage

To summarize

- The fundamentals will stay fundamentals
- MANY chemical processes and materials need to be invented (again).
- Understand and report the difference between statistically solid and weak results (chemical engineers are among the better!)
- Cross-disciplinary collaboration, system understanding and being able to «zoom in and out» to see that a solution is part of an attractive roadmap/platform.

- Materials, separation and electro chemistry likely to become more important than 20 years ago
 - (Combustion likely to become less important due to low 2nd law energy efficiency)
- Recommend to use more examples from the new, green value chains in the fundamental courses

THANK YOU

