Lars Jacobsson
Operation Manager

Bakgrund från Processindustri, Gas och Olja främst landbaserad Naturgas transmission och distribution. Gasföreståndarkompetens.

RKAB sedan 2014

- Styrelseledamot Svensk Vindkraft
- Medlem i Programrådet SWPTC Chalmers
- Ordförande LG EVI Campus Varberg

Hydrogen from RES

Rabbalshede Kraft

Company introduction

Introduction

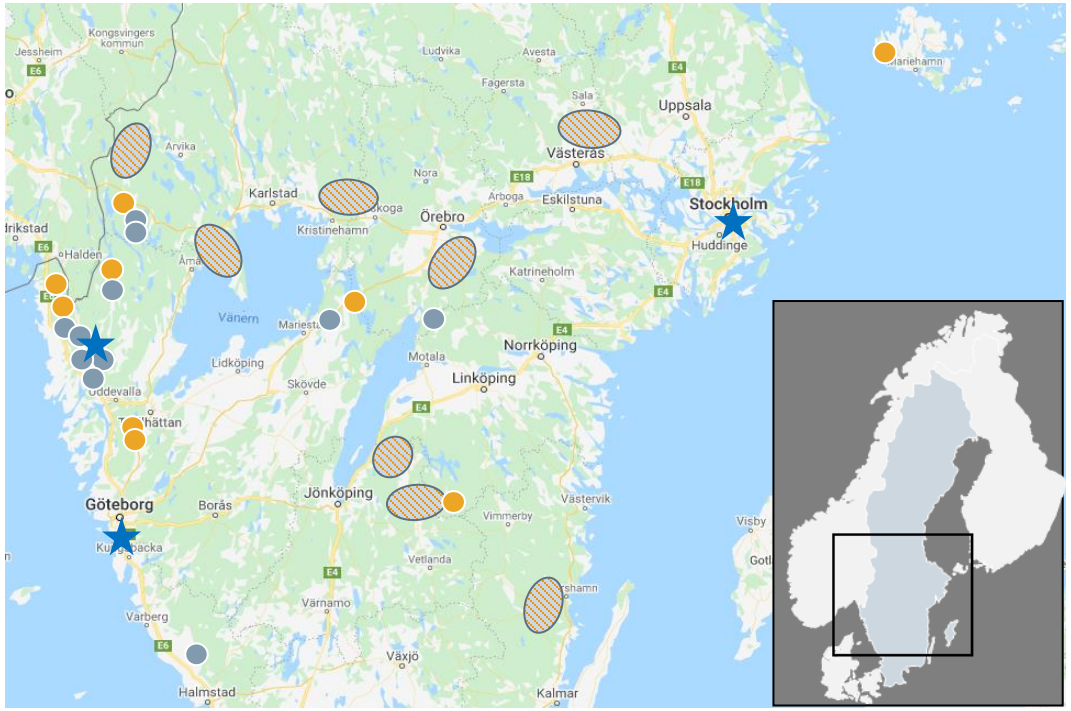
- Founded in 2005 – today 34 employees with offices in Rabbalshede, Göteborg and Stockholm
- TDAM acquired an additional 51% for a total of 87% of shares in Jan 2021
- Develops, builds, operates and owns onshore wind power – manages 200 wind turbines in total
- 1.5 BSEK investments decisions in wind power during 2020
- Onshore wind development portfolio of >2.5 GW in SE3 and SE4
- Transforming into a leading renewable player – expanding within Solar PV and Green Hydrogen

Green Hydrogen

- Ambition to become a leader player within green hydrogen production from wind power in Sweden
- Partnership with Euromekanik (technology partner) since mid 2020
- Member in European Clean Hydrogen Alliance
- CAPEX support “Klimatklivet” of 15.4 MSEK (ca 1.5 MEUR) granted in May 2021
- Qualified for EU initiative IPCEI Hydrogen (Important Projects of Common European Interest)

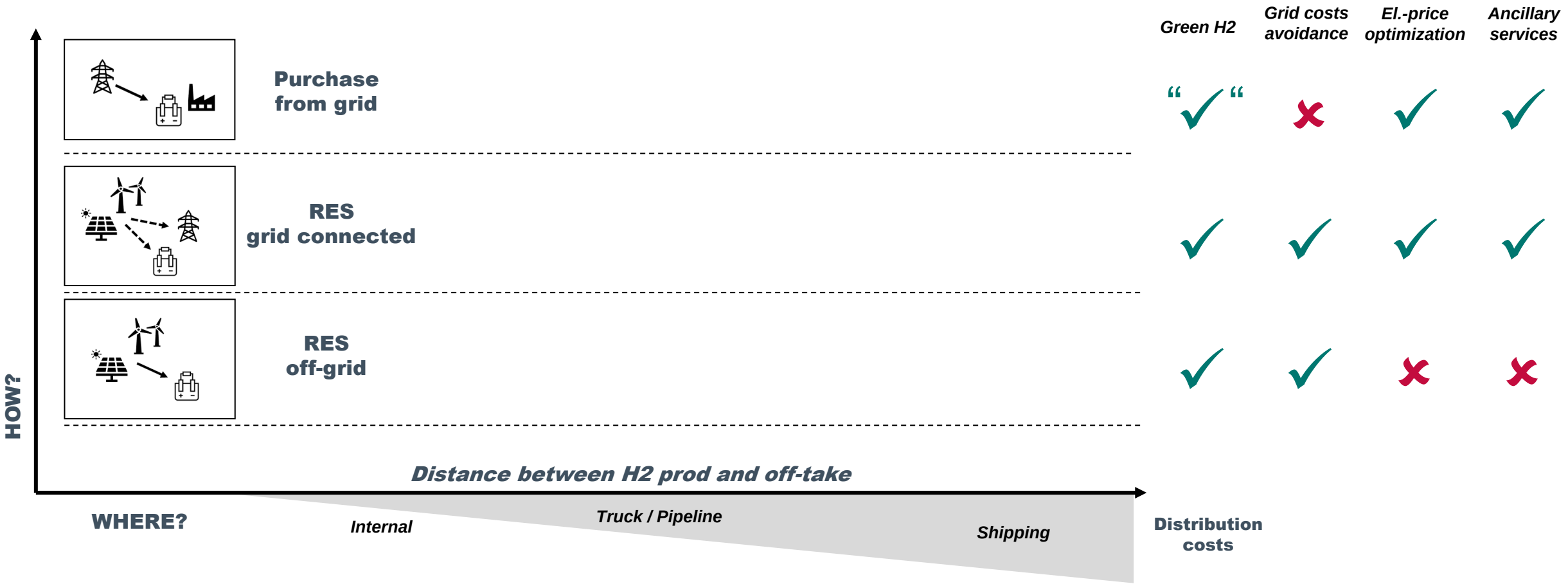
Wind portfolio

- Mature projects under development or construction
- Operational owned projects
- Development projects
- Office



Green Hydrogen supply

Three different production methods for green hydrogen



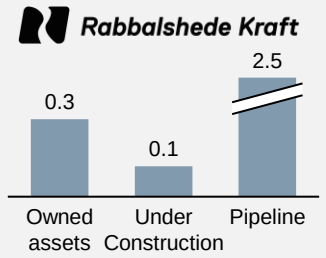
Strategic rationale Hydrogen

We own our assets, have limited PPAs and strategic locations

Is hydrogen something for Rabbalshede Kraft?

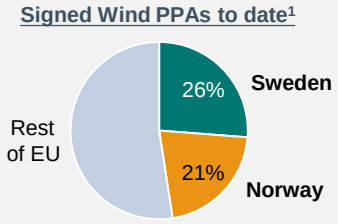
Asset ownership

- We are an IPP with **full asset ownership** over the wind farm's lifetime
- This enables hybrid set-ups and applications, such as green H2, to be added directly to the asset
- Very few competitors with develop-build-keep strategy



Electricity sales

- We are only to a **small extent locked into long electricity sales contracts** (PPAs)
- The merchant exposure is a risk we seek to hedge, but it also enables the use of physical electricity output for hydrogen production
- Competitors often sign PPAs when financing Nordic onshore wind – Sweden and Norway account for almost half of European PPA volumes



Geographical fit

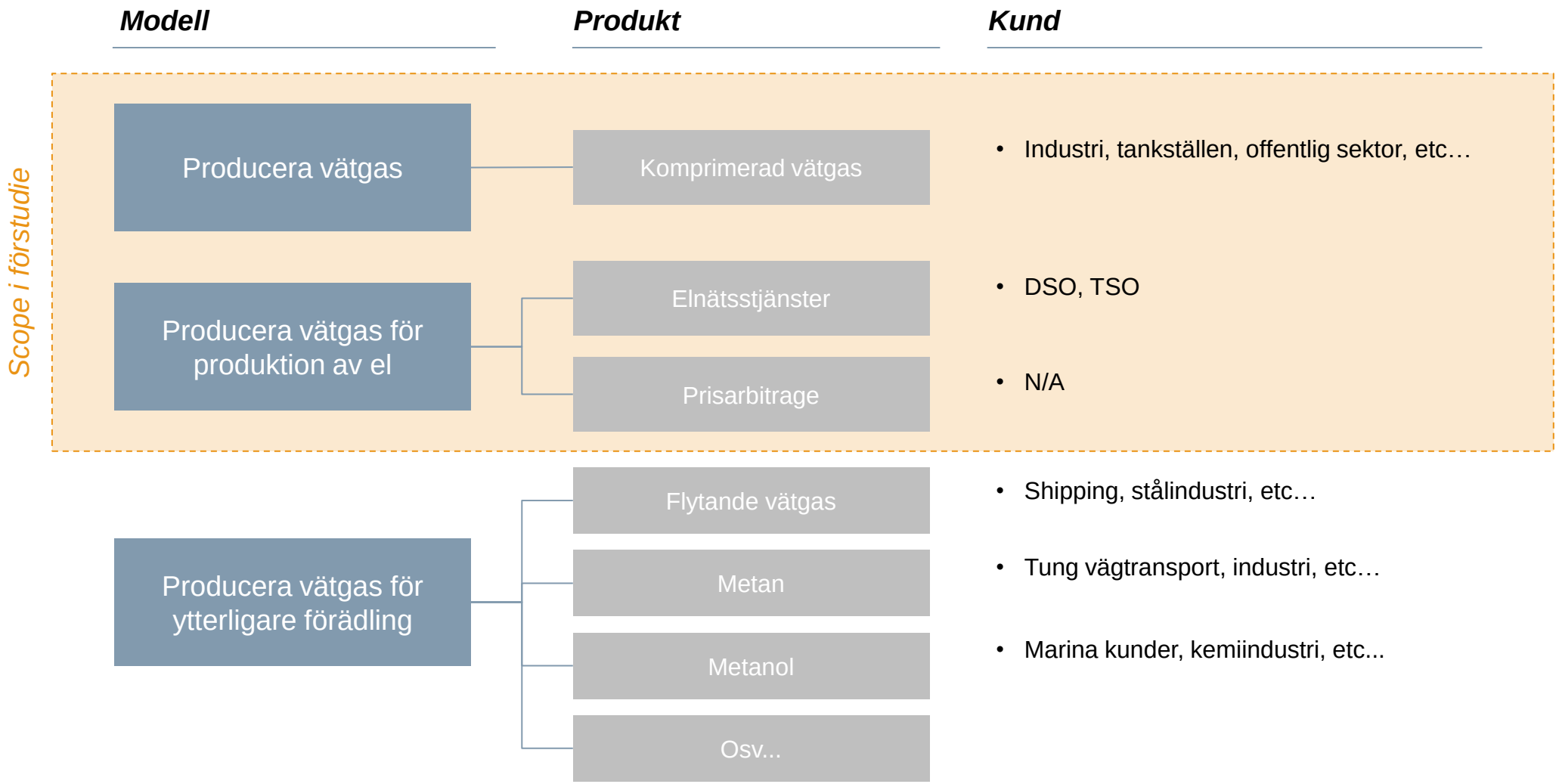
- Our wind portfolio with **great geographical fit** to potential green H2 offtake
- Distance (transport costs) needs minimization if producing H2 at a wind site
- Most wind farms in Sweden are located North, far away from potential green H2 offtake

Hydrogen has a great potential for RKAB to refine its product green electricity. We see opportunities for profitable stand-alone investments with further value through natural hedge towards merchant prices

1) Re-Source, total PPA volumes in Europe 2007-2021 2) Swedish Wind Energy Association, based on contracted volumes (2021)

Rabbalshede Kraft

Vind + vätgas → många möjligheter



Vår planerade pilot – ett samarbete mellan RKAB och Euromekanik

Green Hydrogen Pilot

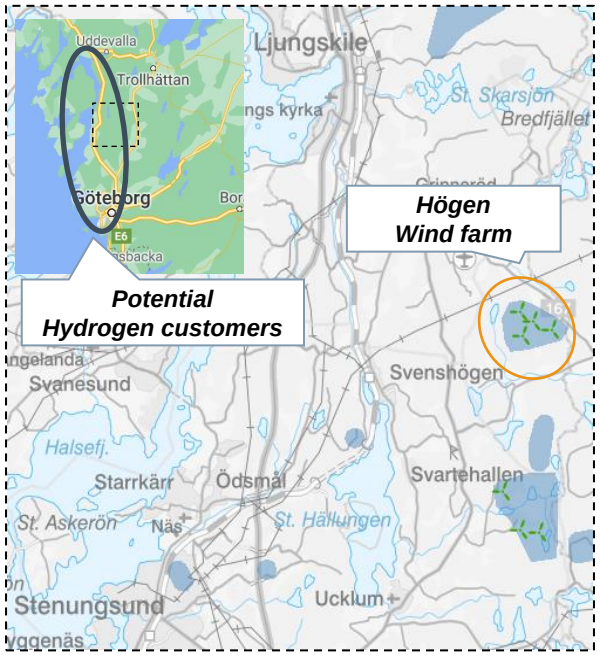
- Samarbete mellan Rabbalshede Kraft och Euromekanik för en pilotanläggning
- Indikativt ~1 MW kapacitet → ca 400-500 kg vätgas per dygn
- Som utgångspunkt placeras vätgasproduktionen vid vindanläggning – 4 möjliga parker, samtliga i sydvästra Sverige
- Kunddialoger pågår

Schematisk skiss

“Green Hydrogen Pilot”

Project Högen - our first step within hydrogen

Map:



Project information:

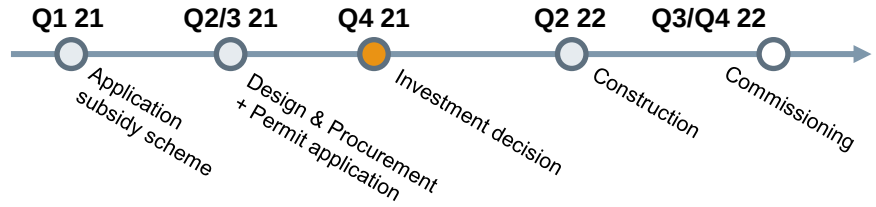
Hydrogen production

Electrolyser capacity	~1 MW
Gas-production	~400 kg/day
Hydrogen storage	400-800 kg

Wind farm

Number of turbines	3
Total capacity	10.5 MW
Electricity-production	37 GWh / year
Commissioning	Feb 2021

Indicative timeplan:



Status:

- ***CAPEX support secured through Klimatklivet***
- Customer dialogue ongoing with several parties
- Permit process started

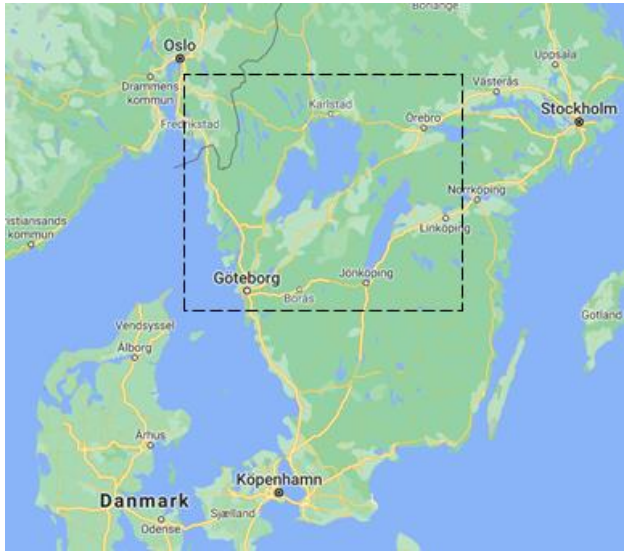
Next steps:

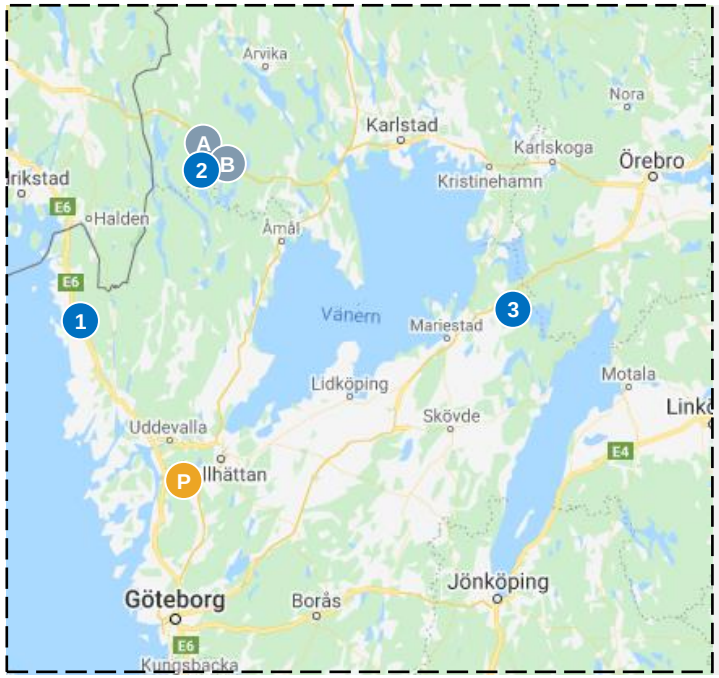
- Start of detailed engineering Q2 2021
- Customer selection Q3 2021
- Permit certainty Q3/Q4 2021

Rabbalshede Kraft

RKAB Green Hydrogen roadmap

Initially ca 50 MW electrolyser delivered with short timeline





P *Högen (Pilot)*

- 1 MW electrolyzer
- ca 25 km to Stenungsund industry cluster

1 *Femstenaberg*

- 10 MW electrolyzer
- 250 m from E6

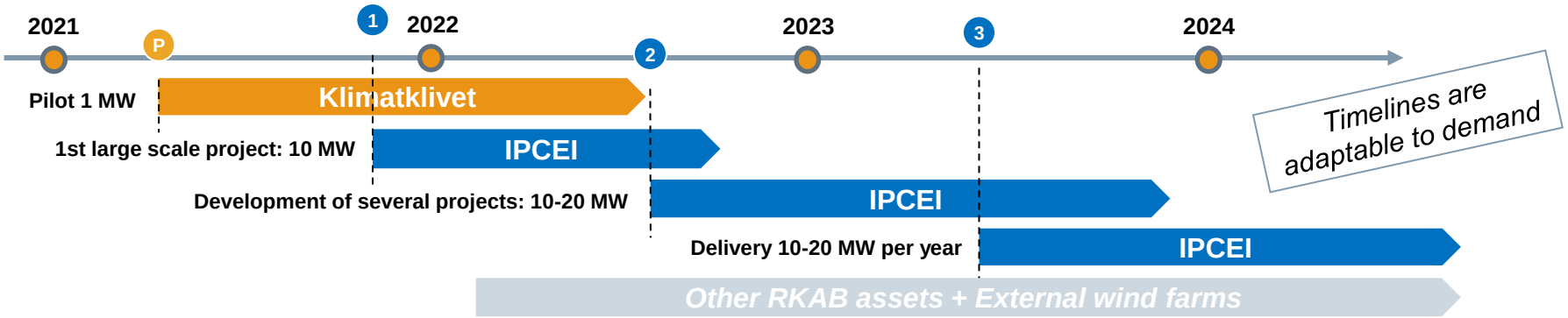
2 *Årjäng cluster*

- 20 MW electrolyzer
- Entrance to wind farm directly from E18 (ca 3 km)

3 *Fägremo*

- 20 MW electrolyzer
- ca 8 km to E20

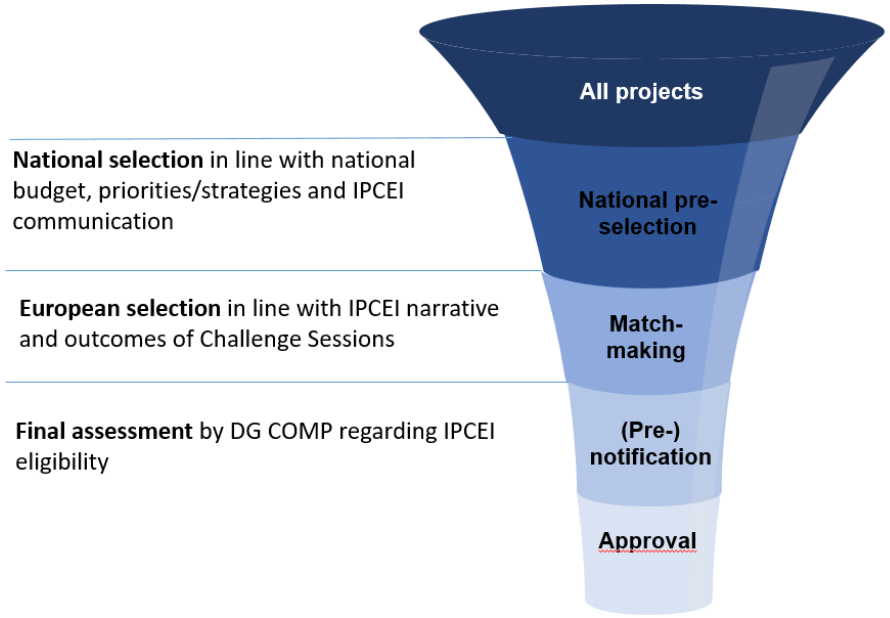
RKAB Green Hydrogen initiative:



Rabbalshede Kraft

IPCEI process

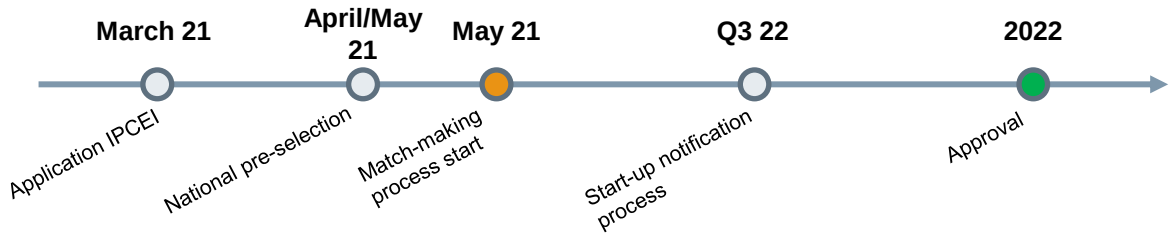
RKAB has been selected for the match-making step



Main EU targets IPCEI Hydrogen
(as mentioned during MS meeting 12/3)

- Increase H2 production and capacity in a sustainable and cost efficient way
- Establish the EU as world leader in green hydrogen technologies
- Significantly reduce CO2 footprint
- Ensure industrial and strategic autonomy
- Coordinate H2 activities across EU to create H2 eco system
- Sustainable distribution of H2
- Boosting zero emission vehicles
- Transfer knowledge
- Support new jobs
- Stimulate life cycle approach

IPCEI timeplan:



IPCEI projects are evaluated based on three factors, this is how RKAB have tackled these:

R&D activities

- RKAB's concept is unique in Sweden and Europe in several ways.
- Enabling proof-of-concept in the areas permit applications, engineering, construction and operation.
- Innovation necessary to optimize on three markets; electricity spot, hydrogen market and grid ancillary services.

First Industrial Deployment

- Industrial roll-out of a concept tested in small-scale (the Pilot).
- New concept entails high research and innovation components the first years of operation.
- Enabling integration of first-in-kind components resulted from the development and industrialization of electrolysis equipment.
- Enabling a new hydrogen infrastructure including production, distribution and usage of green hydrogen.

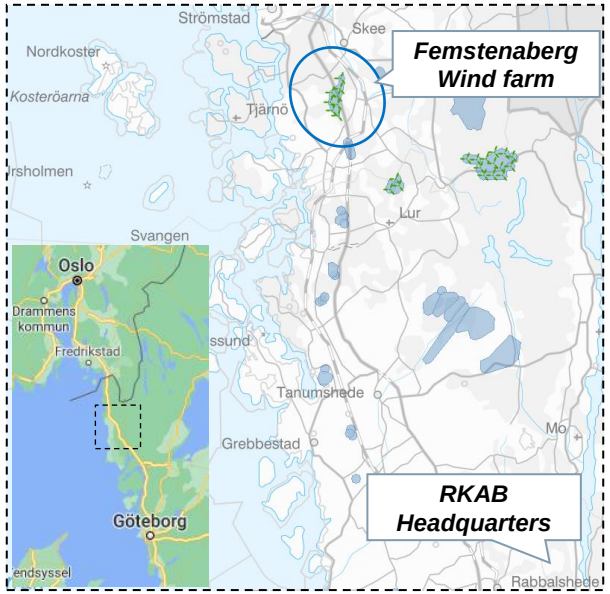
Environmental contribution

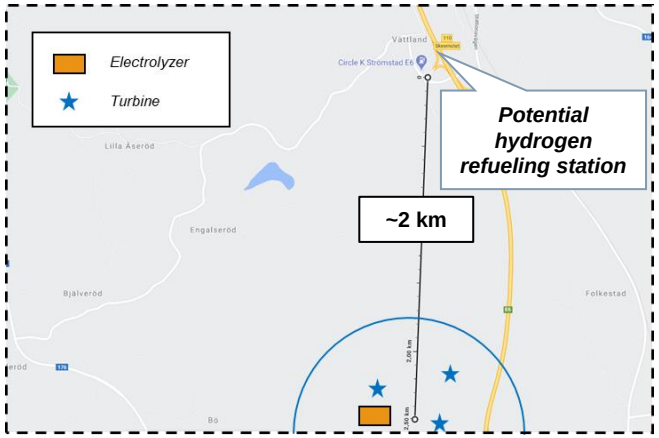
- Enabling deep decarbonization of industry and transport sector by delivering green hydrogen.
- Potential to reduce emissions of ca 91 100 tons of CO2 equivalents per year, if all produced green hydrogen is used to replace diesel in heavy duty transport

Project Femstenaberg

One out of three IPCEI-projects

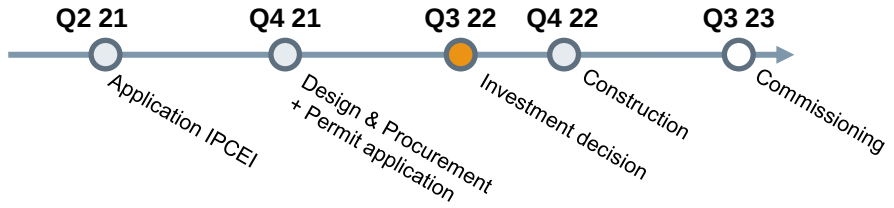
Map:





Pipeline possibility for very cost-competitive hydrogen distribution

Indicative timeplan:



Project information:

Hydrogen production

Electrolyzer capacity	~10 MW
Gas-production	~4000 kg/day
Hydrogen storage	TBD

Wind farm

Number of turbines	7
Total capacity	46.2 MW
Electricity-production	130 GWh / year
Commissioning	Q4 2022

Rabbalshede Kraft

Why Hydrogen?

Use cases and country strategies

Hydrogen will play a major role to achieve deep decarbonisation

Industry

- Industrial feedstock for refineries, ammonia and other chemical production
- Green steel manufacturing
- Injection into gas distribution grid to decarbonise heating fuel supply

Today there are no proven alternatives in decarbonising industry

Mobility

- Heavy road transport where batteries are not sufficient
- Busses and trains for public transport
- Maritime and shipping – eMethanol & ammonia
- Aviation – direct use & synfuels

Current battery technology cannot meet 100% electrification

Power

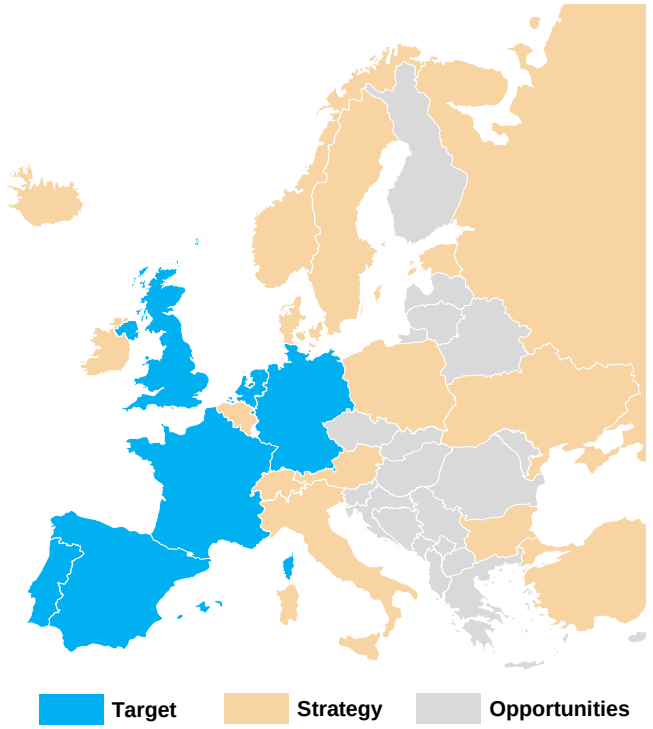
- Power-to-X
- Energy storage & Peak-shaving
- Ancillary services for electricity grid
- Fuel cells

Hydrogen will add value to renewable energy sources and to the grid

EU Targets:

Phase 1: 2020-24	Phase 2: 2025-30	Phase 3: 2030-
6 GW electrolysers 1 Mtonne Green H2	40 GW electrolysers 10 Mtonne Green H2	Large scale deployment

€450 Bn commitment



National targets for 2030

- 5GW (low carbon H2)
- £4Bn investment req.

- 4GW electrolysis
- €35Mn funding per year

- 5GW electrolysis
- €9Bn funding to 2026

- 6.5GW electrolysis
- €7Bn funding to 2030

- 4GW electrolysis
- €8.9Bn funding

- 2GW electrolysis
- €7Bn funding

Rabbalshede Kraft

Swedish Hydrogen Value Chain

Partly pioneering, partly immature

Upstream — **Value Chain** — **Downstream**

Potential RKAB customers

Hardware/Equipment

Green H2 prod.

nel
hystar
SIEMENS

Applications

POWERCELL
VOLVO
SCANIA

- Several **innovative Nordic suppliers driving the H2 development** (electrolysis, fuel cells)
- **Leading suppliers in long-haul transport** – with significant plans for hydrogen driven transport

Supply

Grey

Linde
BOREALIS
Nouryon
Perstorp

Green

NILSSON ENERGY
Rabbalshede Kraft
HYBRIT
H2green steel
Liquid Wind

- **Non-existing competition in green H2 production directly from RES**
- Main production for in-house use (except Nilsson Energy and RKAB)
- **Pioneering green steel** and eMethanol production and planned based on “green” H2 (electricity from grid)

Distribution/Wholesale

Conventional

st1
CIRCLE K
OKQ8

Gas focus

Everfuel
HYNION
Air Liquide
econ
NORDION ENERGI

- **Almost non-existing H2 distribution today** – few H2 fuelling stations but plans are emerging
- Conventional gas companies exploring H2 field (limited actions)
- No H2 pipelines (natural gas pipelines in southern Sweden)

End customer

Industry

BOREALIS
Nouryon
Perstorp
HYBRIT
H2green steel

Transport

Renova
POWERCELL
MARIESTAD

- Industries produce their own grey hydrogen – but open for purchase of green hydrogen
- **Transport sector very limited in demand**

Hydrogen production

3 types of hydrogen based on production process

	Input	Process	CO2 emissions	Future?
Grey H2	Natural Gas	Steam Methane Reformer (SMR)	Released	**Existing solution that must be replaced**
Blue H2	Natural Gas	Steam Methane Reformer (SMR) & CO2 capture (CCS)	Captured, stored or utilized	**CCS technology neither mature or cost-effective today**
Green H2	Renewable electricity	**Electrolysis**	**Zero emissions**	Only solution that today can enable "*deep green transformation*"

Rabbalshede Kraft

Electrolysis

- Technology existed since 1800
- The only carbon-free way to produce hydrogen
- Water + Electricity = Hydrogen + Oxygen + Heat
- H20 + é = H2 + O2 + Heat

3 types of electrolysis technologies:

Alkaline

- Most mature technology
- **Currently the cheapest technology**

PEM (Proton Exchange Membrane)

- Promising technology (not as mature as Alkaline)
- **Quicker response time**
- Wider range of operating loads
- More applicable to intermittent RES

Solid oxide

- Immature technology with higher costs
- Operates at higher temperatures, which means **lower energy requirements** to split water molecules

Tack!