BUSINESS FINLAND

Hydrogen Roadmap for Finland

Juhani Laurikko, Principal Scientist, VTT

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CONTENTS

INTRODUCTION

- **BUSINESS FINLAND CONTRACTED VTT TO PREPARE A NATIONAL HYDROGEN ROADMAP** FOR FINLAND IN JUNE
- **TIME HORIZON** FOR THE FRAMEWORK **WAS SET TO 2030**, AND
- THE MAIN CONTEXT WAS DEFINED **TO VIEW FINLAND AS A MEMBER STATE IN THE EUROPEAN UNION**
- WORK IS MAINLY **BASED ON INFORMATION FROM PUBLIC SOURCES**, BUT
- THE WORK ENCOMPASSED ALSO **INTERVIEWS WITH RELEVANT INDUSTRY** REPRESENTATIVES
- TODAY, **ONLY PUBLIC INFORMATION AND RESULTS OF TEAM VTT'S OWN JUDGEMENTS** ARE PRESENTED

PRESENTATION OF THE CORE TEAM AT VTT

- JUHANI **LAURIKKO**, DTech, Principal Scientist – Project Leader
- JARI **IHONEN**, DTech, Principal Scientist
- JARI **KIVIAHO**, PhD, Senior Principal Scientist
- OLLI **HIMANEN**, DTech, Team Leader
- VILLE **SAARINEN**, DTech, Research Scientist

- Additional assistance from: Markus **Hurskainen**, Robert **Weiss** and Janne **Kärki**

ROADMAP VS. STRATEGY

- IN THIS CONTEXT, WE HAVE CHARACTERISED THAT **A ROADMAP IS A DESCRIPTION OF THE OPERATING ENVIRONMENT**, INCLUDING RULES & REGULATIONS, NECESSARY, AVAILABLE (AND MISSING) ASSETS, GEOGRAPHY ETC, ALL **RELATED TO PRODUCTION AND USE OF "GOOD" HYDROGEN** PRODUCED IN A SUSTAINABLE WAY
- IT **SERVES AS A BASIS FOR SETTING A VISION AND A STRATEGY**, AND **ASSIST IN NAVIGATING** THRU THE LANDSCAPE **TO REACH THAT VISION**

SOME BASIC FIGURES FOR HYDROGEN

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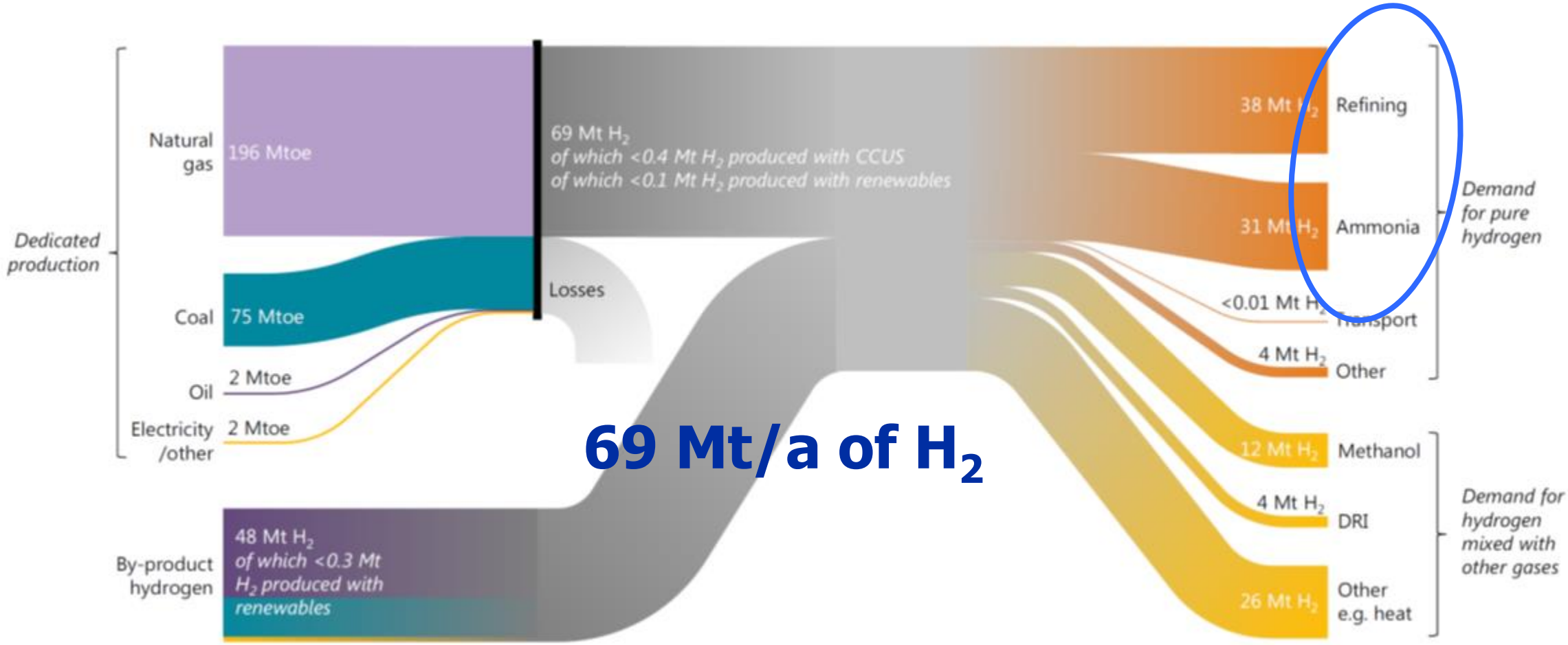
SOME BASIC FIGURES FOR HYDROGEN - GLOBAL



69 Mt/a of H_2

SOURCE: IEA 2019

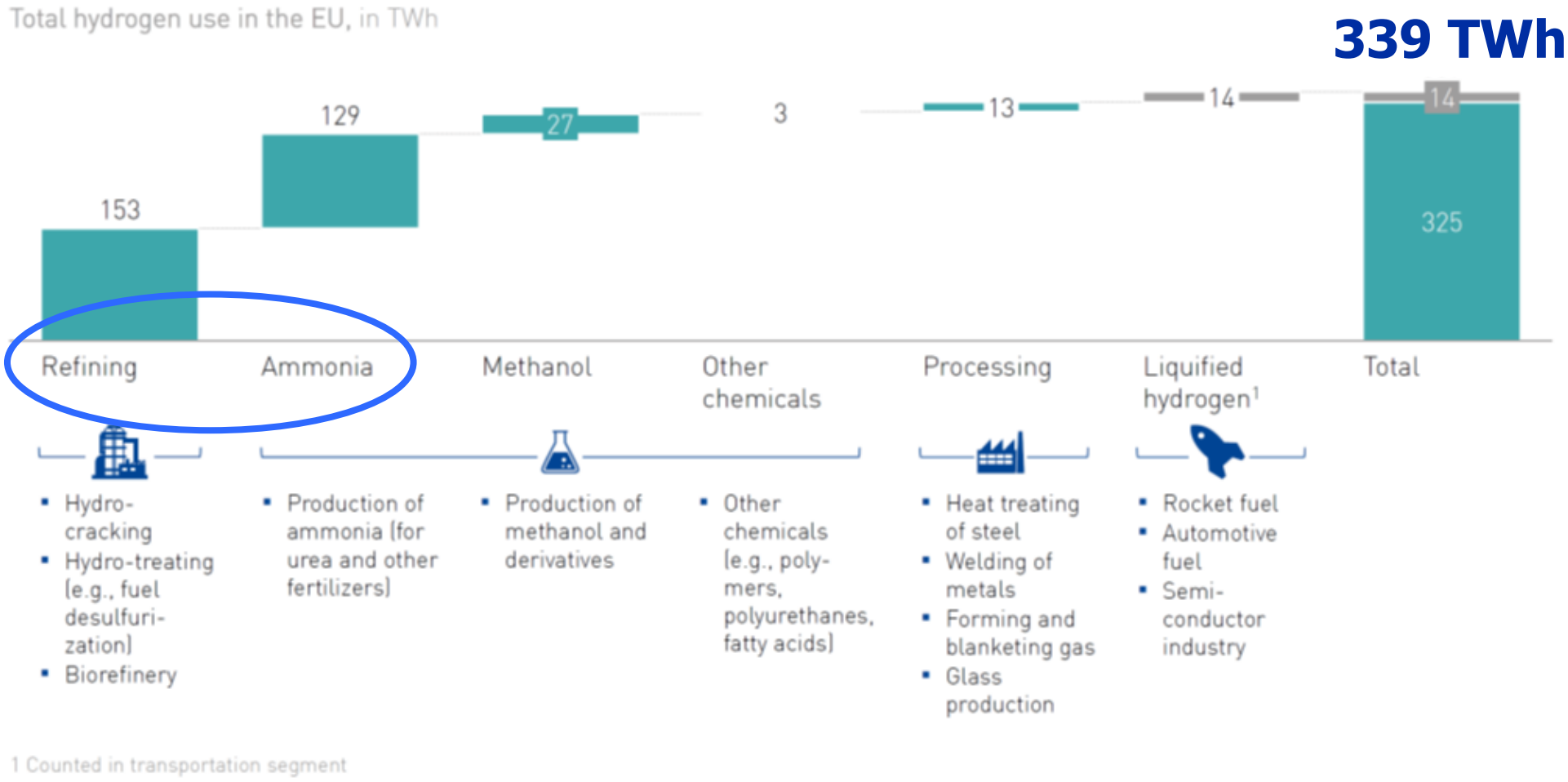
SOME BASIC FIGURES FOR HYDROGEN - GLOBAL

- SCALING TODAY'S OPPORTUNITIES FOR THE FUTURE OF HYDROGEN IN G20:
- **69 Mt/a of H_2 = 2300 TWh (LHV)**
- **NEEDS ABOUT 4000 TWh NEW CLEAN ELECTRICITY GENERATION**, WHICH IS
- **MORE THAN TODAY'S TOTAL ELECTRICITY GENERATION IN EU!**

- IF IMPELEMENTED, **EQUALS CAPTURING OF ABOUT 800 Mt OF CO_2** AND **CORRESPONS TO NEARLY 2% OF GLOBAL EMISSIONS**

SOME BASIC FIGURES FOR HYDROGEN - EU

339 TWh



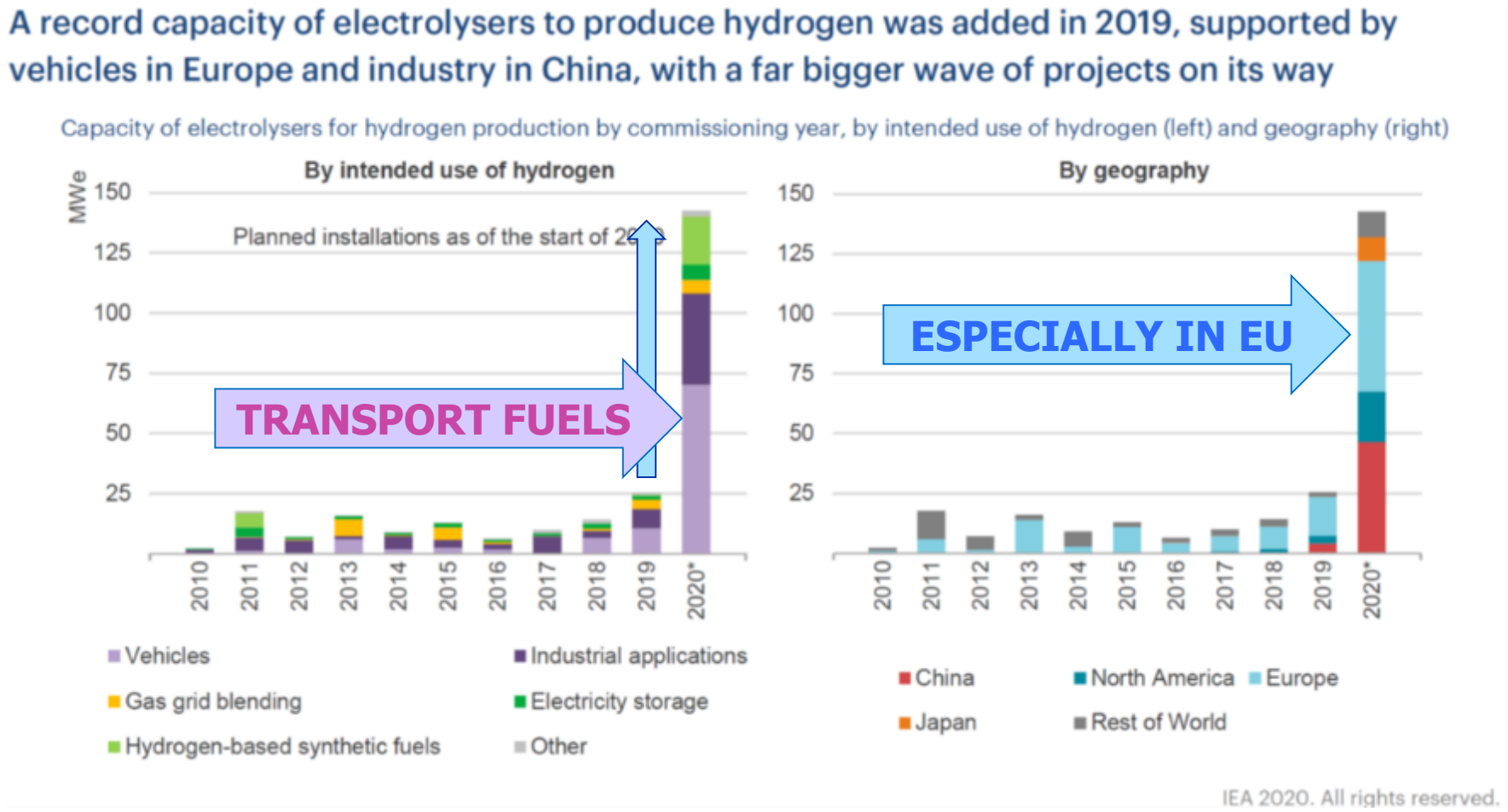
Source: FCH JU (2019) Hydrogen Roadmap Europe

SOME BASIC FIGURES FOR HYDROGEN - EU

- **339 TWh AS HYDROGEN** (LHV), OF WHICH ABOUT
- **200 TWh IS DEDICATED, PURE H_2 PRODUCTION**

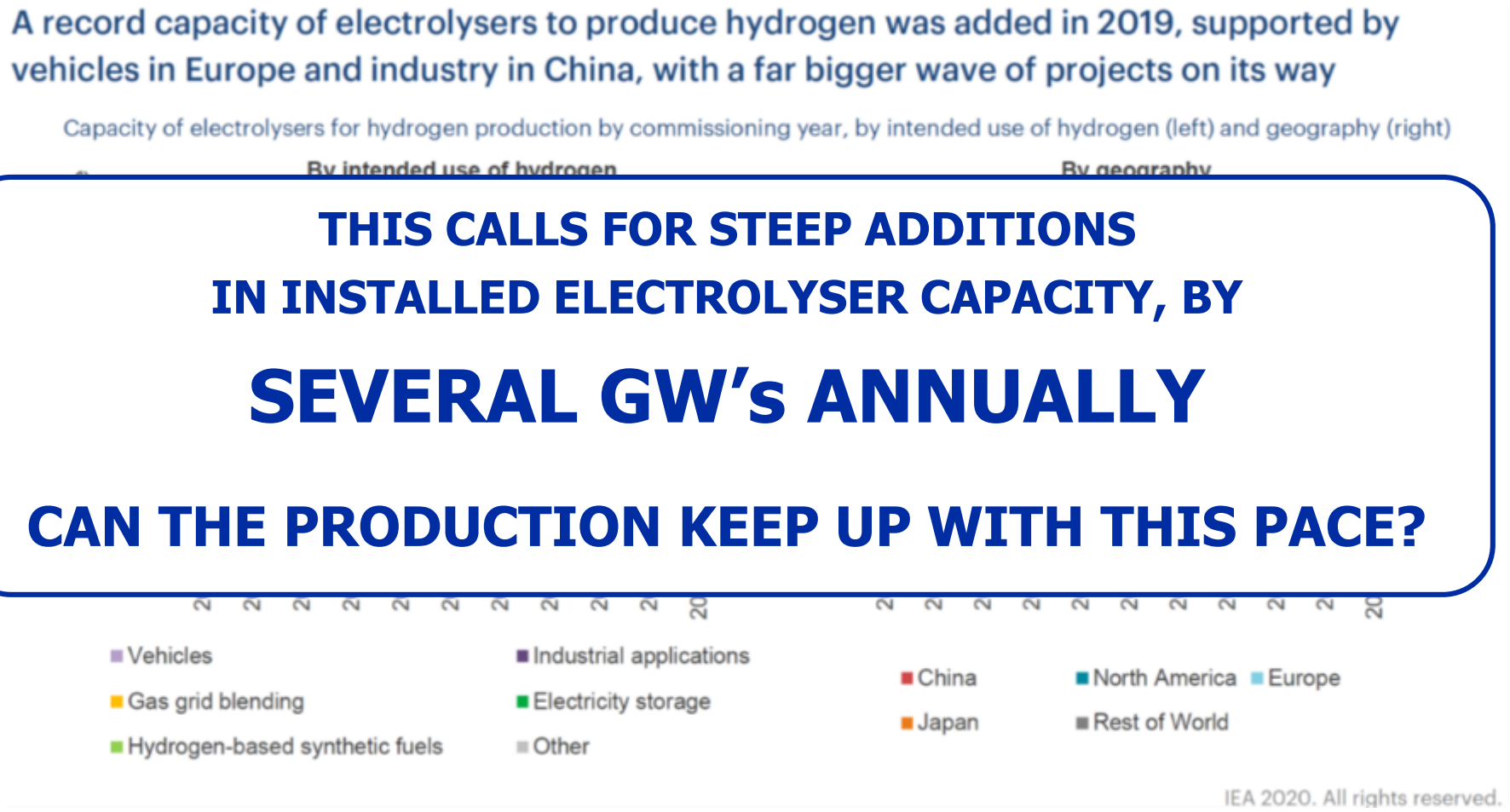
- **EQUALS 300-350 TWh OF NEW, CLEAN ELECTRICITY GENERATION**
- **ABOUT 10% of TOTAL PRESENT CONSUMPTION IN EU**

IEA PREDICTS A STEEP GROWTH



Source: IEA World Energy Investment (2020)

IEA PREDICTS A STEEP GROWTH



THIS CALLS FOR STEEP ADDITIONS
IN INSTALLED ELECTROLYSER CAPACITY, BY

SEVERAL GW's ANNUALLY

CAN THE PRODUCTION KEEP UP WITH THIS PACE?

Source: IEA World Energy Investment (2020)

WHAT ARE THE POSSIBLE PITFALLS?

- THE **TARGETED GROWTH NEEDS MORE THAN 100 TIMES ANNUAL INSTALLATIONS OF ELECTROLYSERS** COMPARED TO NEW INSTALLATIONS IN 2019
  - **CAN THE INDUSTRY SCALE UP** SO FAST?
  - **ARE THE INVESTORS READY** FOR SUCH A "QUANTUM LEAP"?

- THE **AUTOMOTIVE INDUSTRY IS CURRENTLY FACING THE SAME CHALLENGE** IN ELECTRIC VEHICLE (BATTERY) PRODUCTION, **AND NOT WITHOUT DISTRESS**

WHAT ARE THE POSSIBLE PITFALLS?

- THE **TARGETED GROWTH DEMANDS ALSO STRONG GROWTH IN RENEWABLE ELECTRICITY GENERATION**
  - ARE THERE **SUFFICIENT INVESTMENT INTERESTS?**
  - **CAN THE CAPACITY BUILD-UP PROCESS COPE WITH THE PACE**?
    - **PERMITTING AND ACCEPTANCE** OF NEW CLEAN ELECTRICITY PRODUCTION **IS A TEDIOUS AND TIME-CONSUMING PROCESS**

WHY HYDROGEN IS IMPORTANT JUST NOW

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WHY HYDROGEN IS IMPORTANT JUST NOW?

- IN RED II, **RENEWABLE HYDROGEN IS** ACC H
  - AS **TRANSPORTATION FUEL** AND
  - AS **INTERMEDIATE PRODUCT** FOR **REPL NG FOSSIL HYDROGEN IN CONVENTIONAL TRASNPORT FUELS**

"PULL"

- OTHER (GLOBAL) **TARGET PROGRAMMES FOR GHG REDUCTIONS**

- **REDUCTION OF THE COST OF "GOOD" HYD** TO
  - **PROGRESS IN THE TECHNOLOGY** OF ELE
  - **INCREASING** PRODUCTION OF **LOW-COST NEWABLE ELECTRICITY**

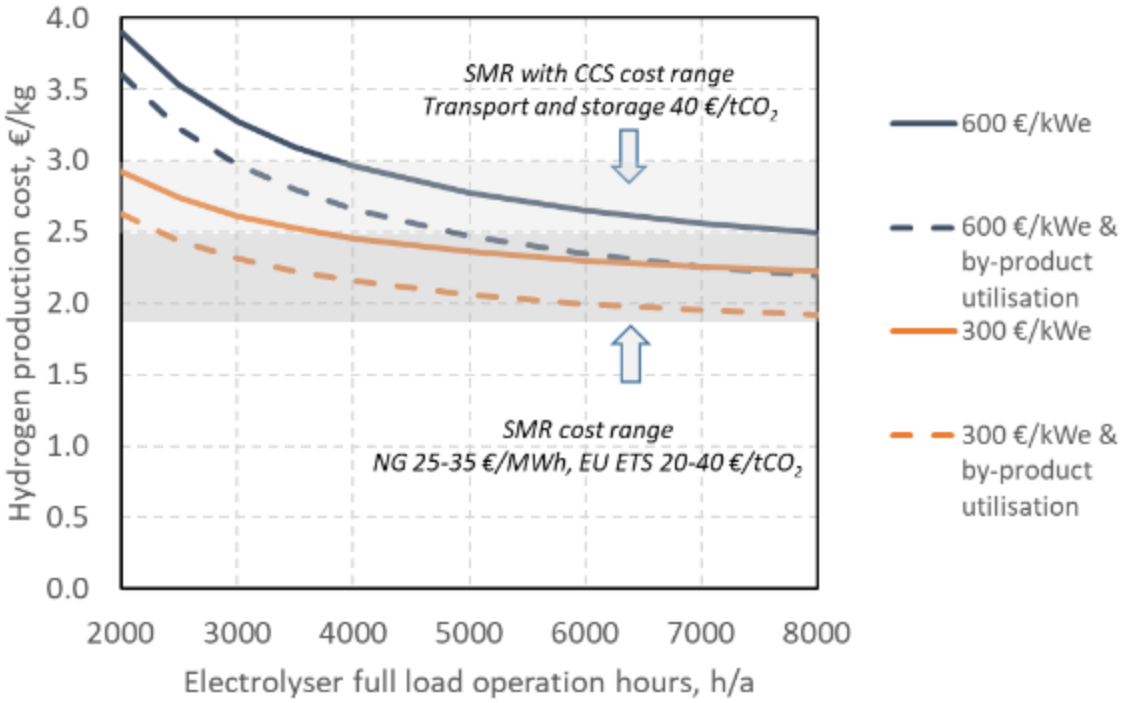
"PUSH"

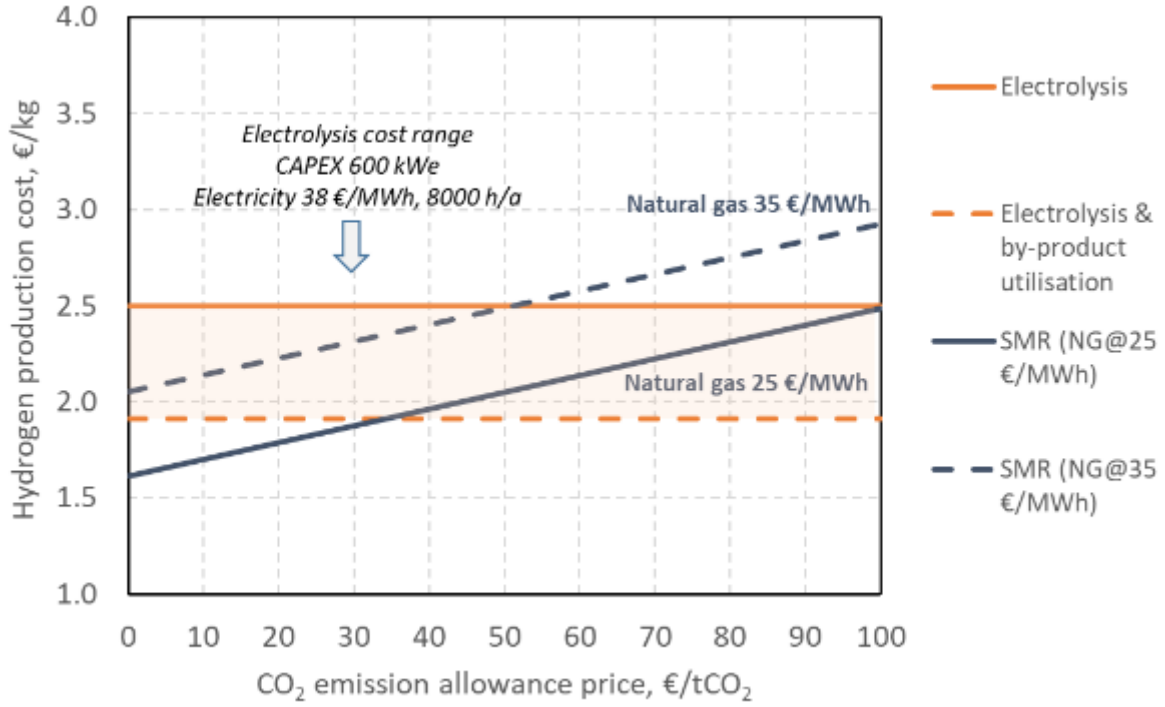
WHAT DEFINES THE MARKET FOR ”GOOD” HYDROGEN?

- **COST OF HYDROGEN AT THE SITE OF USE**
  - INCLUDING PRODUCTION, TRANSPORT, STORAGE etc.
  - ON-SITE COST IS DIFFERENT DEPENDING ON LOCATIONS OF PRODUCTION AND USE
- **ADDED VALUE OF ”GOOD” HYDROGEN**
  - **RED II CREATES ADDITIONAL ”SURGE” FOR COMPLIANT HYDROGEN**, BUT THE VALUE IS DIFFICULT TO ESTIMATE EXACTLY, DUE TO **UNCERTAINTY IN**
  - **COSTS OF HVO AND OTHER PRODUCTS TO FULFILL RED II MANDATE**
- **ALL OTHER, COMPETING USE OF HYDROGEN**
  - ALL PRESENT USE OF FOSSIL-BASED HYDROGEN

COST OF "GOOD" HYDROGEN IS A HIGHLY ELUSIVE FIGURE

PRODUCT COST IS DEPENDENT ON A MULTITUDE OF DIFFERENT FACTORS THAT DEPEND ON LOCATION, TIME ETC.





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Graphs: Markus Hurskainen, VTT

HYDROGEN IN FINLAND

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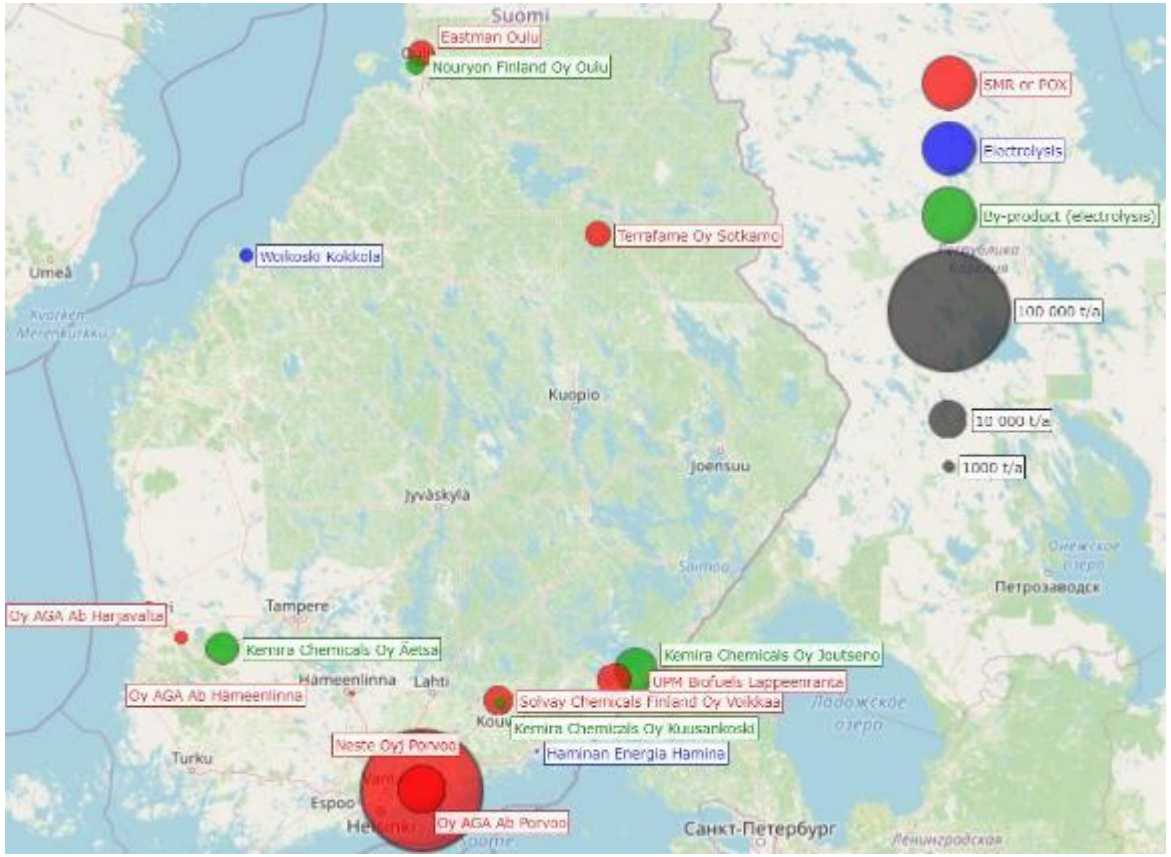
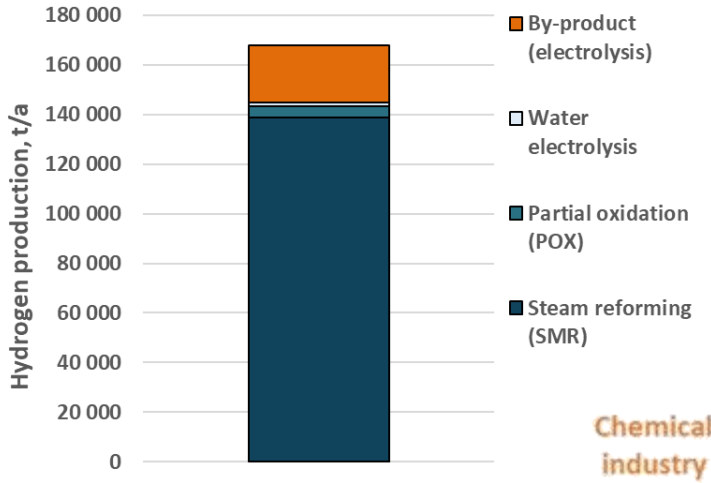
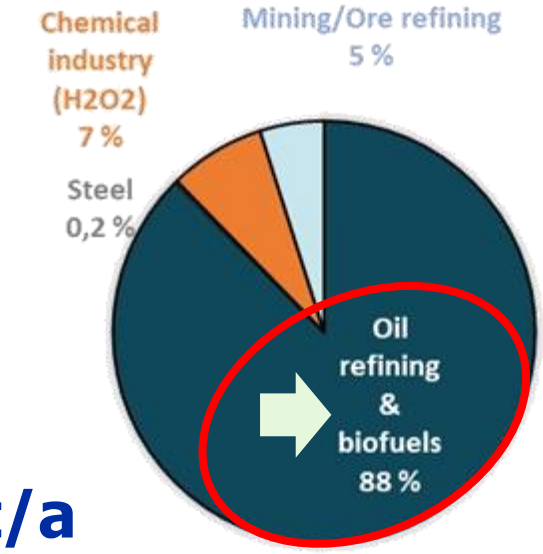
HYDROGEN FINLAND – CURRENT PRODUCTION AND USE







CURRENT PRODUCTION AND USE CA. 150 000 t/a

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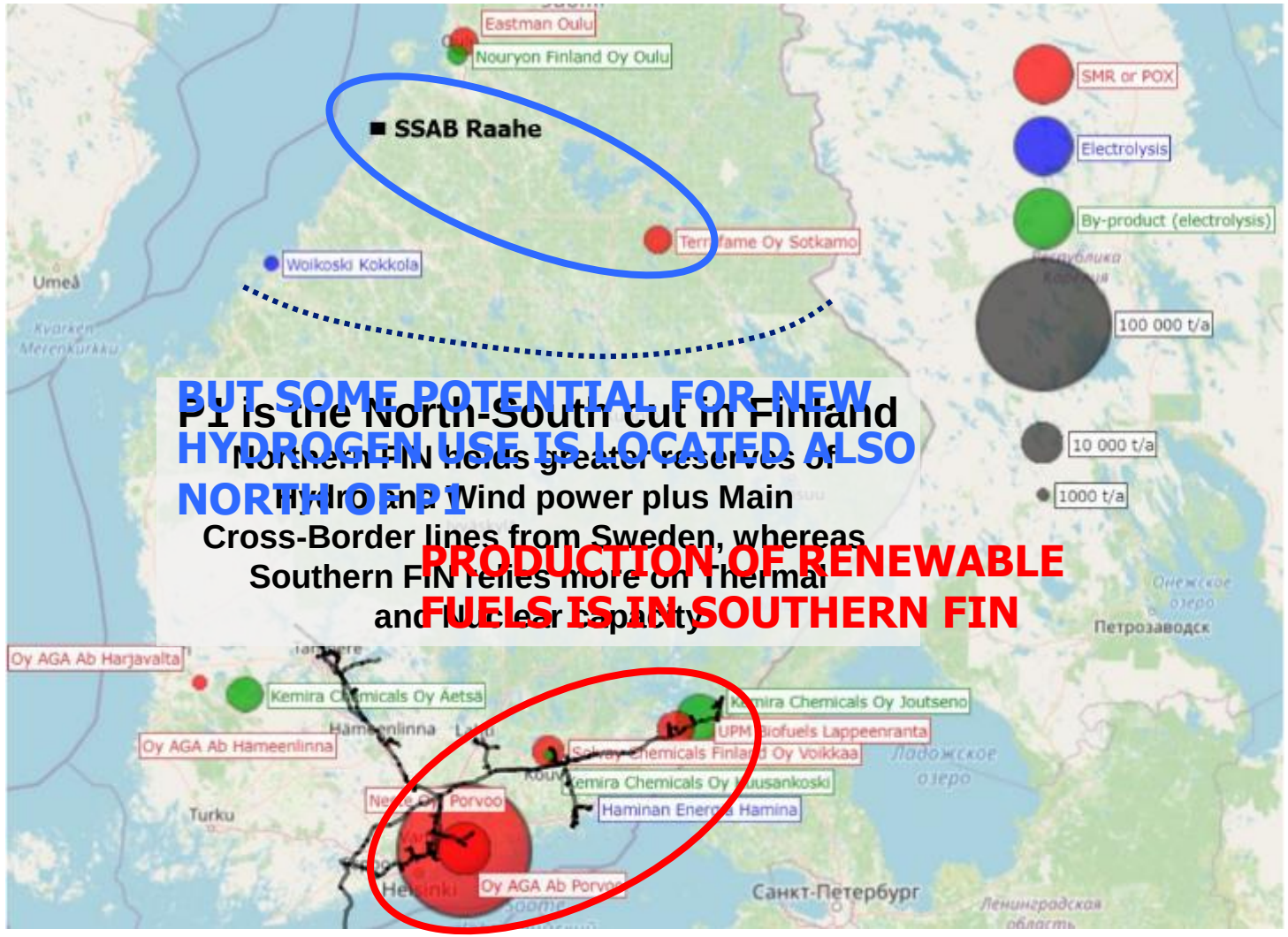
Graphs: Markus Hurskainen, VTT

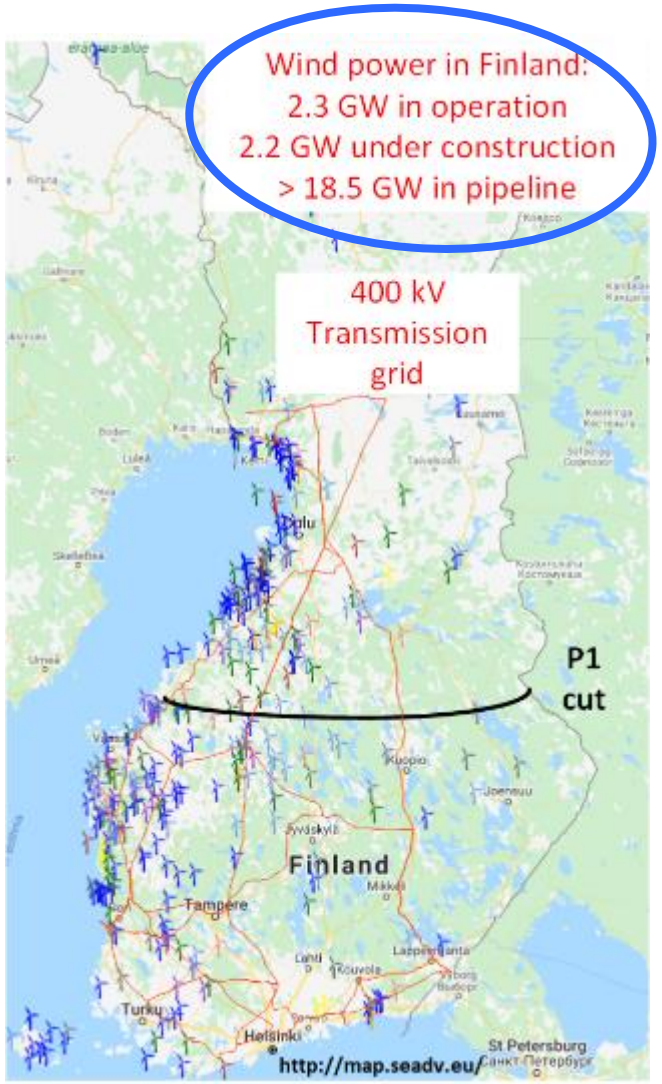
POTENTIAL NEW USE OF HYDROGEN IN FINLAND

- **EXISTING AND ENLARGING PRODUCTION OF RENEWABLE TRANSPORT FUELS**
  - NESTE/PORVOO: HVO/NEXTBTL*
  - UPM KYMMENE/LAPPEENRANTA: HVO/BioVerno*
- **TERRAFAME MINE**
  - SOTKAMO, PRODUCTION OF H_2S FOR THE ORE REFINING PROCESS*
- **SSAB STEEL PLANT**
  - RAAHE, PRODUCTION OF CO_2-FREE STEEL (HYBRIT PROCESS)
- **DIRECT USE IN HEAVY TRANSPORT VEHICLES**
  - USE OF HYDROGEN FUELL CELLS TO LOWER TRANSPORT COSTS IN SELECTED POINT-TO-POINT LOGISTIC CASES

*REPLACING FOSSIL H_2 IN PRODUCTION

A TERRITORIAL DIVIDE IN POWER GENERATION





Graphs: Markus Hurskainen & Jari Ihonen, VTT

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SWOT FOR FINLAND

STRENGTHS	WEAKNESSESS
Good (onshore & offshore) wind resources Strong transmission grid Stable, predictible regulation Industrial hydrogen experience	Higher electricity market price vs. Sweden/Norway Less hydrogen experience outside of industry No hydrogen use in traffic No formations for salt caverns
OPPORTUNITIES	**THREATS**
Production of renewable transportation fuels Cost-efficient decarbonisation of existing hydrogen use CO2-free steel production Lower logistics cost for industry	Unfavourful changes and/or interpretations of RED II directive Price of technology remains high Low fossil fuel and CO2 allowance prices Delayed scale-up of electrolyser manufacturing capacity

SWOT FOR FINLAND – STRENGHTS & ASSETS

- **GOOD WIND RESOURCES – BOTH ONSHORE & OFFSHORE**
- **STRONG TRANSMISSION GRID**
- **STABLE, PREDICTIBLE REGULATION FRAMEWORK**
- **STRONG EXPERIENCE IN INDUSTRIAL HYDROGEN USE**

SWOT FOR FINLAND – WEAKNESSES

- HIGHER ELECTRICITY MARKET PRICE VS. SWEDEN & NORWAY
- LESS HYDROGEN EXPERIENCE OUTSIDE OF INDUSTRY
- NO HYDROGEN USE IN TRAFFIC & TRANSPORTATION
- NO FORMATIONS LIKE SALT CAVERNS (FOR STORAGE)

SWOT FOR FINLAND – THREATS

- CHANGES AND/OR INTERPRETATIONS OF RED II DIRECTIVE THAT COULD PROVE TO BE UNFAVOURABLE FOR FINLAND
- PRICE OF HYDROGEN TECHNOLOGY REMAINS HIGH
- LOW PRICES FOR FOSSIL FUELS AND CO_2 ALLOWANCES
- DELAYED SCALE-UP OF ELECTROLYSER MANUFACTURING CAPACITY

SWOT FOR FINLAND – OPPORTUNITIES

- **EXISTING PRODUCTION OF RENEWABLE TRANSPORTATION FUELS**
- **COST-EFFICIENT DECARBONISATION OF EXISTING HYDROGEN USE**
- **ENABLER FOR CO_2-FREE STEEL PRODUCTION**
- **OFFERS LOWERING THE COST OF LOGISTICS FOR INDUSTRY**

HYDROGEN VALUE CHAIN ANALYSIS FOR FINLAND

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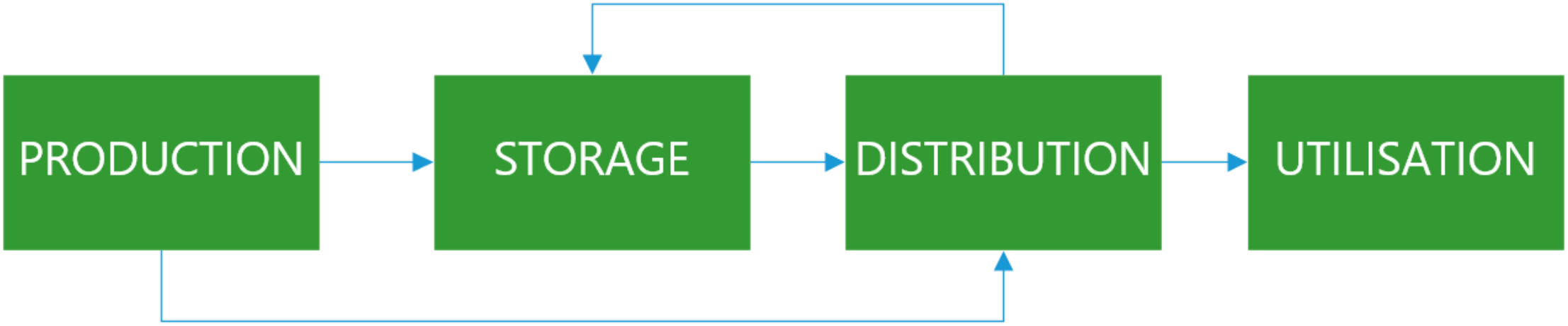
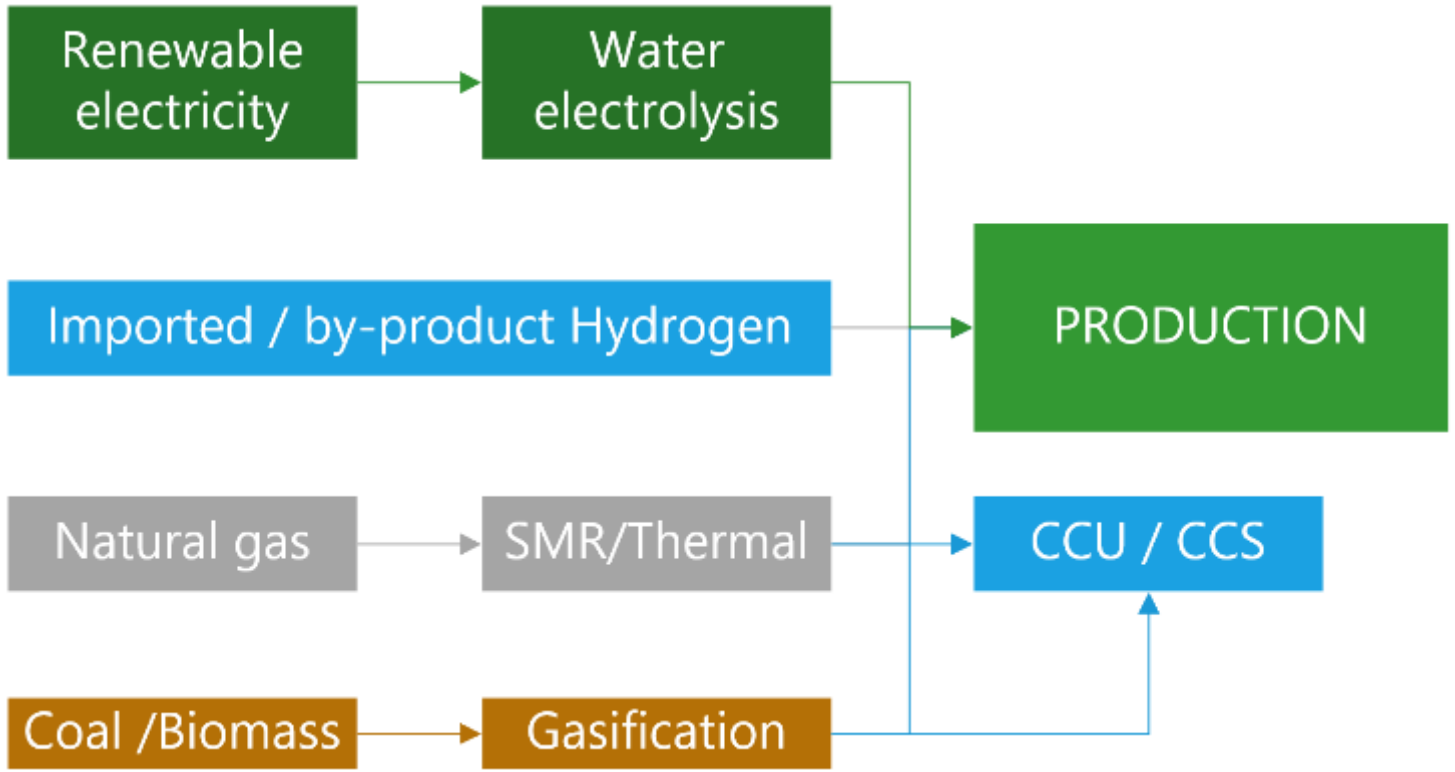
SIMPLE VALUE CHAIN FOR HYDROGEN



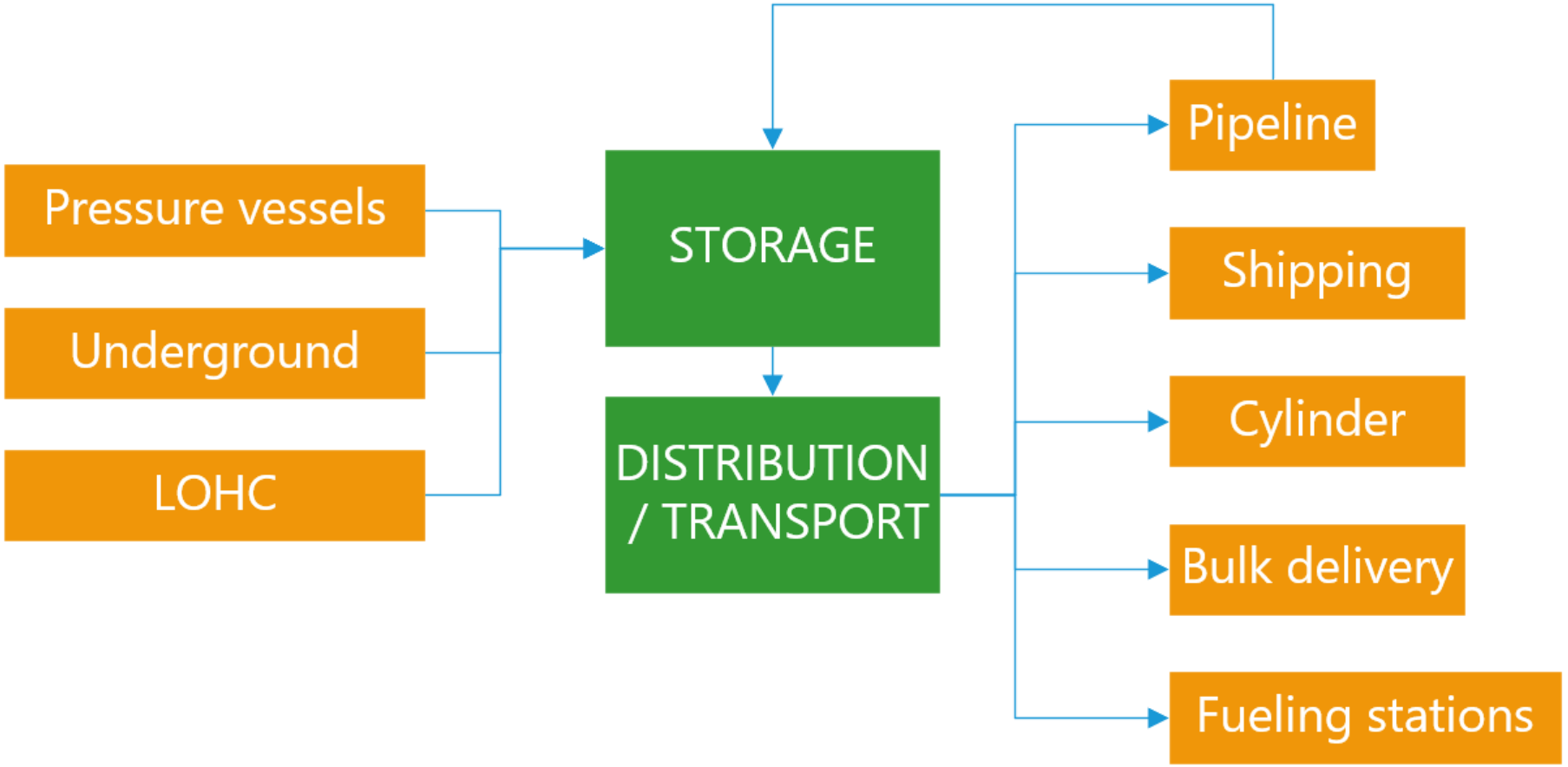
Graphs: Ville Saarinen, VTT

VALUE CHAIN FOR HYDROGEN PRODCUTION



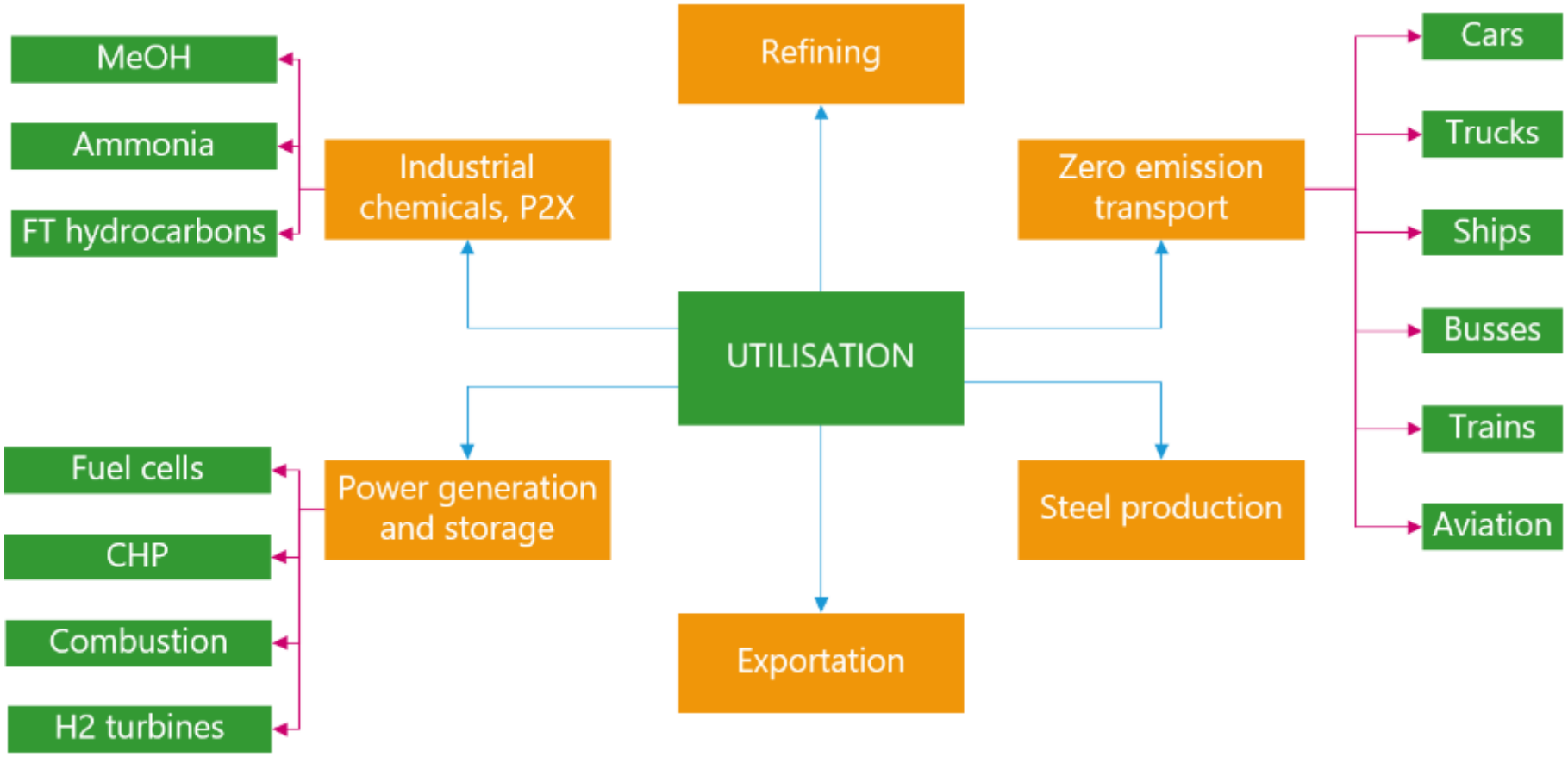
Graphs: Ville Saarinen, VTT

VALUE CHAIN FOR HYDROGEN STORGAGE & DISTR.



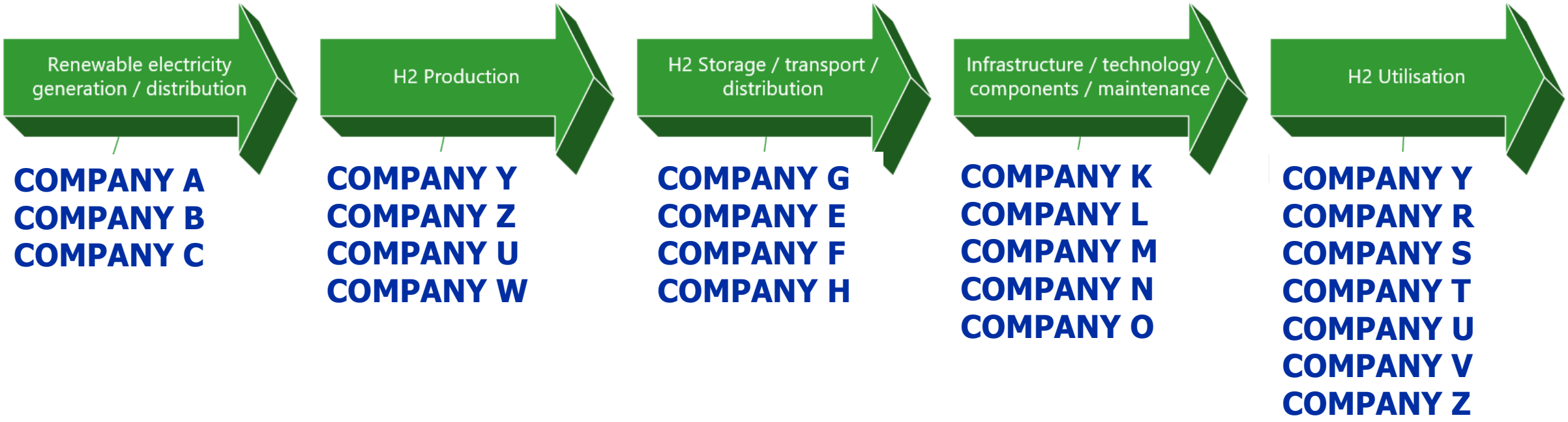
Graphs: Ville Saarinen, VTT

VALUE CHAIN FOR HYDROGEN UTILISATION



Graphs: Ville Saarinen, VTT

VALUE CHAIN FOR HYDROGEN IN FINLAND



THE VALUE CHAIN IS ALREADY QUITE WELL-POPULATED!

RECOMMENDATIONS AND TIMELINE FOR ACTIONS

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RECOMMENDATIONS AND TIMELINE FOR ACTIONS

DOMAINS:
PRODUCTION, STORAGE, TRANSPORT & UTILISATION

TIMEFRAMES:
PRE 2025 AND POST 2025

RECOMMENDATIONS AND TIMELINE FOR ACTIONS

PRODUCTION

- SUPPORT INDUSTRIAL ELECTROLYSER PROJECTS IN FINLAND FOR (PARTIAL) REPLACEMENT OF FOSSIL FUEL BASED HYDROGEN PRODUCTION
- IMPROVE INVESTMENT CONDITIONS FOR NEW RENEWABLE ELECTRICITY PRODUCTION
- ACCELERATE DEVELOPMENT OF ELECTRICITY GRID INCLUDING CROSS-BORDER CAPACITY
- BOOST RD&D OF NEXT GENERATION ELECTRO-LYSER TECHNOLOGIES, WHICH COULD HAVE A DOMESTIC VALUE CHAIN
- ASSIST PARTICIPATION IN LARGE INTERNATIONAL HYDROGEN PROJECTS, AND IDENTIFY MOST POTENTIAL HYDROGEN VALLEY LOCATIONS IN FINLAND

- ENCOURAGE INDUSTRIAL ELECTROLYSER PROJECTS IN FINLAND FOR FULL REPLACEMENT OF FOSSIL FUEL BASED HYDROGEN
- PROMOTE INDUSTRIAL ELECTROLYSER PROJECTS FOR LARGE-SCALE NEW USE OF HYDROGEN
- SUPPORT COMMERCIALIZATION OF DOMESTIC SOLID OXIDE ELECTROLYSER TECHNOLOGY (FOR GO-NOGO DECISION)

2021 ... 2025

2026 ... 2030

RECOMMENDATIONS AND TIMELINE FOR ACTIONS

STORAGE

- **BOOST R&D FOR STORAGE OPTIONS THAT ARE FEASIBLE IN FINLAND (E.G. PIPELINE STORAGE, LINED ROCK CAVERN)**
- **SUPPORT FIRST INDUSTRIAL-SCALE HYDROGEN STORAGE DEMONSTRA-TIONS (E.G. PIPELINE STORAGE)**
- **SPONSOR FIRST LARGE-SCALE INDUSTRIAL HYDROGEN STORAGE**

2021 ... 2025

2026 ... 2030

RECOMMENDATIONS AND TIMELINE FOR ACTIONS

TRANSPORT OF HYDROGEN

- SUPPORT BUILD-UP OF HYDROGEN ROAD TRANSPORT INFRASTRUCTURE
- ENCOURAGE R&D FOR POSSIBLE REPURPOSING OF EXISTING NATURAL GAS PIPELINES
- BOOST R&D FOR DEDICATED HYDROGEN PIPELINES

- PROMOTE FIRST HYDROGEN PIPE-LINES, EITHER NEW OF REPURPOSED NG PIPELINES (GO-NO GO DECISION)

2021 ... 2025

2026 ... 2030

RECOMMENDATIONS AND TIMELINE FOR ACTIONS

UTILISATION

- SPONSOR RD&D FOR USE OF HYDROGEN IN HEAVY VEHICLE APPLICATIONS TO IDENTIFY BEST USE CASES FOR HYDROGEN IN HEAVY INDUSTRIAL TRANSPORT
- PATRON BUILD-UP OF FIRST HYDROGEN REFUELING STATIONS
- SUPPORT RD&D FOR BLENDING HYDROGEN WITH NG/LNG IN INDUSTRIAL APPLICATIONS
- FOSTER RD&D FOR NEW HYDROGEN USE AND SMALL-SCALE DEMONSTRATION PROJECTS

- SUPPORT FLEET APPLICATIONS OF HYDROGEN HEAVY-DUTY VEHICLES IN INDUSTRY TRANSPORT APPLICATIONS (FOR A GO-NOGO DECISION)
- PROMOTE INVESTMENTS FOR NEW HYDROGEN USE (P2X etc.)

2021 ... 2025

2026 ... 2030

SUMMARY AND CONCLUSIONS

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SUMMARY AND CONCLUSIONS (PRELIMINARY)

- FINLAND HAS ALREADY A FAIRLY WELL-POPULATED VALUE CHAIN FOR HYDROGEN PRODUCTION AND USE
- STRONG GRID AND GOOD POTENTIAL FOR NEW RENEWABLE ELECTRICITY GENERATION
- STRONG HIGH-TECH INDUSTRY IN HYDROGEN TECHNOLOGY
- IDENTFIED, POTENTIAL LARGE-SCALE TARGETS FOR NEW HYDROGEN USE
- GOOD POTENTIAL TO ACCELERATE RD&D EFFORTS, BUT ALSO SOME OTHER CASES SUITABLE FOR PUBLIC SUPPORT
- STREMLINING OF RD&D FUNDING PROCESS IS NEEDED
- ENLARGING HYDROGEN-RELATED DOMESTIC MARKET IS NECESSARY

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THANK YOU FOR YOUR ATTENTION!

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beyond the obvious