Electrochemical Conversion and Materials - ECCM

National innovation platform of the Dutch government

www.CO2neutraalin2050.nl

The energy landscape is changing...

"*However, the real milestone is reached when an offshore hydrogen electrolysis system is built utilising the growing surplus* ***electrons*** *from those wind farms…*"

… and the supply of renewable electricity is increasing drastically…

- Strong increase in supply of wind at sea.
- On average, electricity does not become cheaper by definition, but a more volatile energy supply causes price fluctuations.

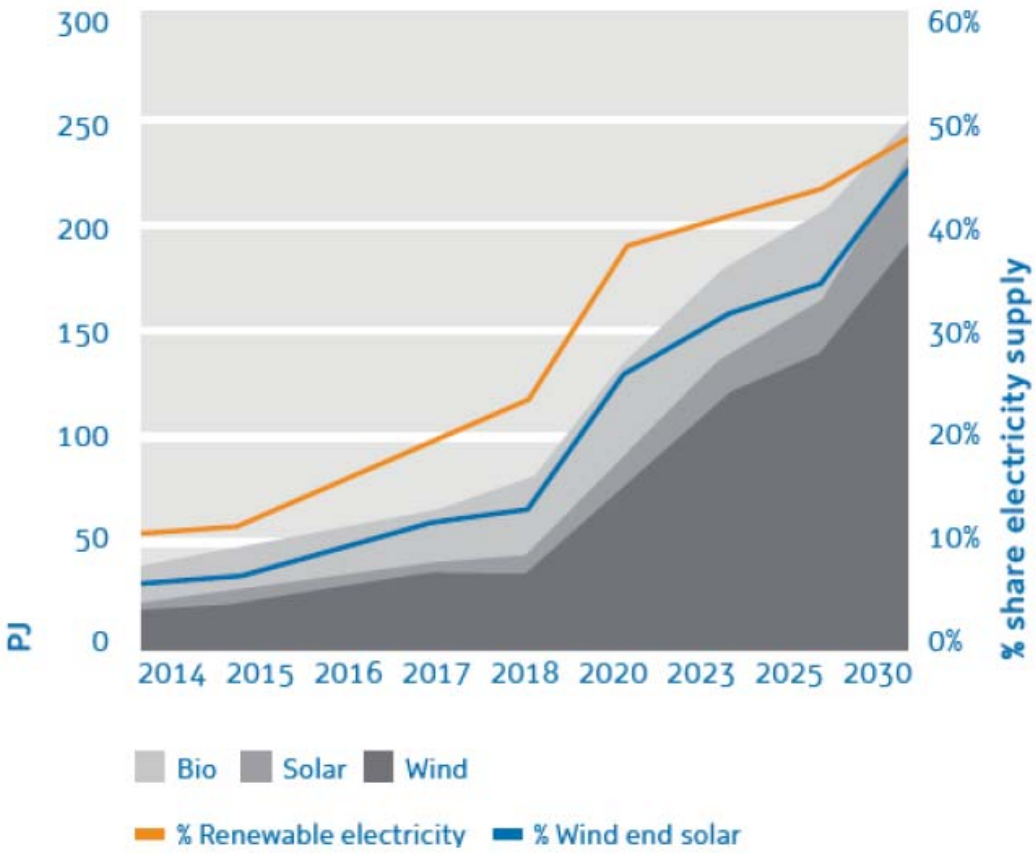
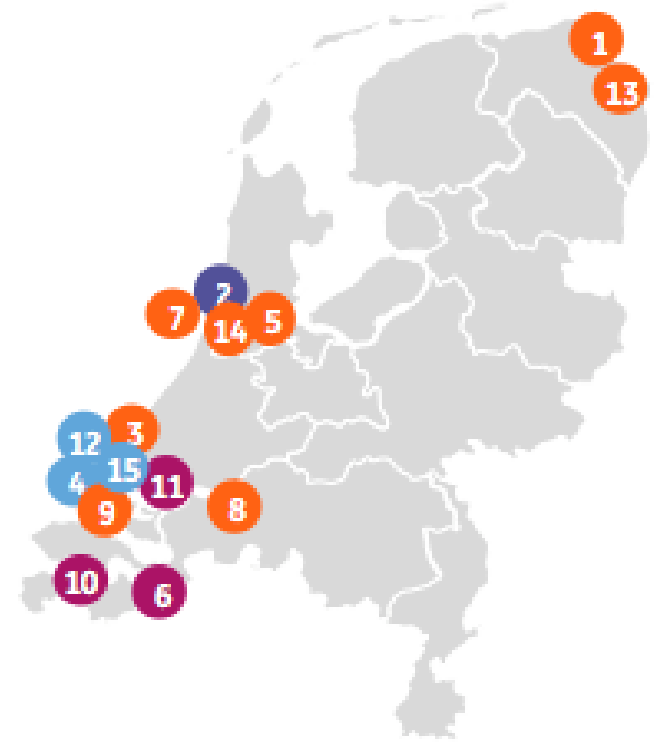


Figure 2 Development of the supply of renewable electricity in the Netherlands.
Source: Electrification in the Dutch process industry. Berenschot, 2017

...while the industry is getting heavy defossilization targets...

	Bedrijf	Provincie	CO_2-uitstoot in megaton
1	RWE Eemshaven Centrale	GR	8,3
2	Tata Steel IJmuiden B.V.	NH	6,3
3	Uniper Maasvlakte Powerplant 3	ZH	4,7
4	Shell Nederland Raffinaderij B.V.	ZH	4,3
5	Nuon Centrale Hemweg	NH	4
6	Yara Sluiskil B.V.	ZE	3,7
7	Nuon Power Velsen (gas)	NH	3,6
8	Essent Amercentrale (Geertruidenberg)	NB	3,5
9	ENGIE Centrale Rotterdam	ZH	3,2
10	Dow Benelux B.V. (Terneuzen)	ZE	2,7
11	Shell Nederland Chemie B.V. Moerdijk	NB	2,6
12	BP Raffinaderij Rotterdam B.V.	ZH	2,3
13	ENGIE Eemscentrale (gas)	GR	2,2
14	Nuon Power IJmond (gas)	NH	2,1
15	ESSO Raffinaderij Rotterdam	ZH	2,1



...translated into the Dutch Climate Agreement

Stating CO_2 reduction goals for each sector – June 2019

Effects of Dutch Climate Agreement

Netherlands Environmental Assessment Agency (PBL), 28 March 2019

Type technologie	Emissiereductie in 2030 *[Mton CO_2-eq]*
CCS	3,2 – 7,0
Elektrificatie	1,0 – 4,2
Procesefficiency	0,2 – 1,9
Overige maatregelen	0,4 – 3,9
Totaal (bandbreedten niet optelbaar)	**6,0 – 13,9**

Calculations for the climate agreement underline the need for an integral multi-year approach to ECCM:

- H_2 from electricity does not get off the ground yet due to high costs
- 80 M€ per year needed for concrete demo projects (now 30-40 M€)
- A growth of 3-4 GW (2030) electrolysis capacity is necessary
- H_2 production does not result in emission reduction; only applying H_2 instead of fossil.
- Synergy with electrochemical conversion for H_2 innovation is required
- 10-20 TWh extra electricity production needed for electrolysis installations.

ECCM committee established - advisory report

2017

Representatives from:

- Private sector
- Applied research
- Science

- Established by the Ministry of Economic Affairs and Climate Policy through its advisory boards (top sectors) for Energy, Hightech and Chemistry, with support from the Netherlands Organisation for Applied Scientific Research (TNO) and the Dutch Research Council (NWO).

- Linked to the climate policy of the government, industry and employer associations, strategies of national fundamental and applied research organizations.

Targets set by the committee:

- By 2030, hydrogen will be produced in a CO_2-poor manner at a price of no more than € 2/kg, and by 2050 at a price of € 1/kg.

- By 2030, at least 20% of the hydrogen and ammonia will be produced without CO_2 emissions.

- By 2050, at least 40% of the industrially produced CO_2 will be used as a resource in the transition to a circular carbon cycle.

- Mobility: by 2050, the entire transport sector will be CO_2-neutral.

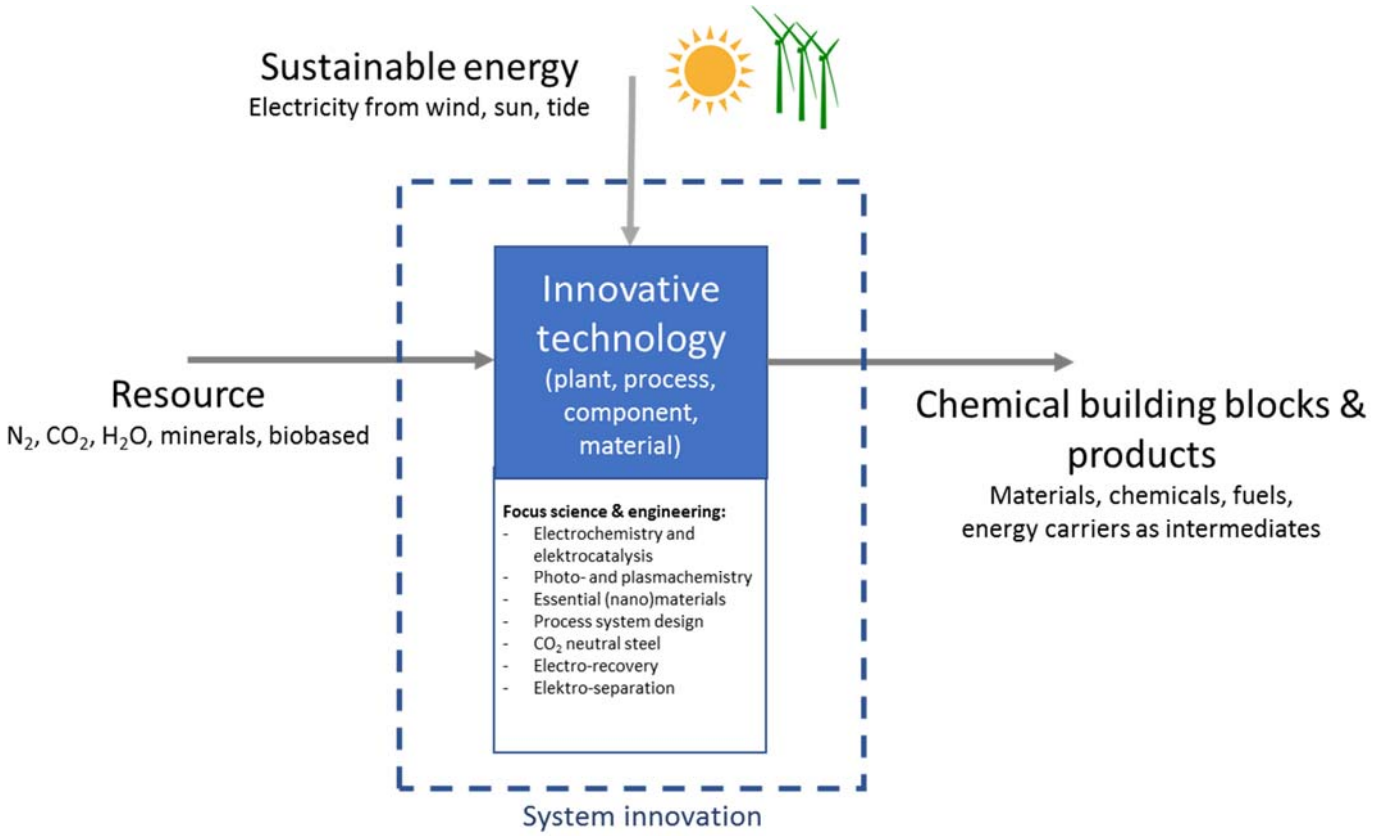
ECCM committee

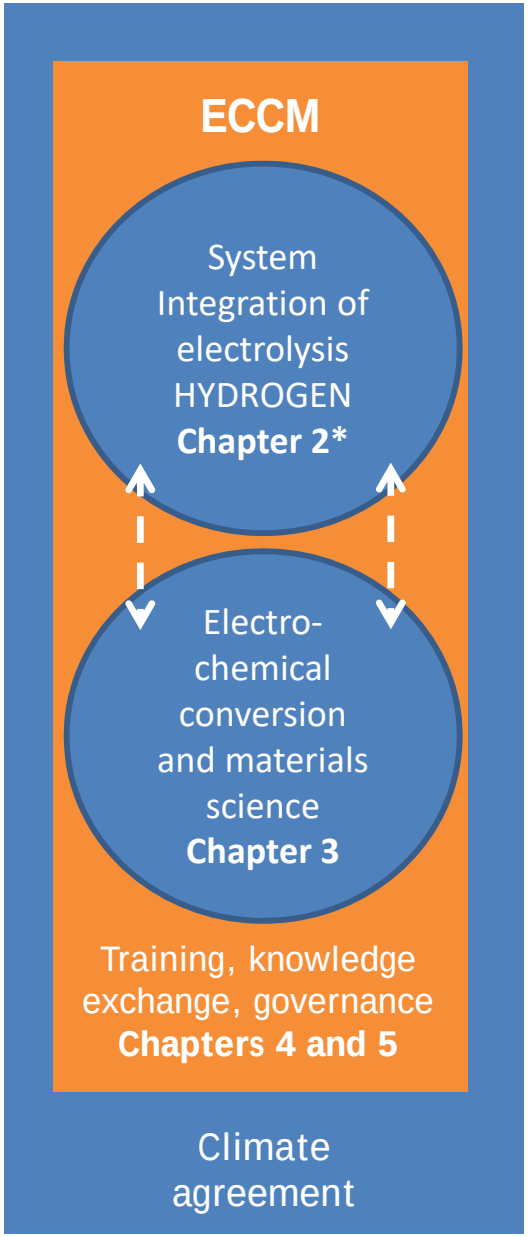
From left to right, top to bottom

- Prof. dr. Richard van de Sanden (DIFFER), *chair*
- Prof. dr. Bernard Dam (TU Delft)
- Dr. Jörg Gigler (Programmatische aanpak H_2)
- Prof. Earl Goetheer (TNO)
- Dr. Klaas Jan Schouten (Avantium)
- Prof. dr. Petra de Jongh (Universiteit Utrecht)
- Prof. dr. Marc Koper (Universiteit Leiden)
- Ir. Geert Laagland (Vattenfall)
- Prof. dr. Guido Mul (Universiteit Twente)
- Dr. Alexander van der Made (Shell)
- Drs. Ton Peijnenburg (VDL ETG)
- Drs. Marco Waas (Nouryon)
- Dr. Hans van der Weijde (Tata Steel)
- Dr. John van der Schaaf (TU/e)
- Dr. Ellart de Wit (HyGear)

Electrochemical Conversion and Materials - ECCM

What is ECCM?





Hydrogen is integrated in ECCM: hydrogen can only be successfully addressed in an integrated approach with system integration in collaboration with the electricity sector, electrochemical conversion and storage in the industry and required materials science (key technology).

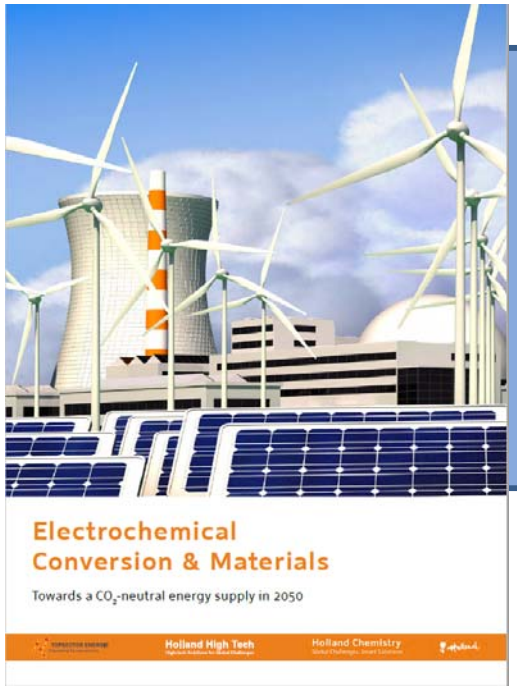
* Chapters refer to the chapters of the advisory rapport of the ECCM committee

ECCM related to innovation policy

Preconditional

MMIP 1
Renewable electricity at sea

MMIP 2
Renewable electricity on land



2017

Key enabling technology ECCM*

MMIP 8 *Electrification and innovative processes*

MMIP 6 *Closing industrial cycles*

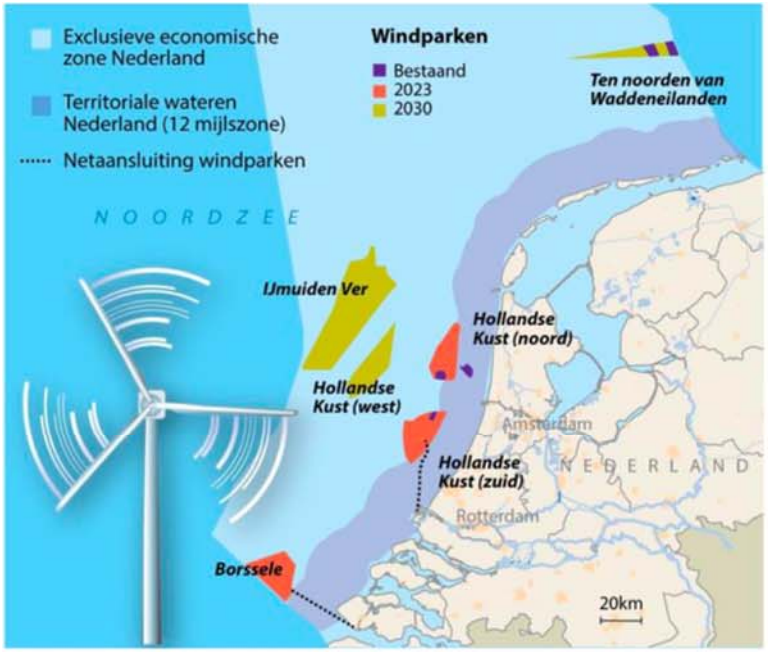
MMIP 13 *Robust and sizeable, supported energy system*

NWA route Energy transition

2030
2050

* Relevant themes for ECCM in the key enabling technology agenda:
05 MJP Direct conversion of solar energy for a circular economy
38 MJP Batteries of the Future
56 MJP Electrochemical Conversion and Materials (ECCM)
70 MJP Catalysis and process technology
71 MJP Measure and detection technology
82 MJP Materials
89 MJP Technology for smart, safe and green mobility

Drivers for ECCM - in the Netherlands

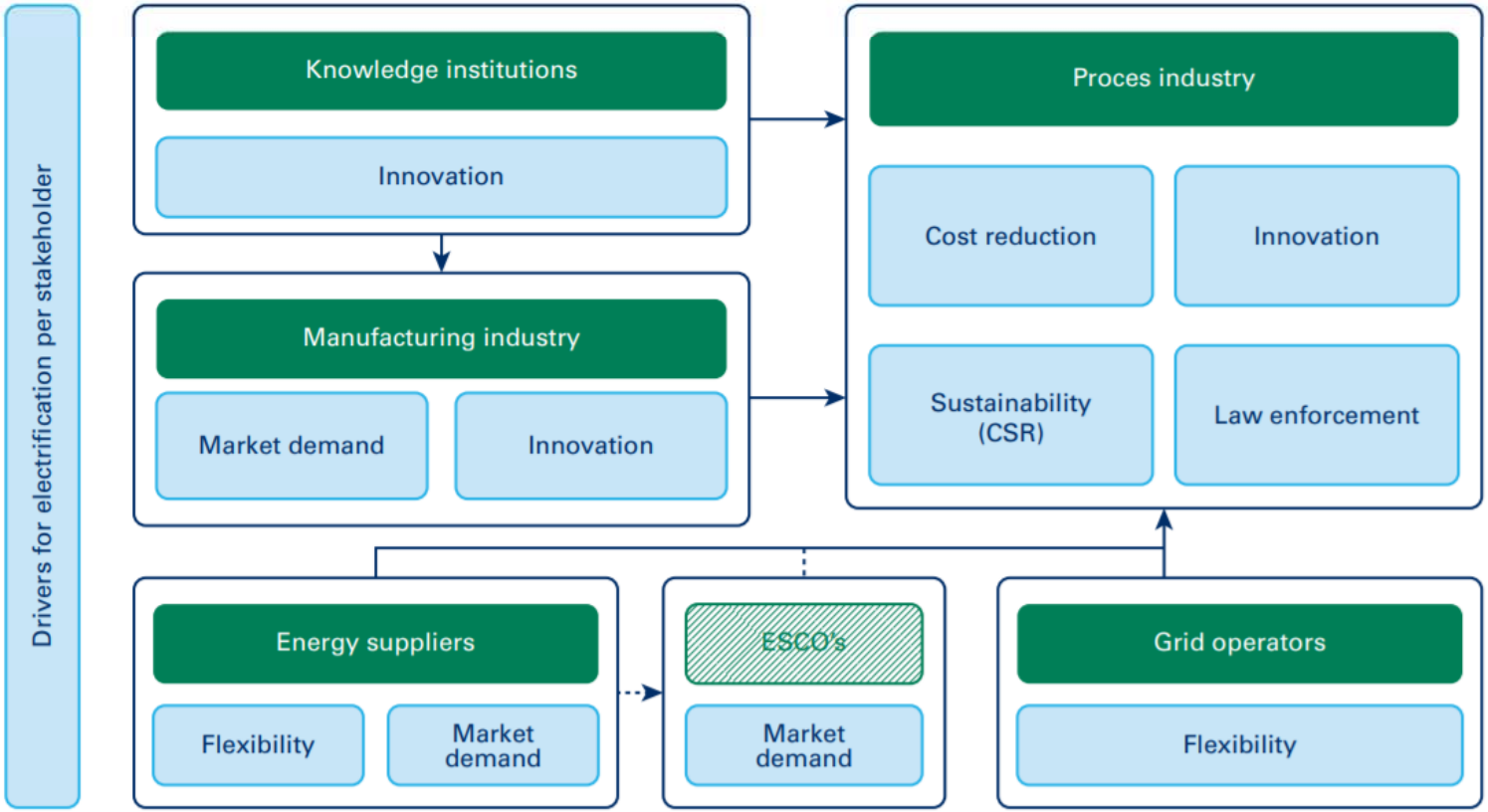


Large offshore wind potential, 11.5 GW in 2030; >>40 GW possible

Extensive on/offshore gas infrastructure, world class gas and offshore know-how

Through the courtesy of Noé van Hulst, Hydrogen Envoy of The Netherlands

Strong elements in the Netherlands



Source: Berenschot 2017

- Chemical Industry, particularly petrochemical
- Gas production and exploitation
- System manufacturing (low and high tech)
- Nano-materials and catalysts
- (micro)reactors en electrolysis

Mission ECCM

GOALS
- In 2030, H_2 will be produced with low CO_2 emissions at a price of a maximum of €2/kg and in 2050 at a price of €1/kg.
- In 2030 at least 20% of the H_2 and ammonia will be produced without CO_2 emissions.
- In 2050 at least 40% of the CO_2 produced in the industry will be used as a raw material.
- Mobility: in 2050 the entire transport sector will be CO_2 neutral.

TECHNOLOGY & SCIENCE
- Integration of electrolysis and H_2 in the energy system and large-scale processes.
- Large-scale development of innovative electrochemistry and materials science.
- System integration, technology transfer to SMEs, business models, LCAs.

SCALING
- Building portfolio of ECCM testing grounds and large-scale open access demos and pilots.

EDUCATION
- Strengthening knowledge base in ECCM.
- Development of multidisciplinary BSc and MSc.
- Encouraging higher professional education courses for upscaling and implementation.

>>

Mission ECCM

>>

REGULATION

- CO_2 pricing and level playing field, including international strategy for collaboration.
- Standards for CO_2 reduction and CO_2 emissions, including involvement of specific ministries.

(INTER)NATIONAL COMMUNITY

Establish knowledge platform across existing communities and sectors (hightech, energy, chemistry).

Impact: employment and economic forecast

Assuming that the Netherlands succeeds in achieving a climate-neutral economy and a strong green chemistry and basic industry,

- **66,000 full-time jobs** and approximately **€16.9 billion in added value** can be maintained for the Dutch economy in various sectors that are still dependent on fossil fuels.

- Scaling up of hydrogen offers opportunities for our high-tech manufacturing industry to build a strong position in the international supply chain for hydrogen projects.

- The total impact on employment of climate-neutral hydrogen and green chemistry has been estimated at **90,000-110,000 full-time jobs** by 2050.

Source: Roland Berger (2020)

Examples of current ECCM initiatives

ECCM Tenure Track program | TRL 1-3

- NWO call (M€ 7) for tenure track (TT) positions with start-up packages; host institution matching required.
- Nouryon, Shell, Tata Steel
- Launched June 21, 2019

NWA call Storage and Conversion | TRL 1-3

- NWA call (M€ 4 total: M€ 2 EZK, M€ 2 NWA) that will be launched together with the ECCM tenure track program.
- Review process is ongoing – final decisions autumn 2020

NWO Crossover call - Reversible Large-scale Energy Storage (RELEASE) | TRL 2-5

- Consortium (M€ 10) that focuses on three technologies for the short (2030) and long term (2050): hydrogen production, hydrocarbon production from CO_2 and flow batteries.
- Awarded December 2019 - start: spring 2020

ECCM fund for German-Dutch collaboration

- Under construction.

Examples of current ECCM initiatives

Faraday lab | TRL 3-5

- Production and small-scale pilots for the development of PEM and Solid Oxide Electrolysis.
- Launched June 21, 2019

Electrification of applied research investments (TNO / VoltaChem) | TRL 3-7

- 2 M€/ year in additional applied research into electrical cracking, SOE & PEM electrolysis, electrochemical conversion of CO_2 and biomass, and Power-2-X system integration.
- Initiation of field labs for industrial electrification in large industrial clusters.
- Launched: June 21, 2019

Hydrohub: MW test center in development (ISPT) | TRL 4-7

- The MW test center (M€ 6) aims to support the technological development of water electrolysis.
- The technological development in the MW test center should lead to a cost price for the electrolysis column of € 50-100 / kW with an efficiency of> 80% (for the first 5 years of use) and a pressure of 30 bar by 2030.
- Start of Hydrohub construction: 21 June 2019

Annual ECCM conference

21 June 2019, The Hague

Time	Activity
9:00	Reception and registration
9:30	Opening conference by Dr. Bertholt Leeftink (Director-General Enterprise and Innovation at Ministry of Economic Affairs & Climate Policy) and Prof. Dr Richard vd Sanden (chair of the Dutch committee for Electrochemical Conversion & Materials)
9:45	Opening lecture by Ir. Diederik Samsom (former politician, advisor in green energy supplies, negotiator for the Dutch Climate and Energy Agreement, Netherlands)
10:15	Keynote: Dr. Behnam Taebi (Delft University of Technology)
10:45	Keynote: Prof. Dr Ib Chorkendorff (Technical University of Denmark, Denmark)
11:15	Coffee break and change rooms for parallel tracks
11:30	Parallel tracks part 1 (1x 30 min + 3x20 min)

	Room: Rotterdam 1 (2nd floor)	Room: Rotterdam 2 (2nd floor)	Room: Rotterdam 3 (2nd floor)
	Materials & Catalysis	Innovative electrochemistry	System integration, business & governance
11:30 - 12:00 (30min)	Keynote: Dipl.-Ing. Thomas Burgler (voestalpine Stahl)	Keynote: Prof. Dr. Annick Hubin (Vrije Universiteit Brussel)	Keynote: Dr. Pieter Boot (PBL Netherlands Environmental Assessment Agency)
12:00 - 12:20 (20 min)	Dr Vera Smulders (UT)	Prof. Dr Emiel Hensen (TU/e)	Rob Terwel, MSc (Kalavasta)
12:20- 12:40 (20 min)	Dr Shiju Raveendran (UvA)	Dr Anja Bieberle-Hütter (DIFFER)	Ing. Rob van der Sluis (MTSA)
12:40- 13:00 (20 min)	Dr Ruud Kortlever (TUD)	Dr Thijs de Groot (Akzo)	Guy Verkoeyen, MBA (Hydrogenics)

13:00	Lunch
13:45	Keynote: Dr. Ajay Mehta (Shell - Long Range Research and New Energy Technologies, United States)
14:15	Keynote: Dr. Günter Schmid (Siemens, Germany)
14:45	Coffee break and change rooms for parallel tracks
15:00	Parallel tracks part 2 (4x 20 min)

	Room: Rotterdam 1 (2nd floor)	Room: Rotterdam 2 (2nd floor)	Room: Rotterdam 3 (2nd floor)
	Materials & Catalysis	Innovative electrochemistry	System integration, business & governance
15:00 - 15:20 (20 min)	Leon Jacobse, MSc (UL)	Dr Roman Latsuzbaia (TNO)	Dr Andreas ten Cate (ISPT)
15:20 - 15:40 (20 min)	Dr Maarten Biesheuvel (Wetsus)	Dr Waldo Bongers (DIFFER)	Drs. Toon van Harmelen (TNO)
15:40 - 16:00 (20 min)	Prof. Joost Reek (UvA)	Dr Thomas Burdyny (TUD)	Dr Frits van Hout (ASML)
16:00 - 16:20 (20 min)	Dr Frans van Berkel (TNO)	Dr Klaas Jan Schouten (Avantium)	Prof. Gert-Jan Kramer (UU)

16:20	Change room for closing lecture
16:30	Keynote: closing lecture: Prof. Dr. Robert Schlögl (Max-Planck-Institut für Ch Energiekonversion, Germany)
17:15	Drinks
18:00	End of programme

Key note speakers

- Prof. Mercedes Maroto-Valer, Director of the Research Centre for Carbon Solutions, Heriot Watt University, United Kingdom
- Prof. Yang Shao-Horn, materials for electrochemical and photoelectrochemical energy storage and conversion, Massachusetts Institute of Technology, United States
- Dr Philipp Dietrich, CEO at H2 Energy AG, Switserland
- Dr Noé van Hulst, Hydrogen Envoy, Ministry of Economic Affairs & Climate, Netherlands
- Dr Yu Morimoto, Principal Researcher at Toyota Central R&D Labs. Inc., Japan
- Dr. Reinhold Achatz, CTO – Head of Corporate Function Technology, Innovation & Sustainability, thyssenkrupp AG, Germany
- Prof. Christian Breyer, Solar Economy, Lappeenranta University of Technology (LUT), Finland
- Dr. Heleen de Coninck, Environmental Science, Radboud University, The Netherlands
- Prof. Ted Sargent, Electrical and Computer Engineering, University of Toronto, Canada


ECCM Graduate School
27-29 November 2019
Fundamentals of Electrochemistr
Electrodes and Materials
Mass Transport and Membranes
Impedance spectroscopy
Spectroscopy and characterizatio
Photoelectrochemistry
Fuel cells ànd electrolysers

ECCM instruments - coordination ECCM committee

Meerjarenafspraken Energie efficiëntie (MJA3/MEE)

RVO
PPS-toeslagregeling

NWO
- Vrije Competitie/ Open Technologie Programma
- Talentprogramma's
- Instituten *(ECCM: DIFFER)*

OCW
- Sectorplannen
- Zwaartekracht *(ECCM: MCEC)*

EU
- ERC

NWA
- NWA actielijn 1: Consortia langs routes
- NWA actielijn 2: confinanciering vakdepartmenten
- *ECCM: Opslag en Conversie*

EU
- FET

NWO (ikv KIC topsectoren)
- Cross-over call
- *ECCM: Reversibele lange-termijn energieopslag*
- NWO PPS-fonds / Partnership / Perspectief
- *TA Stroomlijnen van elektrochemie*
- *Perspectief: Electrons to Chemical Bonds (E2CB)*
- Take-off en Demonstrator
- Industrial doctorates
- *ECCM tenure track call*
- *ECCM Systeemintegratie*

NWO/SIA (Praktijk gericht)
- KIEM (HBO-MKB)
- RAAK (HBO-MKB/Publiek/Pro)

TNO (SMO-ERP)

EU
- Secure, Clean and Efficient Energy, Climate Action, Environment, Resource Efficiency and Raw Materials
- Fuel Cells and Hydrogen 2 (FCH2)
- Sustainable Process Industry through Resource and Energy Efficiency (SPIRE)

TNO (SMO-VP)
- *ECCM: VoltaChem power-2-hydrogen, 2-chemicals,.*
- *ECCM: Faraday lab*

RVO
- Vroege Fase Financiering
- WBSO
- Research & Development Aftrek (RDA)
- Small Business Innovation Research (SBIR)
- Mkb-innovatiestimulering Regio en Topsectoren (MIT)
- Demonstratie Energie-Innovatie (DEI)
- Stimuleringsregeling Duurzame Energie (SDE+)

Regio's

EZK Innovatie via TKIs
- *Cost reduction industrial PEM electrolyzers*
- *Direct electrochemical conversion of CO2 to formic acid*
- *Electrons to Close the Carbon Cycle*
- *Hybride flexible Industrial Utilities*
- *Intelligent Energy Management System voor MKB*
- *ECCM: Hydrohub: MW test center Delfzijl (ISPT)*

EU
- INTERREG
- EFRO

TNO (SMO-VP)
- *ECCM: Initiatie fieldlab Rotterdam-Moerdijk.*
- *ECCM: Initiatie fieldlab BSTC.*
- *ECCM: HydroHub: MW test center Delfzijl.*

EZK
- Klimaatenvelop
- *ECCM: Faraday lab*

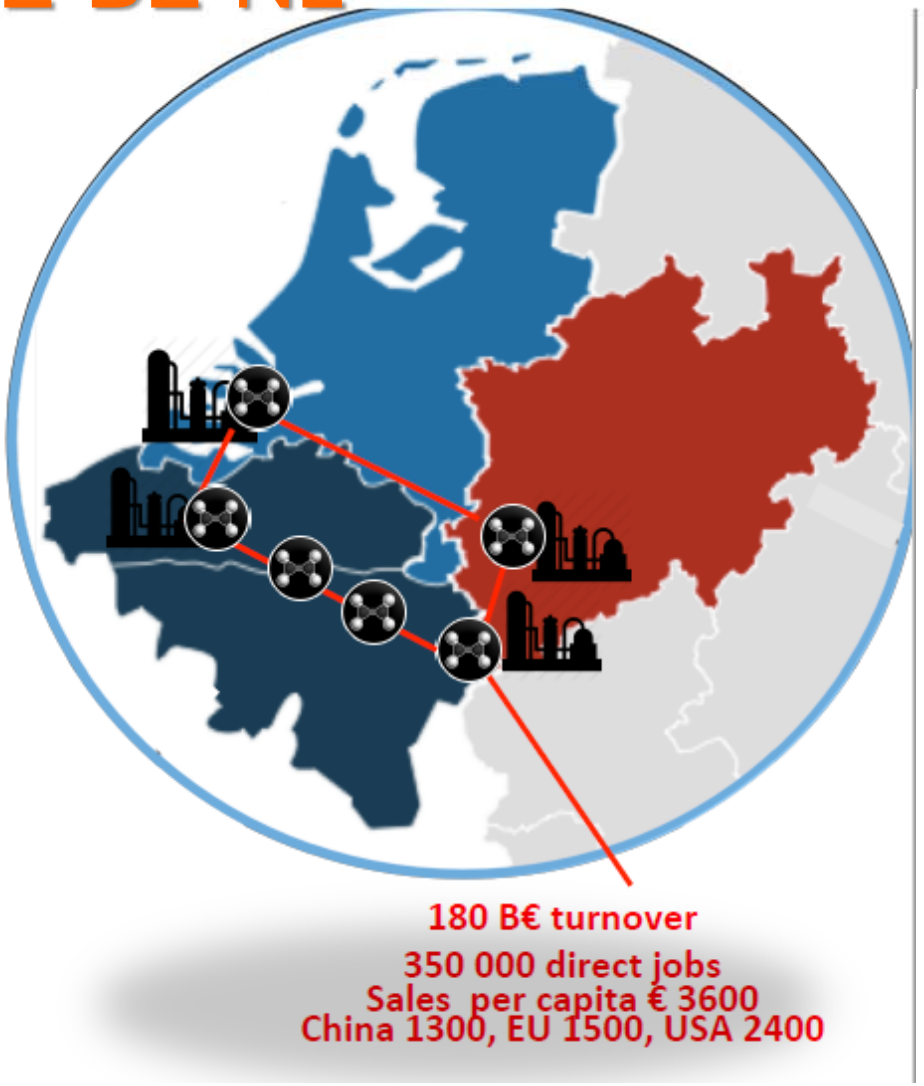
RVO
- Stimuleringsregeling Duurzame Energie (SDE+)
- Energie Investering Aftrek (EIA)
- Milieu-investeringsaftrek (MIA) en de Willekeurige afschrijving milieu-investeringen (Vamil).

EU
- Industrial leadership (LEIT) ICT, nanotechnologies, advanced materials, advanced manufacturing and processing, biotechnology and space

TRL 1 → Incentives for connections across TRLs (various types of co-funding and resource pooling) → TRL 9

ECCM activities within the current range of funding instruments of the Dutch government: includes activities initiated by the committee and activities adopted by the committee.

Trilateral Strategy DE-BE-NL



Commissioned 2017 by NL government, Flemish Region and North Rhine Westphalia
Target: Competitive and sustainable industry cluster
Tables: Innovation – Energy – Infrastructure

Collaboration Germany

- National cooperation
- Additional to regional activities
- BMWi (DE), EZK, OCW, NWO, TNO
- Purpose: bilateral program M€ 8-10
- October 2020 workshop

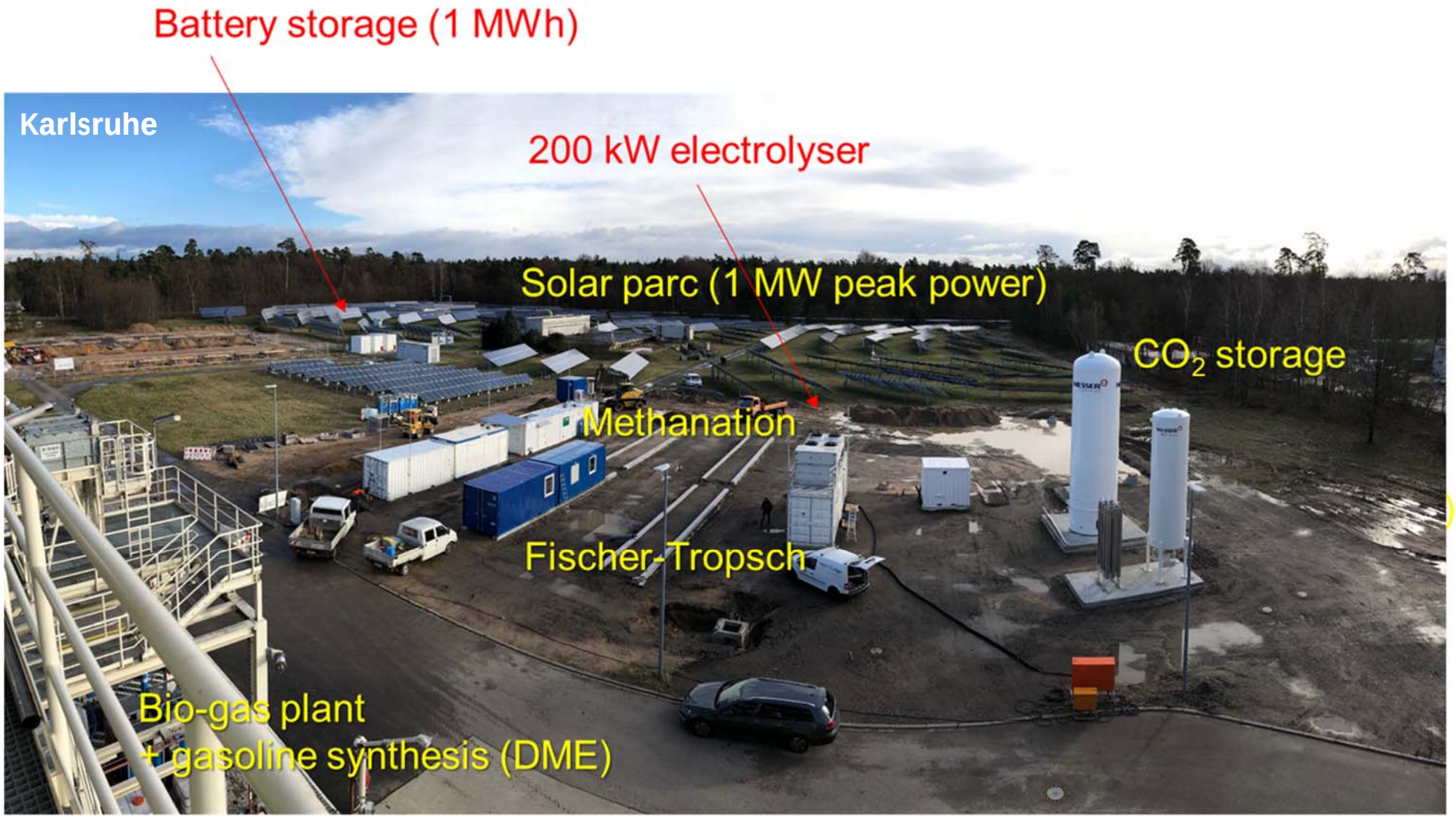
Gemeinsame Absichtserklärung zur Energiewende von Bundeswirtschaftsminister Altmaier und niederländischem Amtskollegen Wiebes unterzeichnet **2 October 2019**

Bundeswirtschaftsminister Altmaier (rechts) und sein niederländischer Amtskollege Eric Wiebes (links)

Organization:

- Prof. Matthias Wessling (RWTH Aachen) - DE
- Prof Richard van de Sanden (chair ECCM committee) - NL
- Dr Thomas Goergen (Covestro) - DE
- Drs. Marco Waas (ECCM / Nouryon) - NL
- Organizing partners and secretariat: ECCM, BMWi, EZK, OCW

Inspirational example in Germany

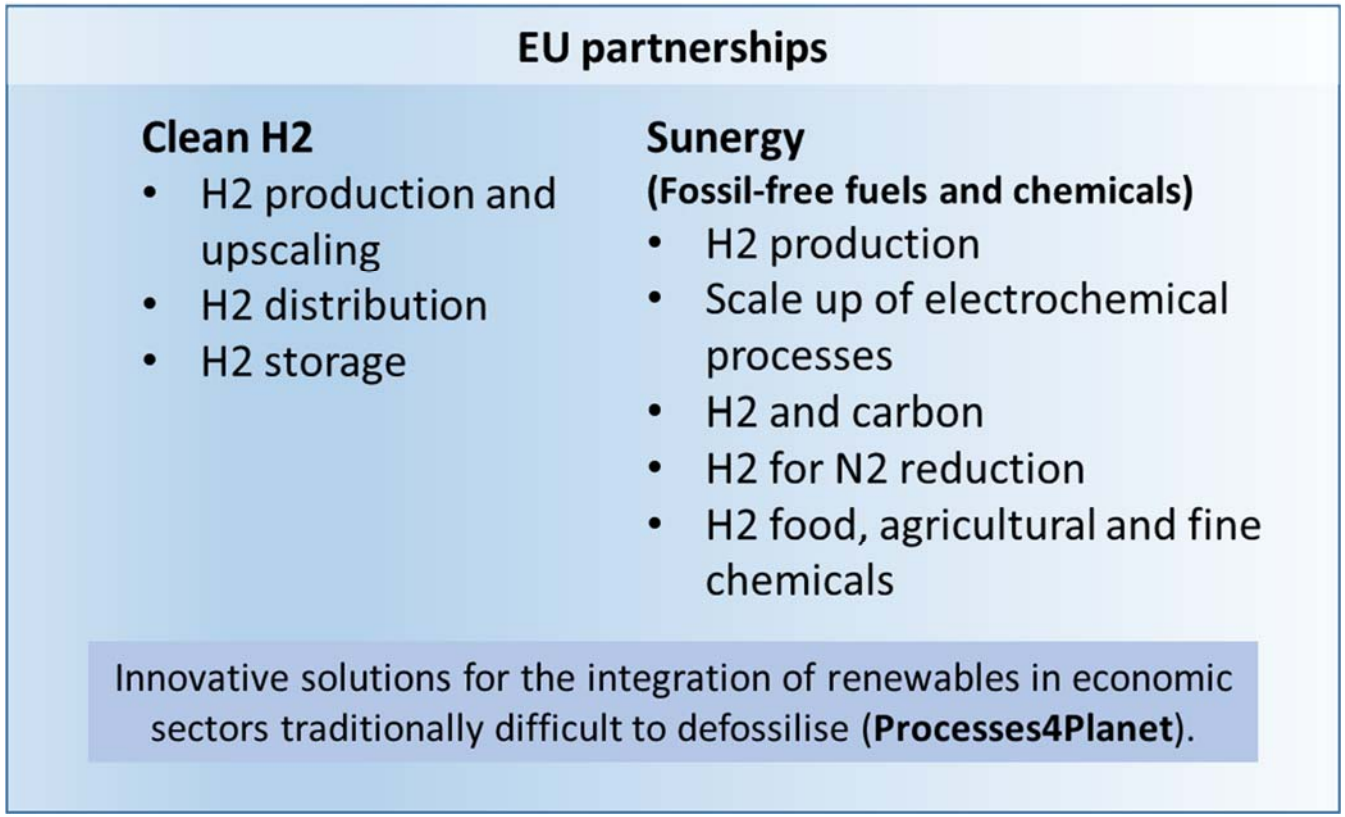


Energy Lab 2.0 @ KIT – Karlsruhe – through the courtesy of Prof. Roland Dittmayer and Prof. Emiel Hensen

Complete pre-competitive knowledge chain in 1 collaboration.

Collaboration Europe and the United States

- **EU dimension** of ECCM



United States

- A bilateral strategic hydrogen/ccus agenda for the Netherlands and the US will be completed by the end of 2020.


Holland High Tech
High Tech Solutions for Global Challenges
TOPSECTOR ENERGIE
Empowering the new economy
ChemistryNL
nationale wetenschaps agenda
WIND
WIND
WIND
ZOUT WATER
ZOET WATER
ECN
ECN
TNO
EUR
TU DELFT
LEI
AMSTERDAM
VU
UvA
UU
TERNEUZEN
ROTTERDAM
FUEL
ARRRA
ARRRA
ARRRA
GOVERNMENT
TECHNOLOGY
PRIVATE SECTOR
SCIENCE AND EDUCATION
EINDHOVEN
WUR
FBR
RU
TNO
TU/e - DIFFER
ANTWERP
UT
DELFZIJL
KUNST MEST
RUG
TNO
GRONINGEN
FUEL
EXPORT
PRODUCTS AND KNOWHOW
EXPORT
PRODUCTS AND KNOWHOW
GELEEN
UM
RUHR DISTRICT
RRRA = industrial cluster Antwerp-Rotterdam-Rijn-Ruhr-area
Ministry of Economic Affairs and Climate Policy
Ministry of Education, Culture and Science of the Netherlands
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