HYDROGEN GENERATION SYSTEM FOR DECENTRAL APPLICATIONS (HYGENESYS)

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SPRONG

HAN + SAXION + company partners

- **Objective SPRONG application**
  - KIA development with partners in field labs (H2Hub, Grohw)
  - Strong Saxion/HAN research group, in 4 years to EU project
  - Building up 20 FTE together, 2 lectors
  - Larger projects (Think East Netherlands)

- **Key partners:**
  - Hogeschool Arnhem-Nijmegen (penvoerder)
  - Oost-NL
  - Cleantechregio waterstofroute
  - KIEMT
  - bedrijven GROHW initiatief Deventer
  - **bedrijven H_2Hub Twente**
  - VDL energy systems
  - Demcon
  - Universiteit Twente
  - ROC van Twente

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H_2Hub

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Project HYGENESYS

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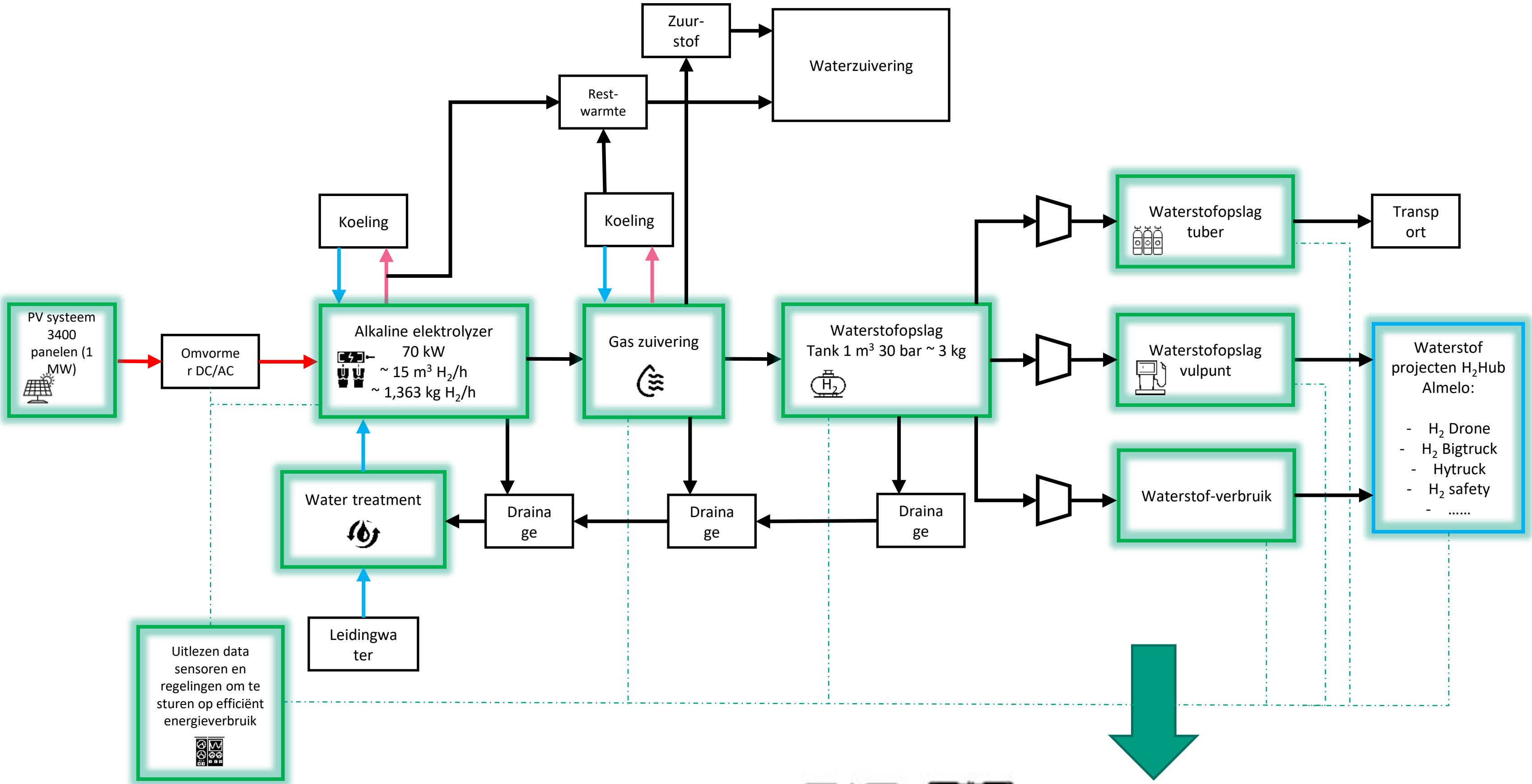
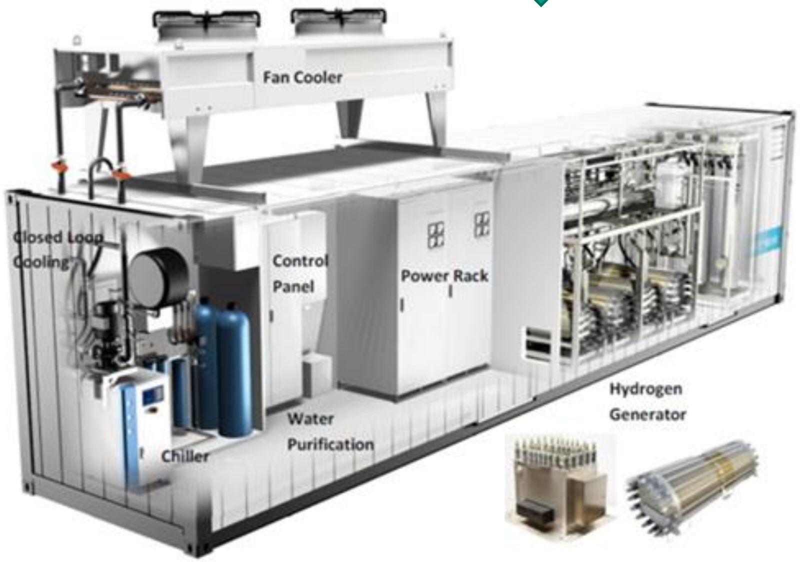
System overview
H_2 electrolyzer





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Overview WP's

Project coördinatie

WP 1
Begeleiding learning community

WP 2 – Concept ontwerp elektrolyse systeem

Resultaat A: process design
- Process flow diagram
- Massa- en energiebalansen
- Process & Instrumentation diagram

Resultaat B: systeem specificatie
- Basis of design
- Functionele specificatie
- Electrical balance of plant
- Mechanical balance of plant

Resultaat C: veiligheidsstudie
- HAZOP veiligheidsanalyse
- Wettelijke vereisten en mogelijke maatregelen
- Input voor concept vergunningaanvraag

WP 3 – Detail ontwerp elektrolyse systeem

Resultaat D: mechanisch ontwerp
- Frame ontwerp
- Piping layout & specificatie
- Mech. equipment specificatie
- veiligheidsdocumentatie

Resultaat E: process engineering
- Process simulatiemodel (flowsheeting)
- Process analyse
- Process equipment specificatie
- Instrumentatie specificatie

Resultaat F: elektrisch ontwerp
- Installatietekening
- Elektrische installatie specificatie
- Bedradingsschema
- Vermogensschema
- veiligheidsdocumentatie

Resultaat G: meet- en regeltechnisch ontwerp
- Meettechnische specificatie
- Functioneel regelsysteem specificatie
- Veiligheidsfuncties specificatie
- Functioneel software specificatie
- Interface specificatie
- Regeltechnisch simulatiemodel

WP 4 – Bestellingen en frame opbouw

Resultaat H: selectie
- Offerten
- Mech. Equipment selectie
- Process equipment selectie
- Instrumentatie selectie
- Elektrische componenten selectie
- Meetsystemen selectie

Resultaat I: bestellingen
- Equipment en onderdelen bestelling
- Overleg met leveranciers
- Controle op leveringen
- Werkplaats en voorraad inrichting

Resultaat J: frame bouw
- Frame onderdelen
- Laswerk
- montagewerk

Resultaat K: systeem opbouw
- Stack montage
- Waterbehandeling montage
- Pijpen en hoofdkabels aanleggen
- Testprotocollen opstellen
- Veiligheidsprotocol opstellen

WP 5 – Montage en oplevertest

Resultaat L: montage E
- Elektrische regelkast installeren
- Kabelgoten installeren
- Vermogensequipment installeren
- Systeemtesten

Resultaat M: montage W & I
- Gaszijdige equipment (koeling, nabehandeling, opslagvat)
- Detectie systemen en sensoren
- Waterzijdige equipment (meng- en doseerunit, pompen)
- Bedrading naar equipment

Resultaat N: meet- en regelsysteem realisatie
- PLC montage
- Sensoren en bedrading
- Actuatoren en bedrading
- Systeemtesten

Resultaat O: oplevertest
- Opstartprotocol uitvoeren
- Operationele testen uitvoeren
- Duurtest uitvoeren

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Development and construction H_2 electrolyzer

- Lead time approx. 2 years, with successive project teams
- Students, lecturer-researchers & company employees (Learning Community)
- Different educational units can join:
  - Minor Engineering of Energy Systems
  - UT Master Sustainable Energy Technology (SET)
  - ROC installation technology & automotive
  - Smart solutions: business & communication
  - Internship and graduation projects from different levels
  - ……
- 'Logical' follow-up to the KIEM project HyWINN, in which exploratory research is being done into a decentralised Hydrogen supply and INNovatielab

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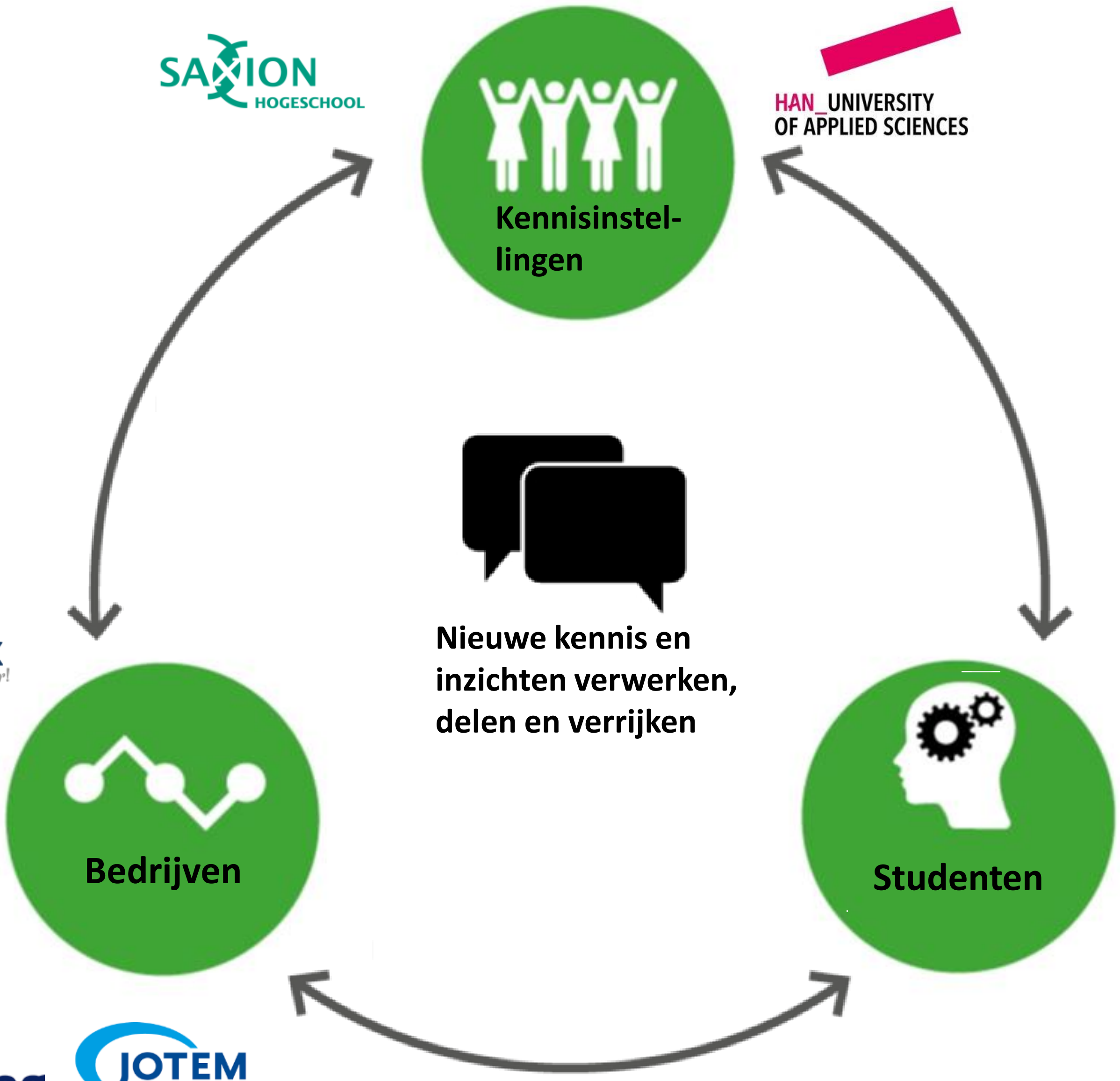
SIA Regieorgaan

Consortium



Chemische Technologie
Werktuigbouwkunde
Technische natuurkunde
Elektrotechniek
Integrale veiligheidskunde

Learning Community

Developing a Learning Community

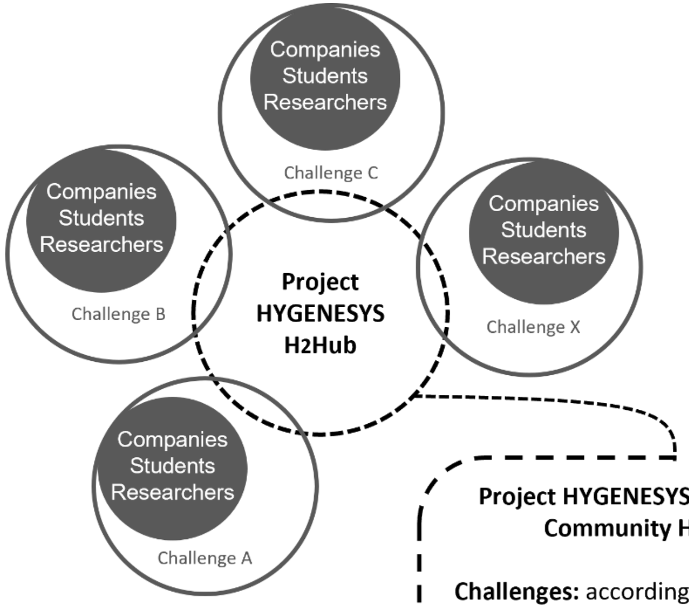
TECH YOUR FUTURE
Centre of Expertise TechniekOnderwijs

WP 2
Concept design electrolysis system

Challenge A: process design
- Process flow diagram
- Massa- en energiebalansen
- Process & Instrumentation diagram

Challenge B: system design
- Basis of design
- Functionele specificatie
- Electrical balance of plant
- Mechanical balance of plant

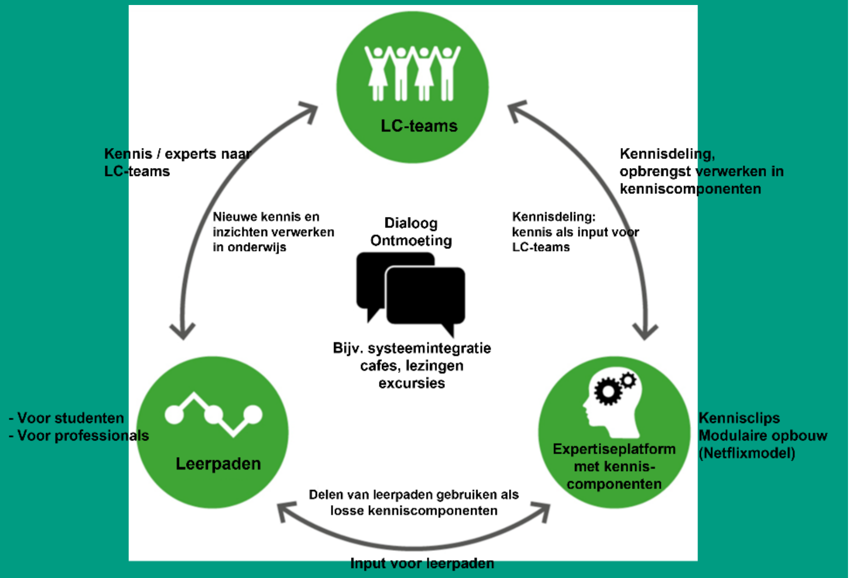
Challenge C: safety study
- HAZOP veiligheidsanalyse
- Wettelijke vereisten en mogelijke maatregelen
- Input voor concept vergunningaanvraag



Project HYGENESYS & Learning Community H2Hub

Challenges: according the projectplan and the V-shaped model a 70 kW hydrogen electrolyser is engineered in four consecutive semesters
Participants: company engineers, students, researchers, facilitators, human capital specialists, teachers

Learning Communities



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- A challenged-based learning community for hydrogen development and application
- Building up knowledge and skills at:
  - Students (Saxion, UT, HAN , ROC)
  - Company employees
  - Lecturer/researchers
- Workshop for technical practical projects: “learning on the job”
- Developing a Knowledge Centre:
  - Knowledge meetings, Work sessions
  - Sharpening knowledge and innovation agenda with consortium/ecosystem
  - Development of successor projects
- Sustainability in large programmes such as SPRONG, VIE and Top Sector Energy (national)

Questions:

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Project HYGENESYS – Design of Experiments

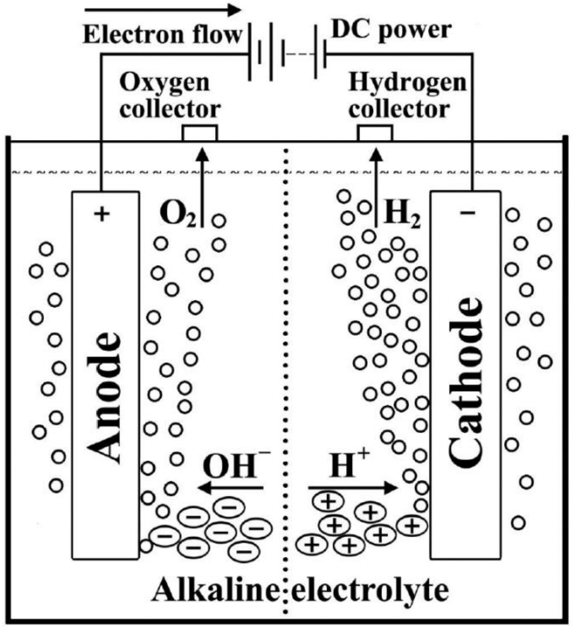
Tjeerd Vogelzang
4th year student Applied Physics

Introduction project

- Optimization alkaline electrolyzer

- Different parameters to determine the hydrogen production
- These parameters are:

  - Different lyes
  - Concentration
  - Temperature
  - Mass flow rate
  - Electric current



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Approach

- Theory research
  - How does an electrolyser system work?
  - Which parameters have an effect on hydrogen production?
- Measuring method
  - MSA (measurement system analysis)
  - Reliable
  - Independent
- DOE / multifactorial design / residual analysis
  - Which parameters / repeats
  - Interactions
  - Useable results

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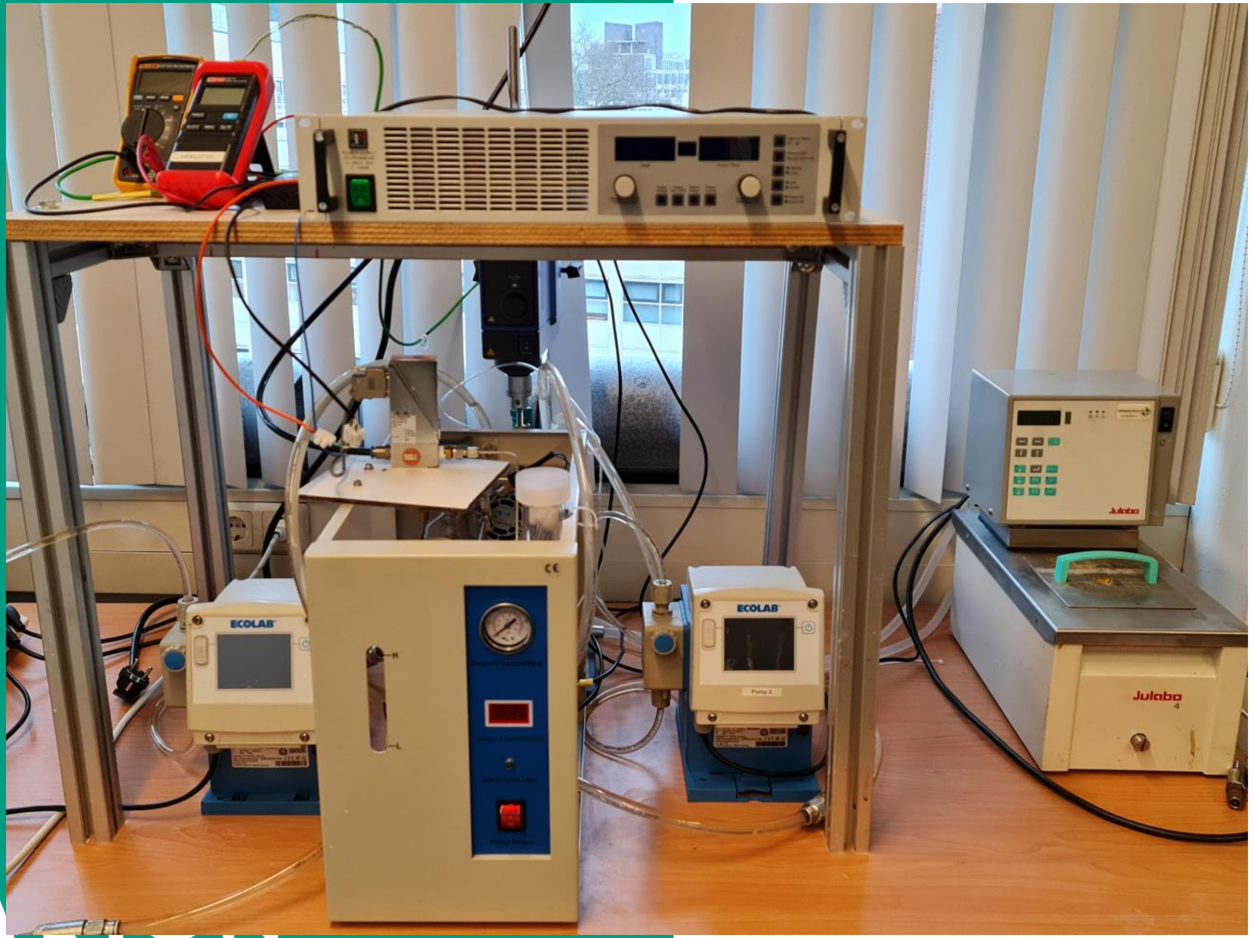
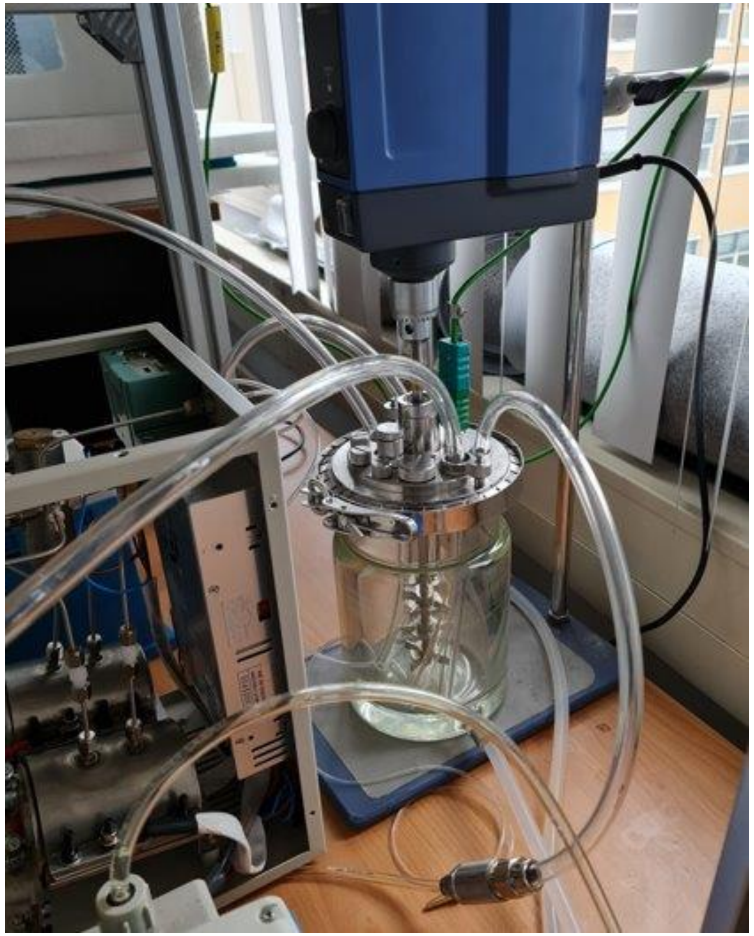
Setup test system





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Measurement system analysis (ml/min)

- Cp-gauge is 134.6
- The measurement system is excellent
  - The test system is sturdy

Measurements Gauge R&R containing 4 positions, 3 Operators and 3 Repeats			Parts / Positions											
			1: Setting 1			2: Setting 2			3: Setting 3			4: Setting 4		
			Repeat 1	Repeat 2	Repeat 3	Repeat 1	Repeat 2	Repeat 3	Repeat 1	Repeat 2	Repeat 3	Repeat 1	Repeat 2	Repeat 3
Operator	15	Day 1	180	180,9	180	531,1	531,1	531,1	532,1	532,1	532,1	313,87	314,9	314,86
	20	Day 1	180	180,9	180,9	531,1	531,1	532,1	532,1	532,1	533,1	314,86	314,9	314,86
	25	Day 1	180	180,9	180,9	531,1	531,1	531,1	533,1	532,1	532,1	314,86	313,9	314,86

Range	353,2
Cp-gauge	134,6

Gauge Capability Cp	Conclusion Gauge evaluation
<5	Unacceptable
5-10	Marginal / Poor
10-50	Acceptable
50-100	Good
>100	Excellent

Design of experiments KOH

ANOVA-Table

Factor /	SS	DoF	MS	F - value	F -Critical	P-value	Conclusion
A	7	1	6,93	48	4,41	0,017	significant
B	740262	1	740262	5077688	4,41	5,51E-43	significant
AB	2	1	2,01	14	4,41	0,173	significant
C	5	1	4,96	34	4,41	0,039	significant
AC	2	1	2,01	14	4,41	0,173	significant
BC	2	1	2,01	14	4,41	0,173	significant
ABC	0	1	0,37	3	4,41	0,551	
Curve	4529	1	4528,6	31063	4,41	4,44E-23	significant
Error	3	18	0,15	X	X	X	X X
Total	744812	26	28647	X	X	X	X X

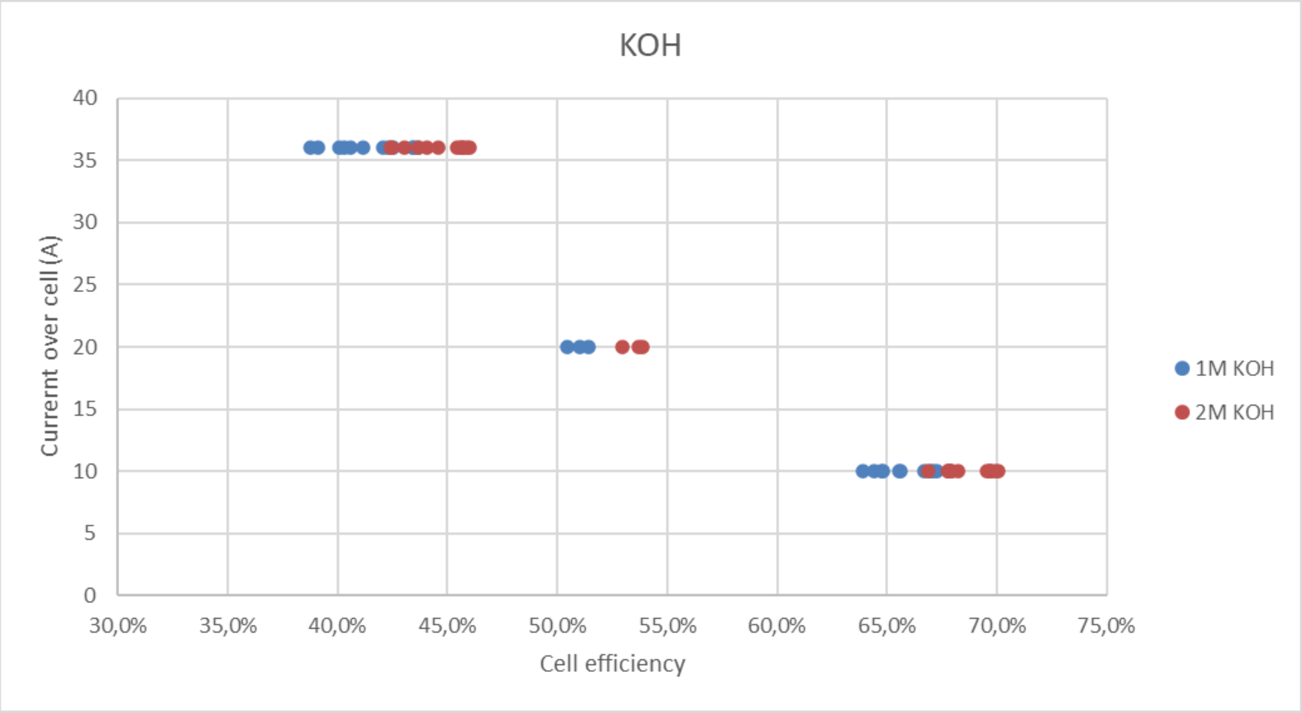
Factor name
A: Temperature
B: Current
C: Flow rate

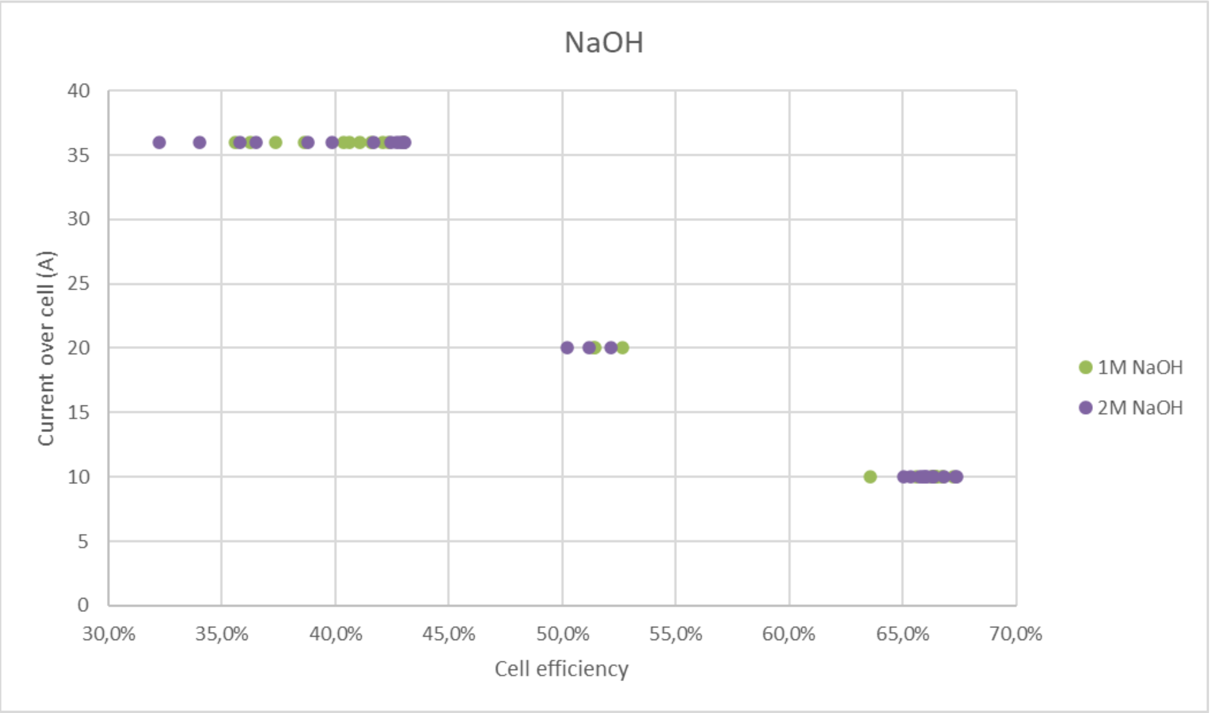
Design of experiments NaOH

ANOVA-Table								
Factor /	SS	DoF	MS	F - value	F -Critical	P-value	Conclusion	
A	0	1	0,04	1	4,41	0,842		
B	743751	1	743751	10203233	4,41	5,282E-43	significant	
AB	0	1	0,04	1	4,41	0,842		
C	0	1	0,04	1	4,41	0,842		
AC	0	1	0,04	1	4,41	0,842		
BC	0	1	0,04	1	4,41	0,842		
ABC	0	1	0,04	1	4,41	0,842		
Curve	4384	1	4384,4	60148	4,41	5,934E-23	significant	
Error	1	18	0,07	X	X	X	X	X
Total	748137	26	28774	X	X	X	X	X

Factor name
A: Temperature
B: Current
C: Flow rate

Design of experiments cell efficienty





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Conclusions

- The kaliumhydroxide is better lye for the production of hydrogen
  - Higher efficiency
  - Less heat build up
- Influence of hydrogen production
  - Current (High influence)
  - Temperature
  - Flow rate
- Better efficiency
  - KOH lye solution (higher molair the better)
  - Less current on the elektrolyser cell

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Project HYGENESYS – Simulatie model alkaline elektrolyser en verificatie

Bas Hupjé
4de jaars student Chemische Technologie

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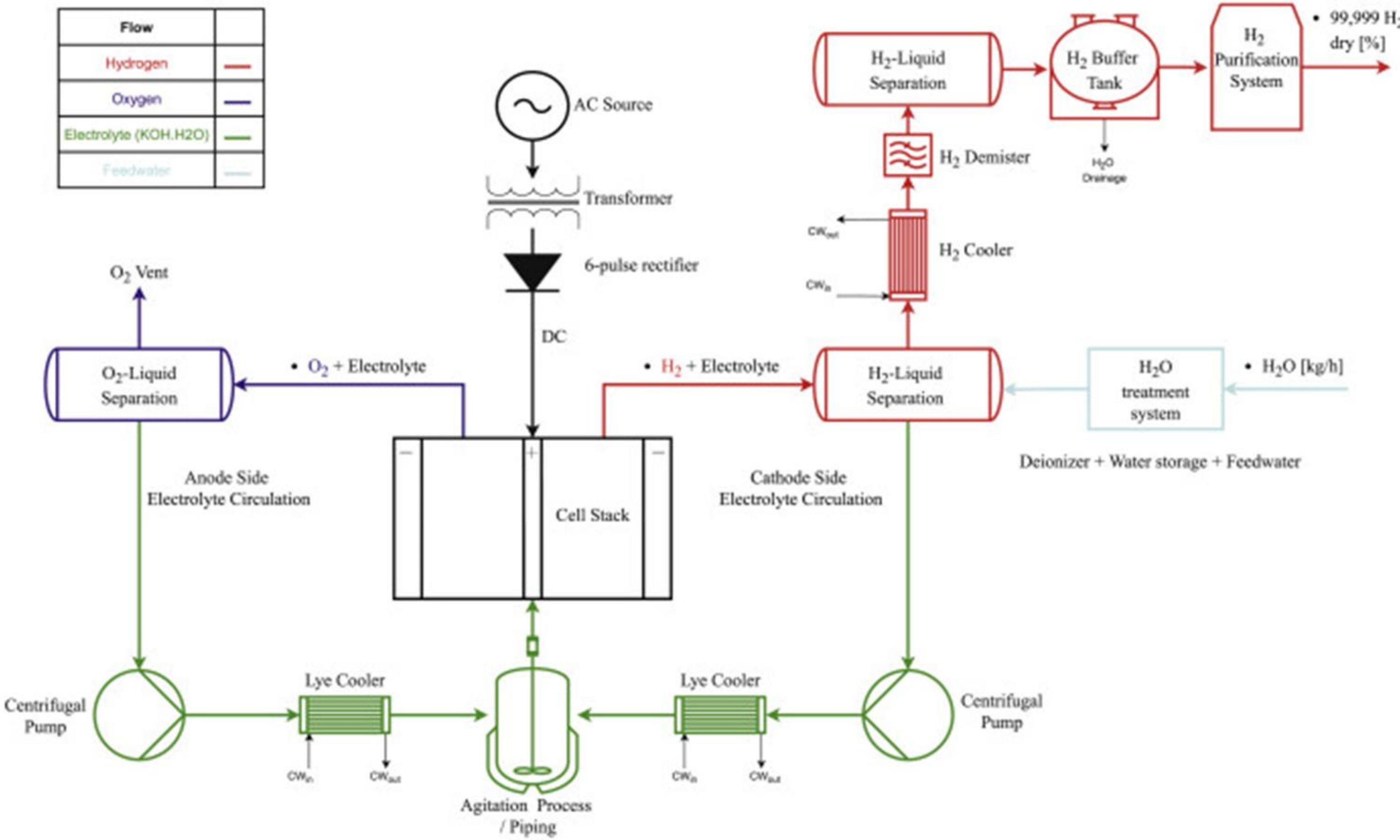
The system

- Assumptions:
  - Steady state
  - Current determines hydrogen production
  - The incoming electrolyte flow cools the stack
  - The splitters are modeled with a split factor
  - Gas does not dissolve in liquid
  - Mixed phase elektrolyser



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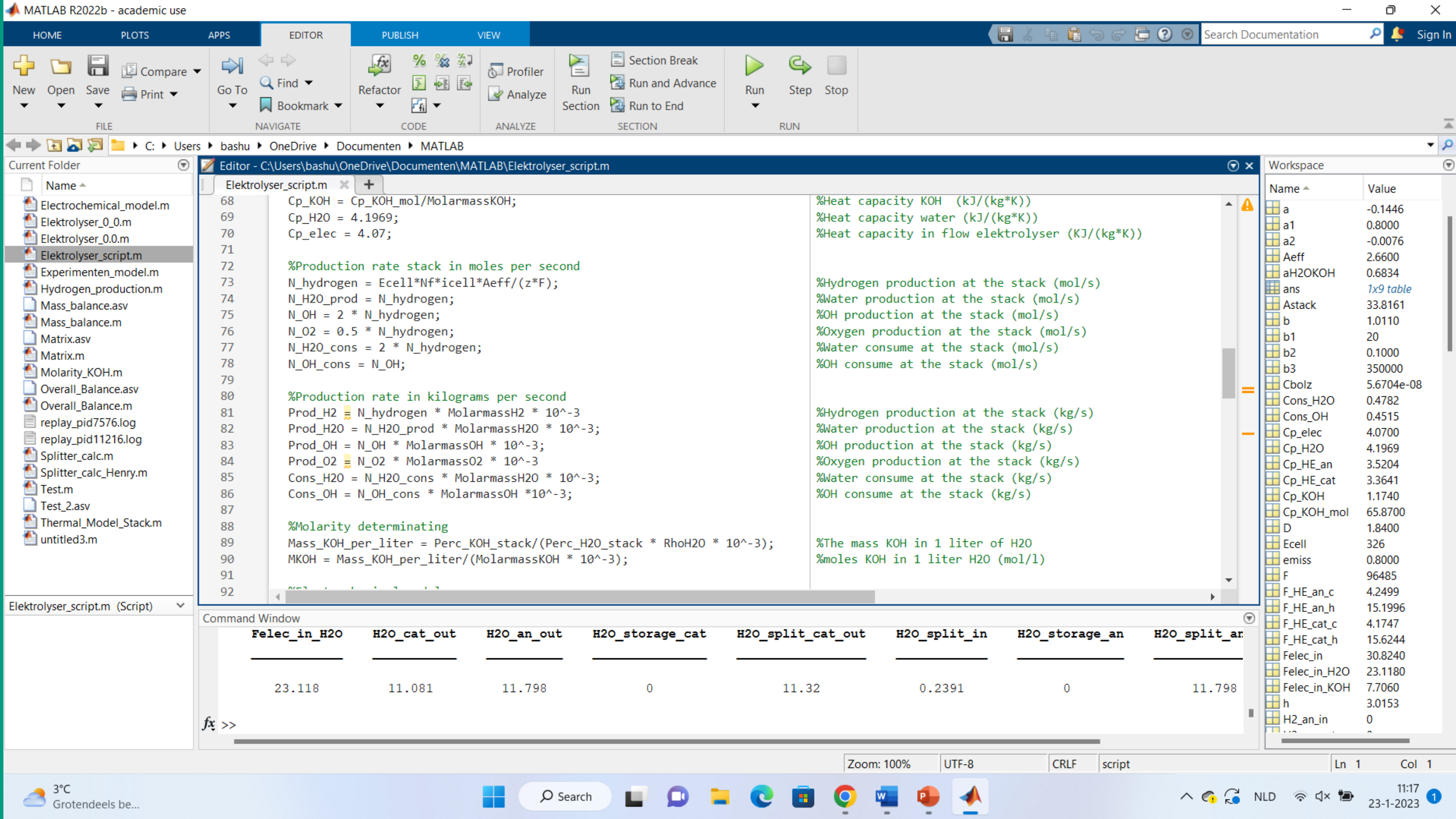
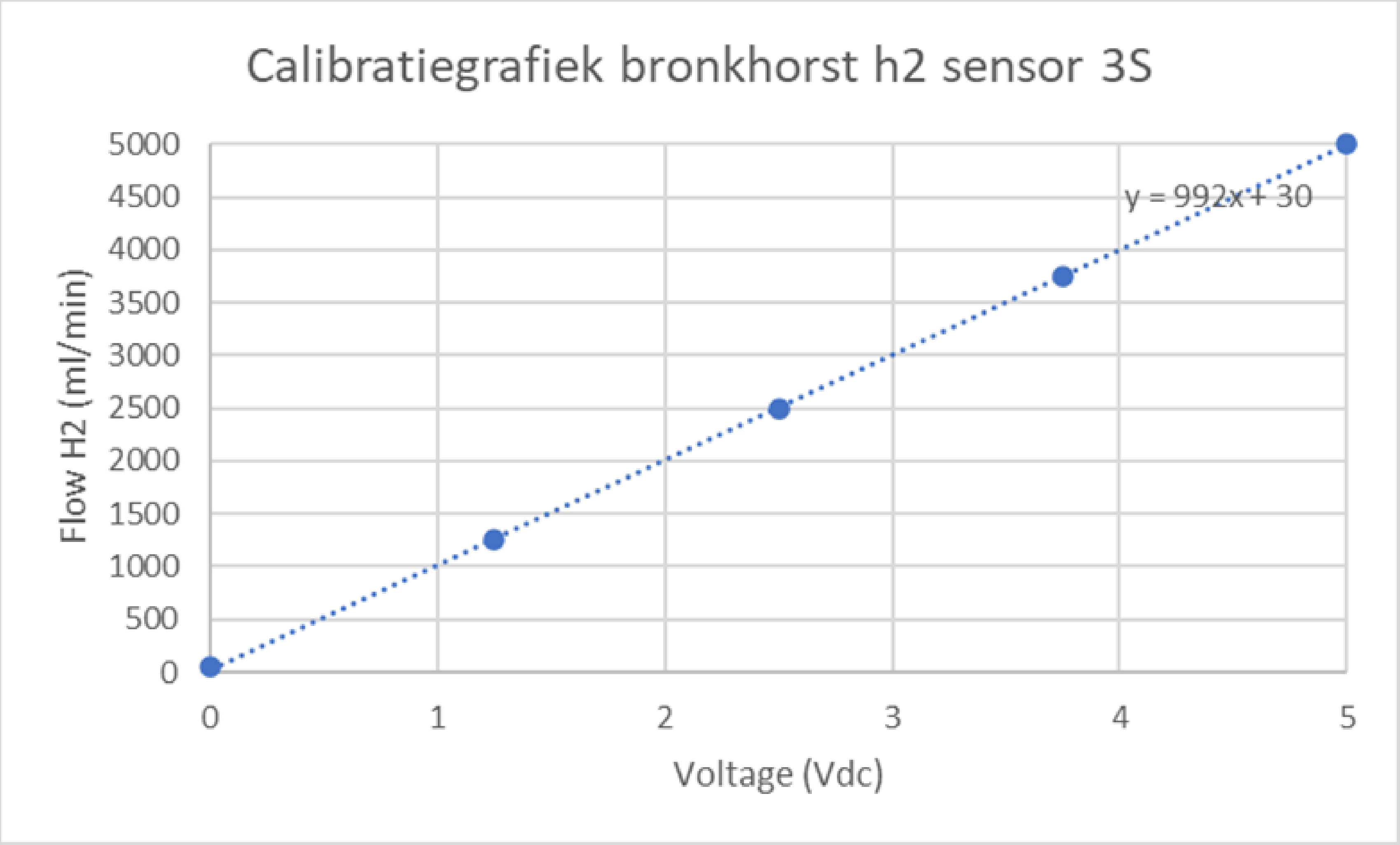
Matlab

- Programming in Matlab



Calibration flowmeter

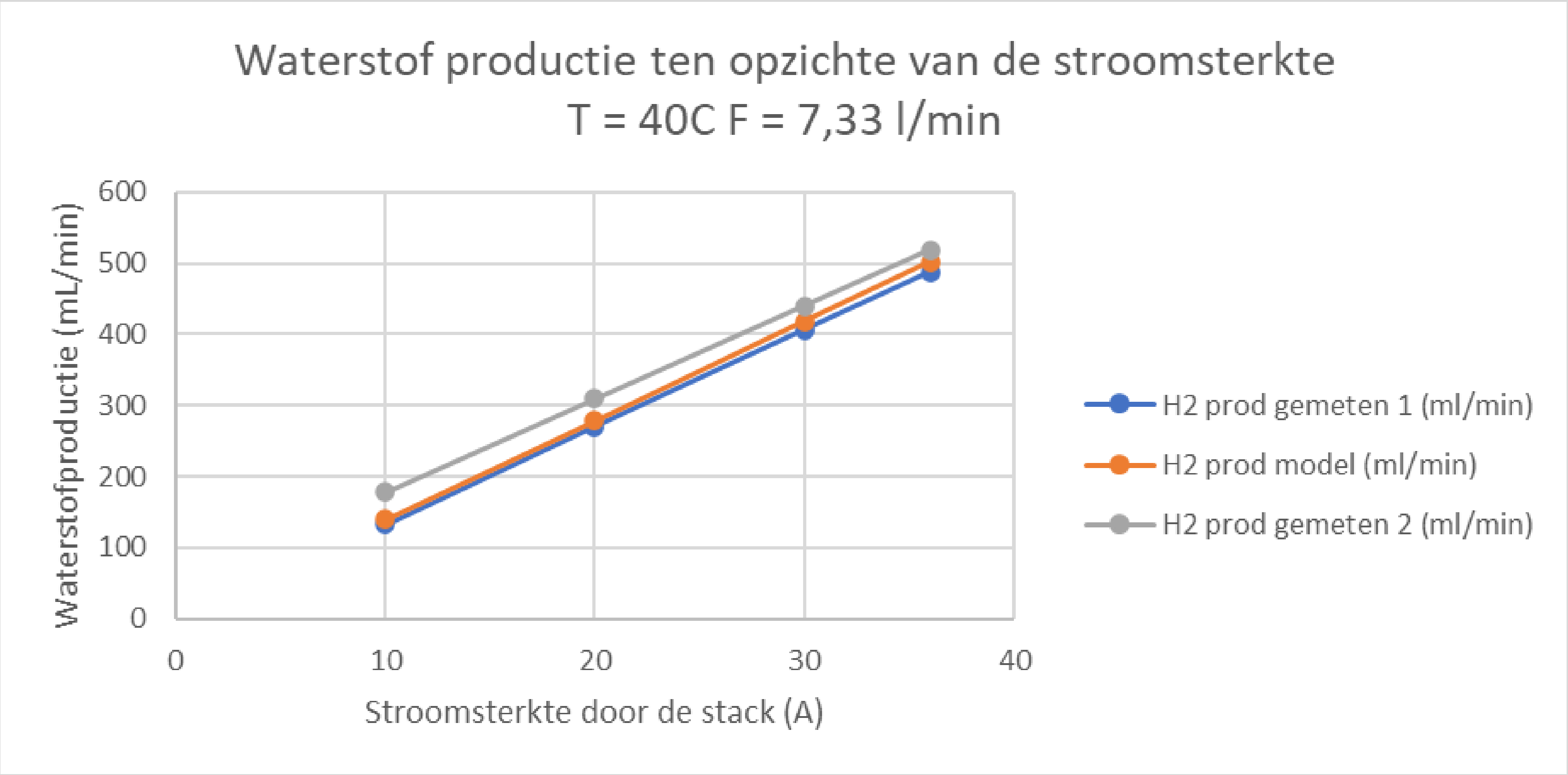
- At a flow of 50 ml/min no voltage is measured
- The working area of the sensor is not the same as the working area of the setup
- 2 Methods used to determine the size of hydrogen production:
  - 1: Flow = 1000*voltage
  - 2: Flow = 960*voltage + 50



H_2 production vs the current

- H_2 prod measured 1
  - Flow = 1000*voltage
- H_2 prod measured 2
  - Flow = 960*voltage + 50
- H_2 prod model in between the 2 lines of H_2 production

$$nH_2 = Ec\left(nf * \frac{i_{cell} * A_{eff}}{z * F}\right)$$



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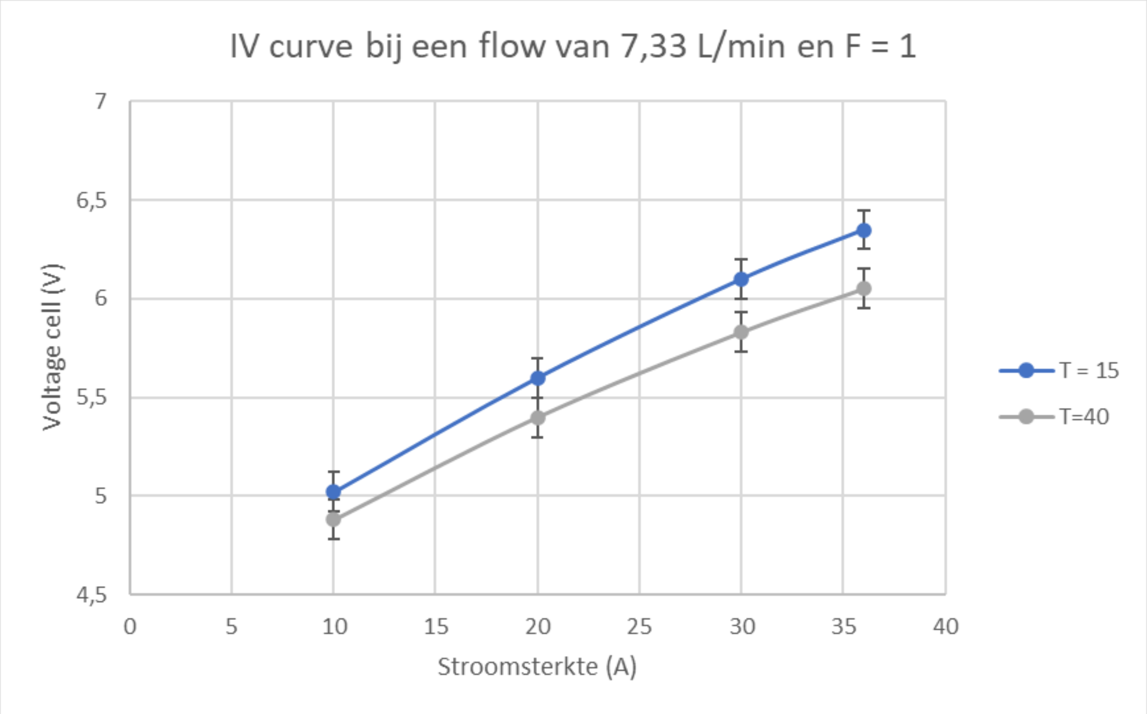
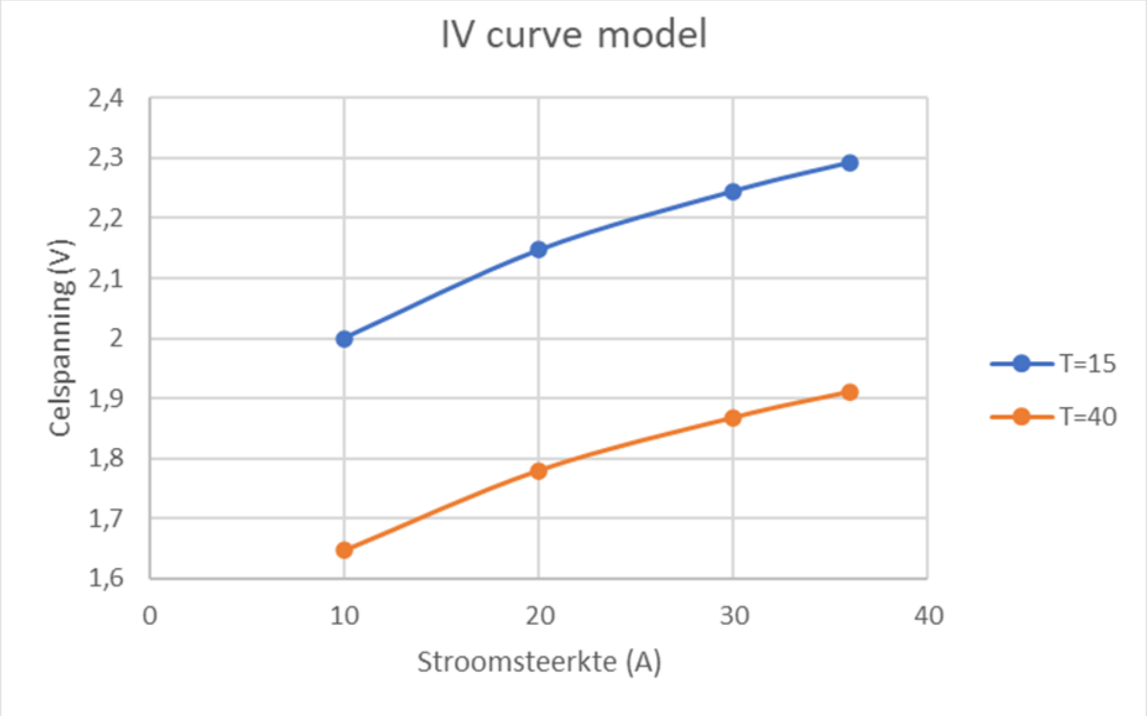
H_2 production vs temperature

- Temperature and H_2 production linked by Nernst equation
- Reversible voltage linked to the cell voltage
- Cell voltage linked to efficiency with thermo-neutral voltage
- Efficiency = Utn/Ucell
- The curves of the model and the measurements give the same course





Conclusions

- Model matches literature quite well
- Model matches well with the measurements
- The higher the current, the more H_2 produced
- Higher temperature leads to higher efficiency

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Questions?