

**HOCHSCHULE
FÜR TECHNIK
STUTT GART**

**SMART CITY
SOLUTIONS**

**BEST
OF 25**

Stuttgart University of Applied Sciences | Master Thesis | Master's Degree Smart City Solutions

Optimization workflow for water balance calculations;

Integration of **Green Hydrogen** production in natural water cycles

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SUPERVISORS:

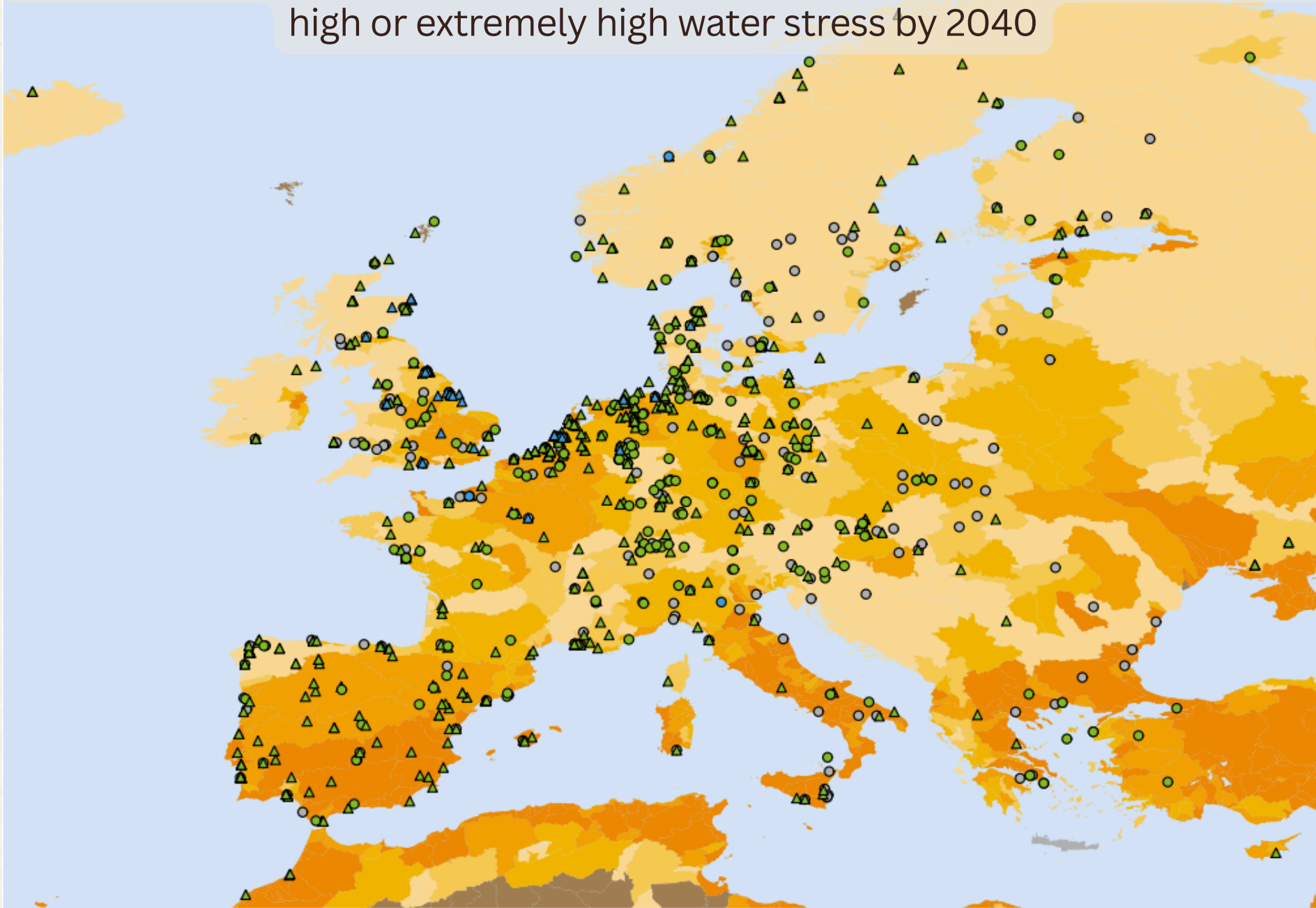
Prof. Dr. Iris Belle,
M.Sc. Philipp Alber

**DREES &
SOMMER**

Problem Statement

Can non-potable, locally available water sources be integrated into hydrogen systems in a technically, economically, and environmentally viable way?

Over 23% of Europe's green hydrogen projects are likely to be in areas under high or extremely high water stress by 2040



Hydrogen production projects

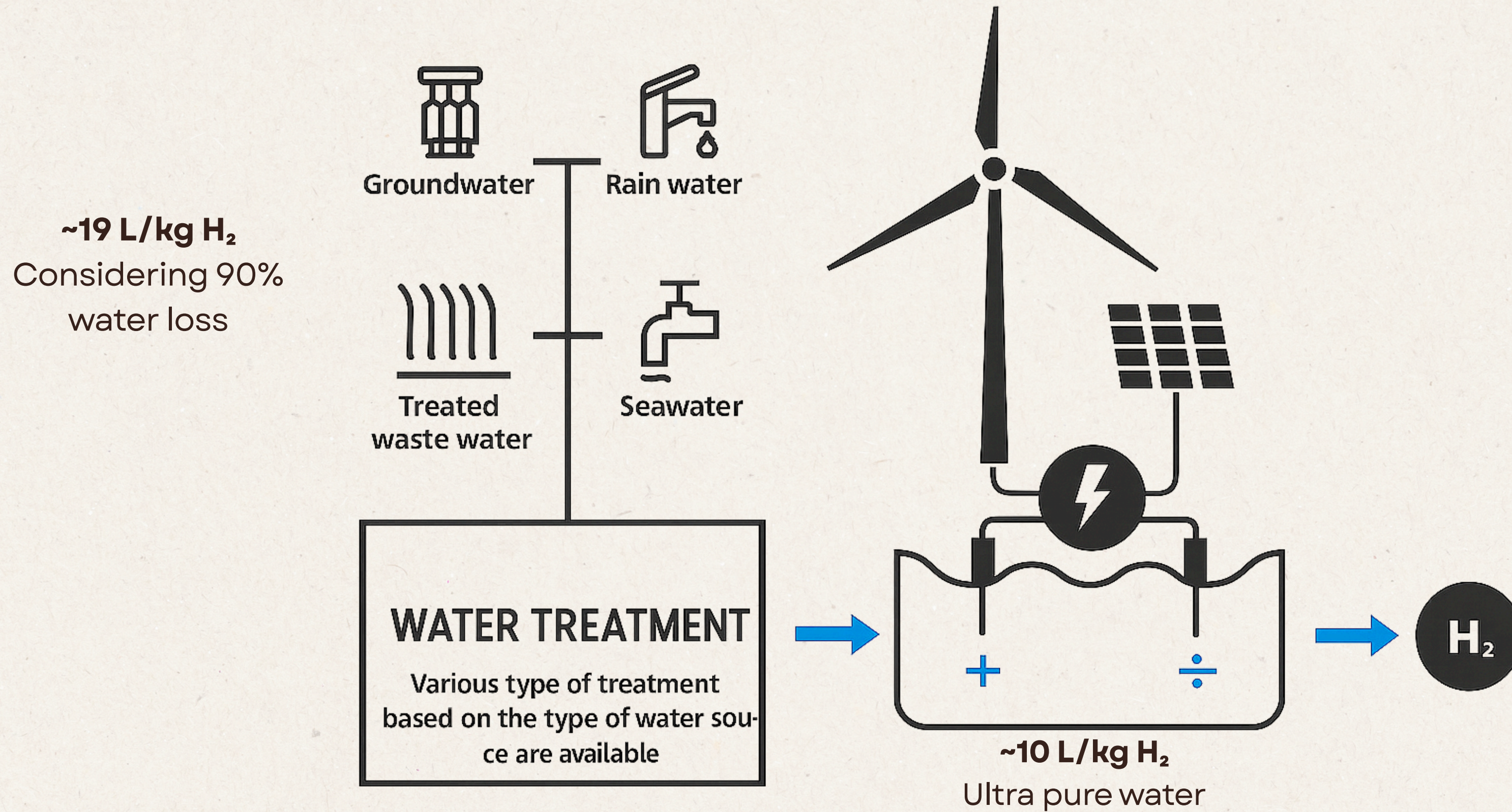
- Grey - Operational
- Blue - Operational
- Blue - Planned
- Green - Operational
- Green - Planned

Water stress conditions in 2040

- Low (<10%)
- Low to medium (10-20%)
- Medium to high (20-40%)
- High (40-80%)
- Extremely high (>80%)
- Arid and low water use
- No data

Based on: European Hydrogen Observatory, 2023; IEA, 2022

Green Hydrogen Production Process



Methodology

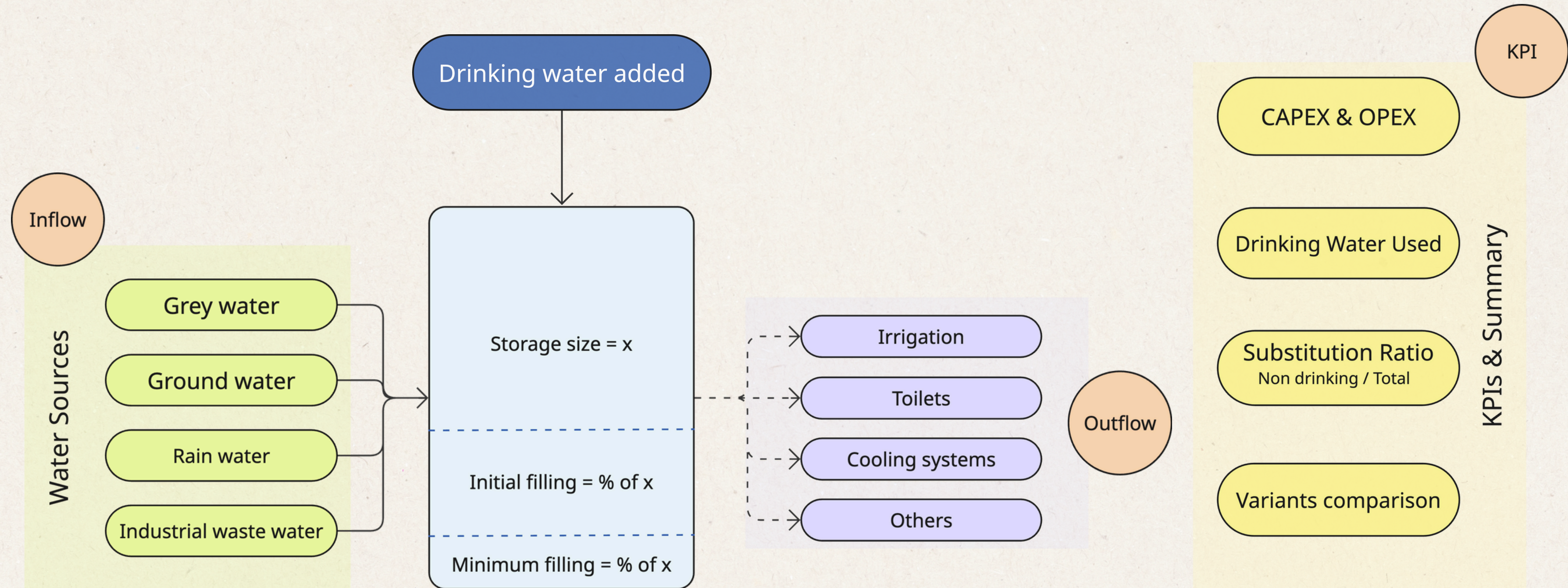
01 Optimization of water balance calculations

- Understand the existing logic
- Data extraction and data preparation
- Automate and optimize the process
- Develop a dashboard

02 Decision-support tool for H2 water demand

- Develop PESTLE model to find the best water source
- Extend dashboard to integrate Hydrogen as an outflow
- Case study application

Current Water Balance Logic



Automated Logic for Data Preparation

Rain data

from DWD (Deutscher Wetterdienst)

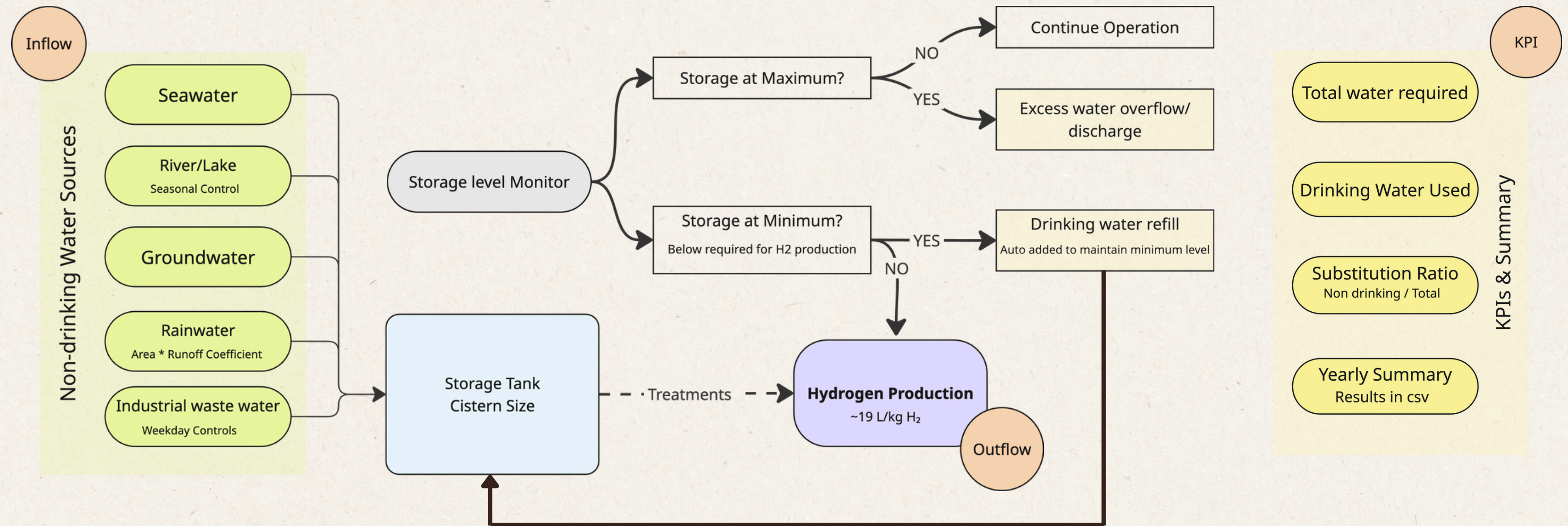
- Python script to find the closest DWD station to the selected site (using latitude/longitude)
- Sort the results based on the length of their continuous data records
- Python script which cleans the downloaded data

STA_ID	Stationsname	Breite	Laenge	distance_km	von_datum	bis_datum	years_with_data
3734	Obersulm-Willsbach	49.1280	9.3525	11.259804	2004.0	2025.0	22.0
7230	Möckmühl/Jagst	49.3078	9.3606	17.423393	2005.0	2025.0	21.0
6245	Neckarwestheim	49.0423	9.1733	15.775961	2008.0	2025.0	18.0
15012	Rappenu, Bad (Kläranlage)	49.2094	9.1034	9.125867	2014.0	2025.0	12.0
7229	Massenbachhausen	49.1739	9.0421	13.043971	2005.0	2010.0	6.0

PESTLE Framework



Hydrogen Production Dashboard Logic



Case Study

- Audi Industrial site
- Location: Neckarsulm, Baden-Württemberg
- Total Area: $\sim 1.35 \text{ km}^2$
- Roof Catchment Area: 55 ha
- Annual Wastewater: $\sim 280,000 \text{ m}^3$

Audi's "Mission:Zero" program targeting 70% waste water reuse by 2025.



PESTLE Economic Evaluation

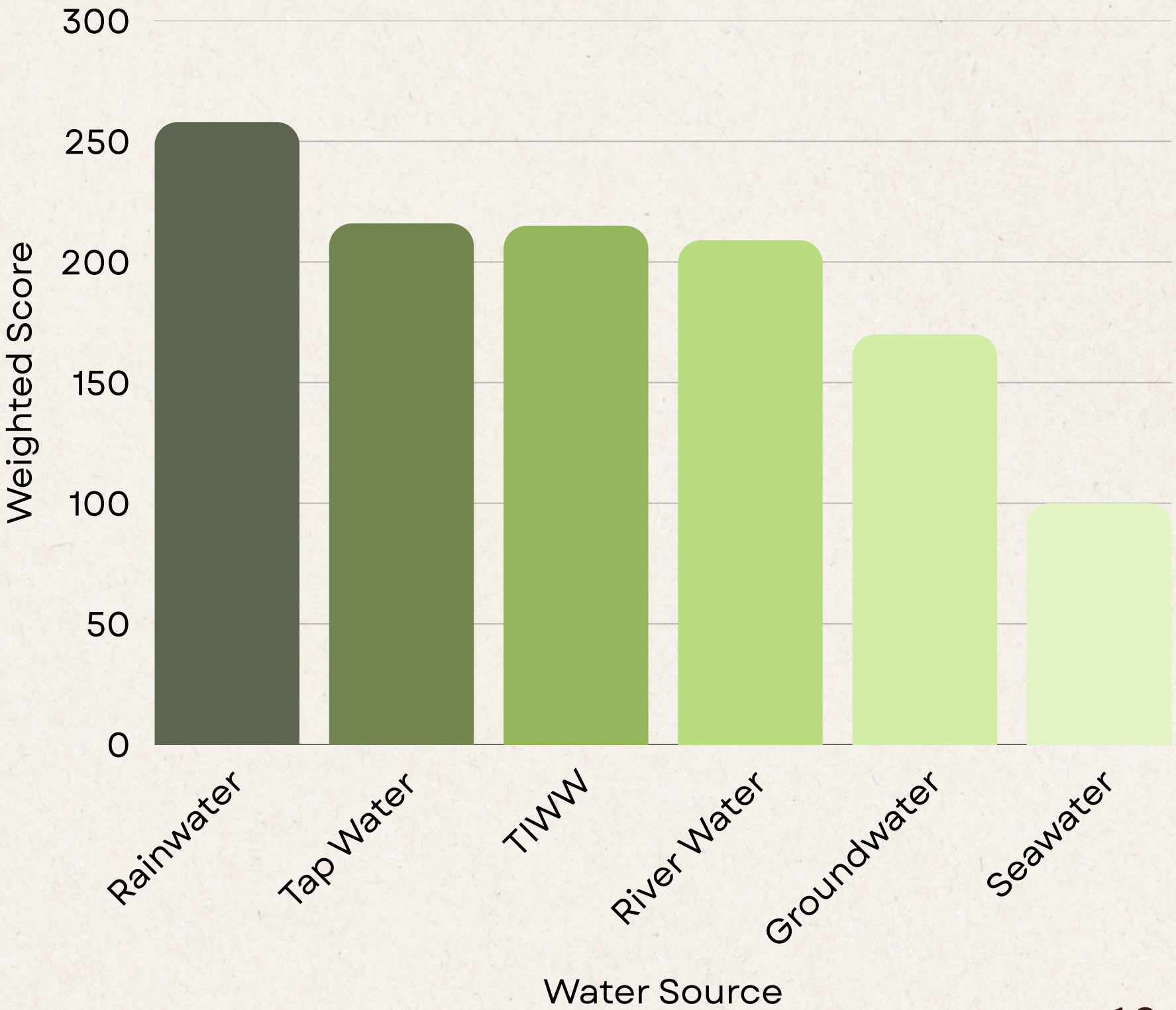
Costs are normalized to €/m³ to allow comparison.
For CAPEX: 10-year system lifespan and a 5% discount rate is considered.

Water Source	CAPEX (€/m ³)	OPEX (€/m ³)	Key Advantages	Key Limitations
Rainwater	4.83	1.5	high sustainability	Seasonal variability
Treated Industrial Wastewater	1.39	2.78	Consistent supply, circular economy	Complex treatment, Coordination with the industry
River Water	1.06	2	Lower infrastructure costs	Permitting challenges, competition
Groundwater	1.17	5.29	Consistent quality	High pumping costs, depletion concerns
Tap Water	0.67	3.53	Immediate availability, minimal treatment	Unsustainable use of potable resources
Seawater	97.62	12.91	Unlimited availability	Prohibitive inland transport costs

Multi-Criteria Decision Analysis

PESTLE Evaluation

Water Source	Weighted Score
Rainwater	258
Tap Water	216
TIWW	215
River Water	209
Groundwater	170
Seawater	100



Data Components

Electrolyzer Characteristics

Electrolyzer Capacity	Water Demand	H ₂ Output
60 MW	21 m ³ /h	~ 6,000 t H ₂ /y
PEM electrolyzer with 62.5% efficiency operating 5,475 hours annually	Base scenario water consumption with 90% system losses	Total projected hydrogen production per year

Data input

Area (CSV file)	Rain data (CSV file)	Storage data (CSV file)
Total roof area: 550,000 m ²	Cleaned DWD data (CSV file)	Storage size: 600 m ³
Total Run off area: 495,000 m ²	11 years rain data	Initial filing: 50% Minimum filling: not < hourly water demand

Scenario 1

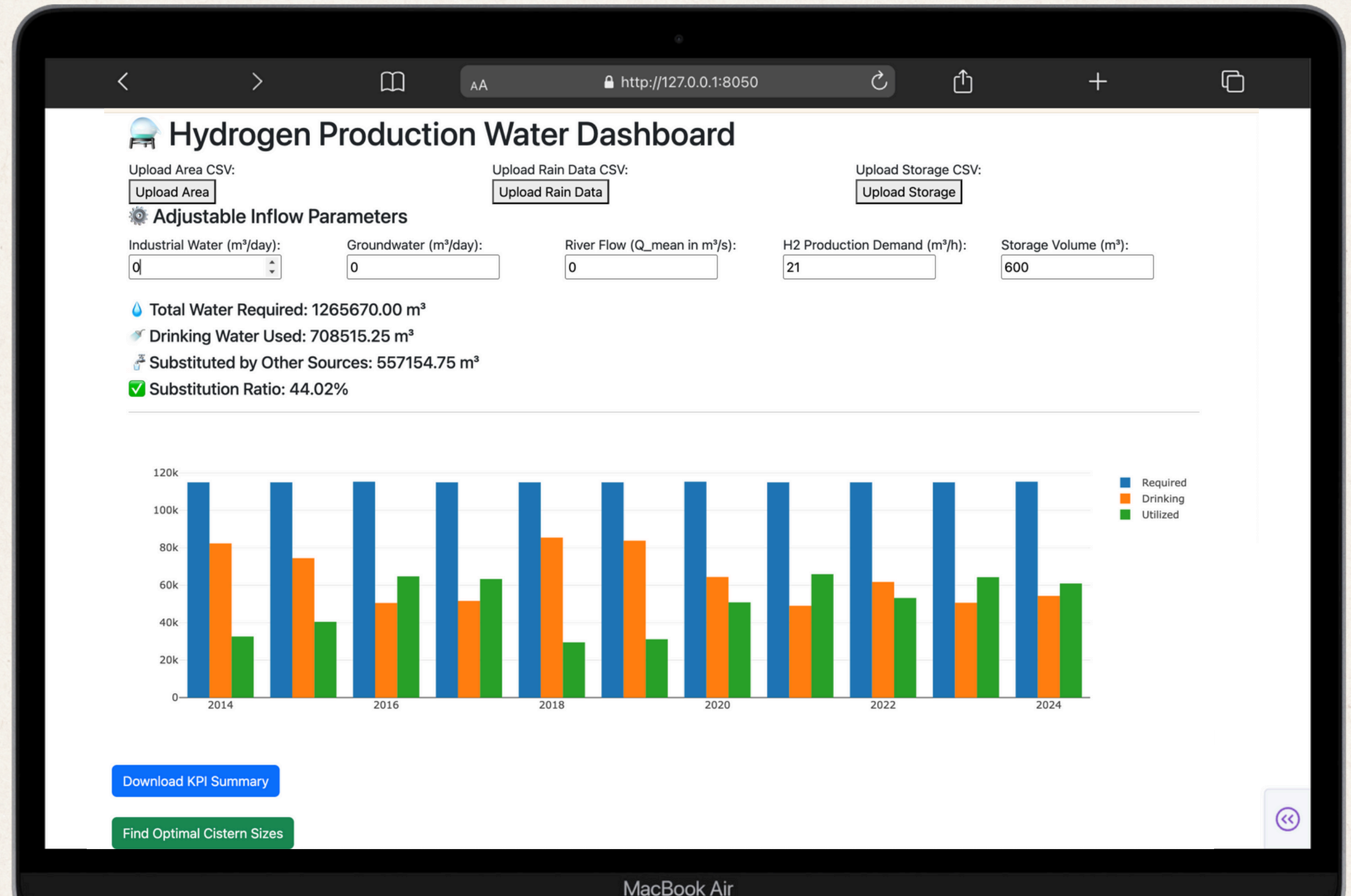
Only Rain water

Input:

- Upload CSV files
- H₂ water demand: 21 m³/h
- Storage size: 600 m³

Results:

- Substitution ratio: ~44%
- Potable saving: ~50,000 m³/y



Scenario 2

Rain water + Treated Industrial
Waste Water (TIWW)

Input:

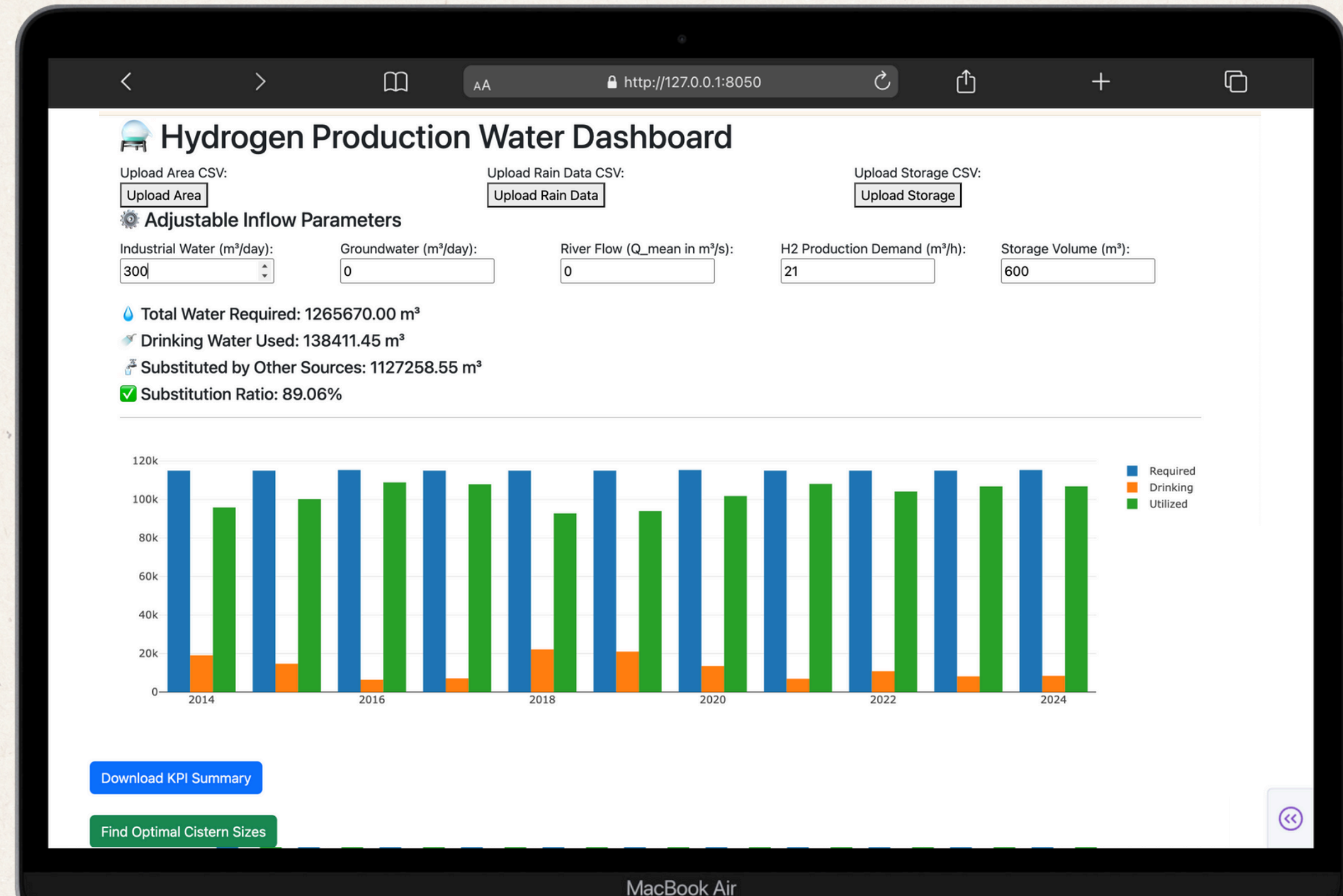
- Use rain water and TIWW as inflow
- Industrial water: 300 m³/d

Total TIWW= ~280,085 m³/year
(70% reused internally by AUDI)

Remained TIWW = ~80,00 m³/year

Results:

- Substitution ratio: ~89%
- Potable saving: ~102,000 m³/y



Conclusions

- **Summary**

This Tool supports decentralized, land-based hydrogen production plans, and can be used in early stages of Hydrogen planning to find the suitable location

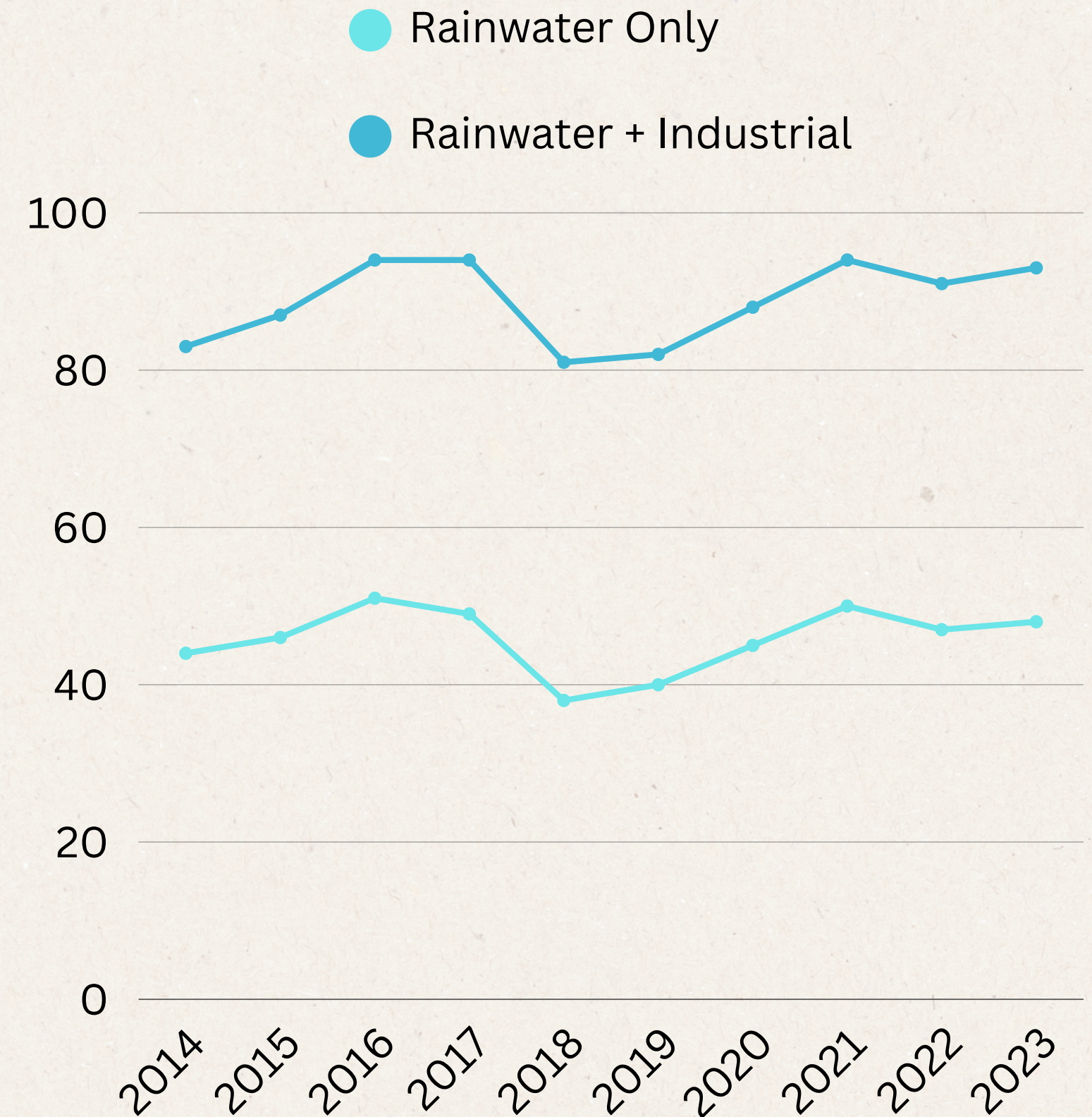
- **Case Study Outcomes**

Environmental: Up to 90% of potable water could be substituted (Combining water sources)

Economical: Save over 100,000 cubic meters of potable water annually at a single industrial site.

- **EU Goals**

Supports European sustainability goals, including circular economy principles, water reuse strategies, and the EU's green hydrogen roadmap.



THANK YOU

For Listening



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