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IAV‘s Expertise: Pushing Hydrogen forward from Well to Wheel

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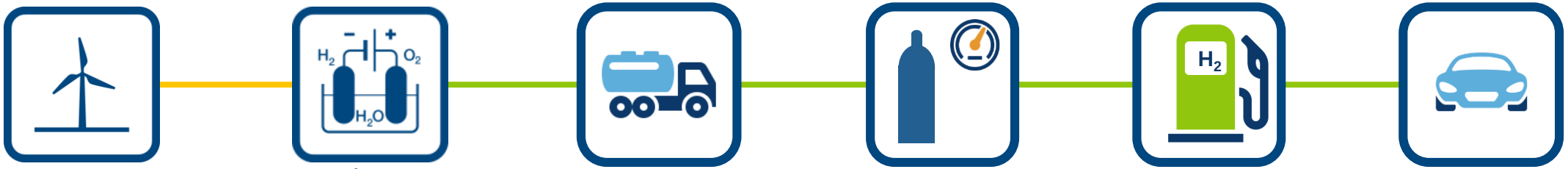
Nonlinear Model Predictive Control for wind turbines („eco4wind“)

Various scientific publications on H_2 supply

Project development of H_2 facilities

Detailed design tool for refuelling stations

Simulation studies on and software development for refuelling processes



Cost reduction of alkaline water electrolysers by 50% („ecoPtG“)

ecoPtG economical. logical.

Bundesministerium für Wirtschaft und Energie

Tank development for vehicles and stations

More than 20 years of experience in the development of H_2 vehicles:

- Fuel Cell
- ICE
- Storage systems
- Integration
- Controls
- Safety

→ **IAV works on and understands the entire hydrogen supply chain**

Techno-Economic Analysis and Design of Hydrogen Supply Chains

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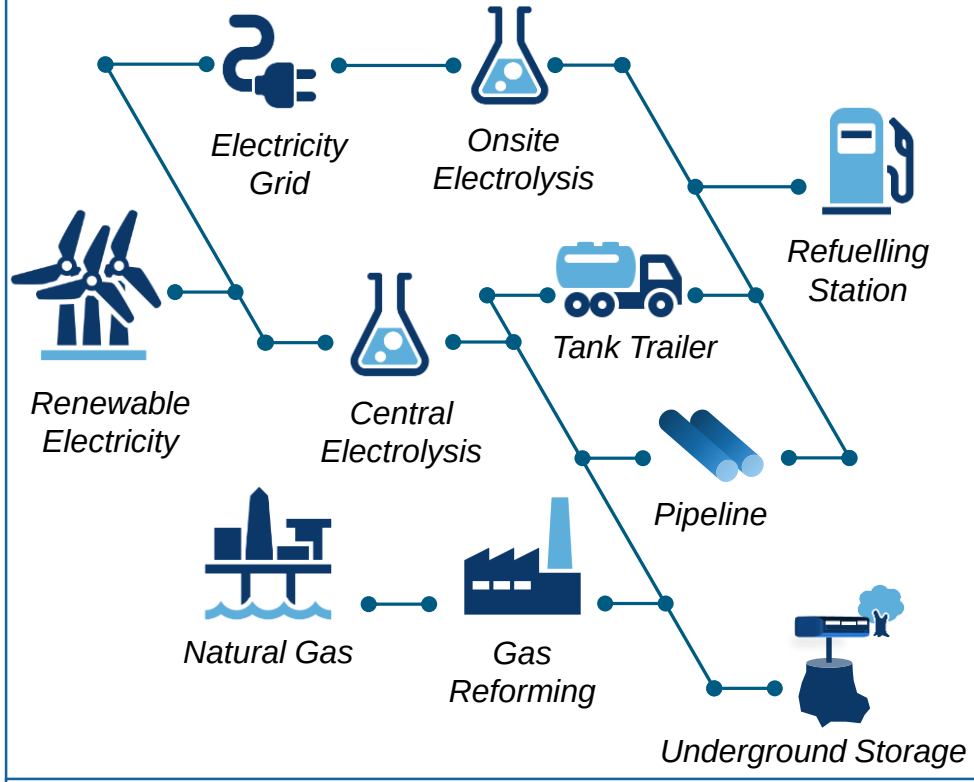
Supply Chain from Electricity to Hydrogen Refuelling Station

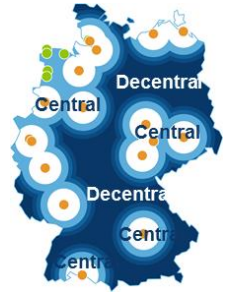


Hydrogen Supply Chains are complex systems that need to be well-designed

Solutions by IAV

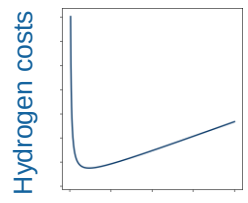
Topics covered

- ✓ Feasibility studies
- ✓ Conceptual design of all supply chain elements including production, storage and conversion
- ✓ OPEX and CAPEX calculation
- ✓ Constrained TCO optimization



Example 1:
Centralized and decentralized production

IAV compares total costs for centralized and decentralized production



Example 2:
Optimal delivery with tank trailer

IAV compares CGH2, LH2 and LOHC and optimizes delivery rates

IAV has developed tools for the evaluation of the entire supply chain

→ **IAV is capable of achieving minimal hydrogen costs due to state-of-the-art in-house optimization tools**

Project and Feature Development of Hydrogen Facilities

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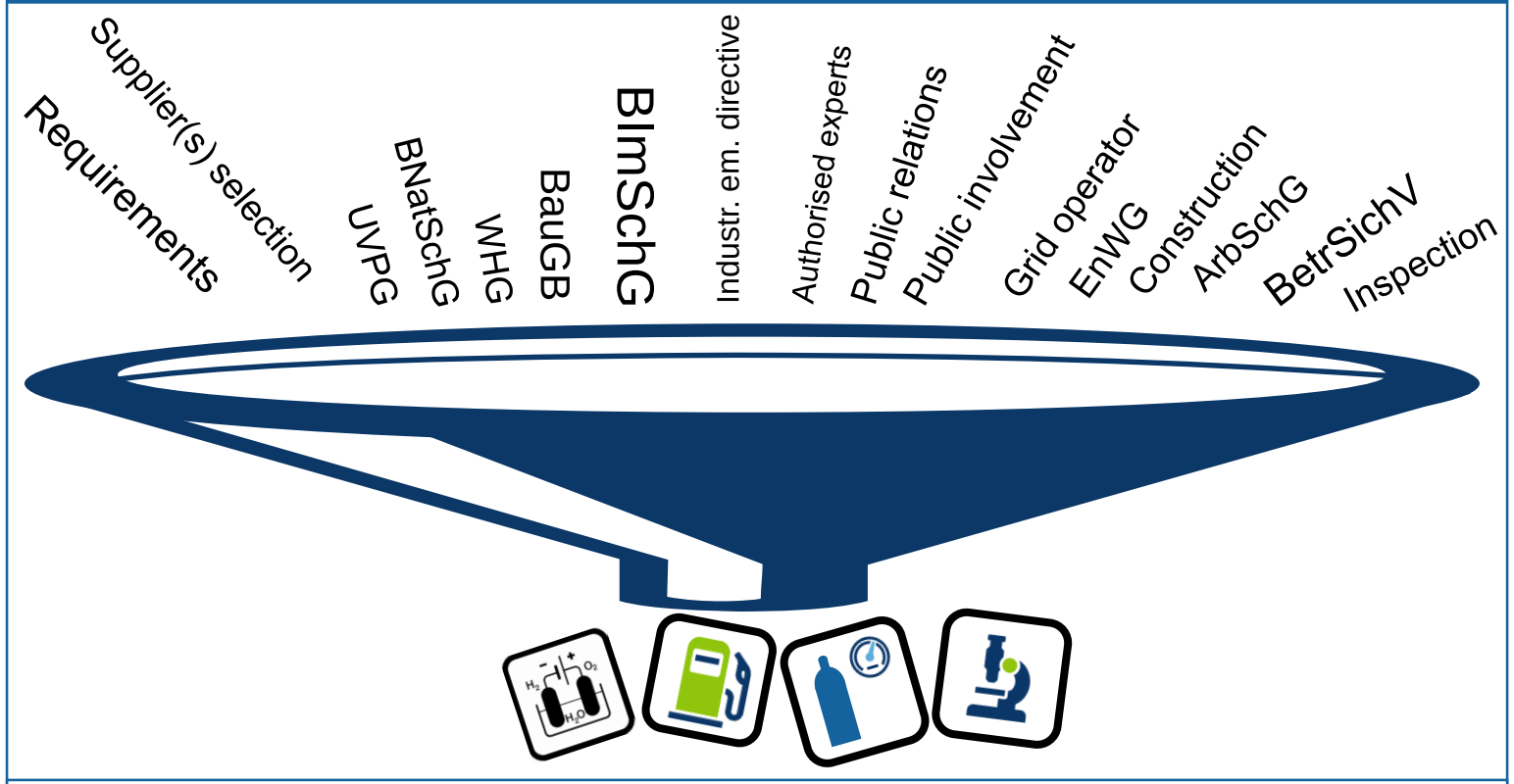
Relevant Aspects for Project and Property Development



Project and property development is based on numerous regulations, codes and standards by the EU, Germany…

Solutions by IAV

- ✓ Complete specification
- ✓ Supplier(s) selection
- ✓ Project development
- ✓ Planning consent
- ✓ Construction supervision
- ✓ Commissioning
- ✓ Inspection for all kind of hydrogen facilities (electrolysers, refuelling stations, storage, test stations…)

IAV offers all necessary services

→ **IAV is your partner to accompany the whole process of development, from requirements to final inspection**

Real Time Energy Flow Management

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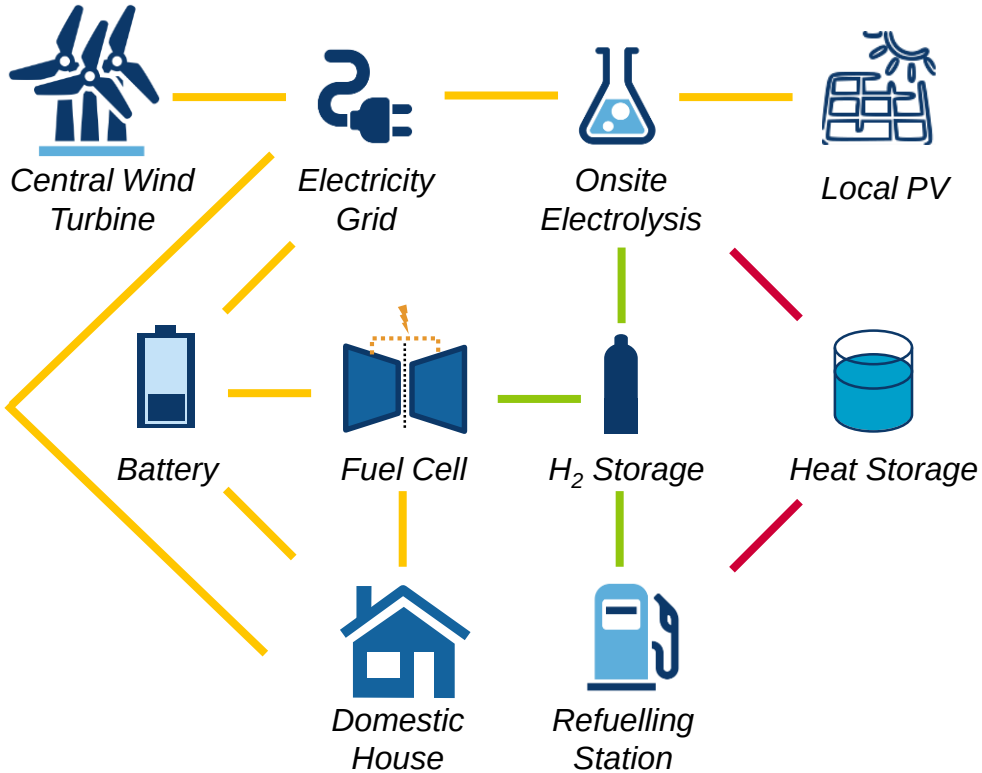
Interconnected Energy Systems



Highly integrated energy systems are a major challenge with respect to control and require predictive strategies

Solutions by IAV

Optimal Control Problems

- ✓ IAV has validated physical simulation libraries available
- ✓ IAV has appropriate optimization and control algorithms available
- ✓ IAV readily combines the simulation and optimization libraries to efficiently solve your specific optimal control problem

IAV determines the best possible control strategy

Robust and practical solutions

- ✓ IAV uses the optimal strategy to develop robust and practical solutions that are easy to implement
- ✓ IAV can readily implement these robust control strategies on your platform of choice
- ✓ IAV offers complete validation and examination for your system

IAV develops and implements robust and practical controllers

→ **IAV offers advanced control strategies that are required for systems including storages and multiple energy flows**

Engineering Services

Hydrogen Refuelling Stations, Electrolysers and Storage Systems

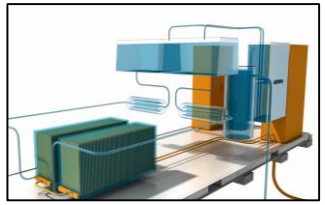
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Electrolyser

Electrics, controls and power electronics

Process engineering

Stack



Chemical, thermal, processing, safety and software engineering required for development of complex hydrogen systems

Solutions by IAV

Services

- ✓ Cost and requirements engineering
- ✓ Production-oriented design
- ✓ Functional safety
- ✓ Mechanical design
- ✓ Thermal management
- ✓ Design of electrics, controls and power electronics
- ✓ Simulation studies of entire hydrogen refuelling stations and electrolysers

References

- ✓ IAV developed a decentralized alkaline electrolyser (with partners)
- ✓ IAV developed and operates test stations for fuel cell (systems), hydrogen combustion engines and associated components
- ✓ IAV is deeply involved in the development of hydrogen storages
- ✓ IAV ensures functional safety in both the automotive and non-automotive industry

IAV has extensive experience and offers engineering for the development of hydrogen refuelling stations, electrolysers, storages…

→ IAV offers a wide range of engineering services for all kind of hydrogen facilities

Production Plant Improvement

Production Plants

Data acquisition / warehousing / analytics

Health Monitoring

(Electro-) chemical engineering

Predictive Maintenance

Process engineering

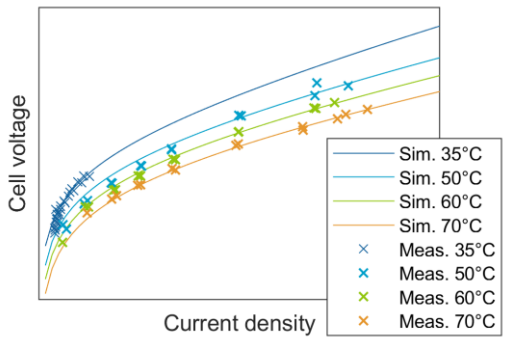
Controls tweaking

Real-time energy flow management

Production plants are complex and large systems consisting of numerous subsystems

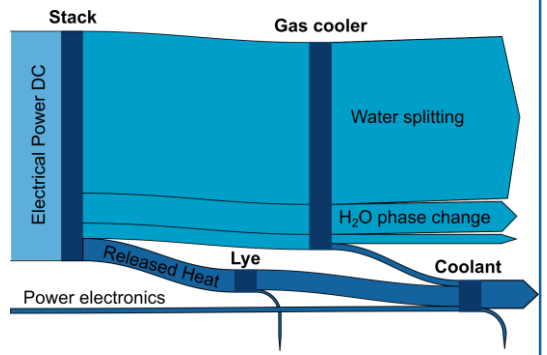
Solutions by IAV

Analysis by simulation



- ✓ IAV offers simulation studies based on in-house first-principle models
- ✓ Models cover multiple scales ranging from molecules to systems

Analysis by measurement



- ✓ IAV conducts measurements both for validation and troubleshooting
- ✓ IAV offers state-of-the-art data analysis and visualization

IAV combines simulation studies and measurements in a meaningful and cost-efficient way

→ **IAV offers a wide range of tools to bring your production plant to the next level**

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