

Chemische Speicher

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- DLR

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- IZES



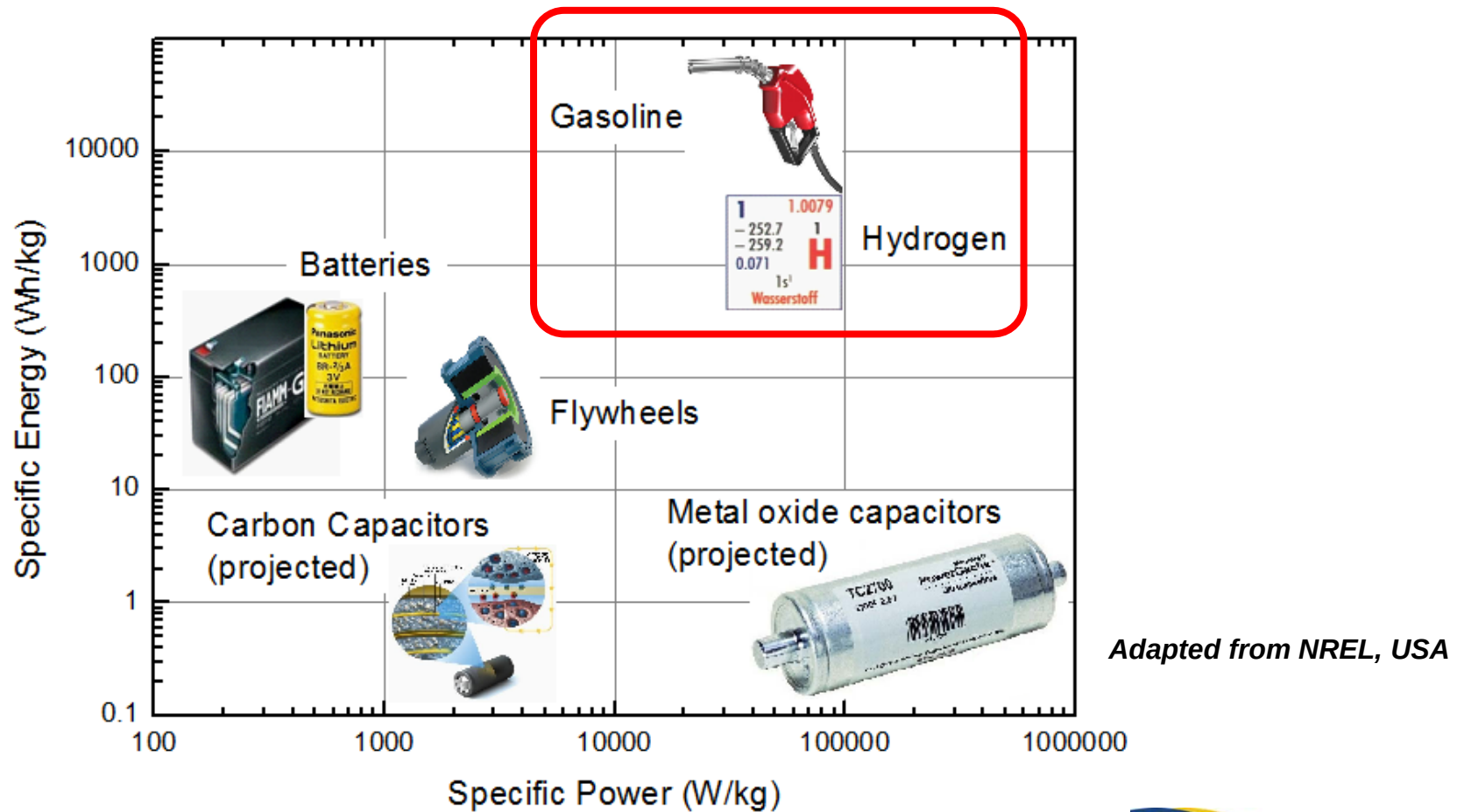
The problem:

- The electricity grid cannot deal with massive, long-lasting fluctuations in supply
- Renewable energy is often generated at a different place than where it is needed most

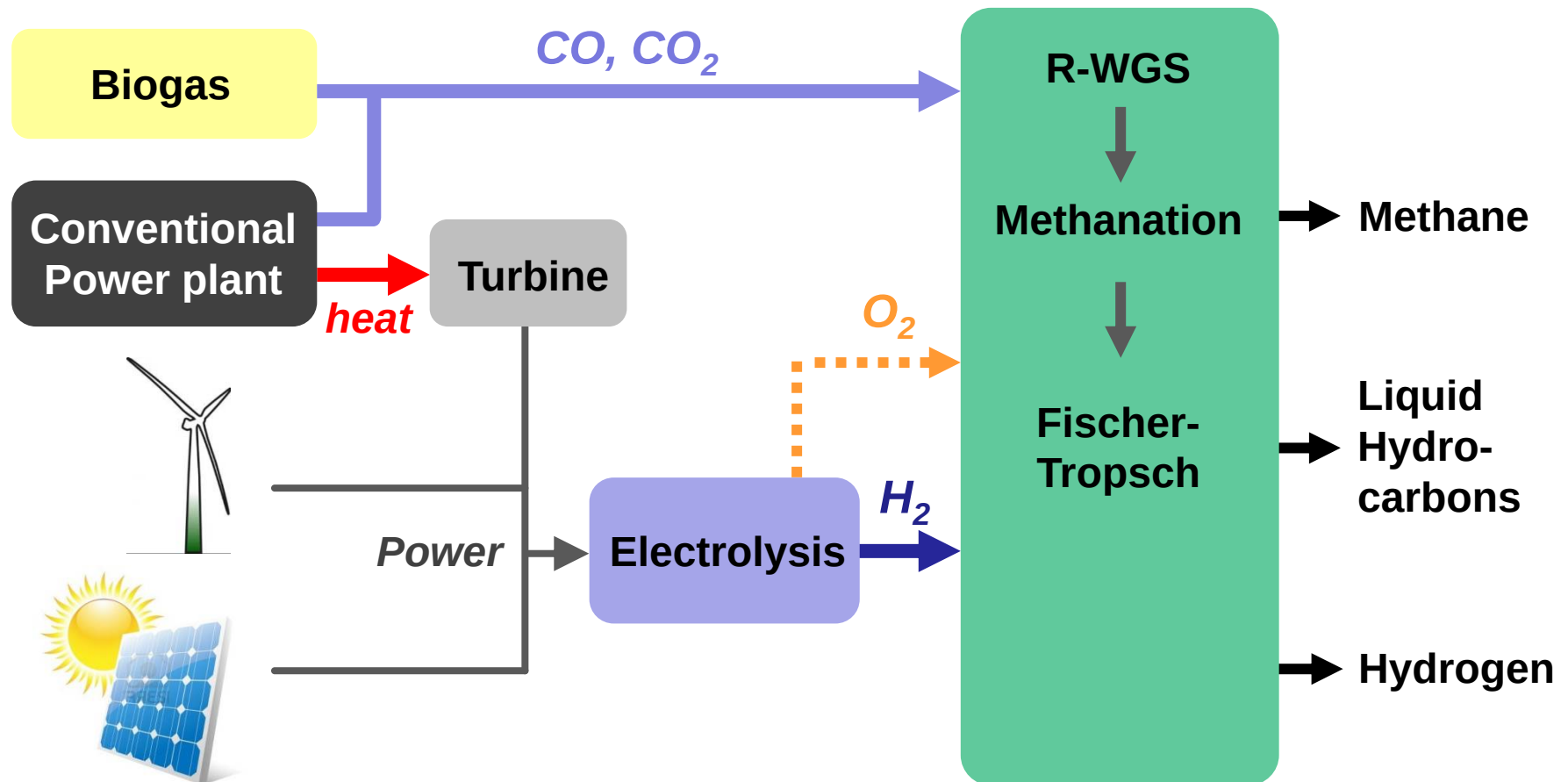


Need for large-scale energy storage solution

For energy storage on a Gigawatt-hour scale, chemical fuels are difficult to beat



Power-to-Gas



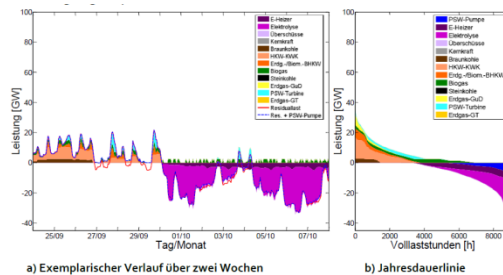
Für IWES ist Power-to-Gas-Technologie zentraler Bestandteil chemischer Speicher – Forschungsschwerpunkt in energiewirtschaftlicher System- und Anlagenebene



Forschungsaktivitäten zu chemischen Speichern

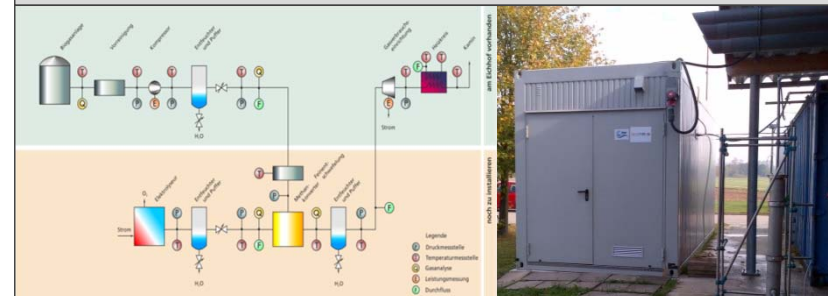
Power-to-Gas-Technologie (H_2 und CH_4)

Energiewirtschaft und Systemanalyse



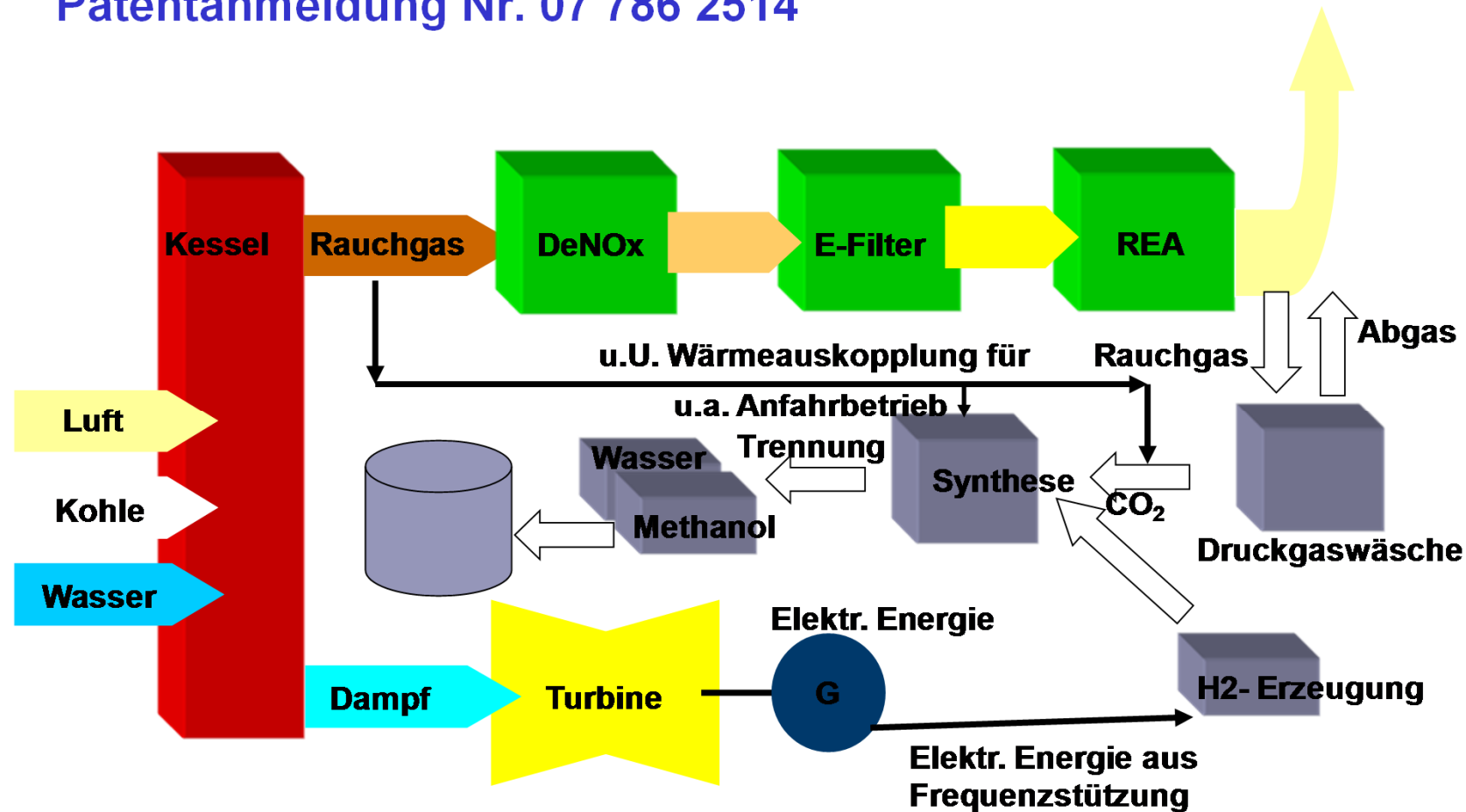
- Technologiebewertung von Power-to-Gas und anderen Speichertechnologien in zukünftigen Energieversorgungssystemen mithilfe europäischer Kraftwerks- u. Speichereinsatzplanung
- räumlich und zeitlich optimaler Power-to-Gas-Einsatz
- sektorübergreifende Analyse der Power-to-Gas-Technologie, d. h. insbesondere Nutzung im Verkehrs- und Wärmesektor
- konvergente Nutzung von Strom- und Gasnetzen

Anlagentechnik



- Direktmethanisierung als direkte Kopplung von Biogasanlagen und der Power-to-Gas-Technologie
- Einbindungskonzepte, Entschwefelung, Sicherheitsmaßnahmen
- Versuchsanlagen am IWES-Standort Eichhof
- CO_2 -Bedarf der Power-to-Gas-Anlagen und nutzbare CO_2 -Potenziale

Blockschema der Abgasreinigung und der Methanolgewinnung im konventionellen, fossil befeuerten Kraftwerk; Europäische Patentanmeldung Nr. 07 786 2514



Synthetic Liquid Hydrocarbons

HGF Energy-Alliance *SynKWS*

Process Concept

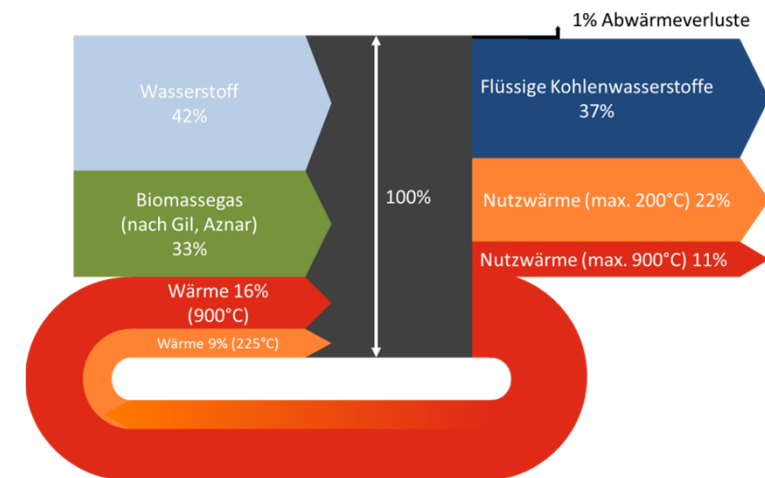
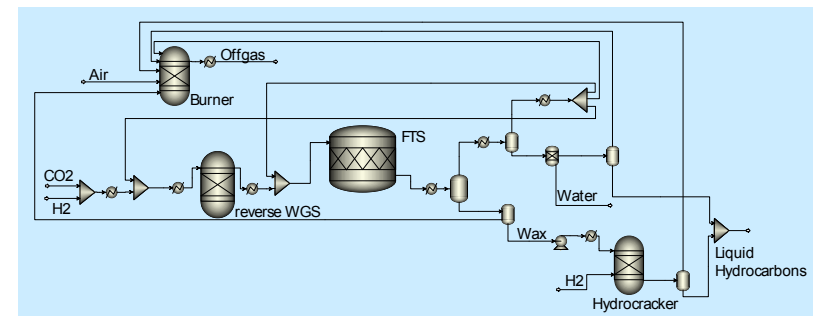
- Primary Renewable Energy Sources: Solar, Wind, Biomass
- Chemical Conversion via Electrolysis, Gasification, Fischer-Tropsch-Synthesis
- Synthesis of tailored hydrocarbons as chemical storage for centralized and decentralized applications (power generation, transportation fuels etc.)

DLR Research Activities

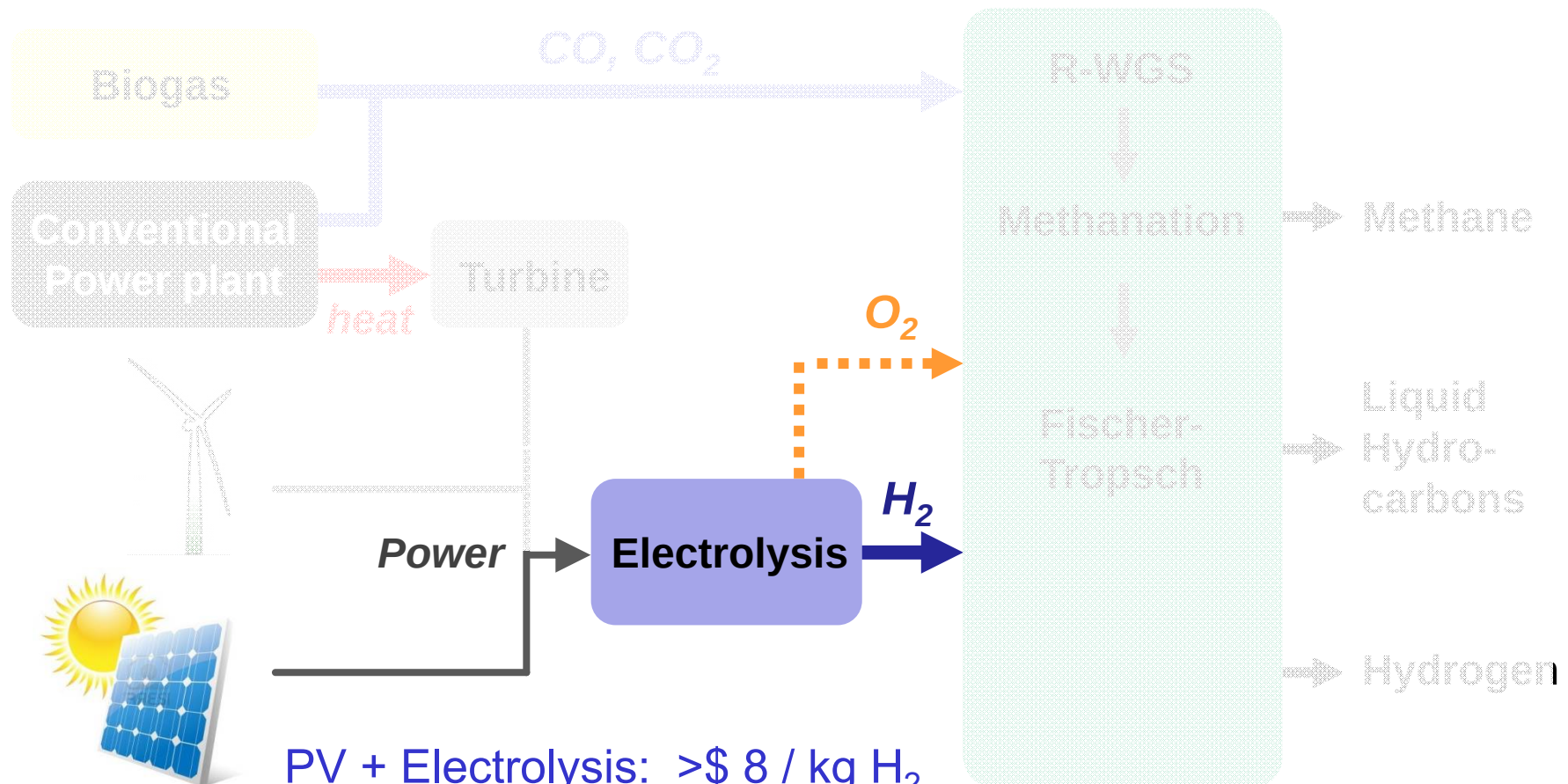
- Systemic evaluation of synthetic hydrocarbons as chemical energy storage
- Process development and techno-economic evaluation
- Evaluation of combustion characteristics



Universität Stuttgart
Germany

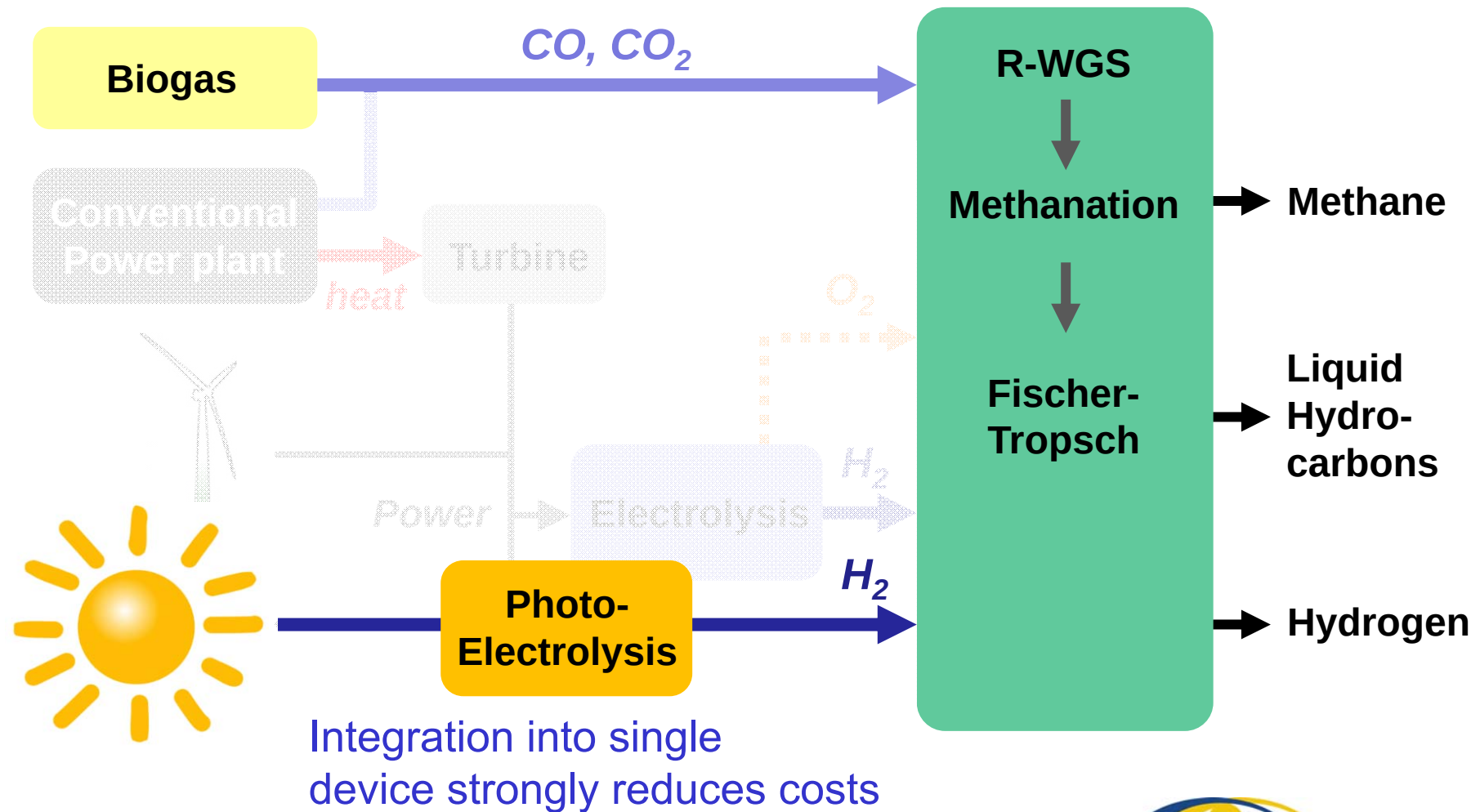


Power-to-Gas

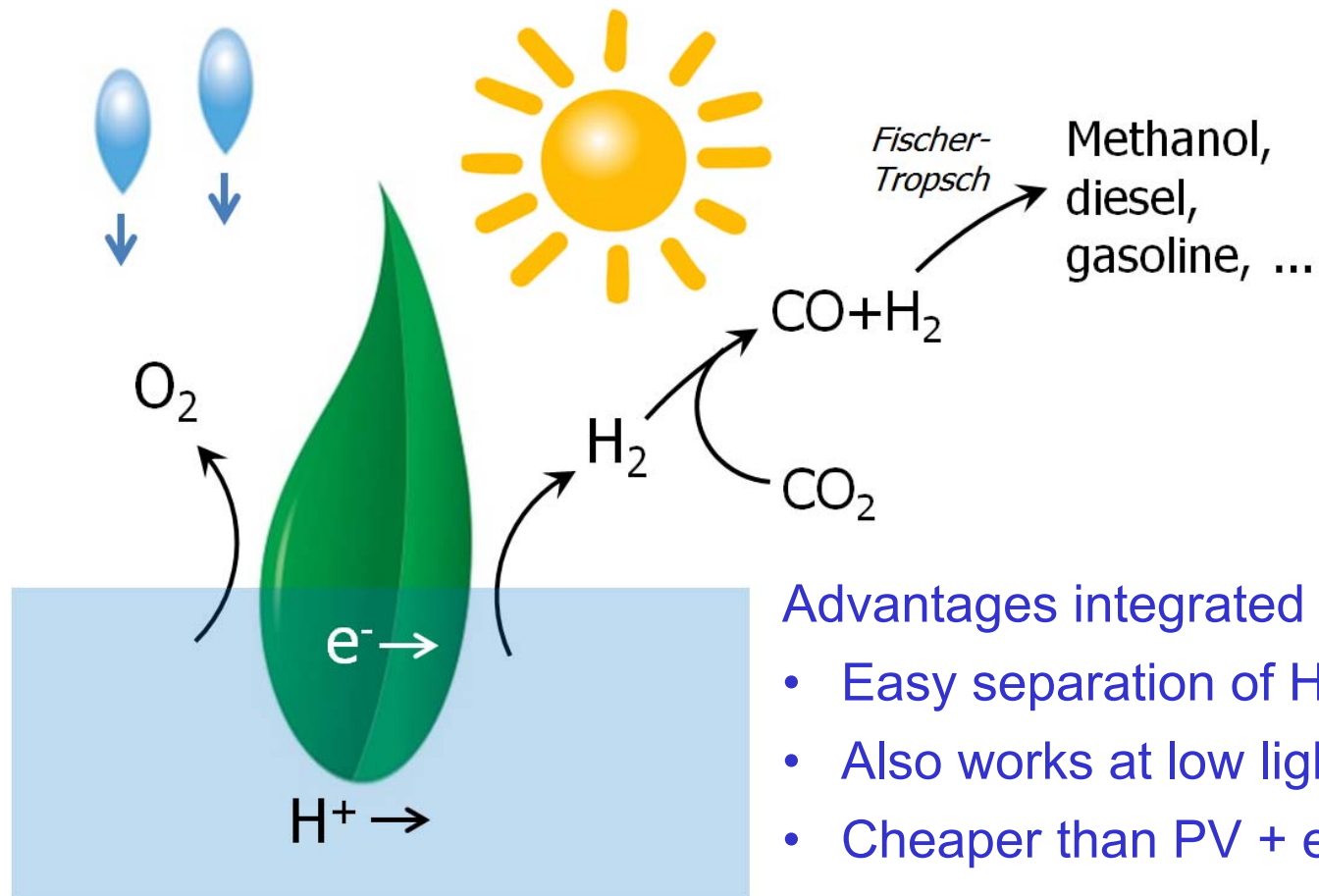


PV + Electrolysis: >\$ 8 / kg H_2
 EU (DOE) targets: < 5 €(\$)/ kg H_2

Power-to-Gas and Power-to-Liquid



Towards Solar Fuels: Photoelectrochemical Water Splitting at an Artificial Leaf

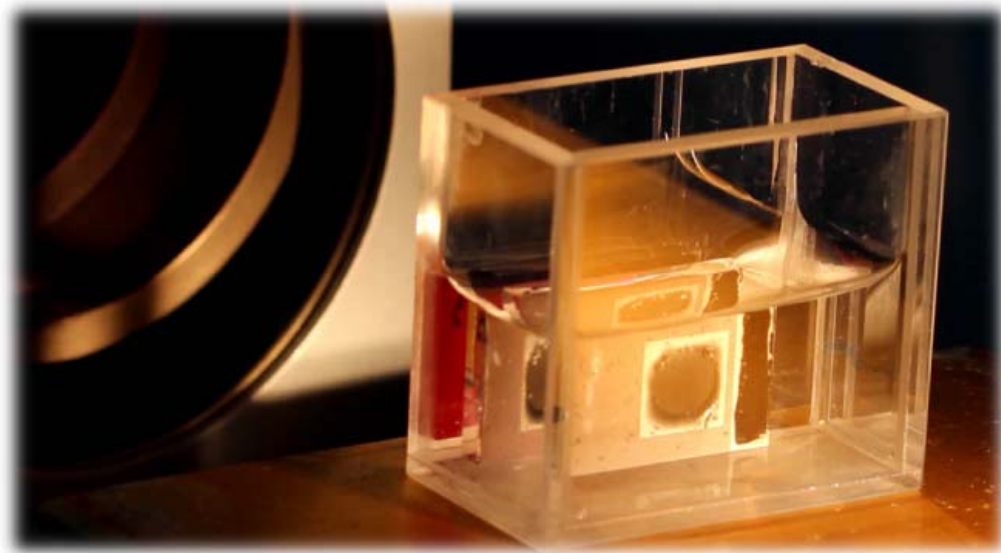
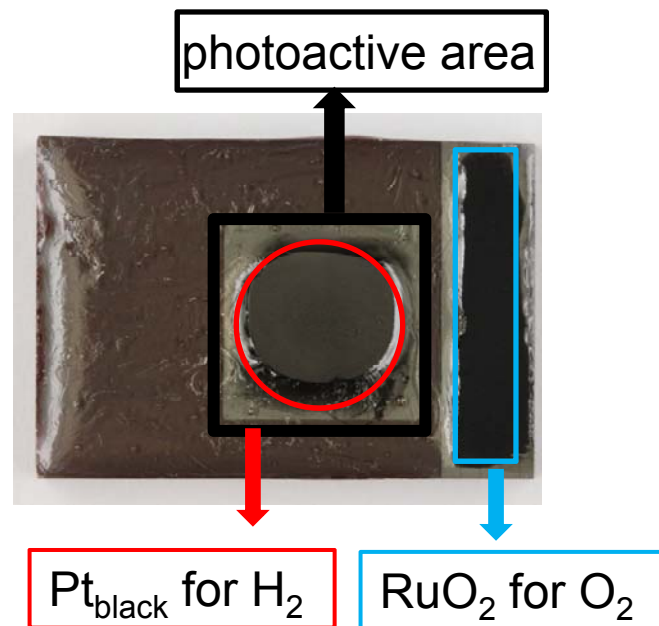


Advantages integrated PEC device:

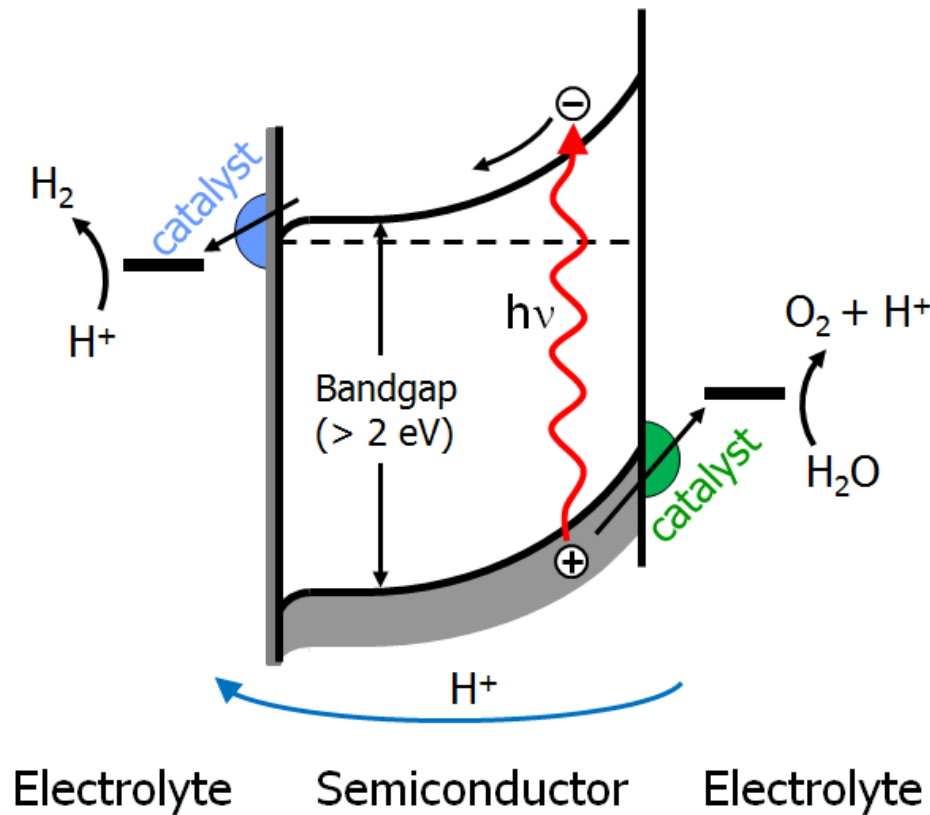
- Easy separation of H_2 and O_2
- Also works at low light intensities
- Cheaper than PV + electrolyzer

An “Artificial Leaf” Based on a Superstrate PV Cell

- a-Si/a-Si/ μ -Si cell provides ~ 1.8 V at working point
- PEDOT:PSS ‘glue’ immobilizes the catalysts
- Superstrate design avoid light scattering by bubbles
- Operation close to maximum power point, $\eta = 3.5\%$
- Less than 10% performance loss in 18 hrs



Chemically-Stable Semiconductors: Metal Oxides



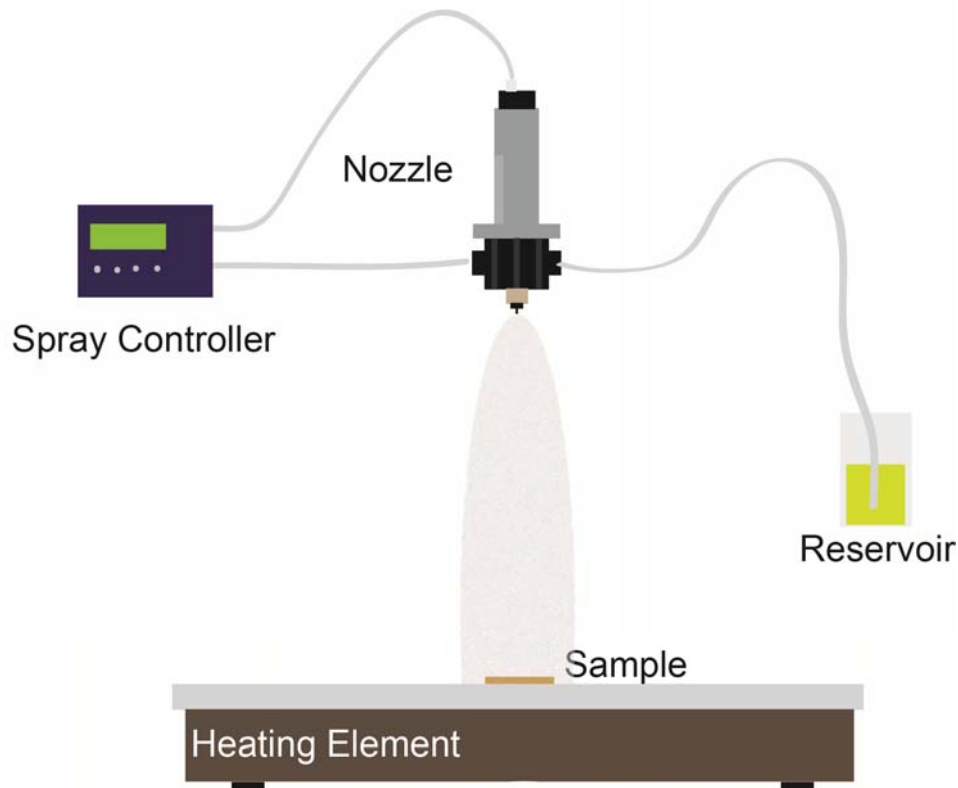
Metal oxide semiconductors

- + Bandgap $> 1.23 \text{ V}$ ($1.5 - 3 \text{ eV}$)
- + Chemically stable
- + Easy to make, cheap
- Poor carrier transport
- Defects $\rightarrow$ recombination
- Slow surface reactions
- Bad energetics for H_2 evolution

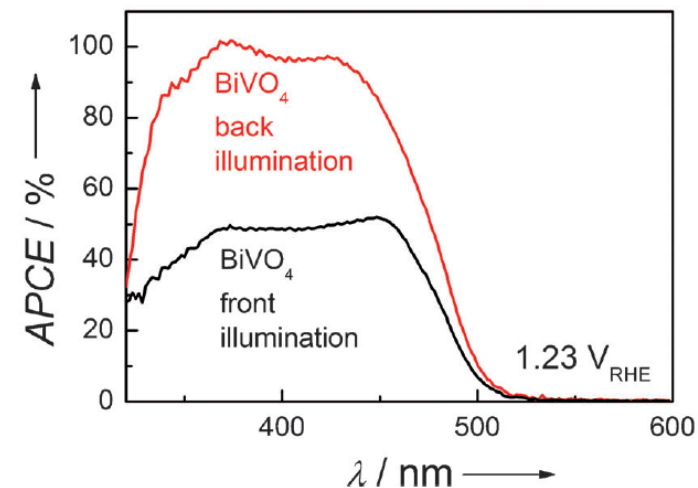
Examples:

TiO_2 , Fe_2O_3 , WO_3 , Cu_2O

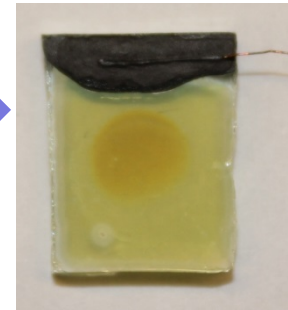
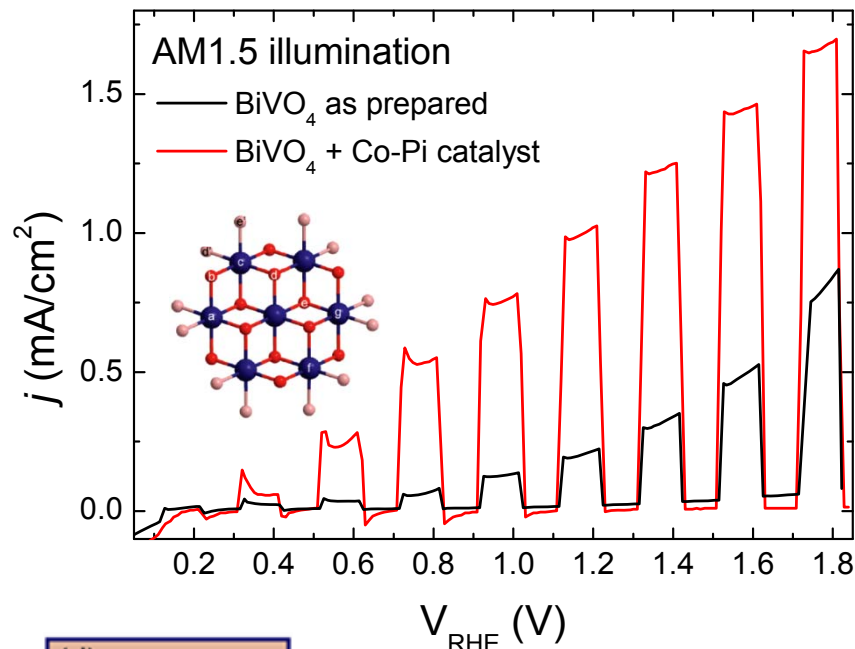
Bismuth Vanadate, BiVO_4



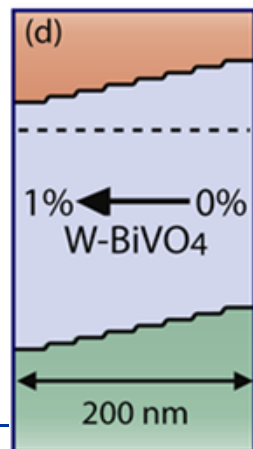
- + Bandgap 2.4 eV ($\eta_{\text{theory}} = 9.3\%$)
- Poor carrier mobility, $0.04 \text{ cm}^2/\text{Vs}$
- + Long lifetime, $\sim 40 \text{ ns}$
- + Int. QE $\sim 100\%$ at low light intensities
 $\Rightarrow$ almost no recombination!
- Low QE under 1 sun conditions



Bismuth Vanadate, BiVO_4

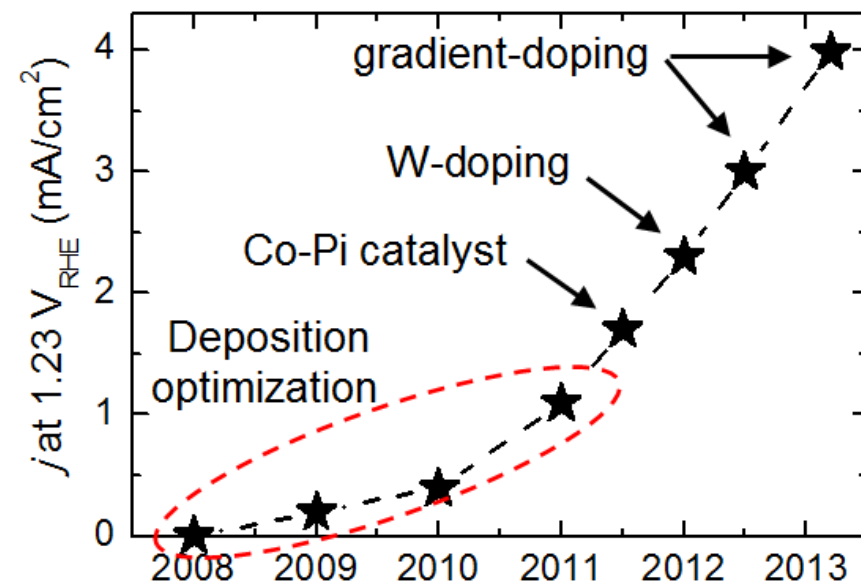


BiVO_4 film on glass with
Co-phosphate catalyst
(Co-Pi)

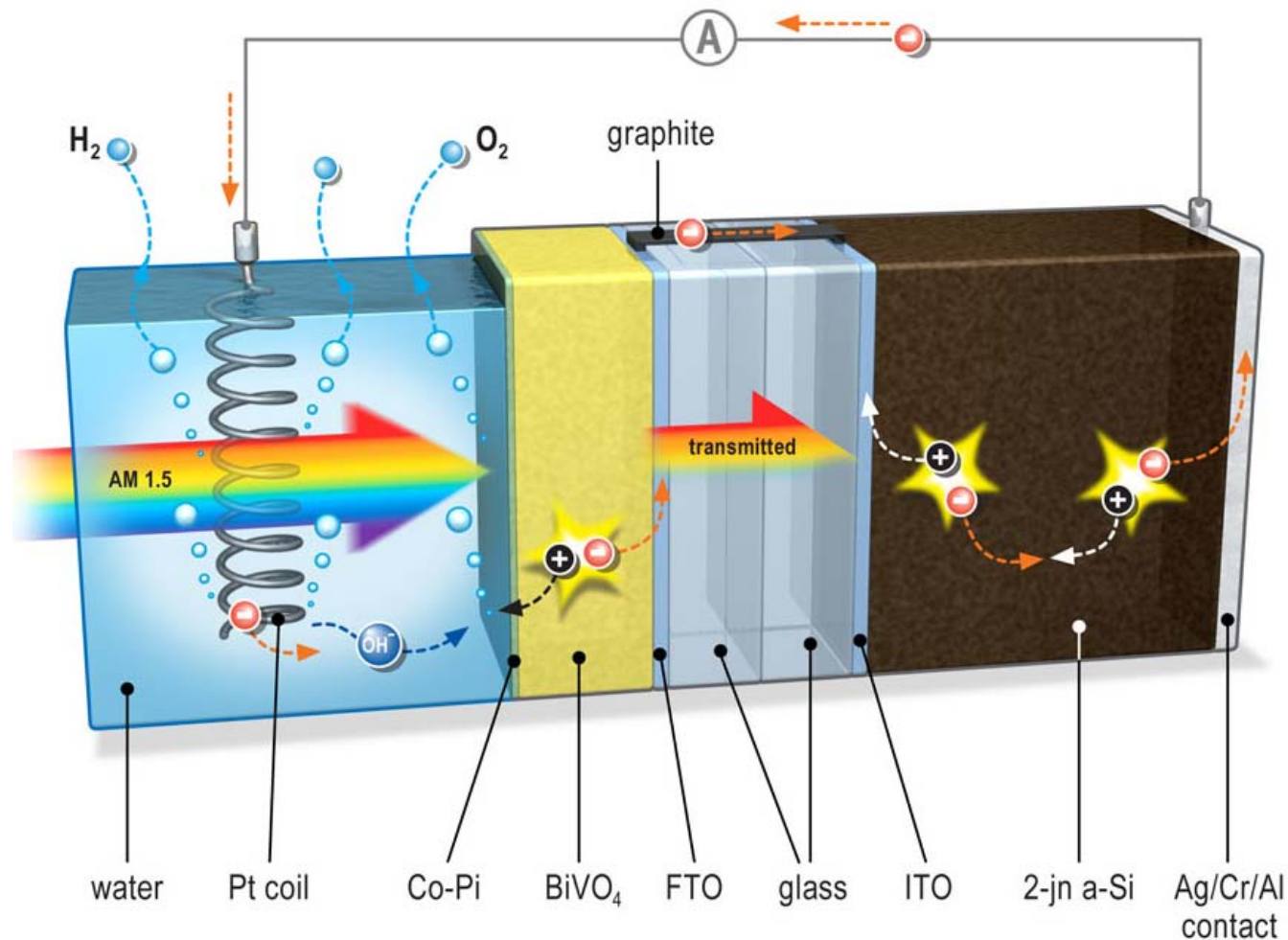


Gradient dopant
profile enhances the
charge separation

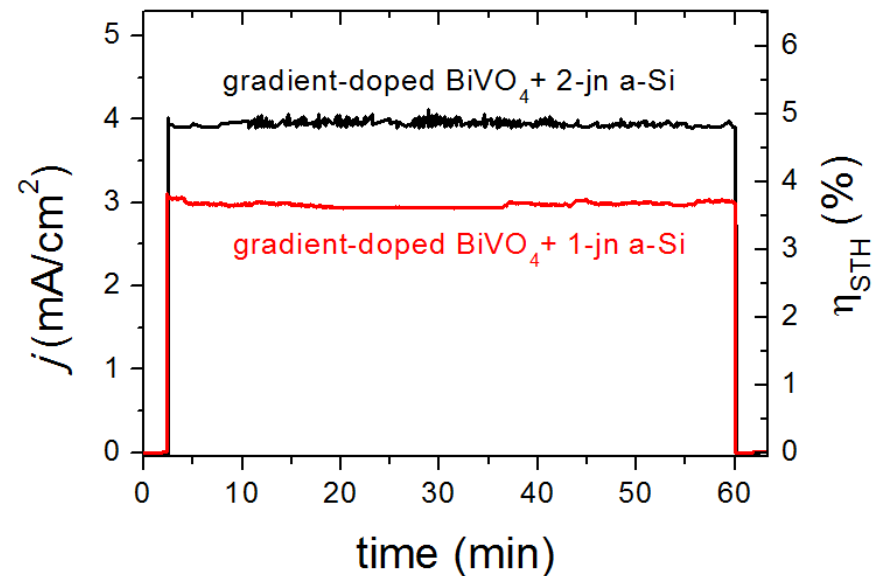
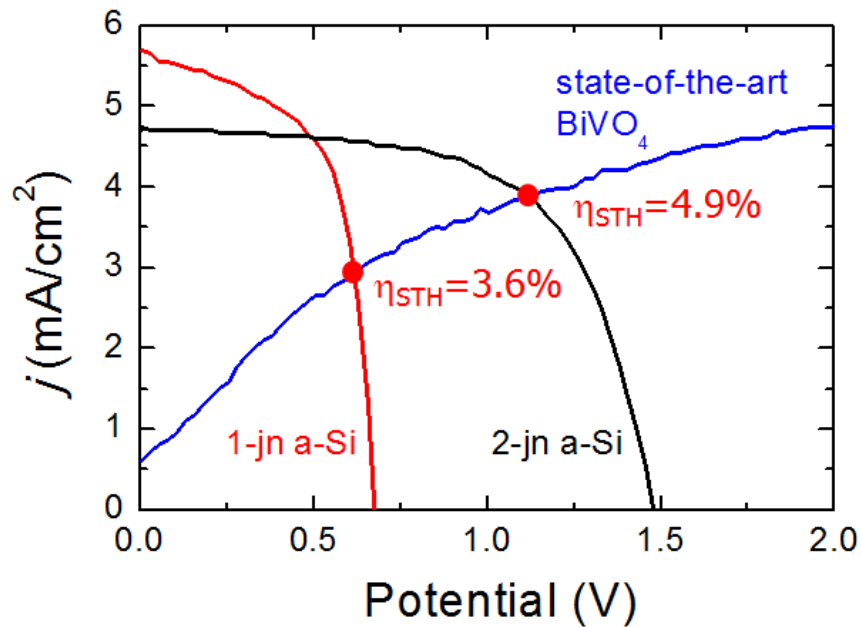
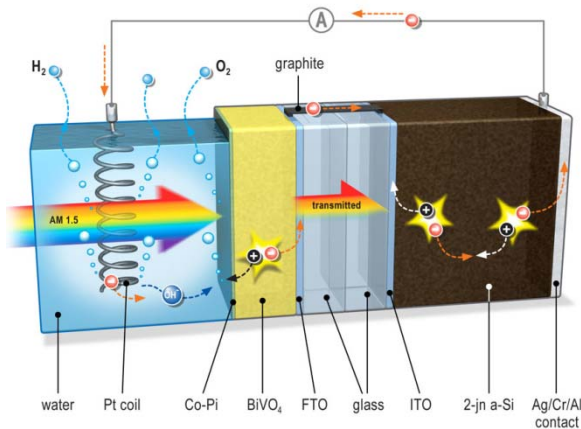
(similar to BSF passivation
in photovoltaics)



Hybrid CoPi-W:BiVO₄ / 2-jn a-Si Water Splitting Device



Hybrid CoPi-W:BiVO₄ / 2-jn a-Si Water Splitting Device



Highest efficiency (4.9%) ever reported for a water splitting device based on a metal oxide semiconductor

Conclusions

- Chemical storage will be an integral part of future energy systems
- Power-to-gas technology is especially important for Germany
- Photoelectrochemical water splitting:
 - Possible alternative for coupled PV / electrolyzer systems, but research is still in an early phase
 - Find new oxides with smaller bandgaps (1.8 – 2.2 eV)
 - Improve understanding of fundamental mechanisms
 - Scale-up to larger areas:
EU Project PECDEMO with DLR, Evonik, and others
Aims: 50 cm², 8% efficiency, 1000 hours lifetime,
cost analysis, systems and life-cycle analysis

Vielen Dank für Ihre Aufmerksamkeit!

