26th World Gas Conference

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SP or TS or ISC number

POWER-TO-GAS

More than storage: system flexibility

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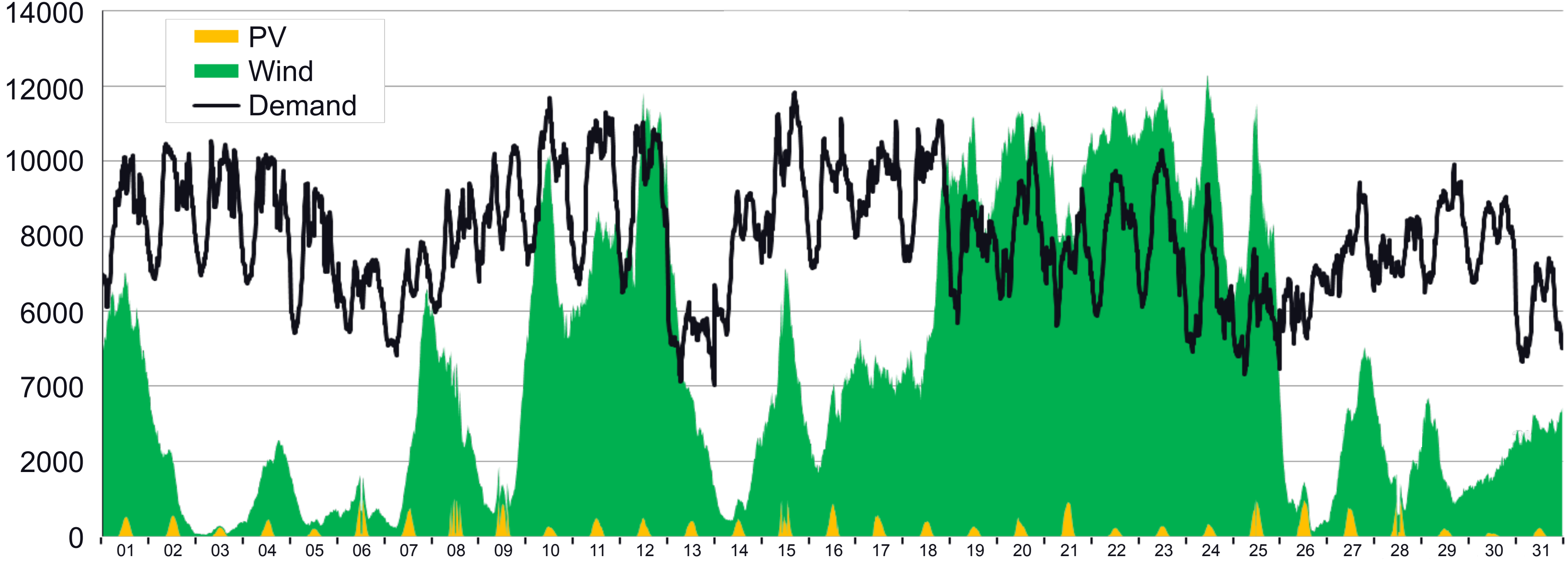
WGCPARIS2015
WORLD GAS CONFERENCE

Integrating intermittent energy: the need for flexibility

WIND & SOLAR GENERATION vs. DEMAND IN NORTHERN GERMANY

MW, December 2014 on the 50Hertz Operated Grid

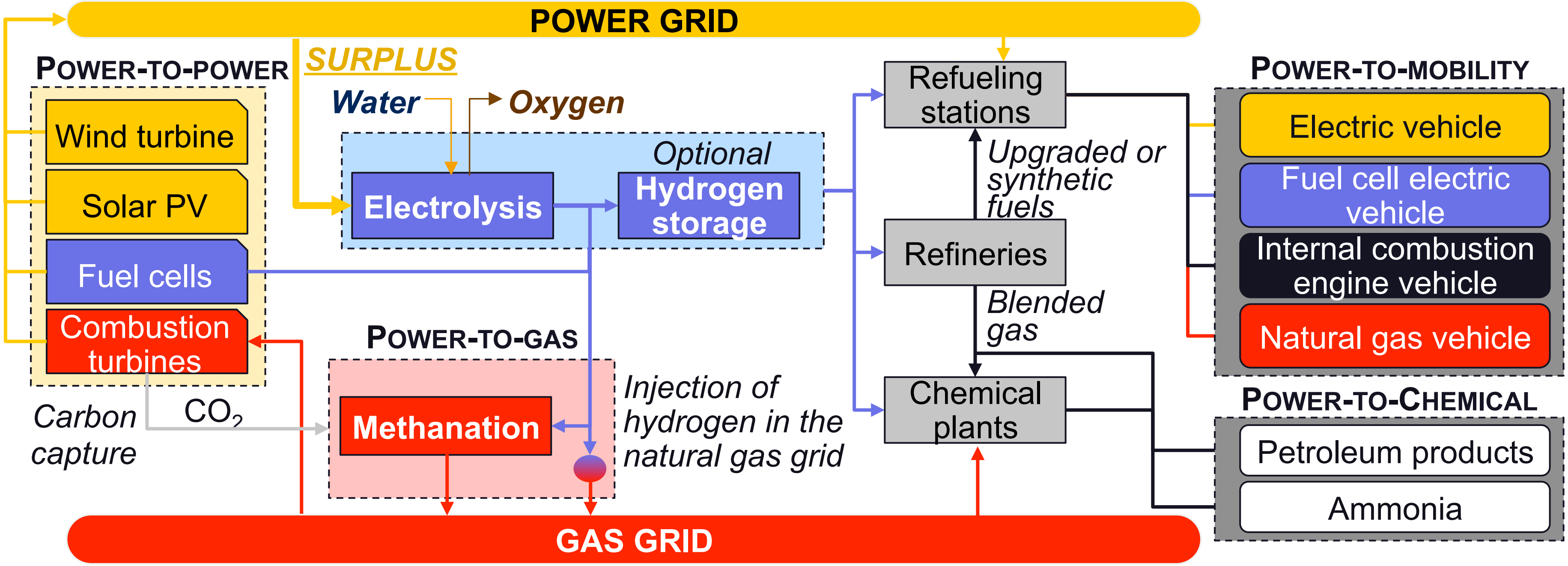


Note: (1) Output is variable on multiple timescales, depending on daily or seasonal patterns and on weather conditions. (2) This variability makes long-term forecasting difficult and certainly less predictable than output from conventional technologies. (3) Wind and solar output are subject to ramp events

Source: SBC Energy Institute Analysis based on 50Hertz data archive (Wind and Solar Actual In Feed 20124, Control Load 2014).

Making the case for hydrogen: system integration

SIMPLIFIED VALUE CHAIN OF HYDROGEN-BASED ENERGY CONVERSION

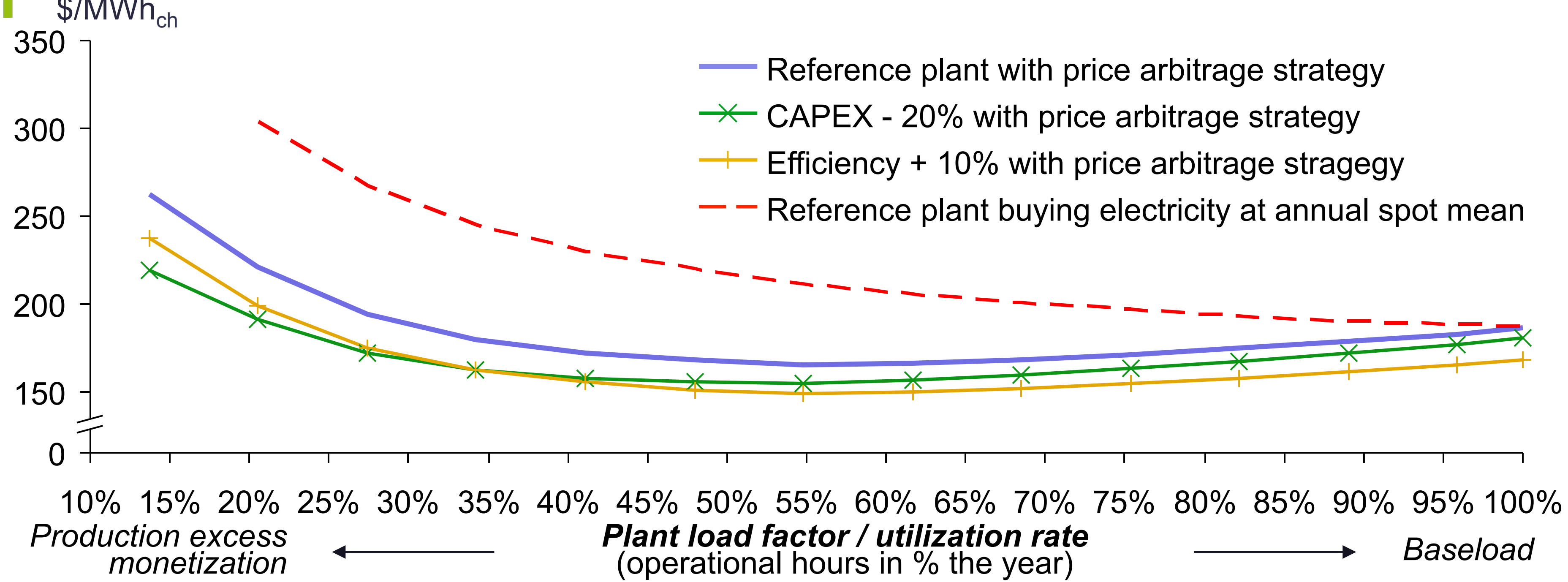


Note: Simplified value chain. End uses are non-exhaustive. Note that the power and gas grids are the main supplier to the residential and commercial end-uses (lighting, heating and cooling, cooking…)

Source: SBC Energy Institute analysis

The missing link: cost-effective electrolysis

LEVELIZED COSTS OF HYDROGEN FOR A GRID-CONNECTED ELECTROLYSIS PLANT



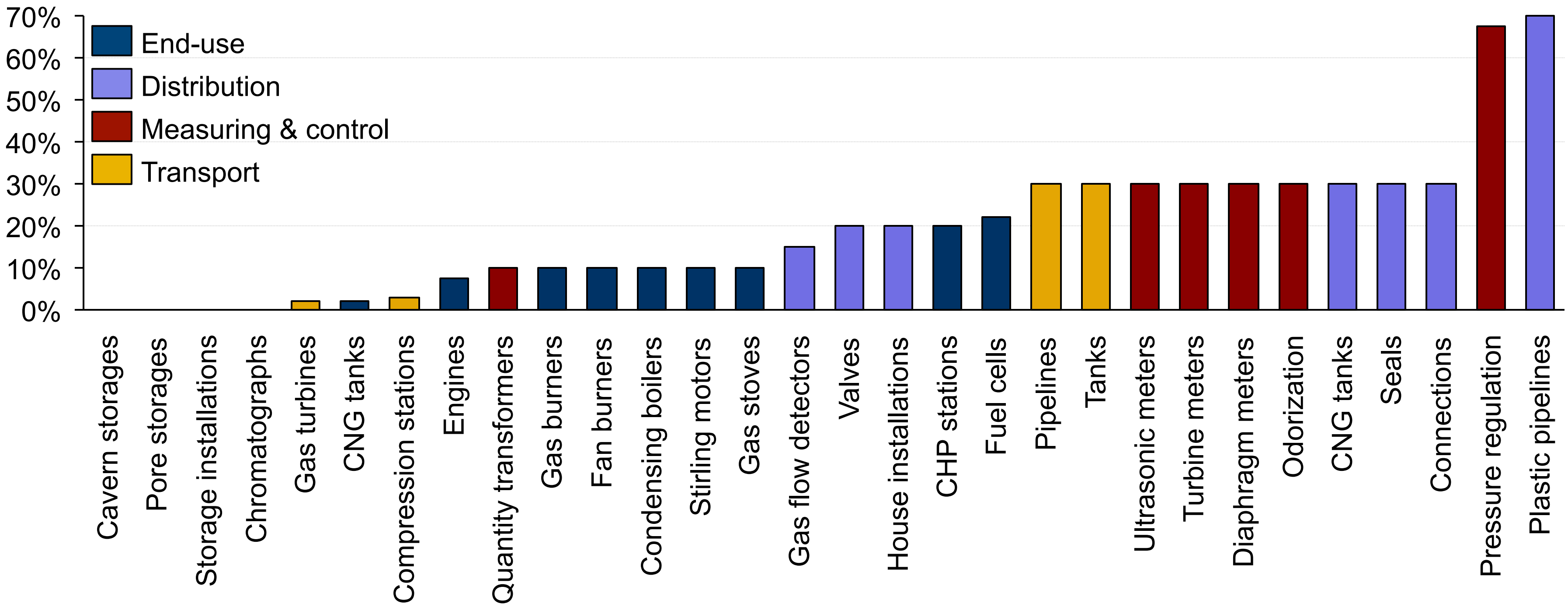
Note: Illustrative example based on 8.5MW$_{ch}$ electrolysis (5 alkaline stacks of 1.7MWch each), with total installed system CAPEX: $765/KW$_{ch}$, Efficiency: 79%HHV, Project lifetime: 30 years and real discount rate after tax:10%.

Source: SBC Energy Institute Simulation based on US DoE H2A Model

Option 1: hydrogen blending into the gas network

LIMIT OF HYDROGEN BLENDING ALONG THE NATURAL GAS INFRASTRUCTURE

H_2 concentration uncritical (vol.%)

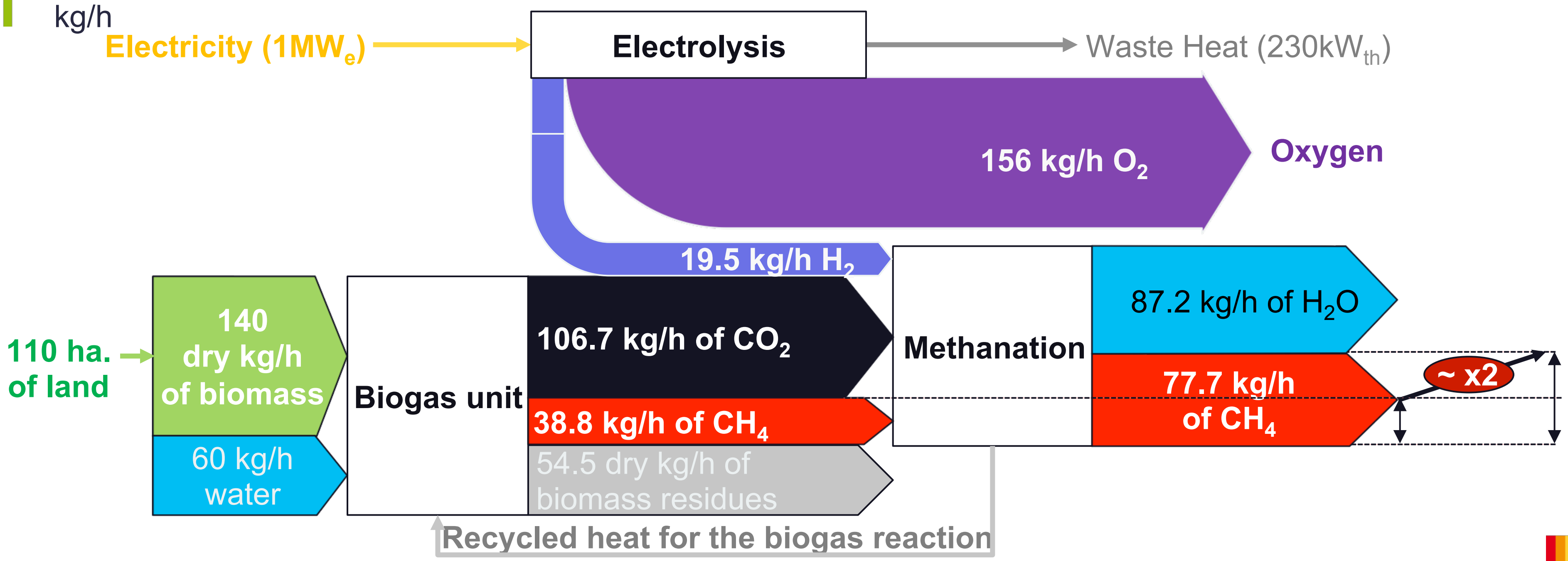


Note: CNG for compressed natural gas.

Source: Adapted from DVGW - German Technical and Scientific Association for Gas and Water (2013)

Option 2: methanation

SIMPLIFIED MASS FLOW CHART OF HYROGEN-ENRICHED BIOMETHANE PLANT

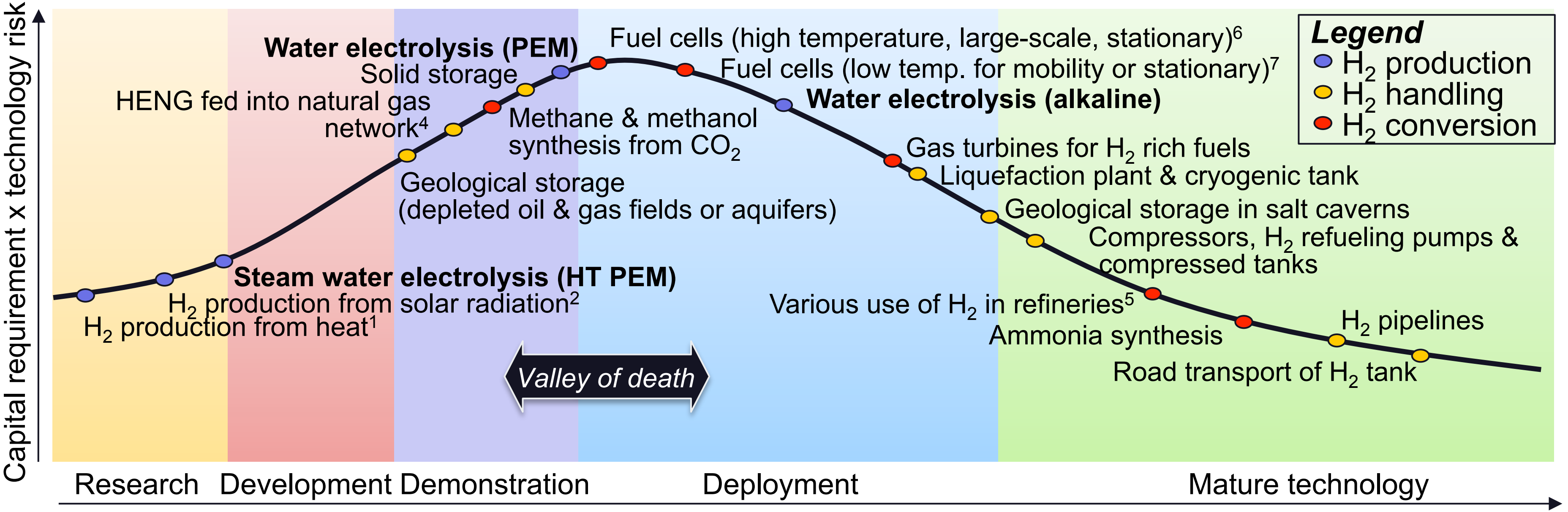


Note: Biomass feedstock is a maize silage of 5kWh$_{ch}$/kg of dry matter, cultivated with a land yield of 0.63MW$_{ch}$ per km²; The anaerobic digestion of maize silage requires heat and has an total efficiency of 68.7%; Thermochemical methanation at 300°C and 77.7% hydrogen-to-methane efficiency.

Source: SBC Energy Institute analysis

Outlooks

HYDROGEN-BASED TECHNOLOGY – MATURITY CURVE



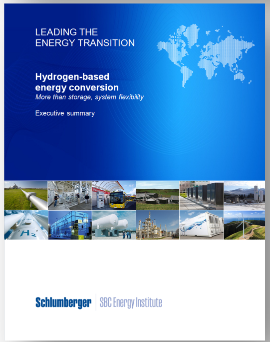
Note: [1]Nuclear or solar thermochemical water splitting; [2]Photolysis, photo-electrolysis or photo-biological water-splitting; [3]By thermochemical processes, principally: methane reforming, the cracking of petroleum fractions, and coal or biomass gasification; [4]HENG: Hydrogen-enriched natural gas; [5]Includes the upgrading of heavy/sour oil and the synthesis of synfuels from syngas (methanol, DME, MtG etc); [6]Includes SOFC, PAFC and MCFC; [7]Includes PEMFC and AFC.

Source: SBC Energy Institute analysis

Thank you very much!

Hydrogen-based energy conversion solutions FactBooks, Abstract & Presentations are available for download:

http://www.sbc.slb.com/SBCInstitute.aspx



Source: SBC Energy Institute