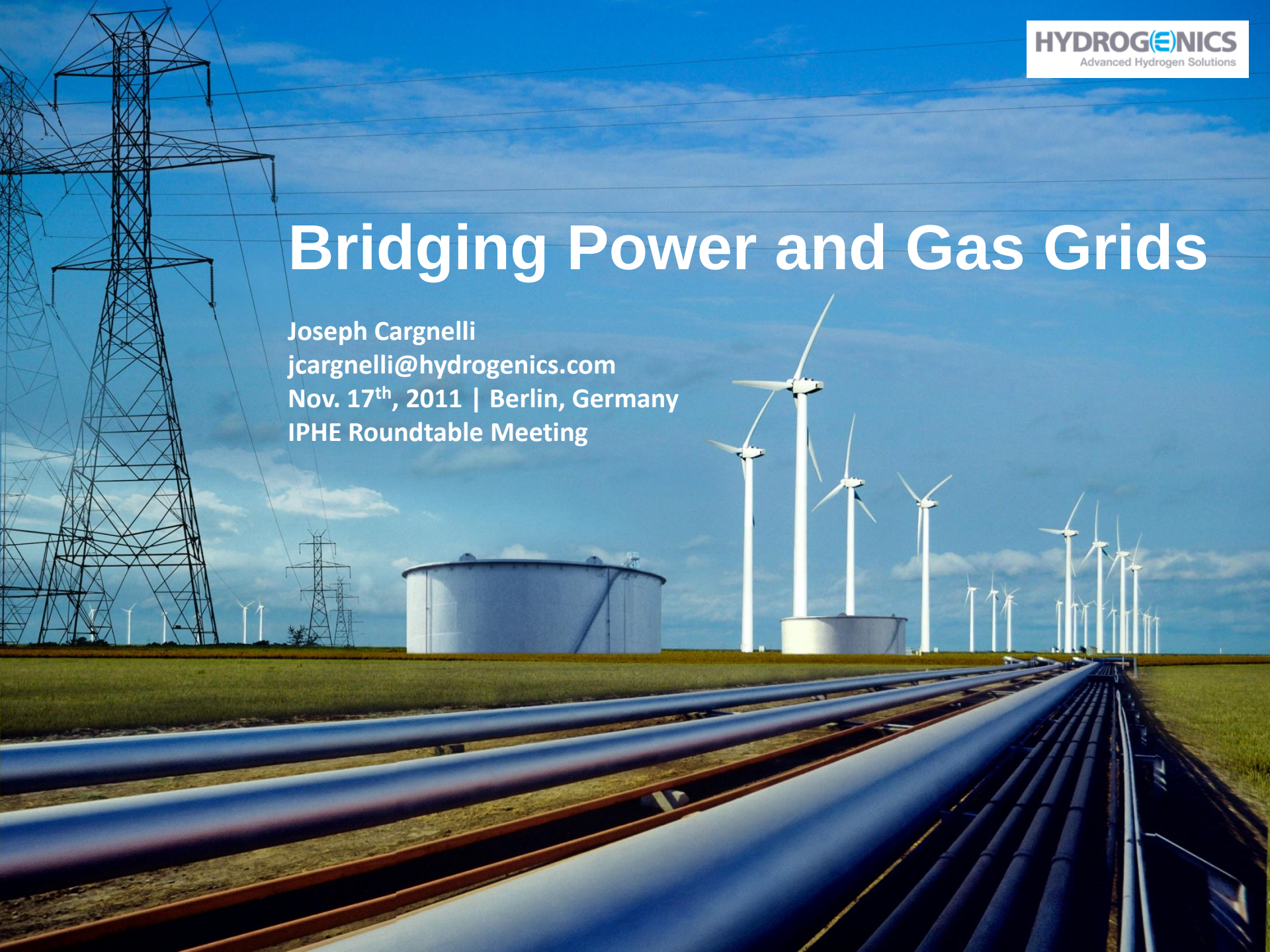

HYDROGENICS
Advanced Hydrogen Solutions

Bridging Power and Gas Grids

Joseph Cargnelli
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Nov. 17th, 2011 | Berlin, Germany
IPHE Roundtable Meeting

Message

Problem: Limited options to store large amounts of electricity

Solution: "Power-to-Gas" is a viable utility-scale energy storage solution

Technology: Electrolysis will be the bridge between power and gas grids

Achievements: Significant technology progress has been made

Readiness: No technology breakthrough for market entry is required

Barriers: Policy impediments to monetize value

Data Storage: Many Needs + Many Tools

Energy Storage is No Different

Why hydrogen? It's all about scale….

Pumped Hydro Facility

Geesthacht Pumped-storage Power Plant

$V = 3.3$ million m^3

$H = 83$ m

$E = 534$ MWh

(3 x 40 MW Turbines)

CAES Facility

EON Huntorf CAES Plant

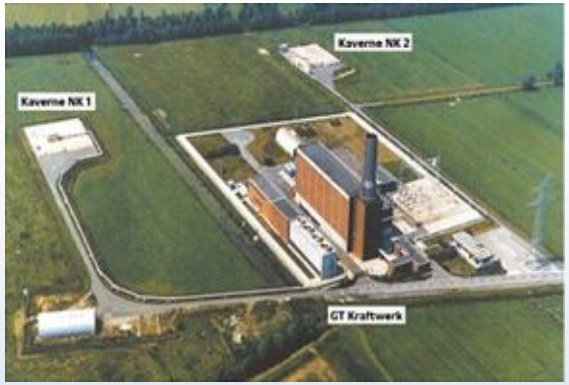
$V_{geo.} = 0.3$ million m^3

$P = 50 – 70$ bar

$E < 580$ MWh

Output: 290 MW < ~3h
Input: 60 MW < ~12h

"Concept" Hydrogen Facility



EON Huntorf converted to hydrogen storage

$V_{geo.} = 0.3$ million m^3

$P = 60$ bar

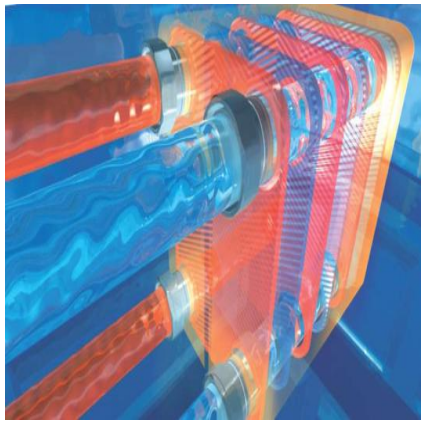
$E_{thermal} = 41{,}832$ MWh

$E_{40\%} = 16{,}733$ MWh

Electrolysis Technology Focus Areas

Significant progress made in four key areas

1. **Increase scale of electrolyzer technology**
2. **Reduction of system capital costs**
3. **Stack Efficiency Improvements**
4. **Development of proprietary IP and fast response**



Major progress in scale and cost

Advanced Electrolysis

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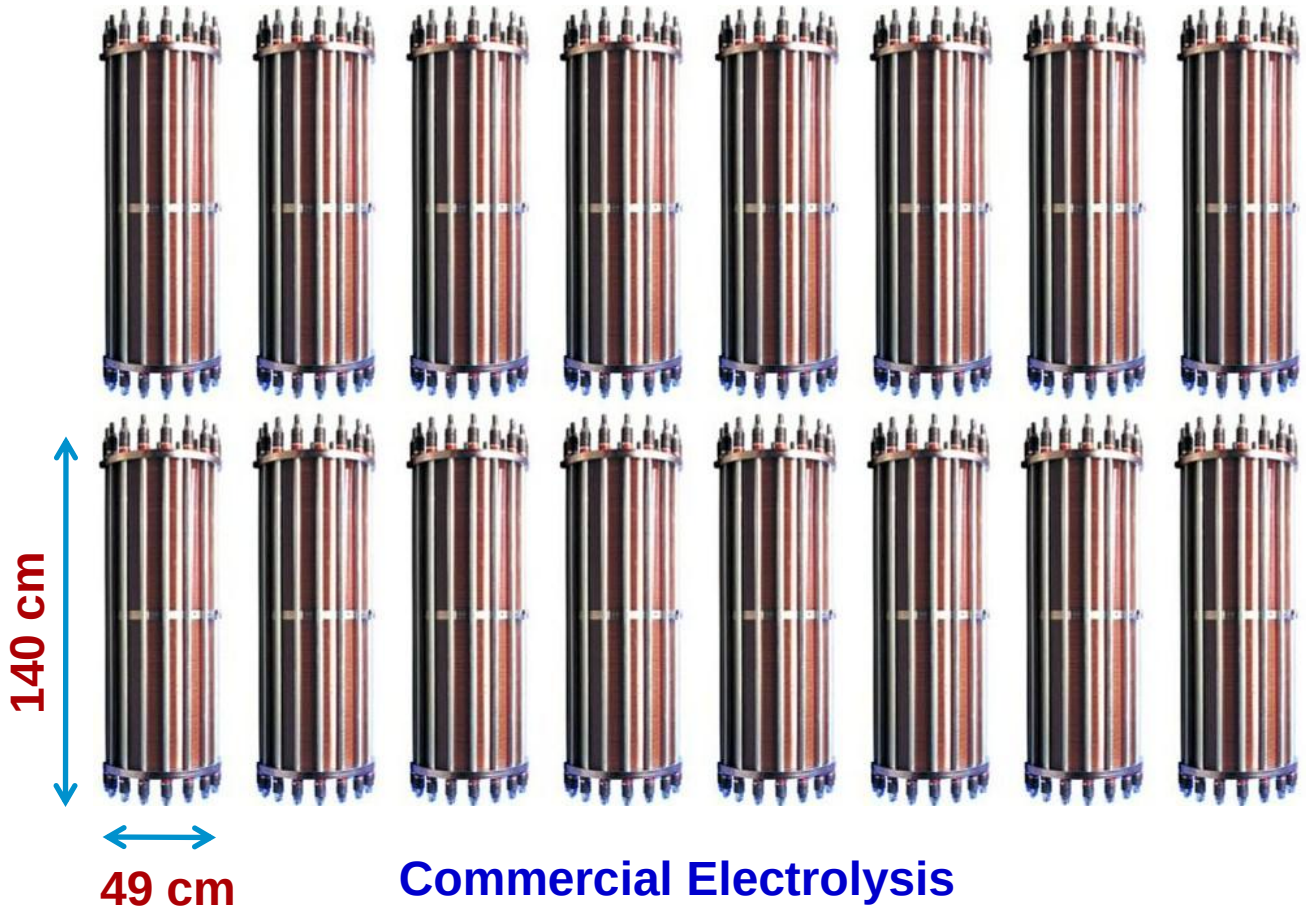
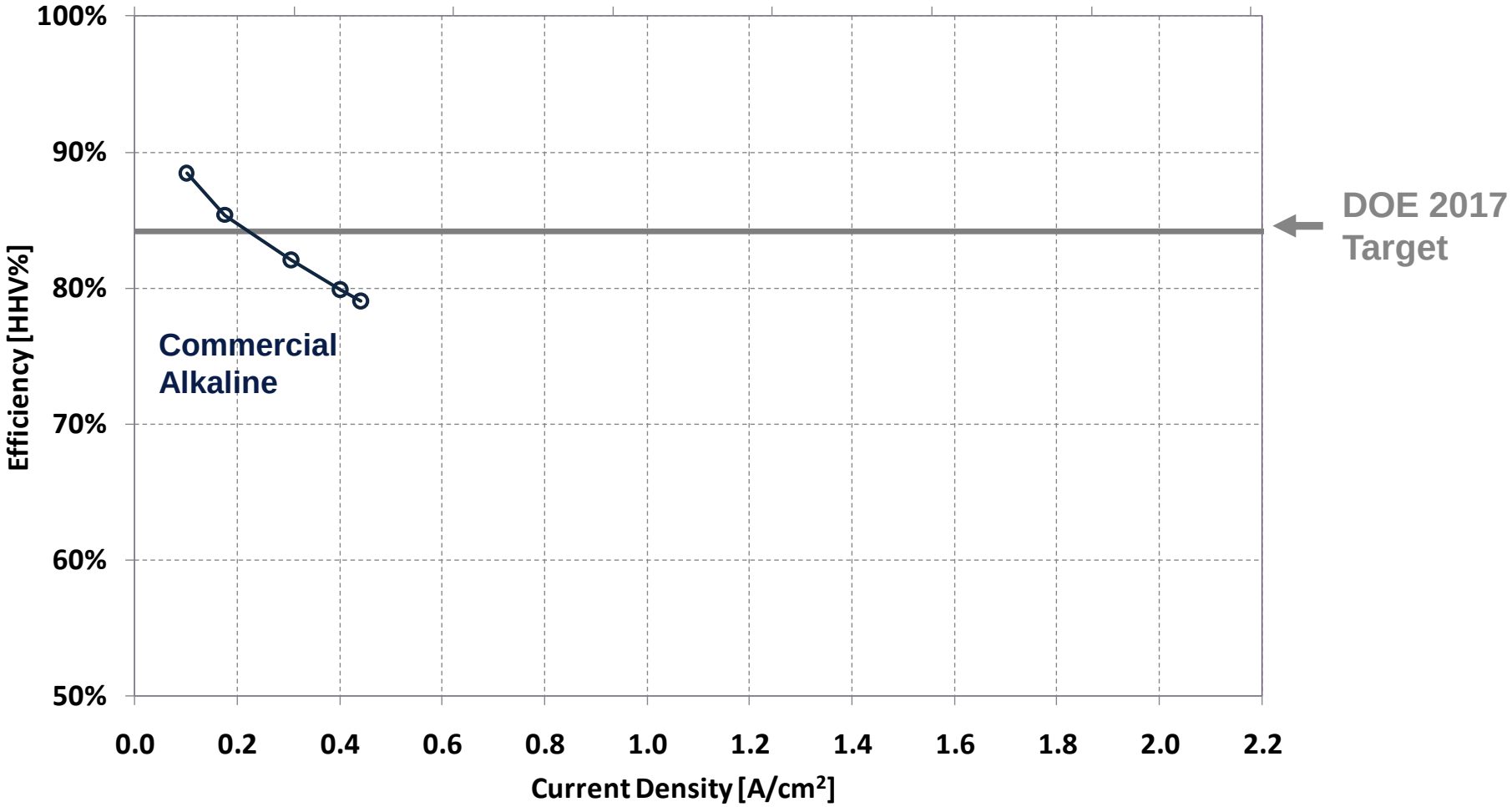
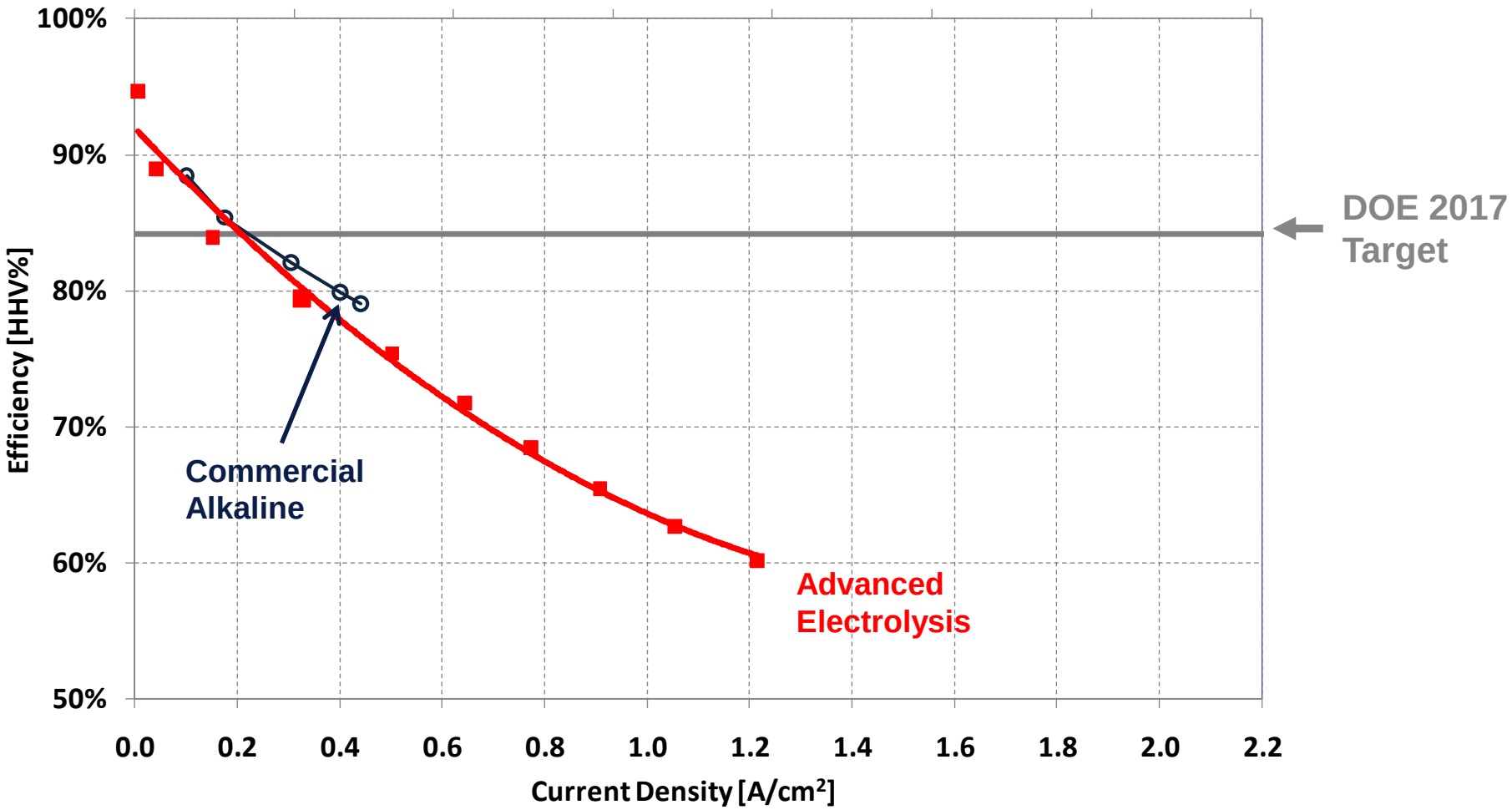


Commercial Electrolysis

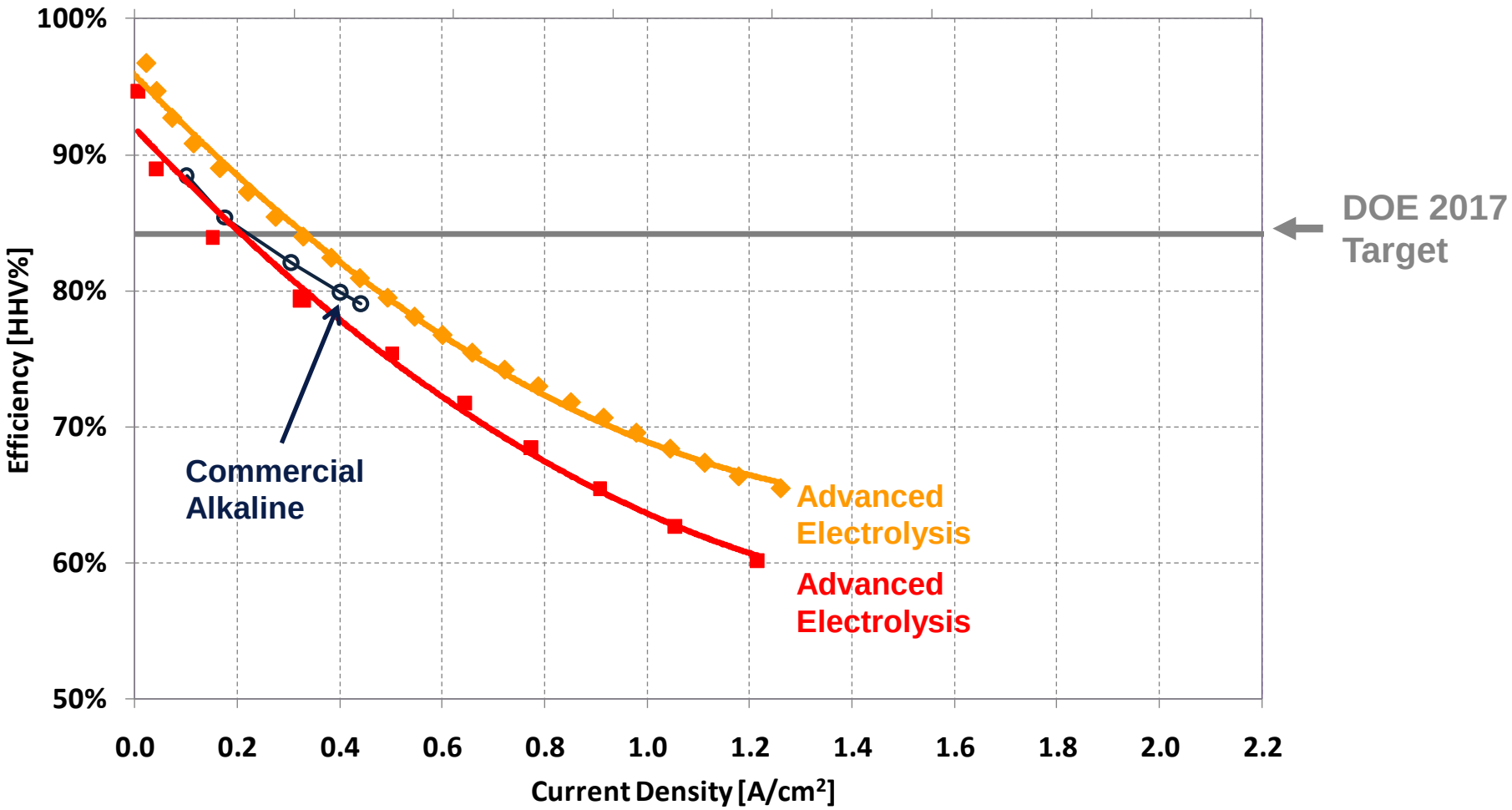
Efficiency Achievements



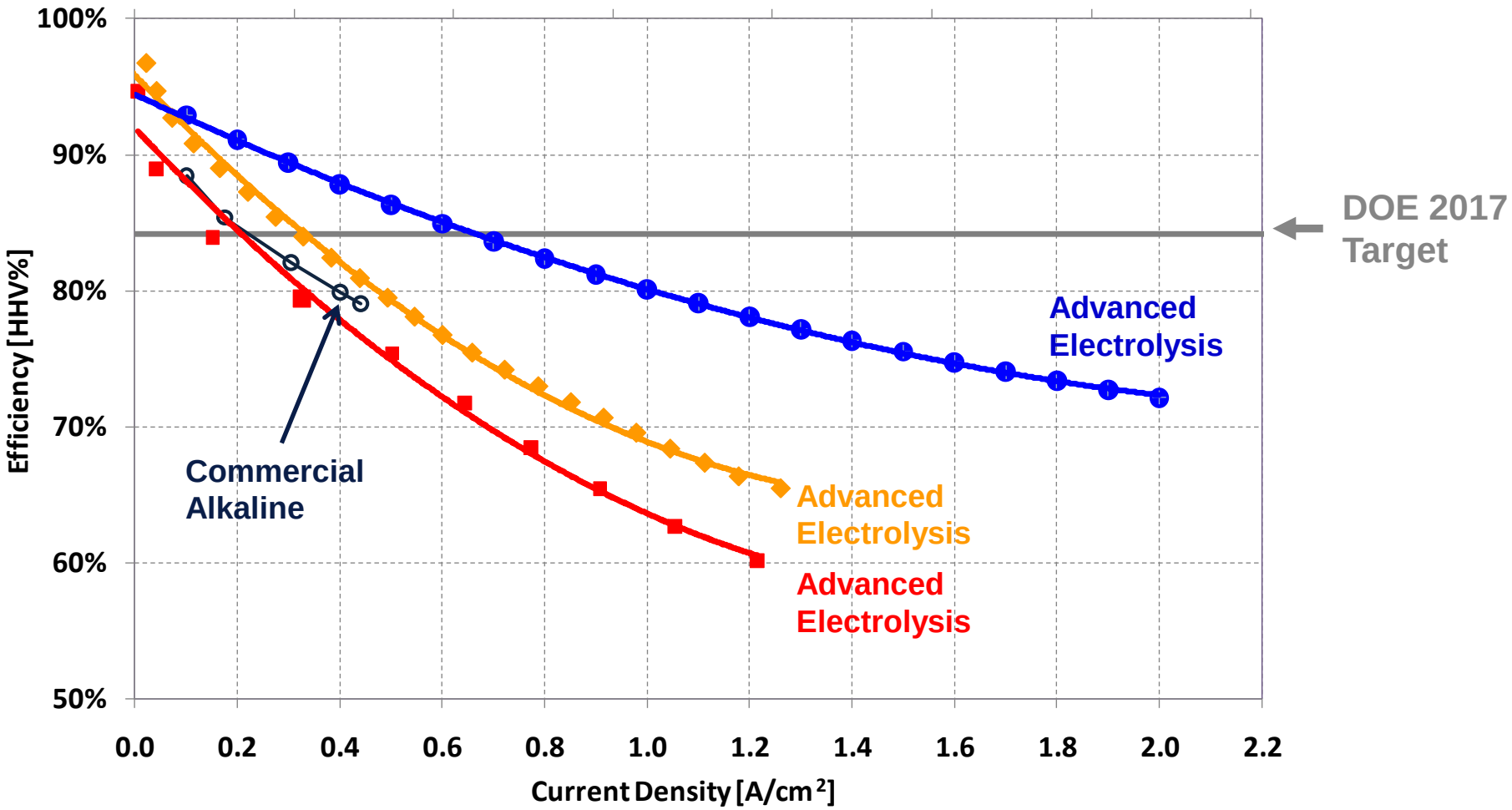
Efficiency Achievements



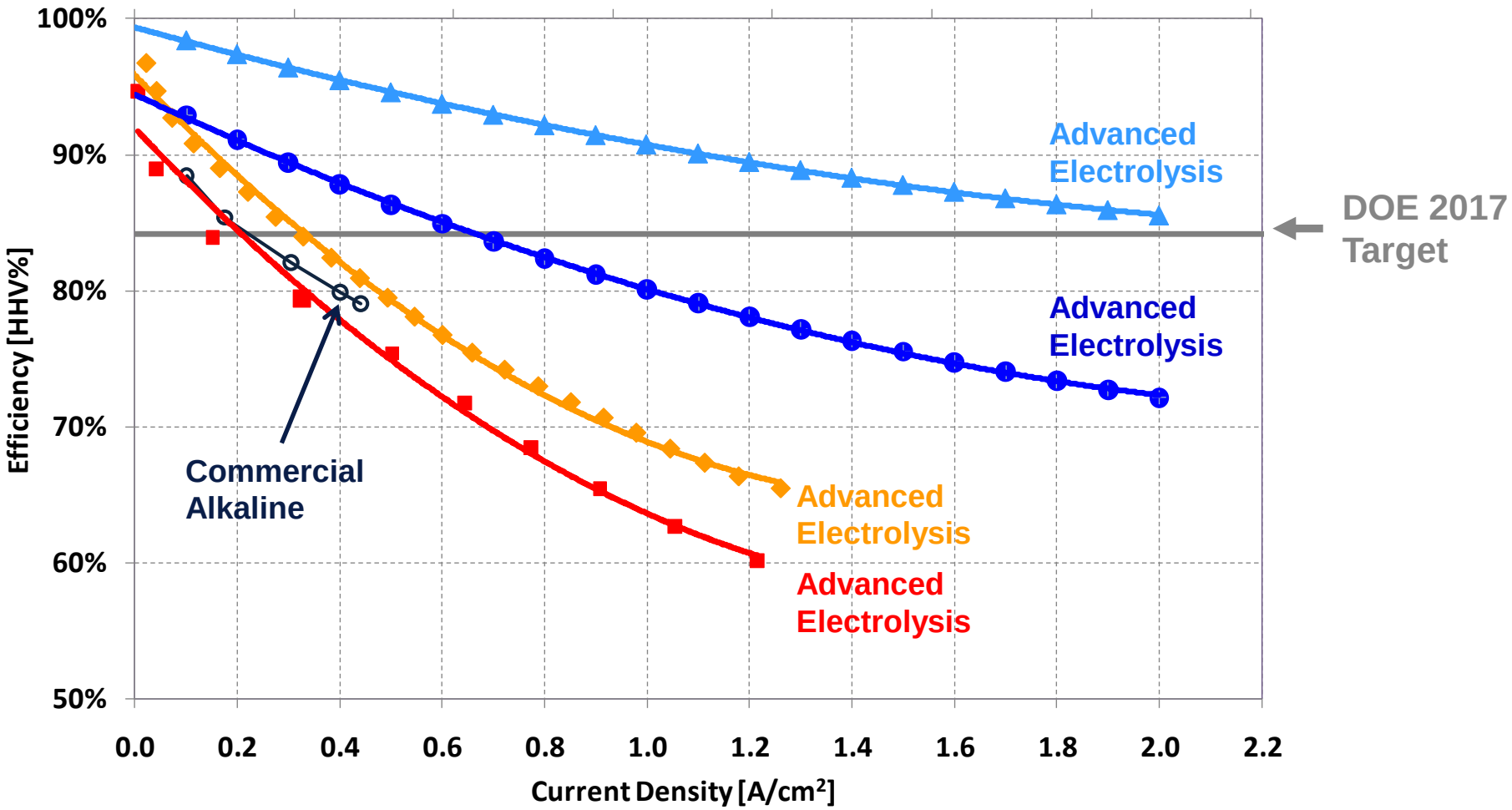
Efficiency Achievements



Efficiency Achievements

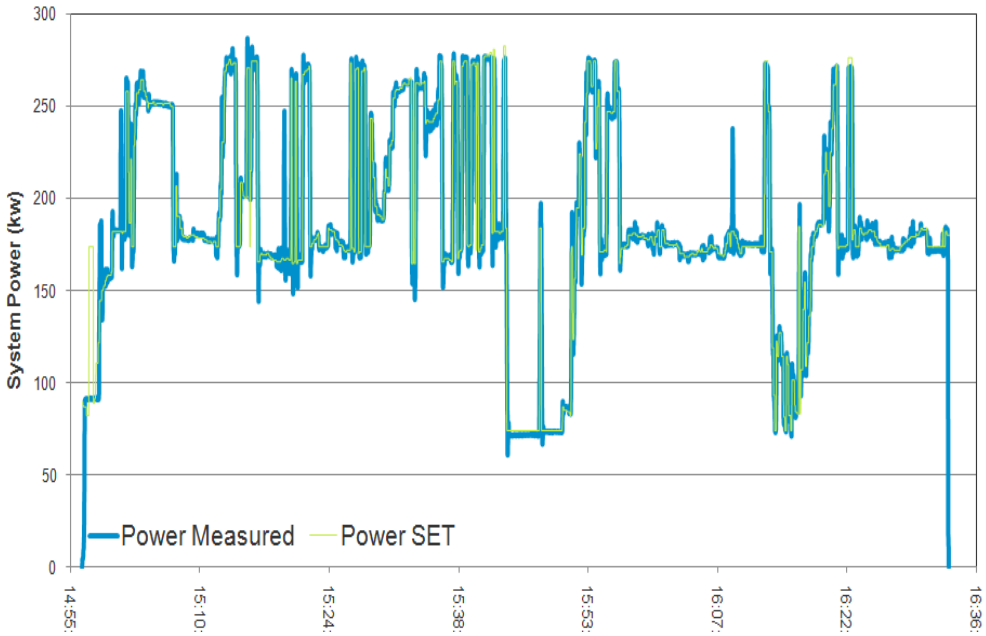


Efficiency Achievements



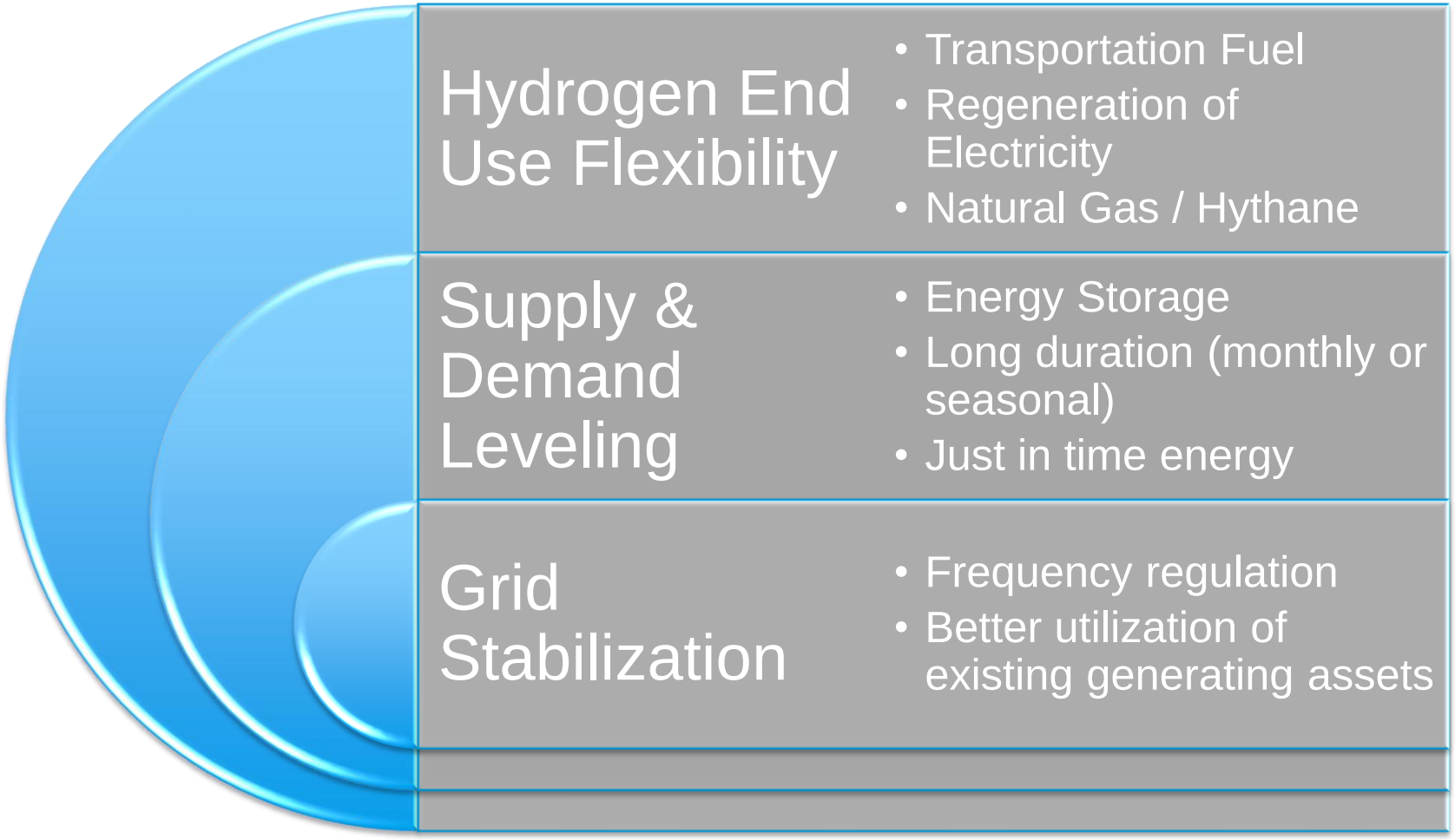
Electrolyzer provides frequency regulation on Ontario electrical grid

ieso



Hydrogenics' HySTAT ™ electrolyzer provided frequency regulation in Ontario by responding to real-time frequency regulation signals from the IESO on a second-by-second basis.

Power to Gas can drive three revenue streams



New Energy Bank - one deposit system (hydrogen via electrolysis)
- multiple paths for withdrawals (revenue)

How will the value of storage be calculated?

$$\Sigma_{value} = V_{commodity\ differential\ (\$/MWh\ peak\ to\ off\text{-}peak\ or\ \$/GJ)}$$
$$+ V_{regulation\ services\ including\ rate\ of\ response\ value}$$
$$+ V_{existing\ generating\ asset\ utilization\ improvement}$$
$$+ V_{energy\ storage\ time\ arbitrage}$$
$$+ V_{energy\ storage\ spatial\ arbitrage}$$
$$+ V_{renewable\ generation\ mix\ flexibility}$$
$$+ V_{offset\ to\ new\ transmission}$$
$$+ V_{carbon\ credits}$$
$$+ V_{energy\ independence\ value}$$

Barriers for bridging power and gas grids

- Lack of policy to monetize the value
- Gas interchangeability standards
- Diverse group of stakeholders
- Local grid mix and operability
- Culture of utility innovation

Thoughts – Catalysts for Change

1. Define challenges; current / future need scenarios
   - Identify localized applications with multiple needs like stabilization services, increased asset utilization, congestion, etc.
2. Group services into “job categories”
   - e.g. Transmission deferral, management of surplus baseload, RE storage, regulation, operating reserves
3. Create evaluation metrics that assist in:
   - Defining the true value and then pay for performance
4. Don’t pick solutions!:
   - post the challenges and see what the market delivers
5. Run competitive RFIs to refine and screen followed by RFP:
   - Learning environment to increase viability of new market participants and foster innovation from established players


WE'RE
READY