STRATEGIES FOR REDUCING LCOX: HONEYWELL'S INNOVATIVE ROLE IN THE FUTURE OF CLEAN ENERGY

MICHAEL KHILLA

AMERICAS GROWTH LEADER – SUSTAINABLE FUELS & CHEMICALS

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AGENDA

01 **GH2 PRODUCERS & OFFTAKERS DILEMMA**

02 LEVELIZED COST OF HYDROGEN - LCOH

03 KEY DESIGN AND OPERATIONAL CHALLENGES

04 STRATEGIES FOR OPTIMIZING & REDUCING LCOX

05 THE DIGITAL UNLOCK - POWER TO X VALUE CHAIN

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BANKABILITY FACTORS
PRODUCERS & OFFTAKERS DILEMMA

Top 3 Reasons for the Dilemma

- Affordability
- Operability
- Traceability

THE DIGITAL UNLOCK

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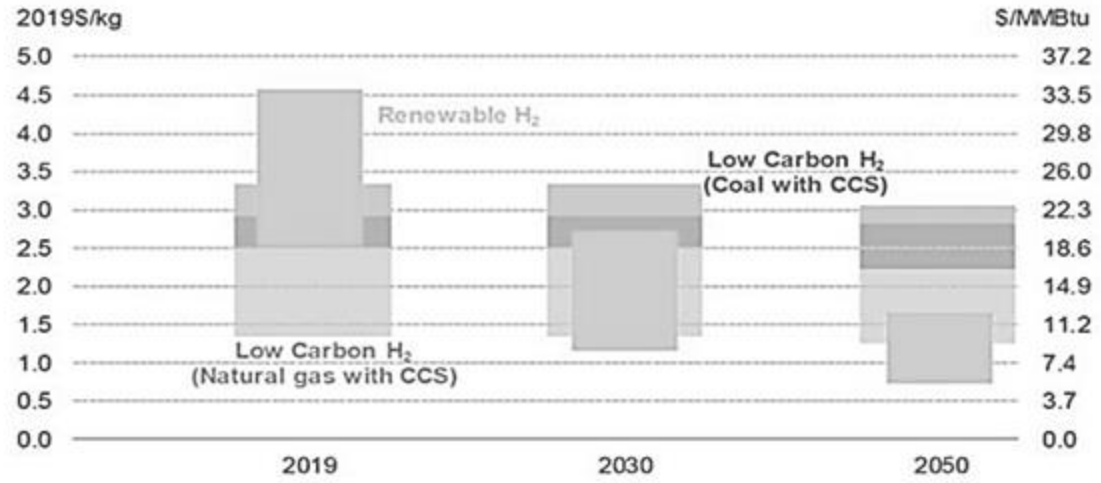
WHAT IS LEVELIZED COST OF HYDROGEN (LCOH)?

LCOH is a key concern for Green Hydrogen producers, and their key focus is to reduce LCOH to less than $2 per kg Hydrogen

$$LCOH = \frac{CAPEX + OPEX - INCENTIVES}{HYDROGEN\ PRODUCED}$$

Totalized for plant life,.



Source: BloombergNEF. Note renewable hydrogen costs based on large projects with optimistic projections for capex. Natural gas prices range from $1.1-10.3/MMBtu, coal from $30-116/t.

Detailed LCOH calculations:

https://www.ises.org/sites/default/files/webinars/180314-IEA-SHC_Webinar_LCOH_Calculation-Print_Version.pdf

https://static.agora-energiewende.de/fileadmin/Projekte/2022/2022-12-10_Trans4Real/A-EW_301_LCOH_WEB.pdf

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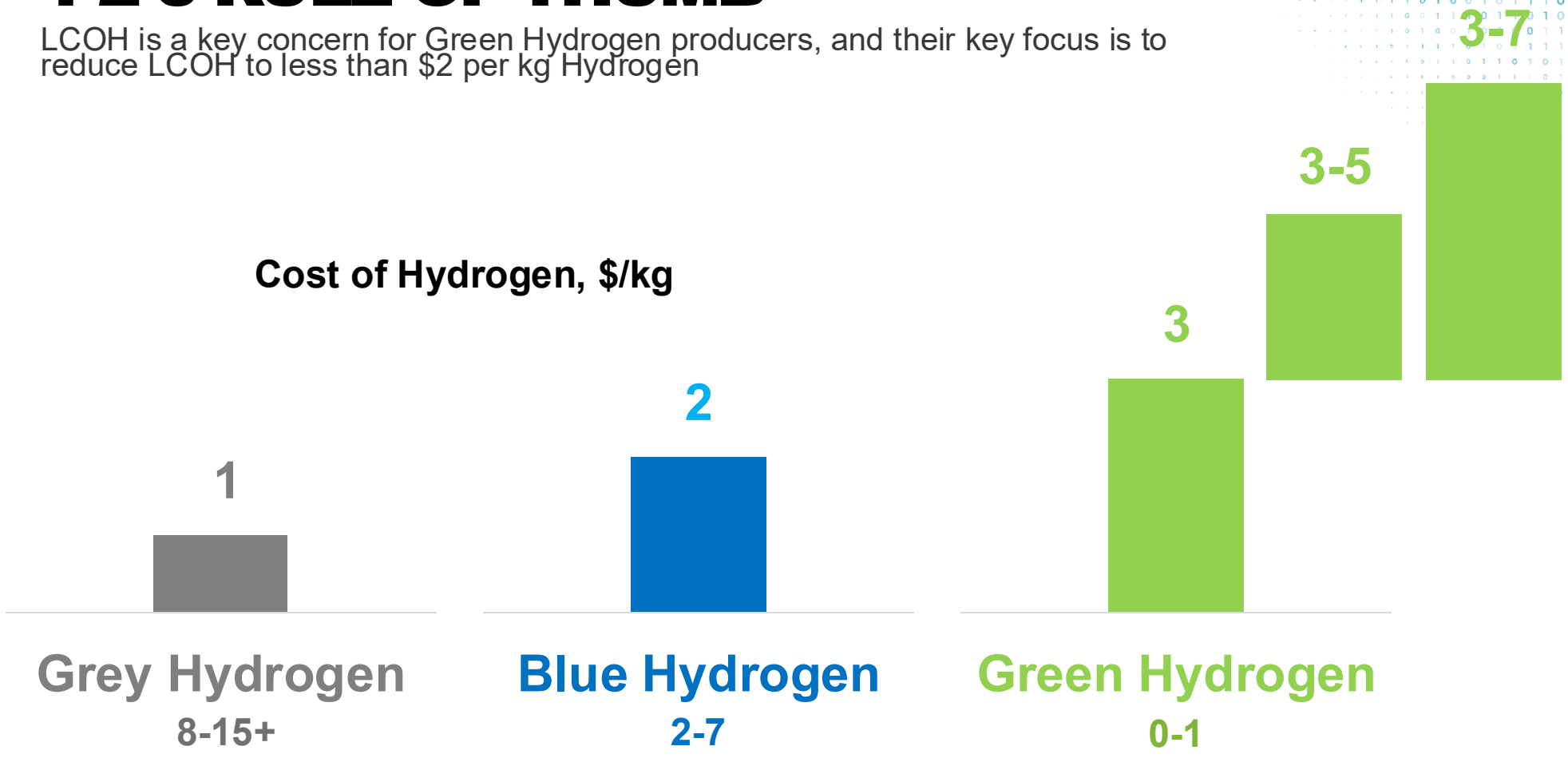
THE COST OF HYDROGEN
1-2-3 RULE OF THUMB

LCOH is a key concern for Green Hydrogen producers, and their key focus is to reduce LCOH to less than $2 per kg Hydrogen



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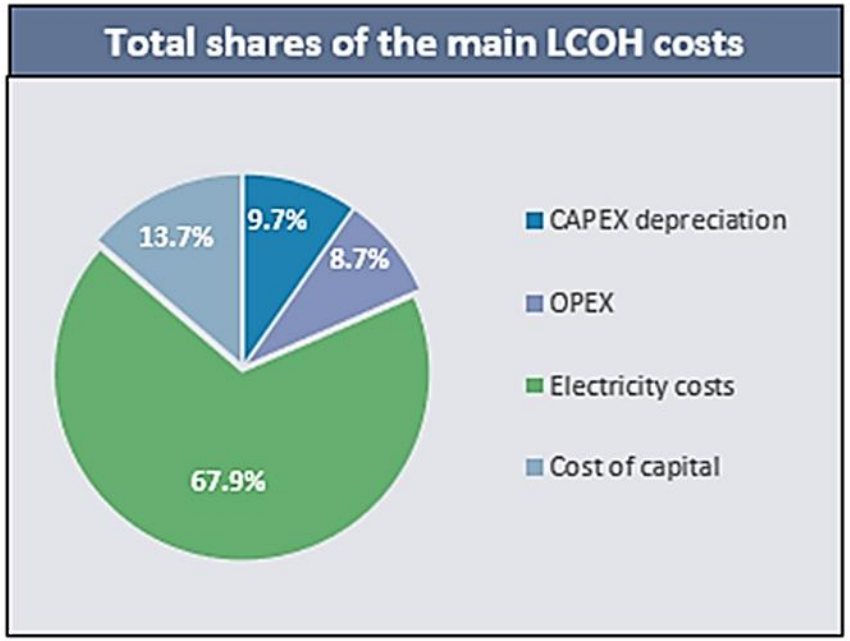
GH2
LCOH MAKE-UP



Electricity constitutes 60-70% of the LCOH for Green Hydrogen.

Electrolyzers constitute ~50% of CAPEX.

How to minimize LCOH?

- **Electricity**
  Reduce Cost & Optimize usage.
- **Electrolyzer**
  Improving Efficiency and Scale.
  Extending Lifetime.
- **Government Incentives**
  Leveraging Government Support and Policy.

REDUCE & OPTIMIZE ELECTRICITY USAGE & COSTS

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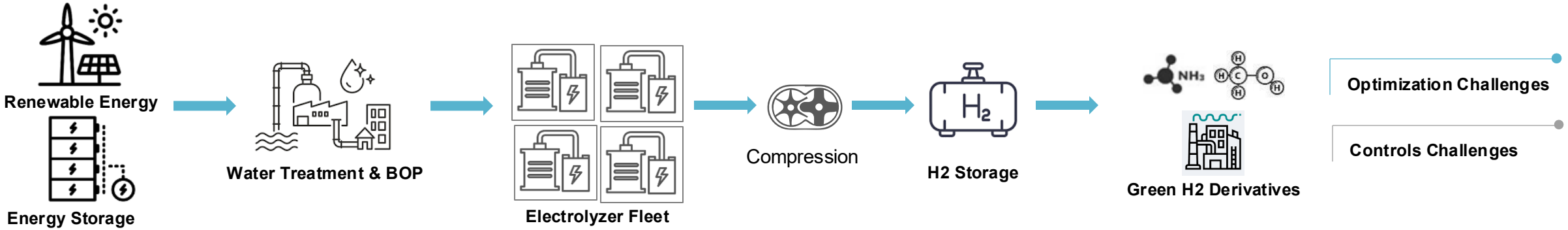
GREEN HYDROGEN PLANT
TOP CHALLENGES

LCOH is a key concern for Green Hydrogen producers, and their key focus is to reduce LCOH to less than $2 per kg Hydrogen

- **Cost of electricity**
  Forecasting electricity cost
- **Electrolyzer degradation**
  Electrolyzer performance prediction
- **Cost of hydrogen production**
- **Power profile variations**
  Renewable energy mix
- **Multiple electrolyzer stacks**
  Manage startup/ shutdown sequence
- **Carbon intensity monitoring and management**
- **Energy storage management**
- **Compressors control & operations**
  Manage turnup & turndown
- **Green hydrogen storage and safety**
  Demand variations



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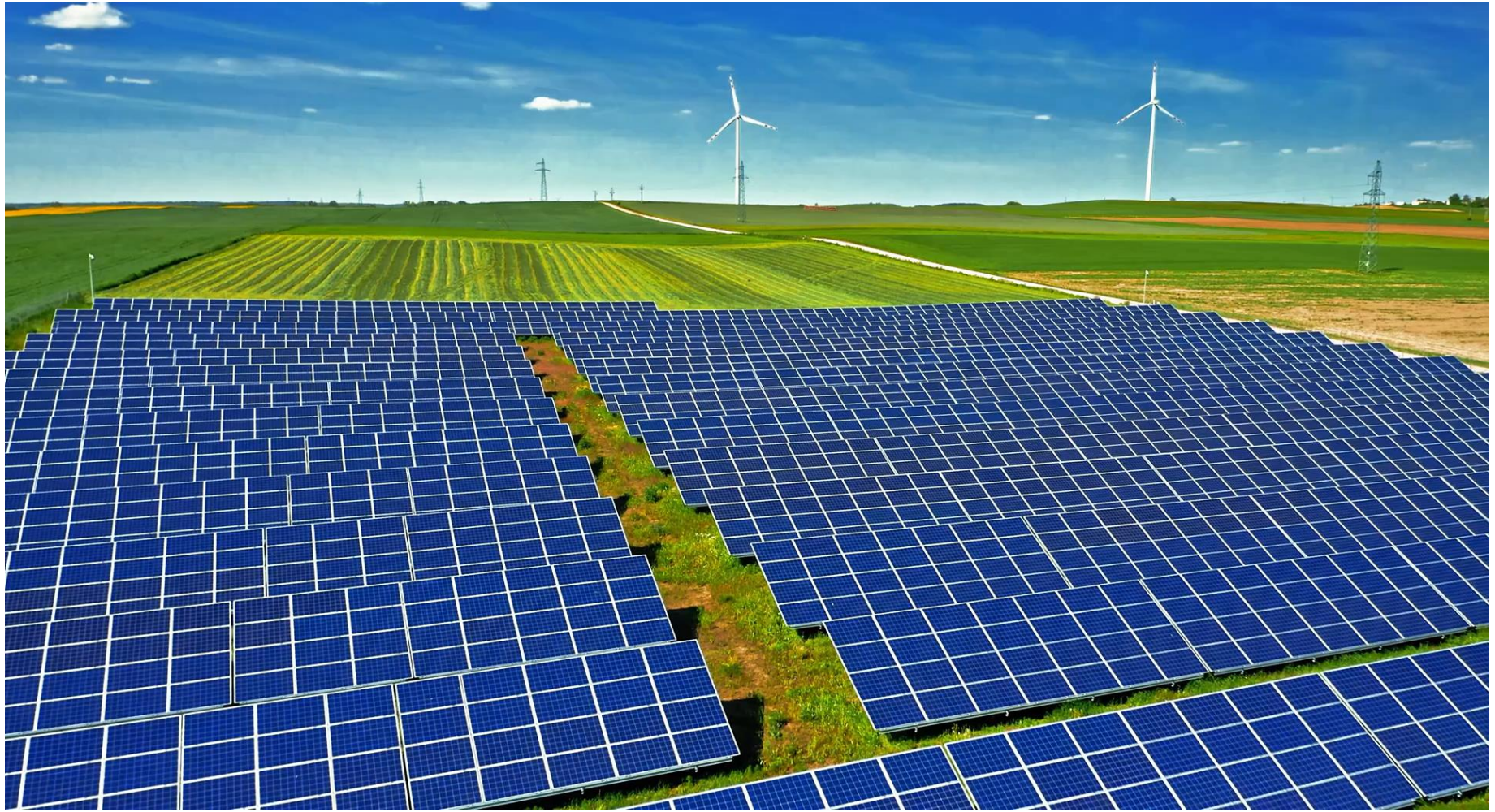
HONEYWELL PROTONIUM™
GREEN HYDROGEN OFFERING



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HONEYWELL PROTONIUM™ GREEN HYDROGEN OFFERING

Planning & Scheduling

Plant Digital Twin

Operator Training Simulation

1 Honeywell Protonium CDO
Concept Design Optimizer

2 Honeywell Protonium UCO
Unified Control & Plantwide Optimizer

4 Carbon Intensity Management

2 Honeywell Protonium Unified Control System: Power Profile and Demand Management, EPU Health Monitor

ENERGY MANAGAMENT SYSTEM

3 Honeywell Protonium HECS
Electrolyzer Control System

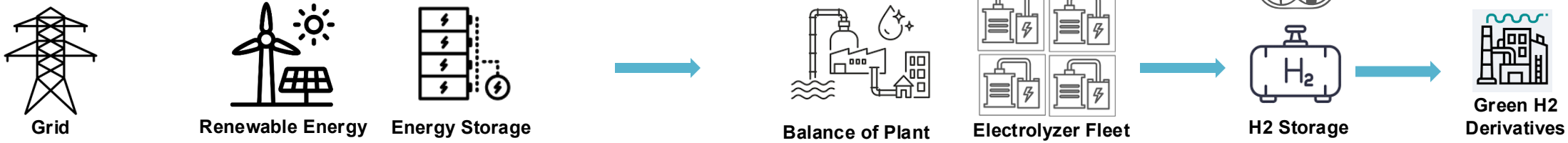
Inventory & Custody Transfer Control

Plant Control System (DCS)

Grid → Energy Storage (Optional) → Electrical Package → EPU OEM Package (Alkaline, PEM, AEM, SOEC) → Production Plant/ Green H2 User

RE Sources

BOP OEM Package



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HONEYWELL PROTONIUM™
CDOCONCEPT DESIGN OPTIMIZATION

Reduce CAPEX and LCOH upfront at concept stage

Fast Techno-Commercial Proposals and Decisions
- Ready to digest information & insights on dashboards/ reports

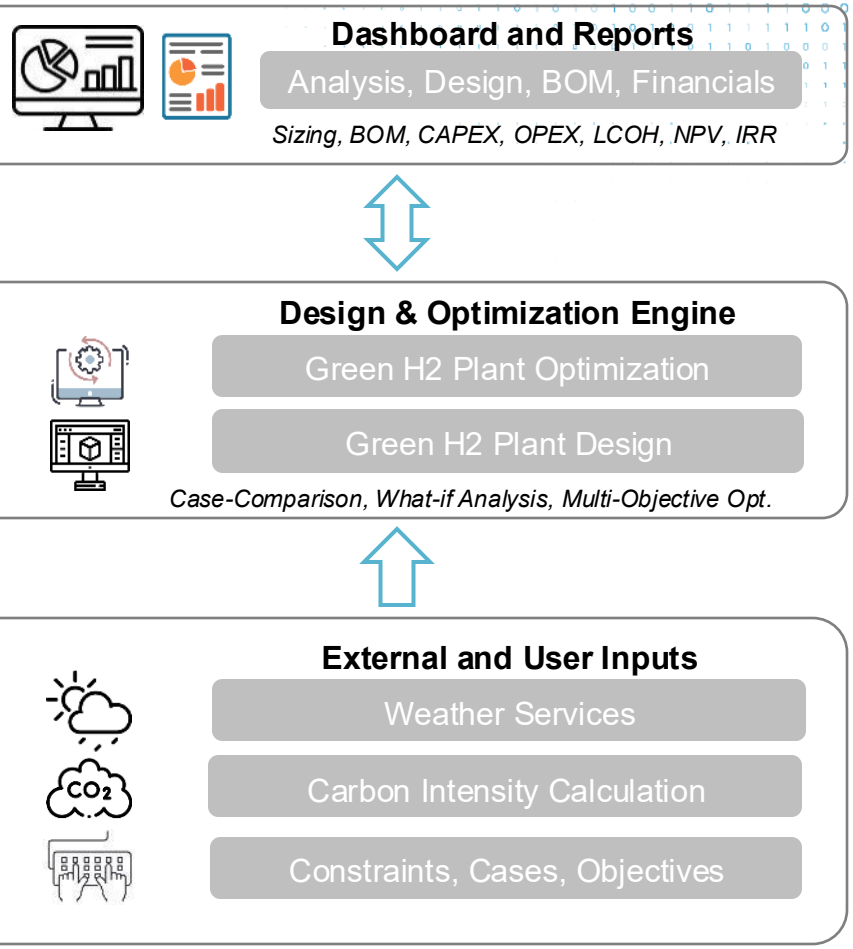
Developed for Green H2 specific Design Challenges
- Power Intermittency, Carbon Intensity, Low LCOH

Flexible for Wide Design Scenarios
- Cover Value-chain (Grid to Gate), User Selectable Objective

High Performance Optimization
- Optimizes design for given objective in minutes

Long Time Horizon
- Accounts for CAPEX and OPEX playout on longer period

Optimize for Carbon Intensity Targets
- Configure CO2 Equivalent Targets, Incentives and Constraints



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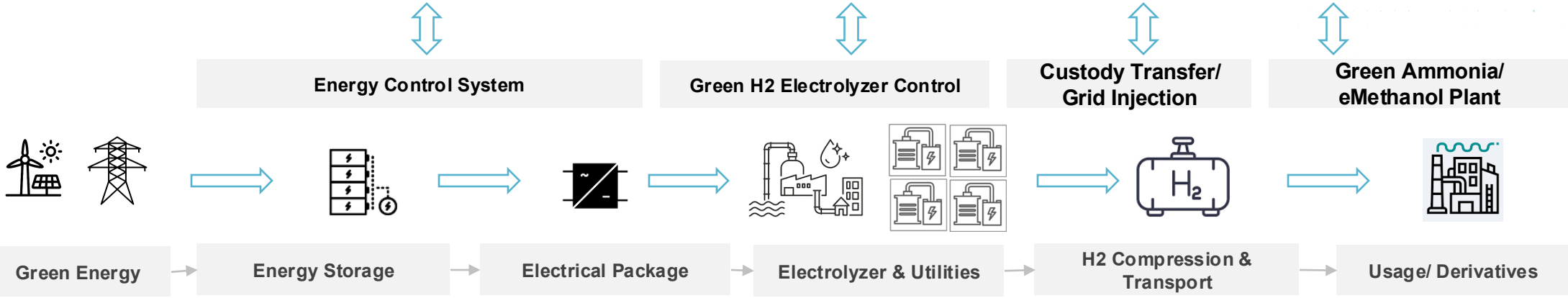
HONEYWELL PROTONIUM™ UCO
UNIFIED CONTROL & OPTIMIZATION

Reduce OPEX and Maintenance cost, Comply with Regulation and Enable Incentives

Honeywell Plantwide Control and Optimization for Green Hydrogen & Derivatives



Effective Power Intermittency Management

- Ensure Plant Safety and Reliability, Demand Fulfillment and Capacity Utilization

Intelligence to make complex decisions at speed

- Energy Mix, Curtailment, Carbon Intensity management, inventory management, electrolyzer life optimization

Schedule, Control and Optimize Production plant

- Plantwide integration, Look ahead scheduling, Minimize Shutdowns, Optimize for lower LCOH and Electrolyzer health

Dynamic Production Planning

- Adjust to Weather forecast, Demand Profile changes, Carbon Intensity

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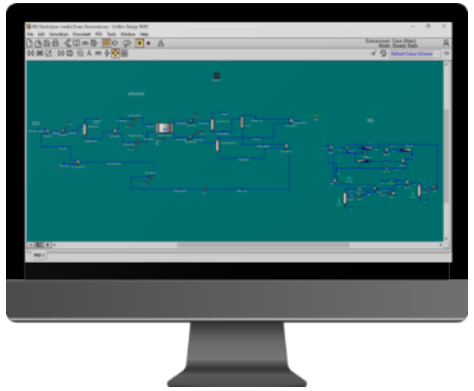
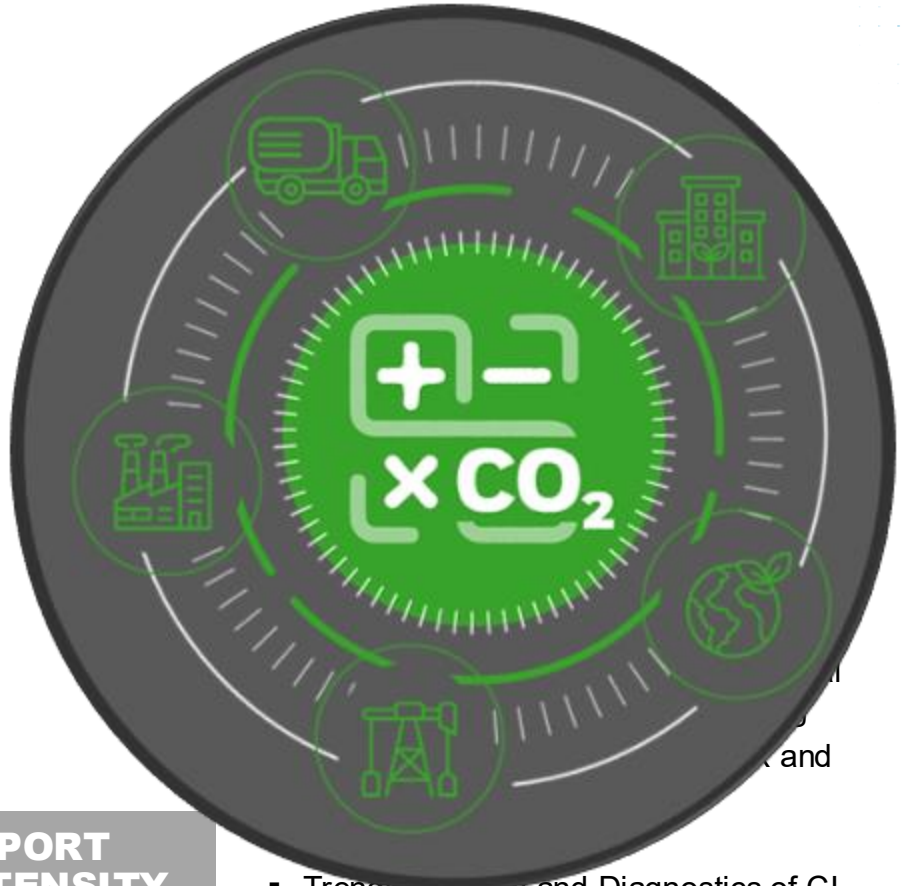
CARBON INTESITY MANAGEMENT





CARBON TWIN

- Digital Twin for Emissions
- **Carbon Intensity Calculation**
- Carbon Intensity “WHAT-IF” Analysis

CARBON OPTIMIZATION

- Carbon Intensity Target Control
- Realtime Energy Optimization
- Power Mix Optimization
- Predictive Asset Effectiveness
- Constraint based CI Optimization

DIGITAL HYDROGEN PASSPORT & OPTIMIZED CARBON INTENSITY

- Trending, Alarm and Diagnostics of CI

ENERGY & EMISSIONS MANAGEMENT LEADS TO A CLEAN PRODUCT PASSPORT

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POWER-TO-X
INTEGRATED SOLUTIONS ACROSS VALUE CHAIN

I-MAC & LEAP™ Approach

Integrated Main Automation Contractor

Cloud Connected
- Manage operations, assets, intelligently from anywhere

Integrated Industrial Cyber Security

Intelligent Operator Cockpit

Biogenic CO_2

Methanol Production

- Plant Automation & Controls
- Terminal Automation for e-Methanol

e-Methanol

eSAF Production

- UOP eFining™
- HON UOP Methanol to Jet process
- Plant Automation & Controls
- Terminal Automation for e-SAF

eSAF

H_2 Production Optimization & Purification
- Electrolyzer Controls & Instrumentation

Renewable Energy

BESS & ECS

Integrated BESS, Monitoring & Controls

DM Water

O_2

Electrolyzer

H_2

Green H_2 Purification

Compressor Control

H_2

Compression

Green H_2

- H_2 Grid Injection & Custody Metering
- 100% H_2 Burners

Air Separation

LOHC

Liquid Organic Hydrogen Carrier for long-haul transport

Ammonia Production

- Plant Automation & Controls
- Terminal Automation for e-Ammonia

e-Ammonia

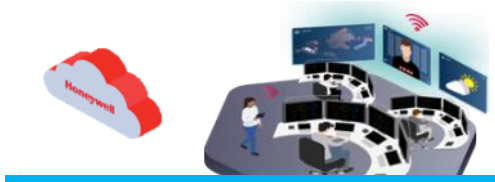
Optimization
- Design Optimizer
- PWO Optimizer

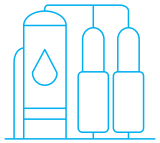
Plantwide Optimization

Carbon Intensity Tracking/ Management - Realtime

Hydrogen Passport

OUTCOME DRIVEN
DIGITAL READY GH2/Derivatives





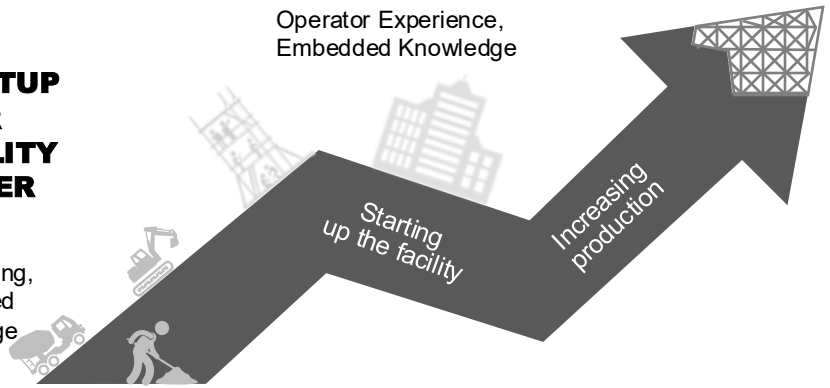
DIGITAL TWIN

REACH TARGET PRODUCTION SOONER

Operator Experience, Embedded Knowledge

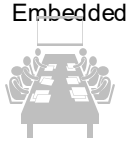
STARTUP YOUR FACILITY FASTER

Agile Engineering, Embedded Knowledge



OPERATE AT PEAK PERFORMANCE

Optimized Performance, Embedded Knowledge



HYPER-SCALING OUTCOMES

- Savings on OT Integration for Day 1 Digital Readiness
- Reduced Schedule for Early Peak capacity
- Savings on Capex
- Increased Productivity, Overall Equipment Effectiveness (OEE) and Capacity Factor
- Reduced Lifecycle Cost of ownership
- Delivering and Tracking Green Premium
- Designed for Cyber Resilience

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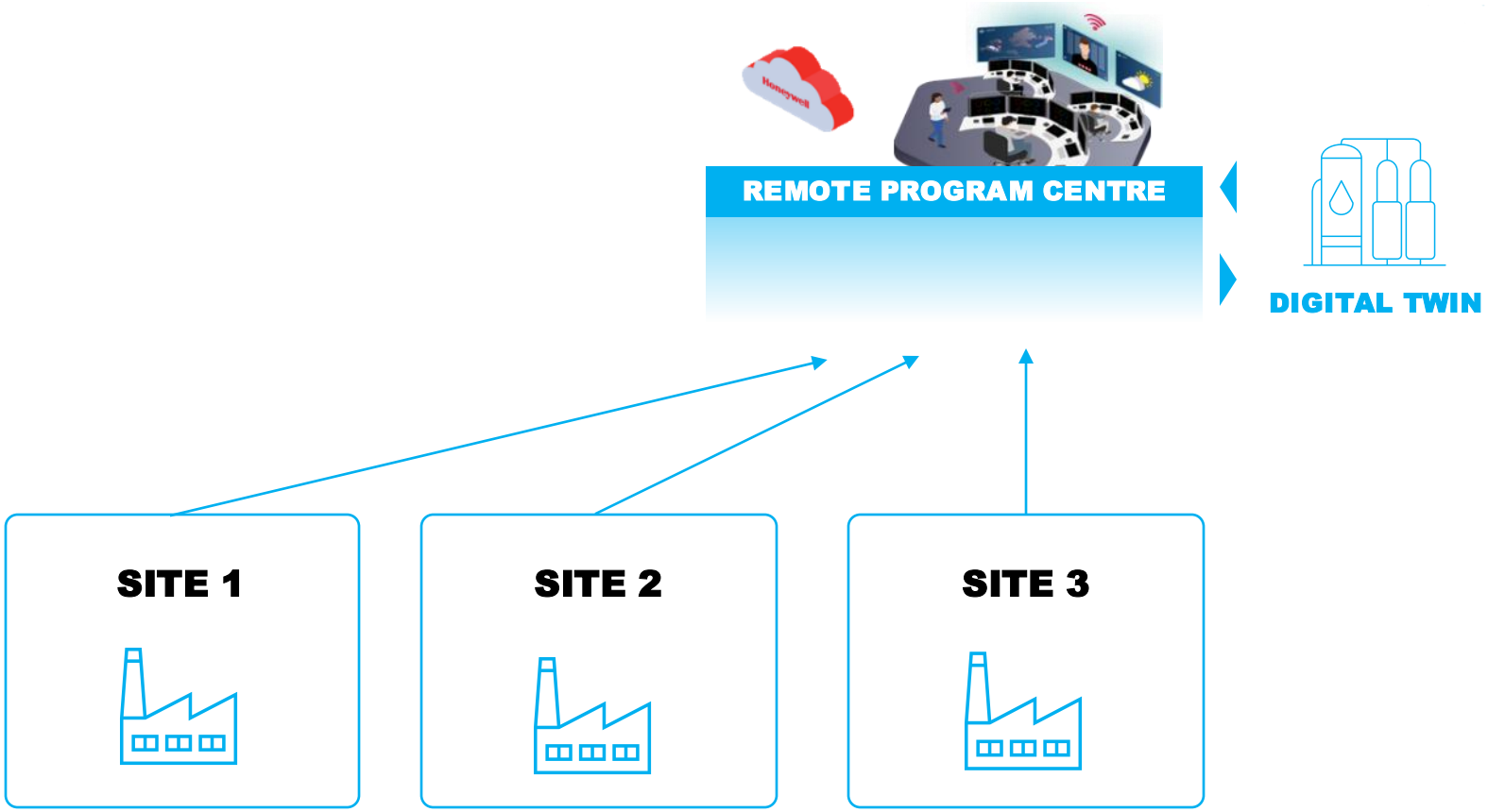
OUTCOME DRIVEN
DIGITAL READY eFuels



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THE DIGITAL UNLOCK
HONEYWELL PROTONIUM™

HONEYWELL PROTONIUM™

Honeywell Protonium CDO
Concept Design Optimization

Feasibility and Bankability

- **Optimize plant design** (Electrolyzer, H2 Storage, BESS, Compressors, etc.).
- **What-If scenarios** for optimized LCOH, CAPEX and OPEX.
- **Fast Techno-Commercial** proposals & Decisions.
- **Optimize** for Carbon Intensity Targets.
- **Define plant operations** philosophy.

Honeywell Protonium HECS
Hydrogen Electrolyzer Control System

Electrolyzer Performance and Longevity

- **Electrolyzer performance & degradation monitoring.**
- **Faster project delivery** and Minimized engineering & testing.
- **Standard function blocks**, HMI and and Pre-built KPIs.
- **Remote monitoring** of electrolyzers performance parameters.
- **Cyber Security out of the box** (ISA Secure CSA L2).

Honeywell Protonium UCO
Unified Control & Optimization

Optimized OPEX and Effective Energy Management

- **Streamlined operations** across the H2 value chain.
- **Effective power profile & intermittency management.**
- Intelligence to make **complex decisions** at speed.
- **Dynamic production planning**.
- Schedule, Control and Optimize Production.

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