Techno-Economic Analysis of Hydrogen Technology Pathways

Strategic Analysis Inc.

Jennie M. Huya-Kouadio

Brian D. James

Cassidy Houchins

Yaset Acevedo

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TEA Methodology

- Techno-Economic Analysis (TEA) is a tool to evaluate an entire system; evaluating the interactions between technical performance and cost.

Create System Model
- -Process Flow Diagram
- -Identify key process steps and variables

→

Conduct Mass/Energy Balance
- -Identify product feed, and product output

→

Identify Key Processes and Key Equip. Info.
- -Unit capacity volume production
- -Process Equipment pricing

→

Estimate System Capital Cost
- -Use DFMA®* to evaluate cost for materials, manufact., & labor for key components

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Evaluate Cost of H_2
- -Input capital cost, operating cost, efficiency, etc. into H2 Analysis (H2A) tool

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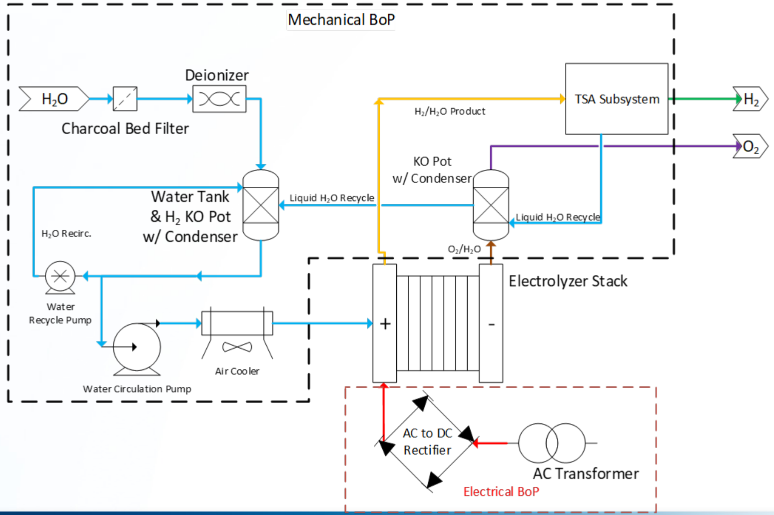
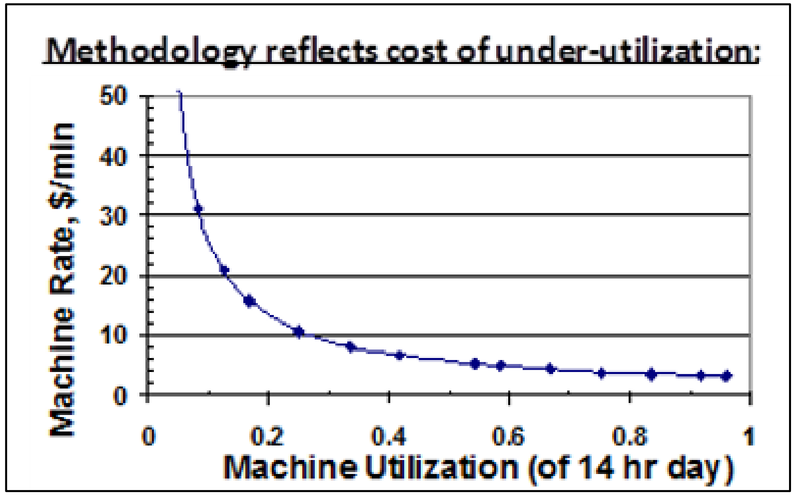
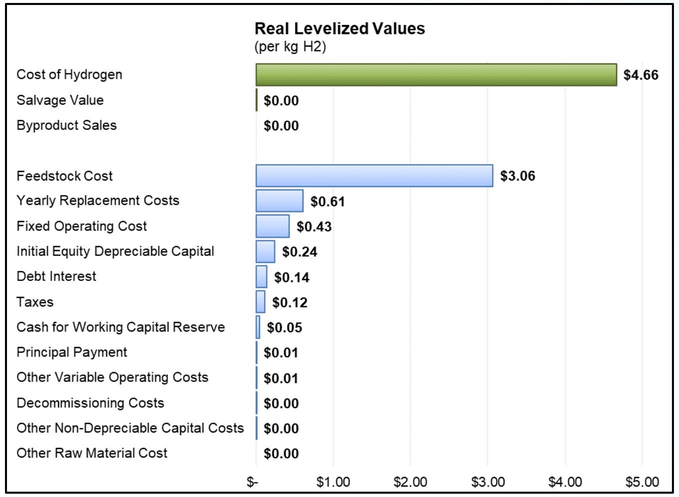
Post Analysis Process
- -Review results
- -Conduct sensitivity analysis







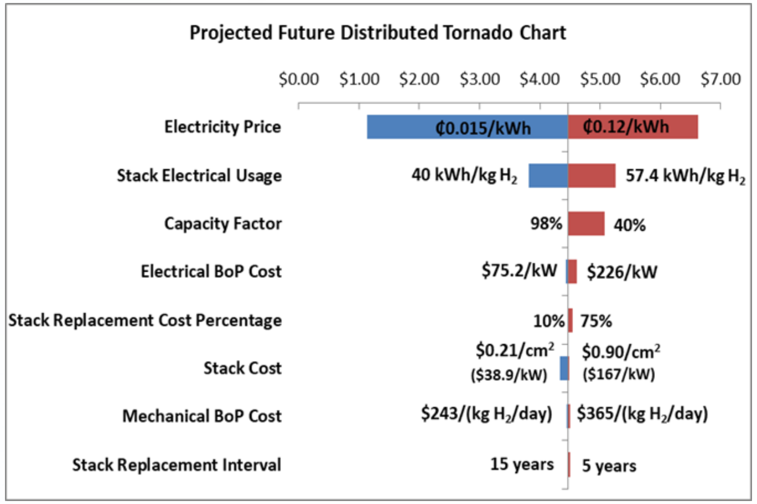
*Design for Manufacture and Assembly (DFMA®)

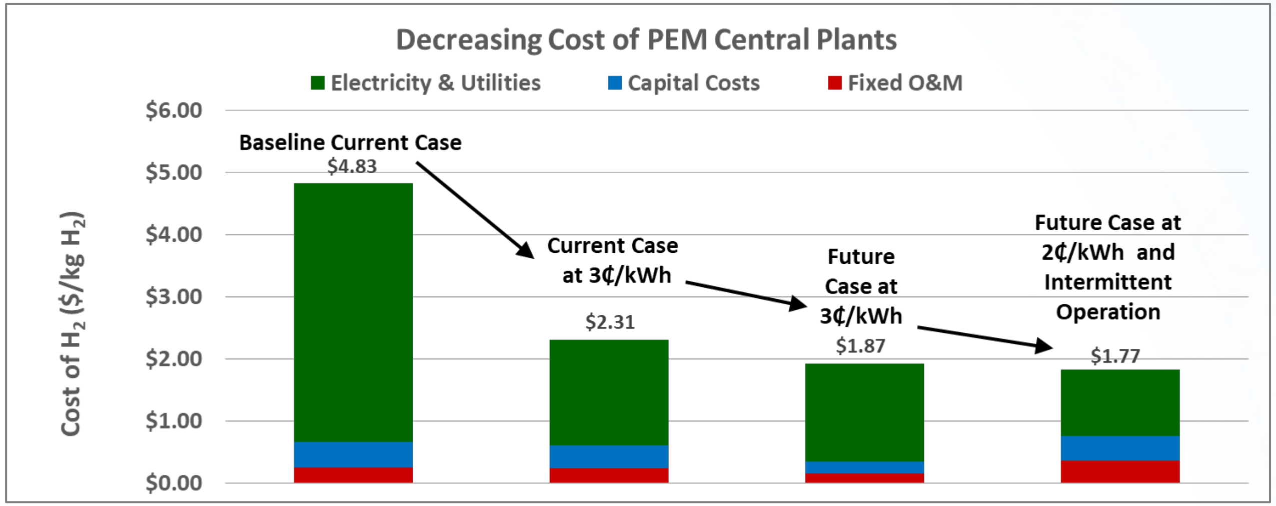
The Value of TEA

- TEA is used to **evaluate the cost to produce H_2 ($/kg)** through various technological production pathways (e.g., electrolysis or photoelectrochemical water splitting) and **measure the cost impact** of technological improvements in those H_2 production technologies

- **Identify key parameters that drive system cost**
  - Adjust research to focus on key parameters
  - Focus cost saving efforts on key parameters

- **Discern cost differences between different designs or manufacturing processes**
  - Use as a tool to pick design/process that leads to lowest cost





TEA Challenges

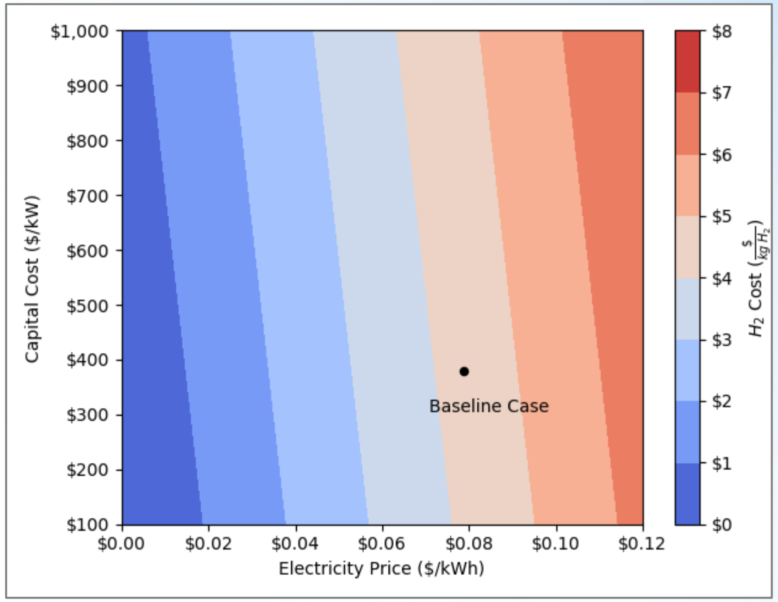
- **Although system economic assessment is especially needed for emerging technologies**
  - High degree of uncertainty in embryonic system designs
  - Sometimes materials have only been tested in a lab environment
  - Lack of validation of assumptions for nascent technologies

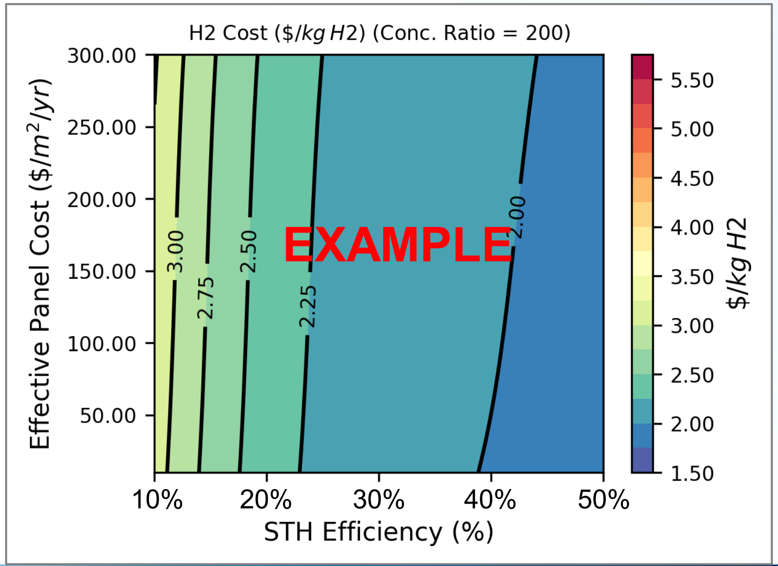
- **Identification of changes between “lab” & “mass-production” design**
  - One-off design might be radically different than mass-produced design
  - Inventive team may not be best group to assess mass-produced design
  - Applies to both design and manufacturing methods

- **For early production systems, difficult to validate assumptions**
  - Information may be withheld as proprietary
  - Information may not exist anywhere
  - Many parameters may have to be simultaneously estimated/projected

Future Opportunities for TEA

- **Use Hydrogen Shot Target $1/kg to guide pathway technical targets**
  - Top-down approach of setting a cost target and determining the bounds of key performance or cost parameters that “must be” achieved
- Assess technology status, evaluate the **cost drivers,** and **identify the technical areas needing improvement** for each technology.
- Provide a **complete pathway definition**, performance, and economic analysis **not elsewhere available**
- Provide analysis that is **transparent, detailed, and made publicly available** to the technical community
- Support **selection of portfolio priorities** through evaluations of technical progress and hydrogen cost status





Thank You

Jennie M. Huya-Kouadio - jhuya-kouadio@sainc.com

Brian D. James – bjames@sainc.com

Cassidy Houchins – chouchins@sainc.com

Yaset Acevedo – yacevedo@sainc.com

Strategic Analysis Inc.
4075 Wilson Blvd, Suite 200
Arlington, VA 22201

International Energy Agency

Life Cycle Assessment as an Analytical Framework for Advanced Hydrogen Pathways

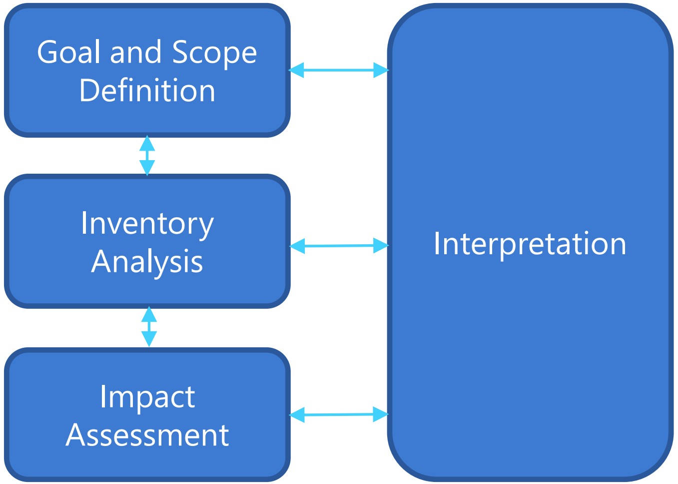
Elizabeth Connelly

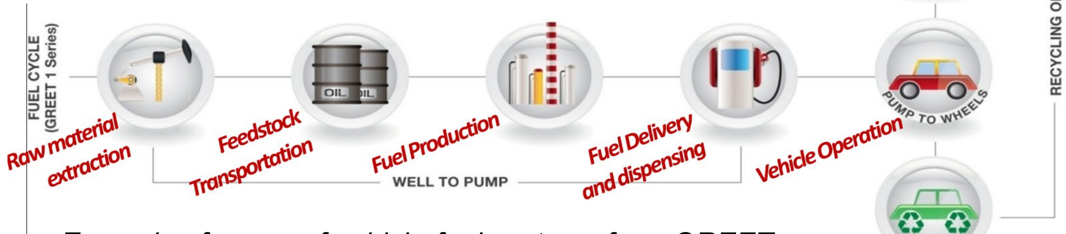
31 August 2021

What is LCA?

- Lifecycle analysis – method used to evaluate the environmental impact of a product through its life cycle
- Lifecycle for hydrogen technologies includes:
  - Feedstock production and transport
  - Hydrogen production
  - Hydrogen delivery (as GH_2, LH_2, other carriers)
  - Hydrogen use
  - Technologies and infrastructure (e.g., vehicles, pipelines, fuel cells, etc.)

Method overview





Example of scope of vehicle-fuel systems from GREET

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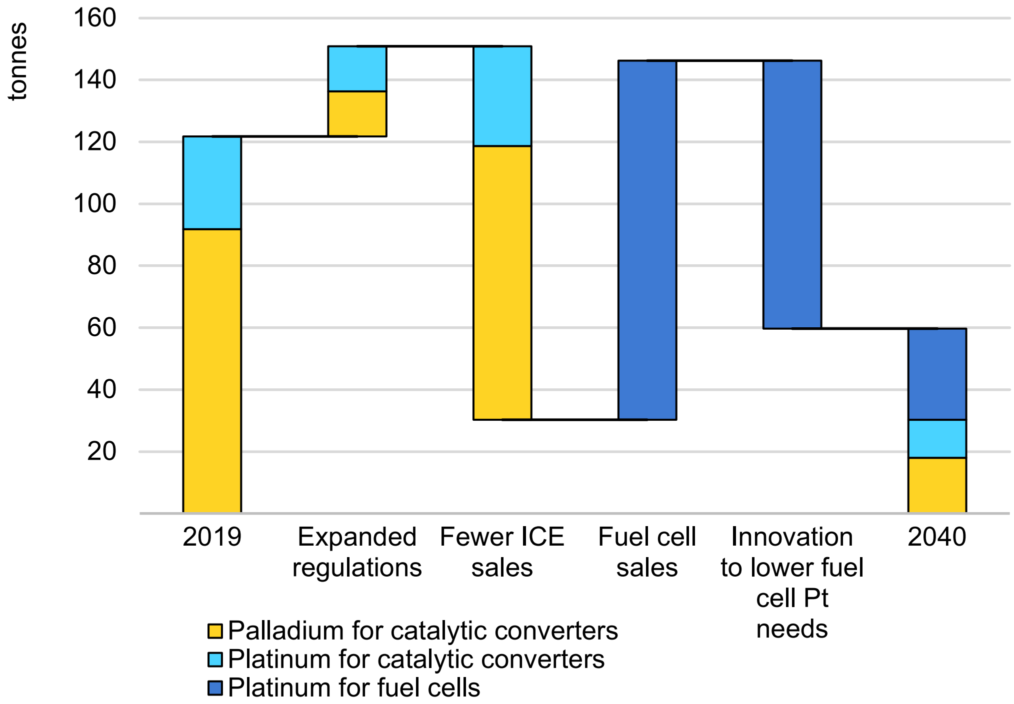
Why LCA?

- Determining the role of hydrogen in the clean energy transition
- Understanding impacts of hydrogen technologies on climate, air pollution, and criterica minerals demand
- Informing R&D and investment decisions

Drivers of PGM demand in a Sustainable Development Scenario, 2019-2040



Source: [IEA Critical Minerals Report]

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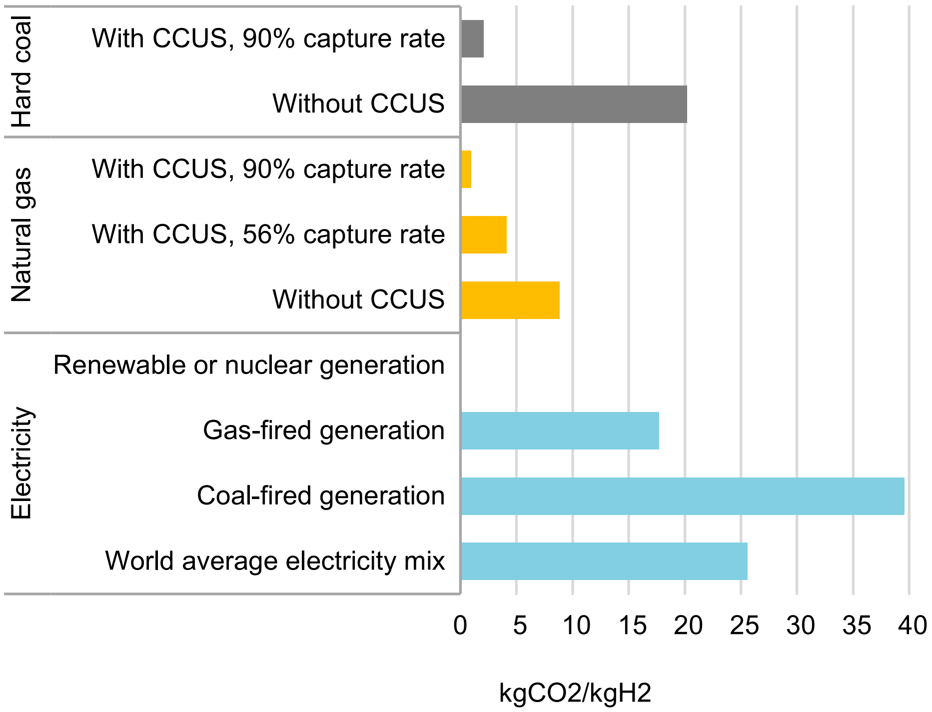
Challenges of LCA

- System boundaries
- Allocation between co-/by-products
  - Energy, mass, market value approaches
- Treatment of biomass/biogenic CO_2
- Regional variability
- Future uncertainties regarding efficiency improvements, feedstock (upstream) emissions intensities, resource availability, etc.

CO_2 intensity of hydrogen production



Source: IEA Future of Hydrogen

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Opportunities for LCA

- Ensuring hydrogen contributes to the vision of net-zero emissions
- Informing end-of-life and recycling approaches for hydrogen technologies
- Supporting coordination and alignment on methods and definitions of clean hydrogen
- Guiding a global strategy on technology development
- Enabling international trade of clean hydrogen

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QUESTIONS?