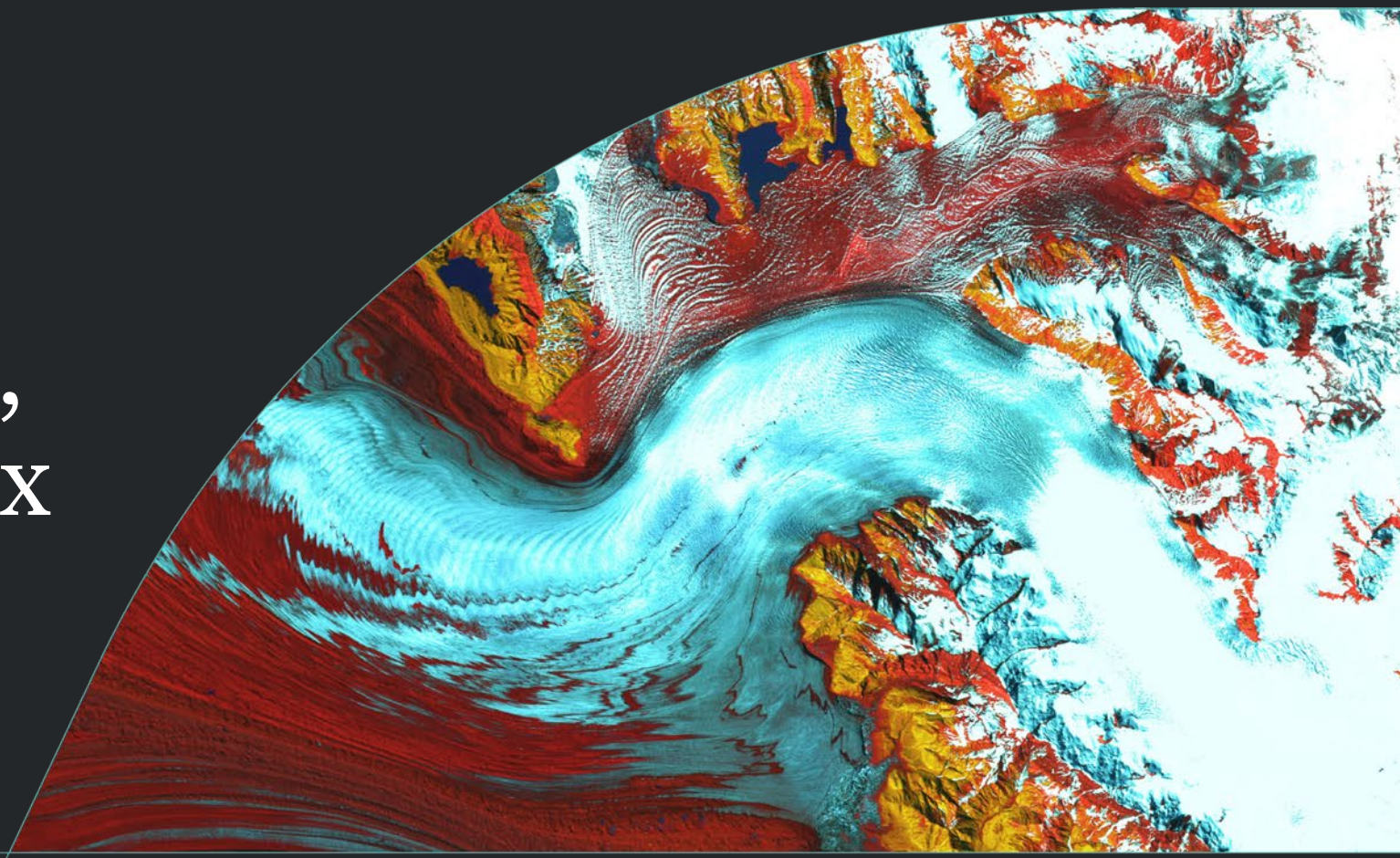
Hydrogen Lifecycle Analysis, Eligibility, and Tax Credits

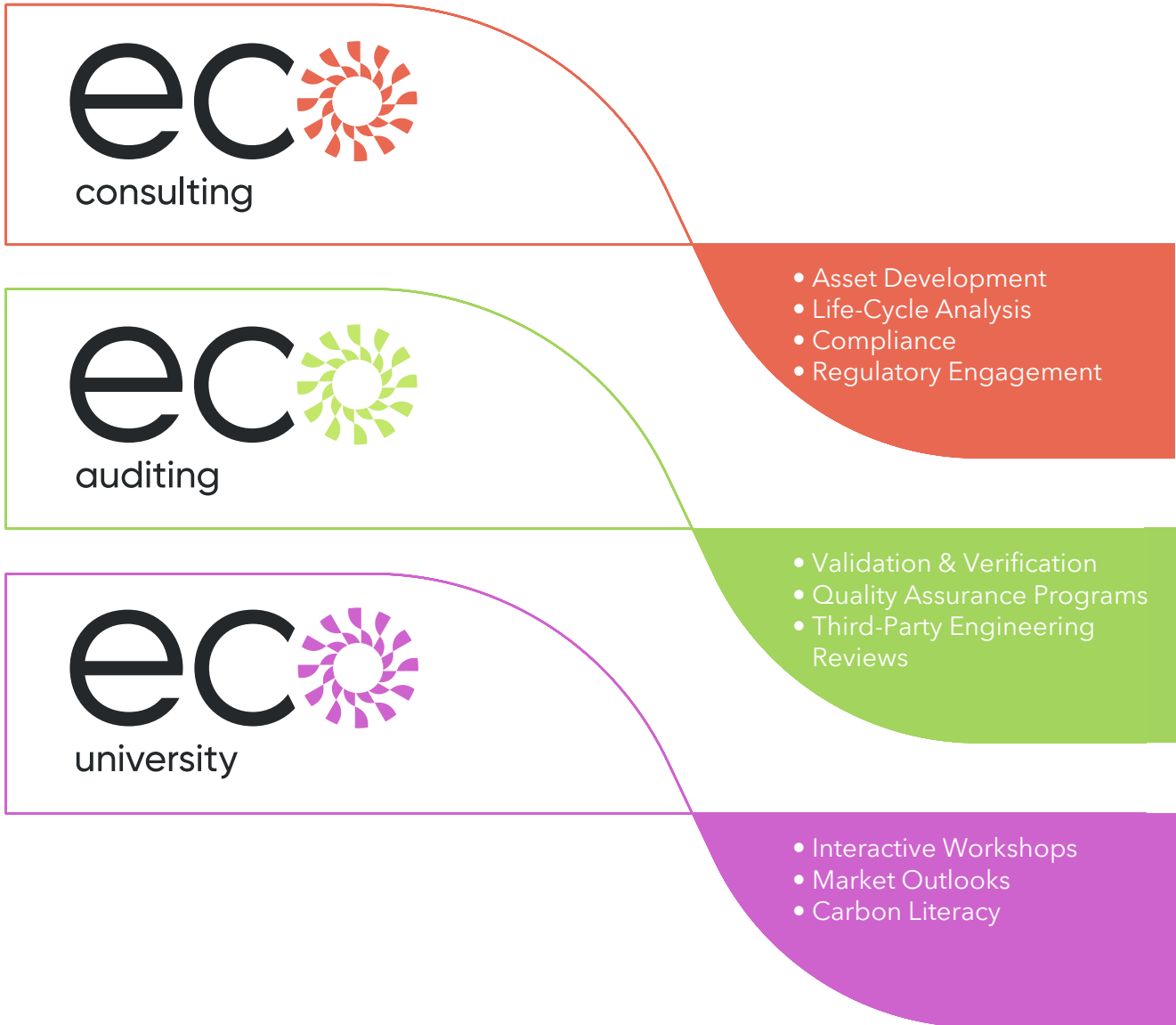


2nd Annual Kentucky Hydrogen Summit

06.26.2024

We Are EcoEngineers

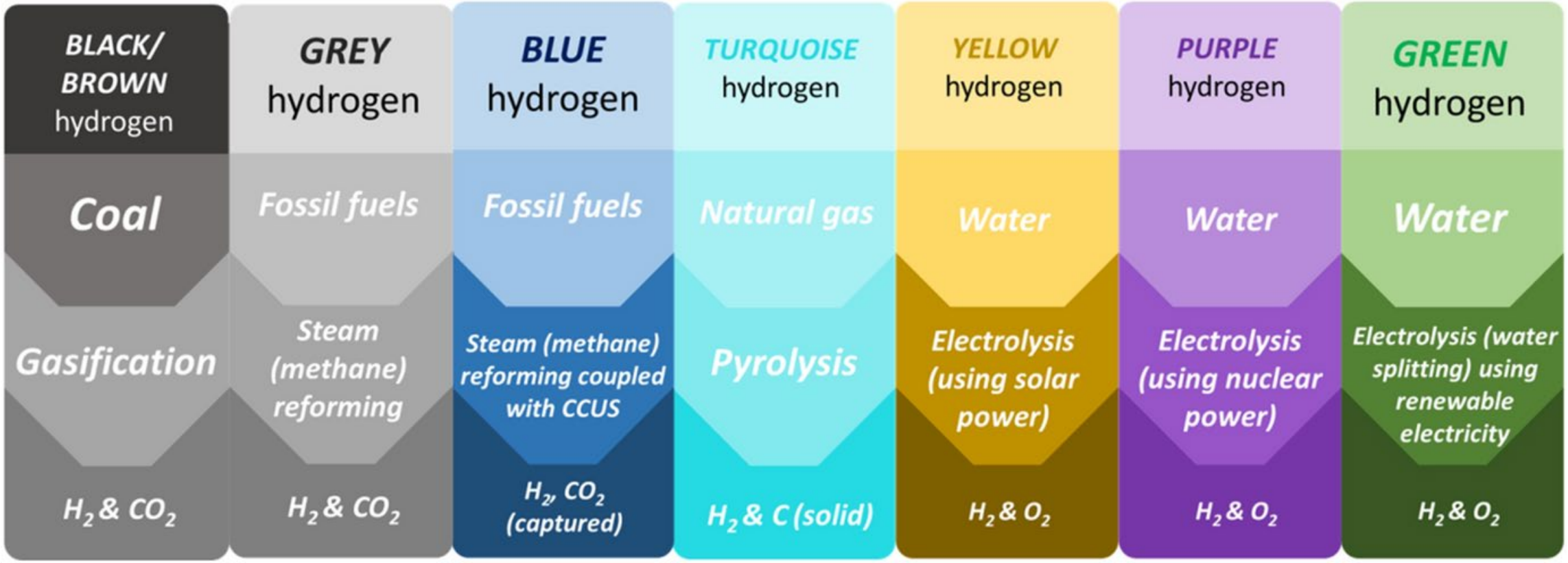
- **An advisory firm with an exclusive focus on the energy transition**
- **A team of engineers, scientists, auditors, consultants, and researchers passionate about their work**
- **Living and working at the intersection of climate policy, innovative technologies, and the carbon marketplace**
- **Helping clients navigate the disruption caused by carbon emissions and climate change**



Today's Agenda

- Hydrogen key definitions
- Lifecycle Analysis
- Hydrogen Incentives in the US
  - IRA
  - Hydrogen Hubs
  - Low Carbon Fuel Standards
- Incentives Stackability and Value

The Hydrogen Rainbow



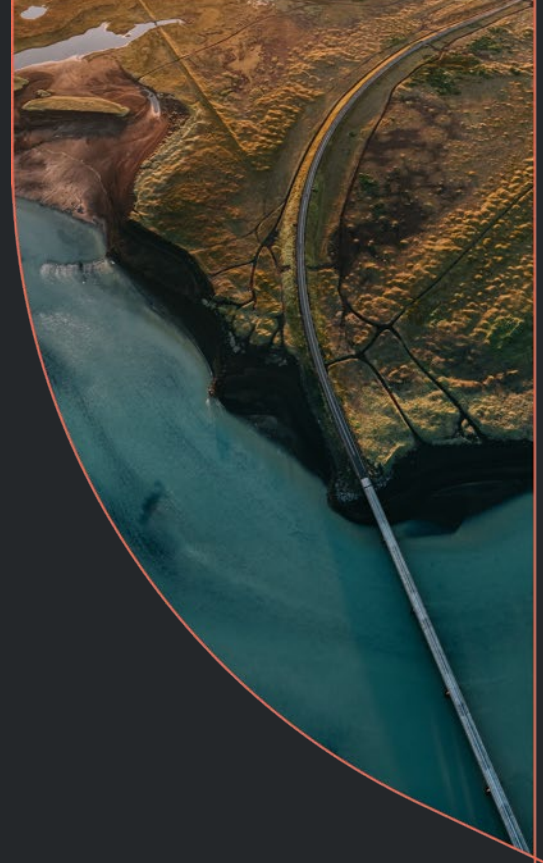
Source: Skillen et al., 2022

The Hydrogen Rainbow

Source: Skillen et al., 2022

Hydrogen Key Definitions

- **Clean Hydrogen / Low Carbon Intensity Hydrogen (LCI H2):**
  - Defined in the Bipartisan Infrastructure Law (2021) as produced with a carbon intensity of 2 kg or less CO_2/kg of H2 at the production site
  - Defined in the Inflation Reduction Act (2022) as 4 kg or less CO_2/kg H2 on a life-cycle (well to gate) basis
- **Renewable Hydrogen:**
  - Made from renewable electricity or eligible biomass feedstocks



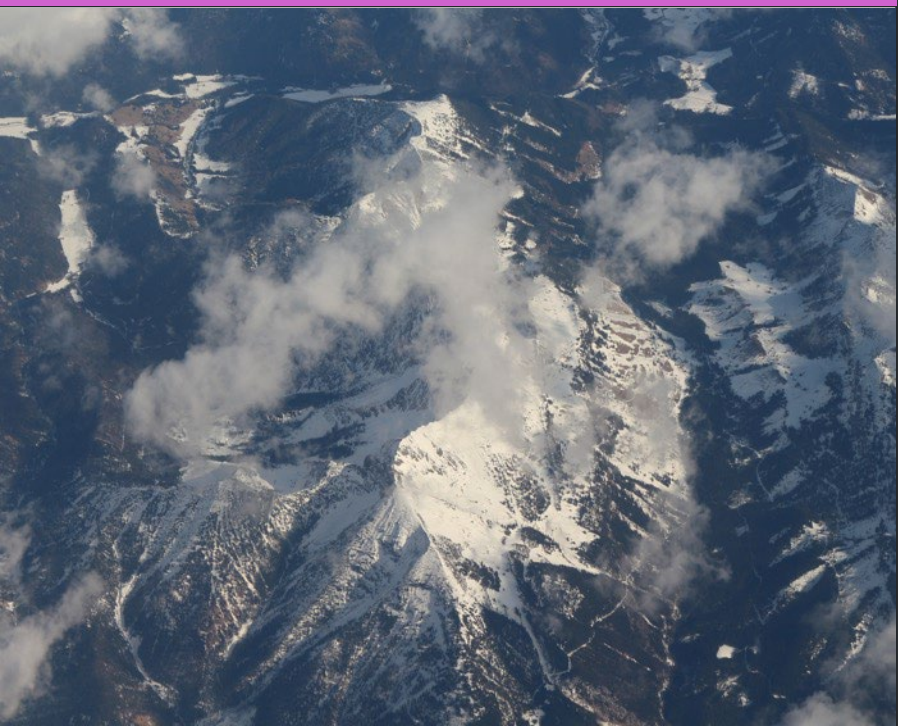
Life-Cycle Analysis (LCA)

What is LCA?

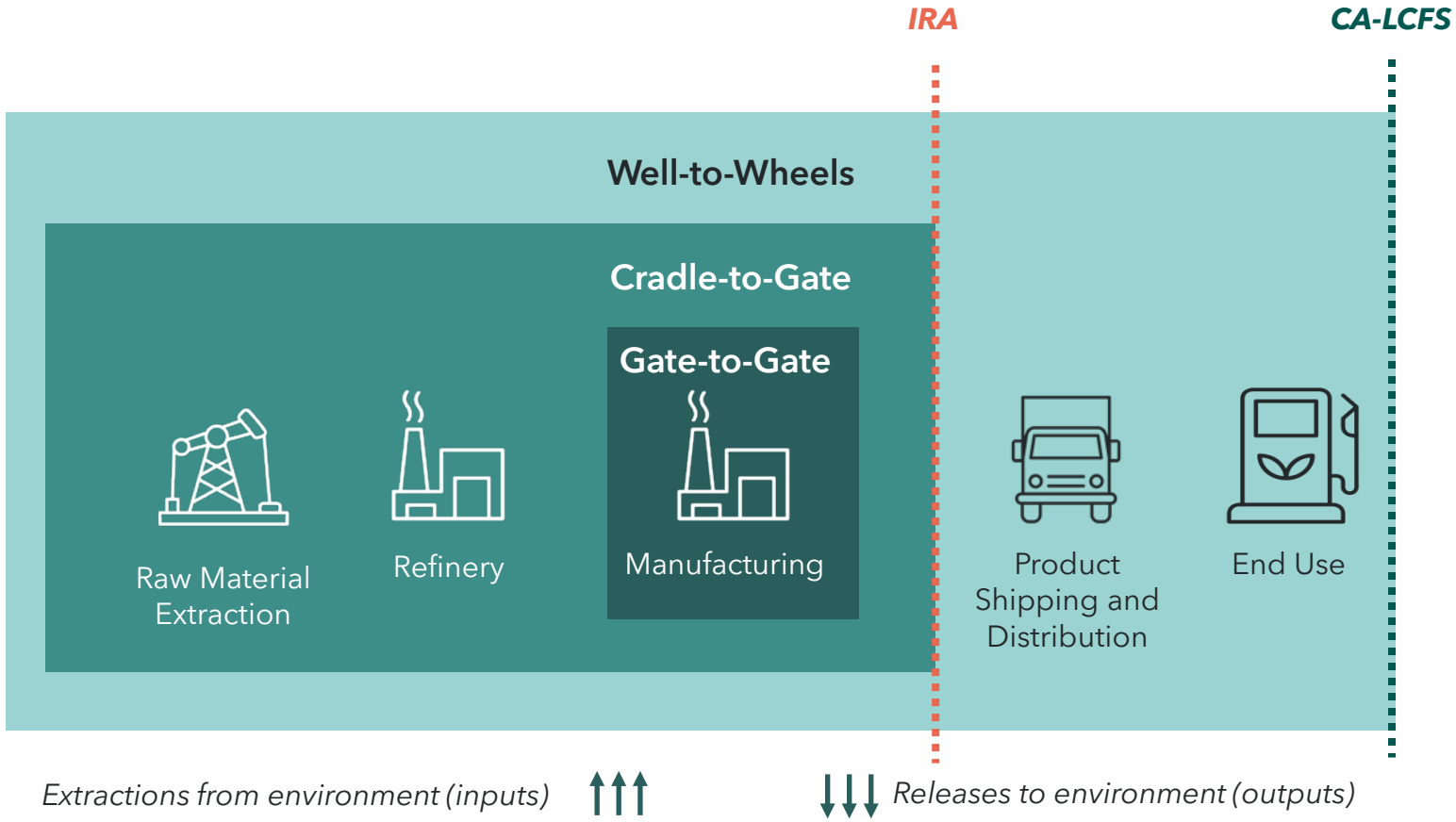
- **LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by:**
  - Compiling an inventory of relevant energy and material inputs and environmental releases
  - Evaluating the potential environmental impacts associated with identified inputs and releases
  - Interpreting the results to help you make a more informed decision

Source: Wiki Commons

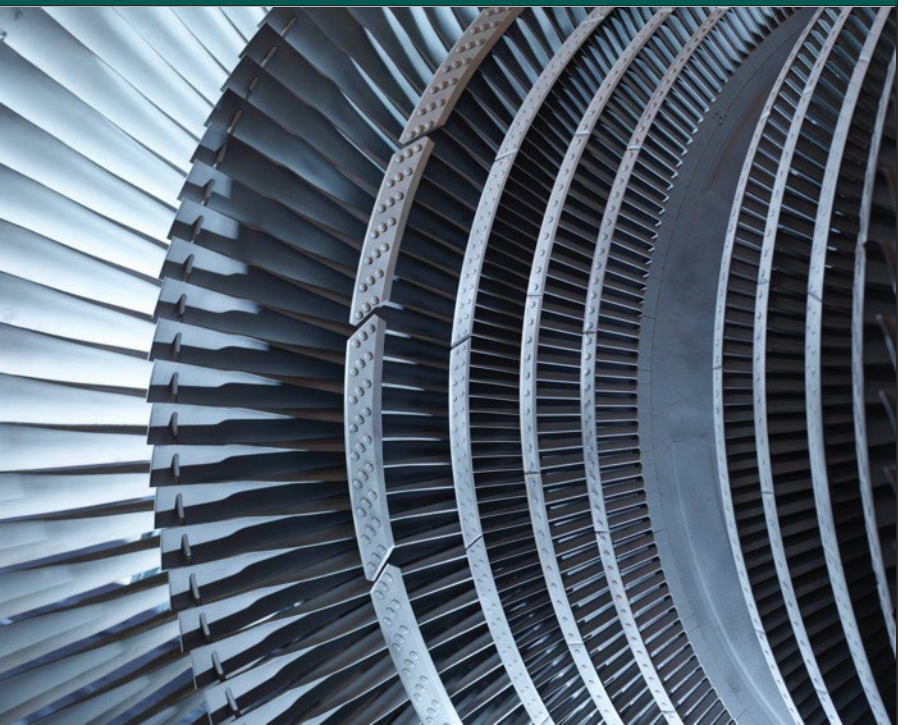
LCA Boundaries



- **Selecting boundaries**
  - Direct and/or indirect environmental impacts
  - What is relevant to the analysis? E.g., inputs, outputs, processes, impacts
  - Include elements that can be changed in the process



LCA Tools



- **LCA tools offer the means to calculate the impacts of a product using various databases as well as user inputs**

- **GREET – Fuel pathways**
  - California LCFS CA-GREET 4.0
  - Oregon CFP OR-GREET
  - USEPA RFS (Argonne GREET)
  - Section 45V PTC 45VH2-GREET
- **GHGenius – Fuel pathways**
  - British Columbia LCFS
- **OpenLCA**
  - Canada CFR
  - Section 45Q
- **Others typically focused on a specific product/industry segment**

Hydrogen Incentives: Carbon and Tax Credits

Key Policies Accelerating Hydrogen In the US

- **Federal:**
  - Low-carbon hydrogen deployment targets (e.g., 10, 20, 50 MM tons by 2030, 2040, and 2050 respectively)
  - DOE's Hydrogen Shot ("**1** kg of H2 for **$1** in **1** decade")
  - Inflation Reduction Act (IRA) tax credits (e.g. 45V, 45Q)
  - Bipartisan Infrastructure Law H2 hubs
  - Buy Clean Initiative (US$650 billion annual federal procurement)
- **State-Level**
  - 19 states adopted policies, laws, and regulations governing the use of hydrogen.
  - California: Low Carbon Fuel Standard (LCFS); Cap-and-Trade; climate goals; Buy Clean Act. 19 Years supporting H2.
  - 264 State Laws (enacted) that mention or support hydrogen in some way (alternative fuels, fuel cells, etc.).

IRA & Bipartisan Infrastructure Law

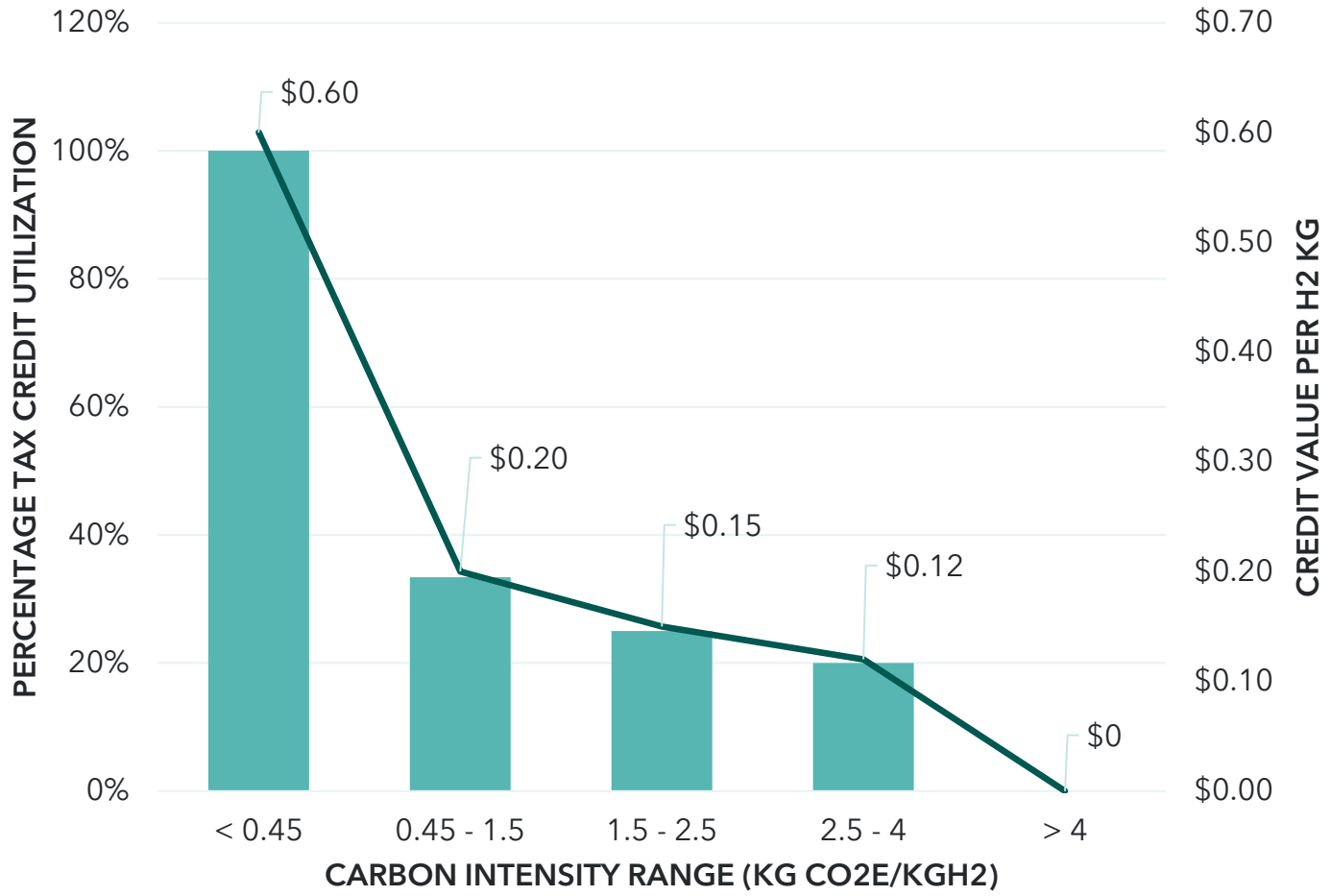
IRA: H2 Tax Credits

Tax Credit	Projects affected	Preliminary credit pricing	Timing	Specifications
45Q: Extension & Modification of Credit for Carbon Oxide Sequestration	Electricity generation; direct air capture (DAC); carbon capture utilization and sequestration projects	- $85/metric ton (MT) of CO2 sequestered - $60/CO2 MT for utilization/EOR. - DAC is $180/CO2 MT and $130/MT CO2, respectively.	Projects starting construction by Jan. 1, 2033	Still much to be learned. Minimum capture of 12,500 MT CO2 per year (or 1,000 MT CO2 if DAC). It cannot be stacked with 45V. CI requirement.
45V: Clean Hydrogen Production Tax Credit	LCI H2 production	Base credit: As high as $0.60 per H2 kg depending upon LCA, with a 5X multiplier if certain conditions are met ($3/kg)	Fuel produced Dec. 31, 2024, and before Dec. 31, 2027	Still much to be learned. The draft guidance was issued *"Three Pillars": Incrementality, hourly matching, deliverability.* CI requirement. 10-year term.
48ITC: Extension and Modification of Energy Credit	Expanded to include standalone energy storage, qualified biogas property, and LCI H2 production facilities	Base credit: 6%, with a 5X multiplier if certain conditions are met (30%) +10% Domestic Content + 10% Energy Communities	H2 projects placed in service after Dec. 31, 2022; construction must begin by Dec. 31, 2024	It cannot be stacked with sections 45, 45V, and 45Q. Irrevocable election. CI requirement.

IRA 45V Production Tax Credit

5x multiplier when Prevailing Wage and Apprenticeship requirements are met.

Tax Credit can go up to $3/kg H2



SOURCE: The U.S. Hydrogen Demand Action Plan, Energy Futures Initiative

IRA 45V Production Tax Credit

LCA Model:

45VH2-GREET

Hydrogen Pathways:

- ***Steam Methane Reforming (SMR) of natural gas, with potential CCS***
- ***Autothermal Reforming (ATR) of natural gas, with potential CCS***
- SMR of landfill gas with potential CCS
- ATR of landfill gas with potential CCS
- Coal Gasification with potential CCS
- Biomass gasification with corn stover and logging residue with no significant market value with potential CCS
- Low-temperature water electrolysis using electricity
- High-temperature water electrolysis using electricity and potential heat from nuclear power plants.

If the feedstock or production technology is not included in the 45VH2-GREET pathway a Provisional Emissions Rate (PER) can be submitted to DOE.

Hydrogen Hubs

- Federal funding of up to $7B
- Goal to develop a national network of clean hydrogen producers and consumers.
- Support for production, storage, delivery and end-use of hydrogen.

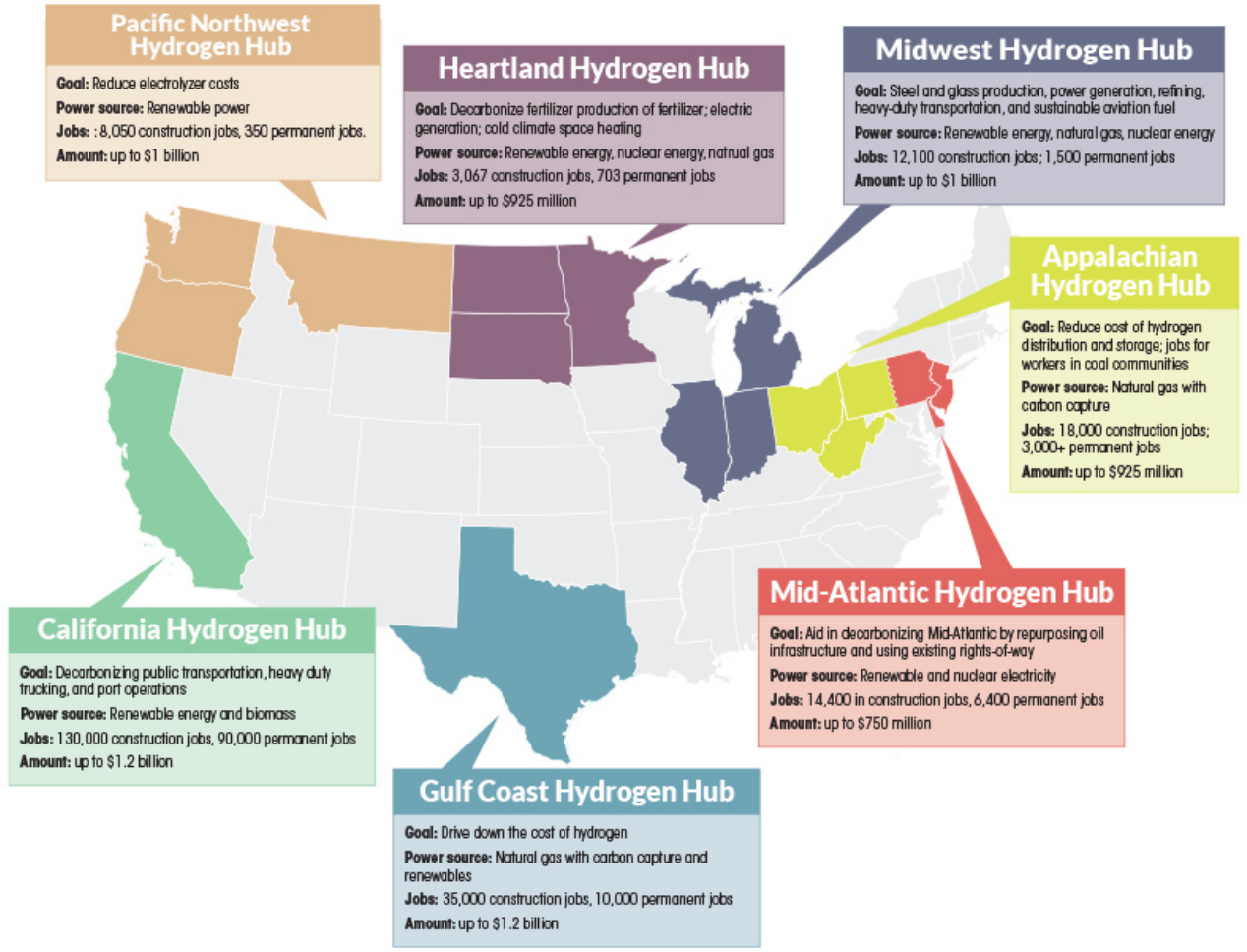
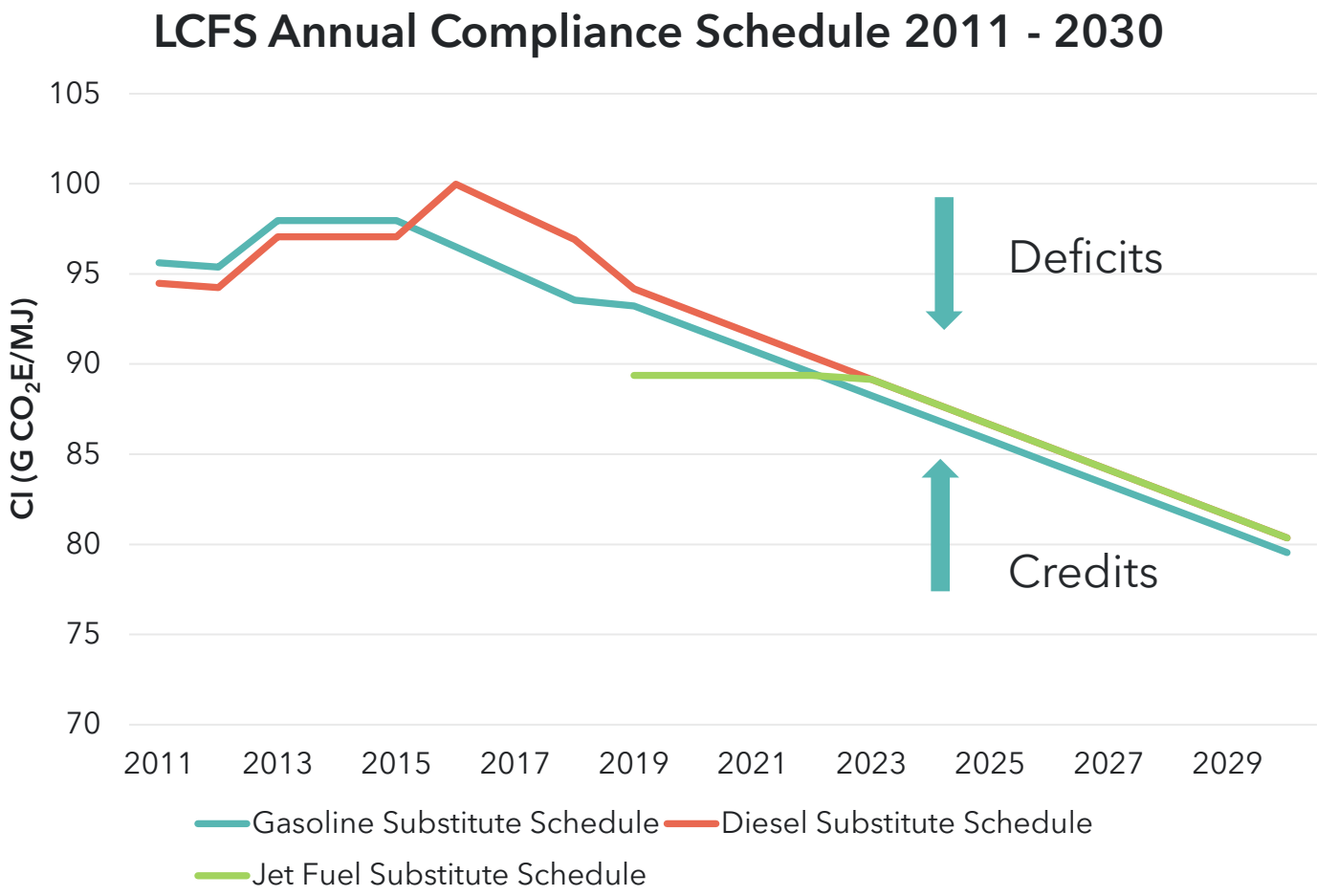


Image: RTO insider

California LCFS

California Low Carbon Fuel Standard

- **Gasoline:** 100.82gCO2e/MJ
  Diesel: 100.45gCO2e/MJ
  Fossil CNG: 79.21gCO2e/MJ
- **Hydrogen has three pathways to generate LCFS credits in California:**
  - Fuel dispensing (light-duty, medium- & heavy-duty, and forklifts).
  - Capacity credits (HRI)
  - Clean fuels refining.



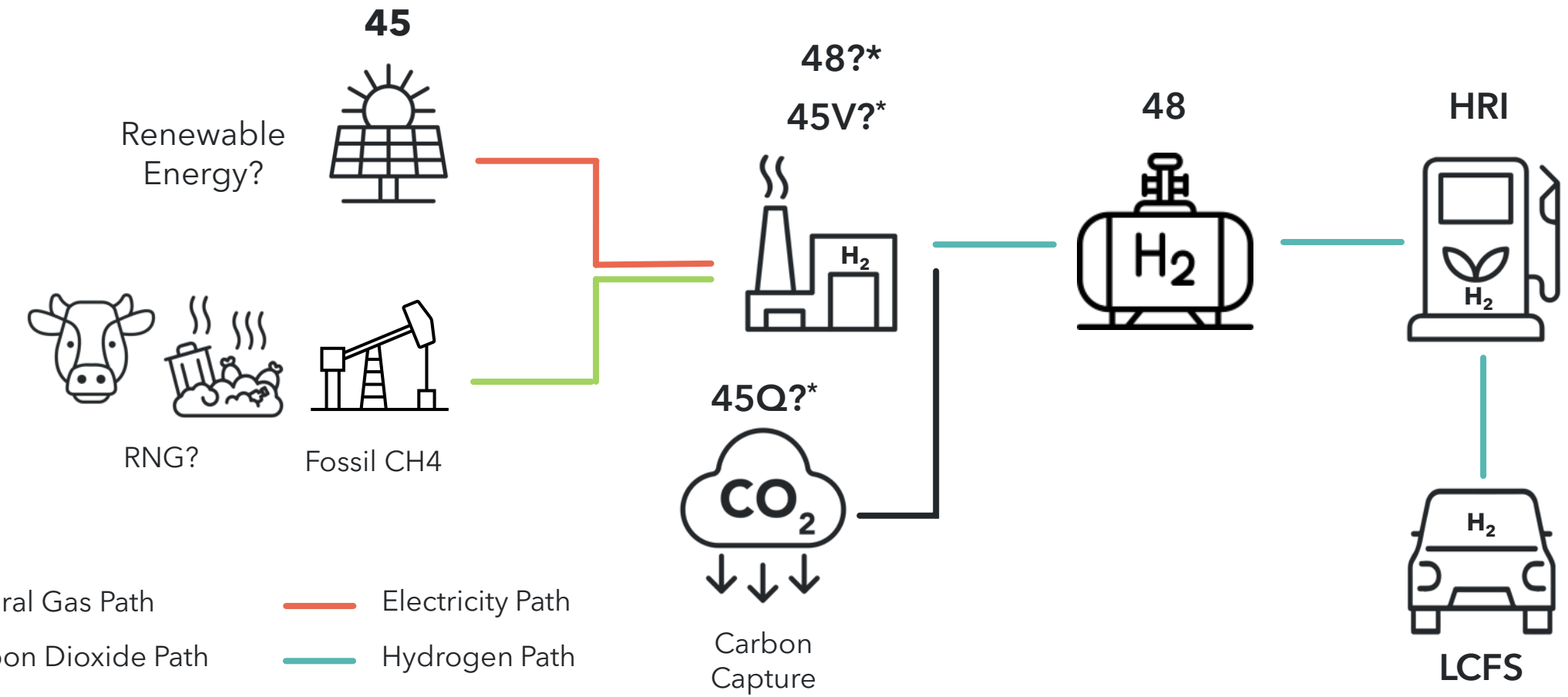
LCFS: Examples of Approved Hydrogen Pathways

Unit: gCO_2e/MJ

CO_2 Utilization not recognized in California (boundary)

Feedstock	Certified CI (gCo2e/MJ)	Certified CI (kg CO2 / kg H2)
Hydrogen produced via **electrolysis** using **solar** electricity (compression adds 10.51gCO2e/MJ)	0	0
Compressed H2 produced in California from **electrolysis** using California **average grid** electricity	164.46	19.74
Biomethane from **dairy manure** from Indiana to gaseous hydrogen produced in Wilmington	-287.07	-22.45
Compressed H2 produced in California from **SMR** of **biomethane** from North American **landfills**	99.48	11.94
Liquefied H2 produced in California from **SMR** of **biomethane** (renewable feedstock) from North American **landfills**	129.09	15.49
Compressed H2 produced in California from **SMR** of North American **fossil-based NG**	117.67	14.12
Liquefied hydrogen from North American **NG**, produced in California transported as liquid hydrogen to liquid fueling stations in California	153.91	18.47

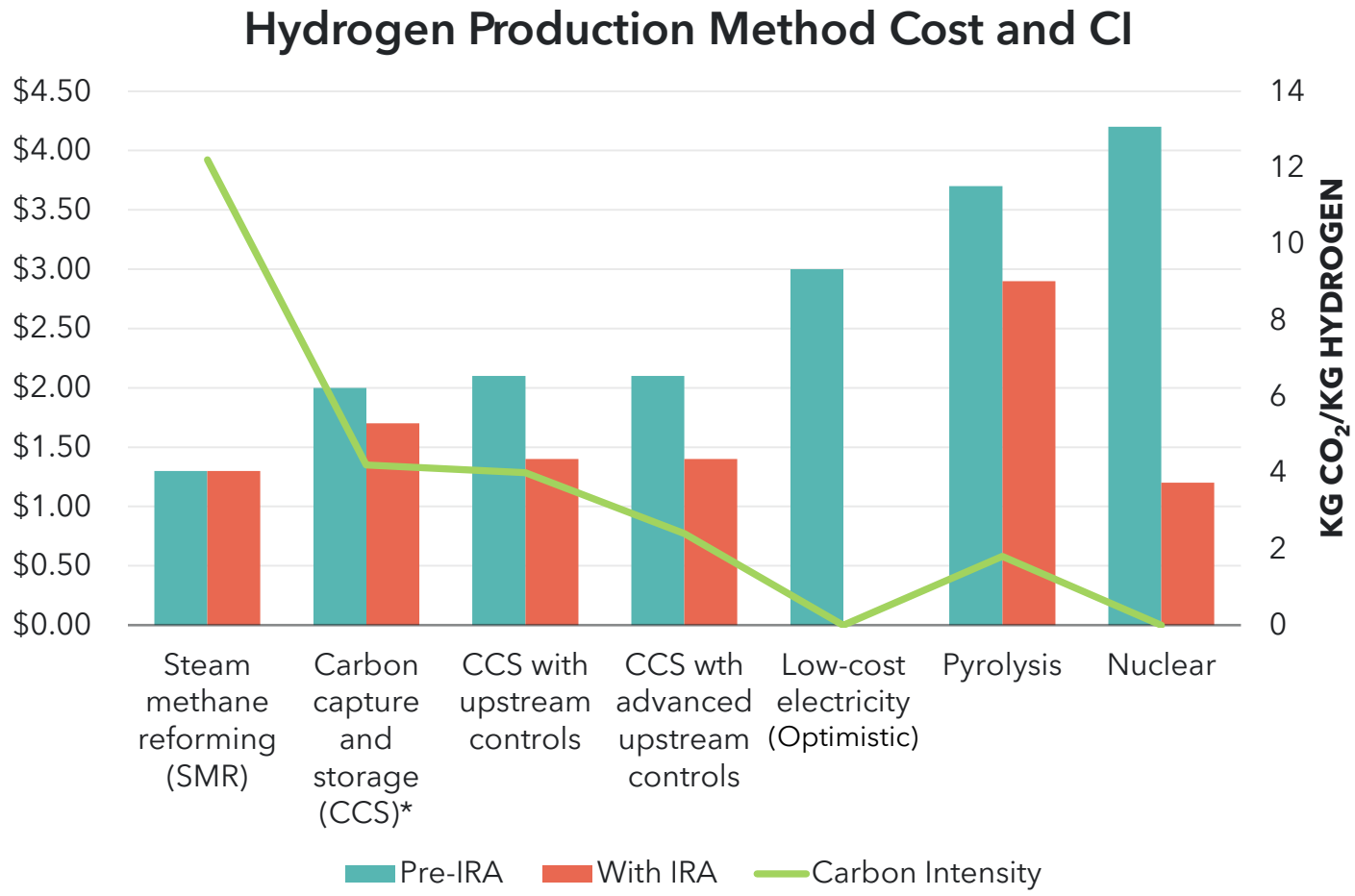
Example: Hydrogen for Transportation



*** 48, 45V and 45Q are not stackable for the same facility**

Hydrogen's CI Impact

Cost of Hydrogen with the IRA



Source: The U.S. Hydrogen Demand Action Plan, Energy Futures Initiative.

*Using 45Q

Hydrogen LCA Example

Production Tax Credit Value: $0.12/kg H2

($0.60/kg H2 with multiplier)

CCS Tax Credit*: $0.65/kg H2

*Assuming all conditions are met. Sequestration case.

Hydrogen CI example for Hydrogen ATR (well-to-gate, gaseous H2), Argonne GREET	
Contributor	**CI** ($kgCO_2e/kgH_2$)
On-site emission (NG)	8.39
Electricity	1.95
Upstream NG	1.34
CCS	-7.77
Total	**3.91**

Incentives Value Example I

CA-LCFS credit: $70/tn CO_2

Hydrogen Station Capacity: 1,200kg H2

Station utilization: 90 days, dispensing 40%.

*Assuming all conditions are met. Sequestration case.

**Light-duty case

Contributor	CI Score (kg CO2 / Kg H2)
Hydrogen CI – Well-to-Gate	3.91
Gaseous Hydrogen Transport*	0.87
Compression and Precooling*	1.32
Hydrogen CI – Well-to-Wheels	**6.1**

Incentive	Value
45Q*	$0.65
CA-LCFS**	$1.40
Total ($/kg H2)	**$2.05**

Incentive	Value
45V*	$0.60
CA-LCFS**	$1.40
Total ($/kg H2)	**$2.00**

Incentives Value Example II

100% CO2 capture

Renewable Energy/Nuclear

CA-LCFS credit: $70/tn CO_2

Hydrogen Station Capacity: 1,200kg H2

Station utilization: 90 days, dispensing 40%.

*Assuming all conditions are met. Sequestration case.

**Light-duty case

Contributor	CI Score (kg CO2 / Kg H2)
Hydrogen CI – Well-to-Gate	1.34
Gaseous Hydrogen Transport*	0.87
Compression and Precooling*	1.32
Hydrogen CI – Well-to-Wheels	**3.53**

Incentive	Value
45Q*	$0.71
CA-LCFS**	$1.58
Total ($/kg H2)	**$2. 29**

Incentive	Value
45V*	$1.00
CA-LCFS**	$1.58
Total ($/kg H2)	**$2.58**

Q + A

Thank You

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