Build a Hydrogen Supply Chain

FACILITATOR INSTRUCTIONS

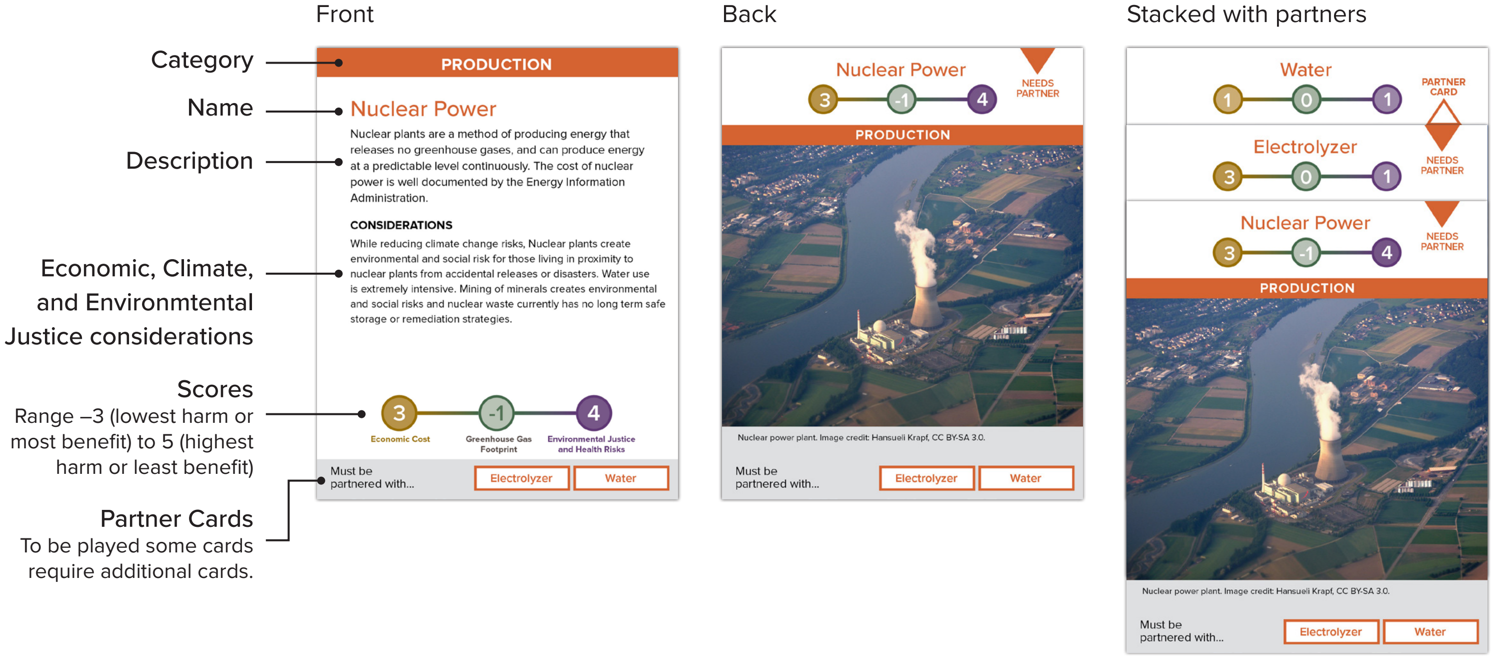
Welcome to Harnessing Hydrogen a collaborative activity in which you'll learn about how Hydrogen can be made and used. You'll also explore the economic costs, climate impacts and environmental and energy justice issues associated with different hydrogen production processes and uses.

In this activity you'll be working as a team to explore how you would design a hydrogen infrastructure that most helps to address climate change and most reduce the risks of hydrogen systems.

1. **Deal the cards**
2. **Review the different parts of the cards (see below)**
3. **Build the supply chains described below**

3–4 Participants: 5 cards each
5 Participants: 4 cards each
6–8 Participants: 3 cards each

SAMPLE CARD



Build a Hydrogen Supply Chain

FACILITATOR INSTRUCTIONS

ROUND 1

Build a Supply Chain with the Lowest Economic Cost

1. Start with the **Production Cards.**
2. Have each participant review their orange production cards.

   If no options are available in that card category, i.e., no one has a production card, participants can discard three cards and be given three new cards by the facilitator.

3. Read any of their cards in the production category (orange cards) and note the lowest economic score (the dark yellow circle).
4. Participants should discuss options and add the lowest scoring production card to the supply chain.
5. Move onto the next card category, **Transport**.

   If no options are available in that card category, i.e., no one has a transport card, participants can discard three cards and be given three new cards by the facilitator.

6. Go through each card category until the supply chain is complete (**Production, Transport, Storage, End Use, Permitting and Safety**)
7. Tally up the total scores for the supply chain's *economic*, *greenhouse gas* and *environmental justice* score and add the total scores in the scoring circles.
8. Record the supply chain with a photo.
9. Discuss what the participants think about this supply chain.

ROUND 2

Build a Supply Chain with the Lowest Greenhouse Gas footprint

1. Provide new cards to any participants who played their cards in the last round.
2. Repeat the steps in the previous round but focus on the Greenhouse Gas score, the middle circle on the card.
3. Try to build the supply chain with the lowest Greenhouse Gas Score.

   Hint! Participants can add more than one end use to further reduce the Greenhouse Gas Footprint.

4. Tally up the total scores for the supply chains economic, greenhouse gas and environmental justice score.
5. Record the supply chain with a photo.
6. Discuss what the participants think about this supply chain.

ROUND 3

Build a Supply Chain with the Least Environmental Justice & Health Concerns

1. Provide new cards to any participants who played their cards in the last round.
2. Repeat the steps in the previous rounds but focus on the purple score, the far-right circle on the card.
3. Try to build the supply chain with the lowest Environmental Justice Concern Score.
4. Tally up the total scores for the supply chains economic, greenhouse gas and environmental justice score.
5. Record the supply chain with a photo.
6. Discuss what the participants think about this supply chain.

ROUND 4

Build your own *Optional*

1. Decide if your table would like to try to build your own supply chain optimized for your values.
2. Participants can choose from any of the cards and reuse cards from other supply chains.
3. Participants can add multiple end-uses and multiple production, transport and storage pathways.
4. Tally up the total scores for the supply chains economic, greenhouse gas, and environmental justice score.
5. Record the supply chain with a photo.
6. Discuss what the participants think about this supply chain.

Discussion

Once all the supply chains are made, lead the table in discussing what they learned.

- What are the significant differences between the supply chains?
- What similarities do they see?
- Are there any cards they didn't play?

Based on the supply chains they have built:

- Which do they feel most comfortable with and why?
- Which do they have the most concerns about and why?

Build a Hydrogen Supply Chain

APPENDIX ON SCORING

Economic Score

These scores are based on an economic scale and the commercial availability and technology costs in the current market as compared to the other technologies represented here (1 to 5, with 5 being most expensive). The DOE is heavily involved in documenting and estimating cost for hydrogen production, delivery, storage, and other infrastructure. A recent program record documents the levelized cost of hydrogen (LCOH) from PEM electrolysis in a range from ~$4 to $6/kg-H2 and also includes LOCH from independent entities such as International Renewable Energy Agency (IRENA), Hydrogen Council, Bloomberg New Energy Finance, and Energy + Environmental Economics (E3) which are in general agreement.

DOE Hydrogen and Fuel Cells Program Record - Cost of Electrolytic Hydrogen Production with Existing Technology—2020

The National Energy Technology Laboratory has provided cost analysis for fossil-based hydrogen production pathways documenting a LCOH at ~ $1/kg from hydrogen form natural gas steam methane reforming, and $1.64/kg for SMR with carbon capture (Exhibit ES-6).

NETL - Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies

---

The delivery and dispensing of hydrogen can be costly depending on the method. Currently tube trailers are the most common delivery method contributing $8-10/kg to the LCOH. Hydrogen pipelines present an alternative for transportation with a much lower transmission cost < $2/kg but with additional installation costs and permitting considerations.

DOE Hydrogen and Fuel Cells Program Record - Hydrogen Delivery and Dispensing Cost—2020

The Development of Natural Gas and Hydrogen Pipeline Capital Cost Estimating Equations—2022

Greenhouse Gas Score

This score is based on the intensity of the technology's greenhouse gas emissions relative to the other technologies represented here (-3 to 5, with 5 being greatest GHG emissions and -3 meaning reduced GHG emissions as compared to the widely used alternatives). GHG scores don't consider the GHG in producing the technology. For example, they don't consider the GHG to produce wind turbines. Scores were informed by these sources:

Hydrogen-Council-Report_Decarbonization-Pathways_Part-1-Lifecycle-Assessment.pdf (hydrogencouncil.com)

Electricity in the U.S. - U.S. Energy Information Administration (EIA) Cement and steel — nine steps to net zero (nature.com)

Build a Hydrogen Supply Chain

APPENDIX ON SCORING

Justice Score

This score includes environmental issues beyond the effects of greenhouse gases along with environmental and energy justice concerns inclusive of cultural and social impacts.

The Justice Score are less easily quantified. The following represents the issue areas that were included in the calculation. Maximum 5 points, minimum -2 total:

-1 = potential benefit to deployment site, such as reduced criteria pollutants.

1 = Negative socio & cultural impacts

1 = Negative Health impacts

1 = Potential for leakage and explosions

1 = Co-pollutant emission e.g. criteria air pollutants

1 = Use of hazardous chemicals

1 = Mining: environmental and human rights impacts

Sources for Environmental Health and Environmental Justice concerns

DOE reports on EEJ concerns

- Pathways to Commercial Liftoff: Industrial Decarbonization
  See page 67 “Section 3c: Workforce and Energy and Environmental Justice (EEJ)”
- U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov)
  Regulation and Permitting Card page 64-65

Direct concerns expressed by leading Environmental Organizations, Environmental Justice organizations and leaders

- Don't Believe the Hydrogen Hype
  August 22, 2023 Letter - “Re: Don’t believe the “Hydrogen Hype” - signed by 180 organizations.
- False Solutions in Justice40 Letter
  Letter to Secretary Granholm September 19, 2022 Environmental Justice Leadership Forum “False Solutions” Letter.

Factors not included in scores:

- Potential job benefits to communities are not included in the economic or justice score.
- Potential future technical advancements that further reduce GHGs or environmental risks.
- Potential cost reductions from federal and market investments.

Scoring disclaimer: The scores are based on Hydrogen technologies alone, not their comparison to technologies they would substitute. For instance, the environment and health risk of a Hydrogen Fuel Cell truck are summarized in our scoring system as reduced air pollution (-1) and flammability risk (+1) for a net score of 0. However, a hydrogen fuel cell truck would likely replace a diesel truck that also has a flammability risk. A comparative scoring approach might therefore give a score of –1. We opted for a none-comparative approach because the substitution is not always clear, and this activity aims to identify the technical risks and benefits of Hydrogen to mitigate and distribute.