Hydrogen Production Alternatives: Resolving Disparities and Examining the Stability of Decision Making Amongst Divergent Stakeholders

Elvin Yuzugullu
Environmental and Energy Management Program
The George Washington University
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Background

- Need to switch to a sustainable energy system
- Hydrogen production considerations
  - Resources
  - Impacts
- Complexity due to
  - Hydrogen production process
  - Novelty of hydrogen energy
  - Divergent views of decision makers
Problem Statement

Disagreements over hydrogen production methods may hinder transition to the hydrogen economy.
Solution: Multiobjective Decision-Aiding Model

- Design, evaluate and test the robustness of a multiobjective decision making model to aid decision makers in selecting among hydrogen production technologies.
- Utilize results to identify areas of disagreement and facilitate convergence of opinion.
A Hydrogen Production Multiobjective Decision-Aiding Model

- Test beds for model evaluation:
  - Steam Methane Reforming of natural gas
  - Wind Electrolysis

- Data from economic, life-cycle environmental and environmental valuation studies

- Interactions with decision makers to obtain judgment on key aspects of model
Relevant Literature

- Techno-Economic Studies
- Life-Cycle Environmental Assessments of SMR and wind electrolysis
  - Resource Requirements
  - Air Emissions
  - Global Warming Potential (GWP)
  - Energy Use
  - Water Emissions
  - Solid Wastes
- Environmental Valuation Methods
Research Steps (1)

- Model Design & Development -

- Problem Formulation
- Choice of Method
- Selection of Mix of MCDM Procedures
- Identification of Decision Makers
- Identification of Method to Obtain Knowledge
- Development of Objectives Hierarchy
- Selection of Criteria
- Specification of Weights
Research Steps (2)
- Model Application, Assessment & Testing -

1. Development of Input Data
2. Optimization
3. Sensitivity Analysis of the Weights
4. Refinement of the Weights
5. Determination of Decision Making Baseline
6. Comparison of Decision Model with Baseline
7. Model Refinement
Problem Formulation

- Literature on hydrogen, its characteristics, drivers and barriers
- Analyses of direct economic costs of hydrogen production methods and life cycle environmental effects
- Structured approach to considering all criteria and preferences to aid decision making has not been established
- Debate over sources of hydrogen and conflicting opinions of stakeholders
Choice of Method

- Alternatives for producing hydrogen
- Multiple conflicting aspects
- Multiple criteria methods most suitable for hydrogen production alternative selection problem
Selection of MCDM Procedures

Appropriate mix of MCDM methods will be chosen by considering:

- Ease of use
- Validity
- Restrictions
- Appropriateness
- Software Availability
- Decision Makers
- Time
Identification of Decision Makers

- Decision makers to be selected from:
  - State energy offices
  - Utility companies
  - Hydrogen production companies
  - Fuel cell companies
  - Manufacturers (automobiles, wind turbines, etc.)
  - Government agencies
  - National laboratories
  - Non-profit organizations (energy and environmental)
  - Universities
Identification of Method to Obtain Knowledge

Knowledge acquisition method: Delphi

Series of surveys with feedback

Enables idea generation without need to be in the same place

Reduces group pressure involved in expressing opinions
Development of Objectives Hierarchy

- Based on literature survey, an illustrative objectives hierarchy will be presented to decision makers, with criteria considered relevant.
- Decision makers will answer survey in order to determine objectives hierarchy, based on their knowledge and experience.
- Decision makers also asked to rank the criteria that they have determined.
Selection of Criteria

- Objectives hierarchy preferences indicated by decision makers will be analyzed and organized.
- Ranking provided by decision makers will aid in this process.
- A set of relevant and important criteria, with an optimum level of detail, will be determined.
Specification of Weights

Second survey will be presented to decision makers in several rounds:

- Provide judgments on weights for the criteria
- Consider judgments of other decision makers
- $/\text{kg H}_2$ values also presented for consideration when making judgments
Model Application, Assessment & Testing

Application:
- Development of Input Data
- Optimization

Assessment & Testing:
- Sensitivity Analysis of the Weights
- Refinement of the Weights
- Determination of Decision Making Baseline
- Comparison of Decision Model with Baseline
- Model Refinement
Development of Input Data

Matrix of attributes and alternatives
Alternative 1 – Natural Gas Steam Methane Reforming (SMR):
  ● Production at central facility
  ● Hydrogen sent to vehicle refueling stations via pipeline
  ● Hydrogen compressed, stored and dispensed at refueling stations
  ● Upstream processes also considered as part of life cycle

Alternative 2 – Wind Electrolysis:
  ● Wind farm generates electricity
  ● Electricity sent to the electric grid
  ● Electrolyzer on site at vehicle refueling station uses equivalent electricity from grid to produce hydrogen
  ● Hydrogen compressed, stored and dispensed at refueling stations
  ● Upstream processes also considered as part of life cycle

Cost and environmental impact data from literature survey
Optimization

Elements of the decision model:
- Criteria
- Attributes
- Weights
- Alternatives

These elements will be assessed with mix of MCDM methods selected

Result will be the determination of the optimum alternative, in relation to the criteria and preferences
Sensitivity Analysis of the Weights

**Issue:** differing value judgments and priorities of decision makers

**Aim:** discover how robust the decision model is

Weights (determined by the decision makers) will be varied for sensitivity analysis

Judgment of decision makers solicited again – consider areas of disagreement
Determination of Decision Making Baseline

Decision makers will be asked to determine:

- How decision would be made in the absence of model
- What the procedure would be
Comparison of Decision Model with Baseline

Feedback from decision makers on the model, with regard to:

- Helpfulness in making decisions
- Time, effort and knowledge required
- Effect on defensibility of decisions
- Strengths and weaknesses
- Additional considerations
Model Refinement

- Continued interactions with decision makers
- Model refinement based on feedback