

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

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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

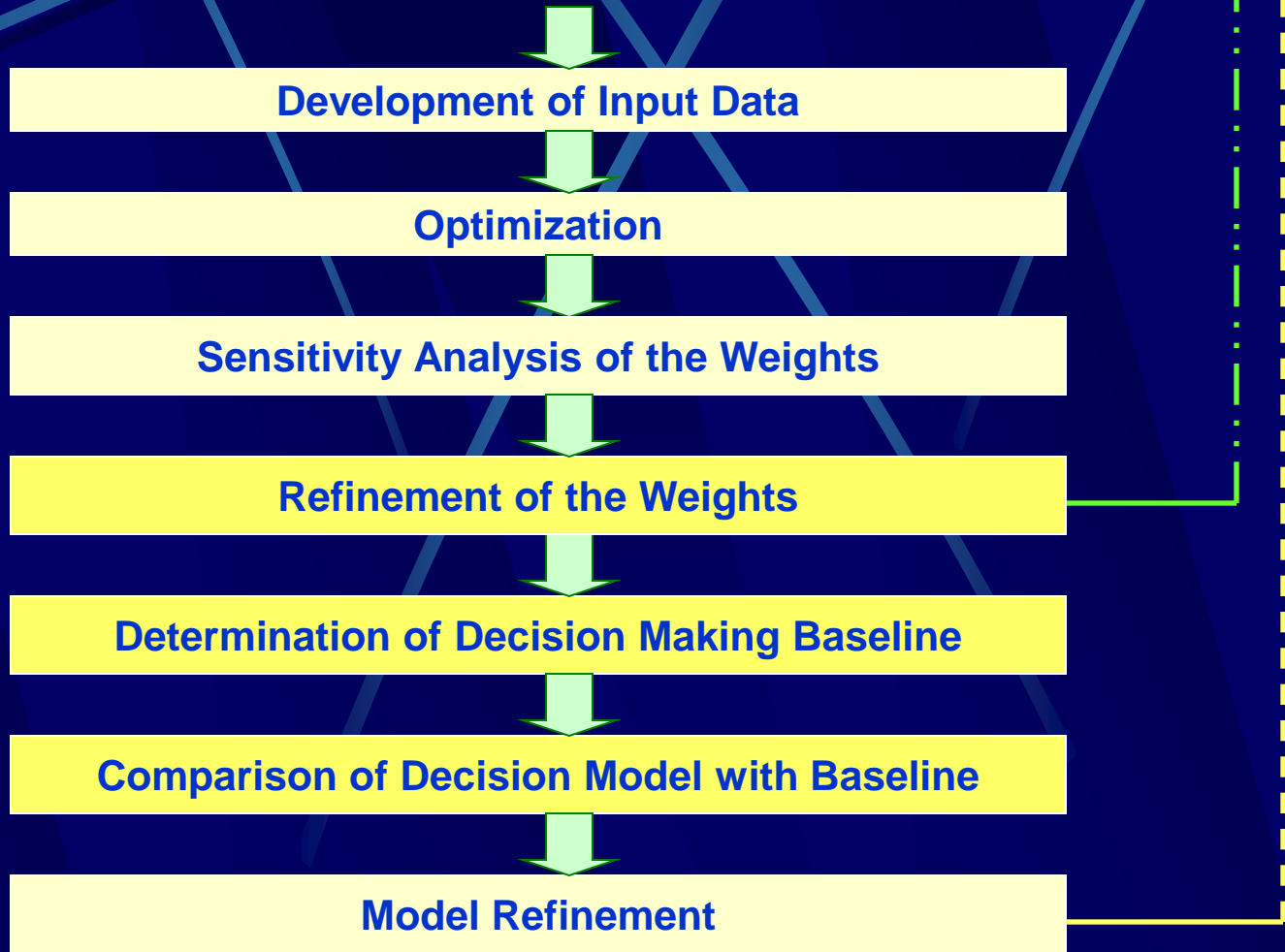
- Test beds for model evaluation:
 - Steam Methane Reforming of natural gas
 - Wind Electrolysis
- Data from economic, life-cycle environmental and environmental valuation studies
- Interactions with decision makers to obtain judgment on key aspects of model

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 (2)

- Model Application, Assessment & Testing -



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

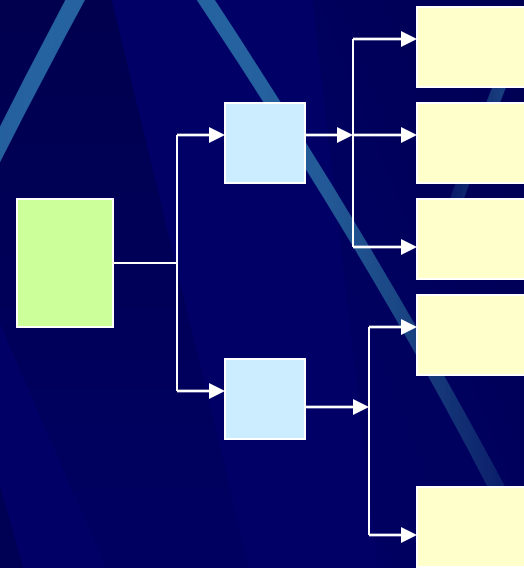
- Decision makers to be selected from:
 - State energy offices
 - Utility companies
 - Hydrogen production companies
 - Fuel cell companies
 - Manufacturers (automobiles, wind turbines, etc.)
 - Government agencies
 - National laboratories
 - Non-profit organizations (energy and environmental)
 - Universities

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
 - \$/kg H₂ 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



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