Natural Gas Utilities Options Analysis for the Hydrogen Economy

> **Hydrogen Pipeline R&D Project Review Meeting**
> 6 January 2005
> Oak Ridge National Laboratory
> Oak Ridge, TN

Mark E. Richards
Manager, Advanced Energy Systems

Gas Technology Institute

- GTI is an independent non-profit R&D organization
- GTI focuses on energy & environmental issues
  - Specialize on natural gas & hydrogen
- Our main facility is an 18-acre campus near Chicago
  - Over 350,000 ft^2

GTI’s Main Research Facility

GTI’s Energy & Environmental Technology Center

GTI RD&D Organization

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Robert Stokes
Vice-President

Energy Utilization Center
Hamid Abbasi
Executive Director

- **Residential Appliances**
- **Commercial Appliances & Use**
- **Industrial Processes & Use**
- **Central Power Generation**
- **Air Quality**

Hydrogen Energy Systems
Gerry Runte
Executive Director

- **Hydrogen**
- **Fuel Processing**
- **Low-Temperature Fuel Cells**
- **High-Temperature Fuel Cells**
- **Vehicle Fuel Infrastructure**

Distributed Energy Applications
John Kelly
Executive Director

- **Distributed Generation Products, Services, and Technologies**
- **Space Conditioning**
- **Combined Heat and Power**

Exploration & Production Technology
Kent Perry
Executive Director

- **Earth Science**
- **Resource Assessment**
- **Gas Storage**
- **Liquefied Natural Gas**
- **Gas Hydrates**

Distribution & Pipeline Technology
Steve Gauthier
Executive Director

- **Pipeline Design & Construction**
- **Pipeline Operation & Integrity**
- **Pipeline Inspect & Corrosion**
- **Metering & Automation**
- **Materials/Plastics**

Gasification & Gas Processing
Francis Lau
Executive Director

- **Gasification & Hot Gas Cleanup**
- **Process Engineering**
- **Thermal Waste Stabilization**
- **Gas Processing & Conditioning**
- **Catalytic Synthesis**

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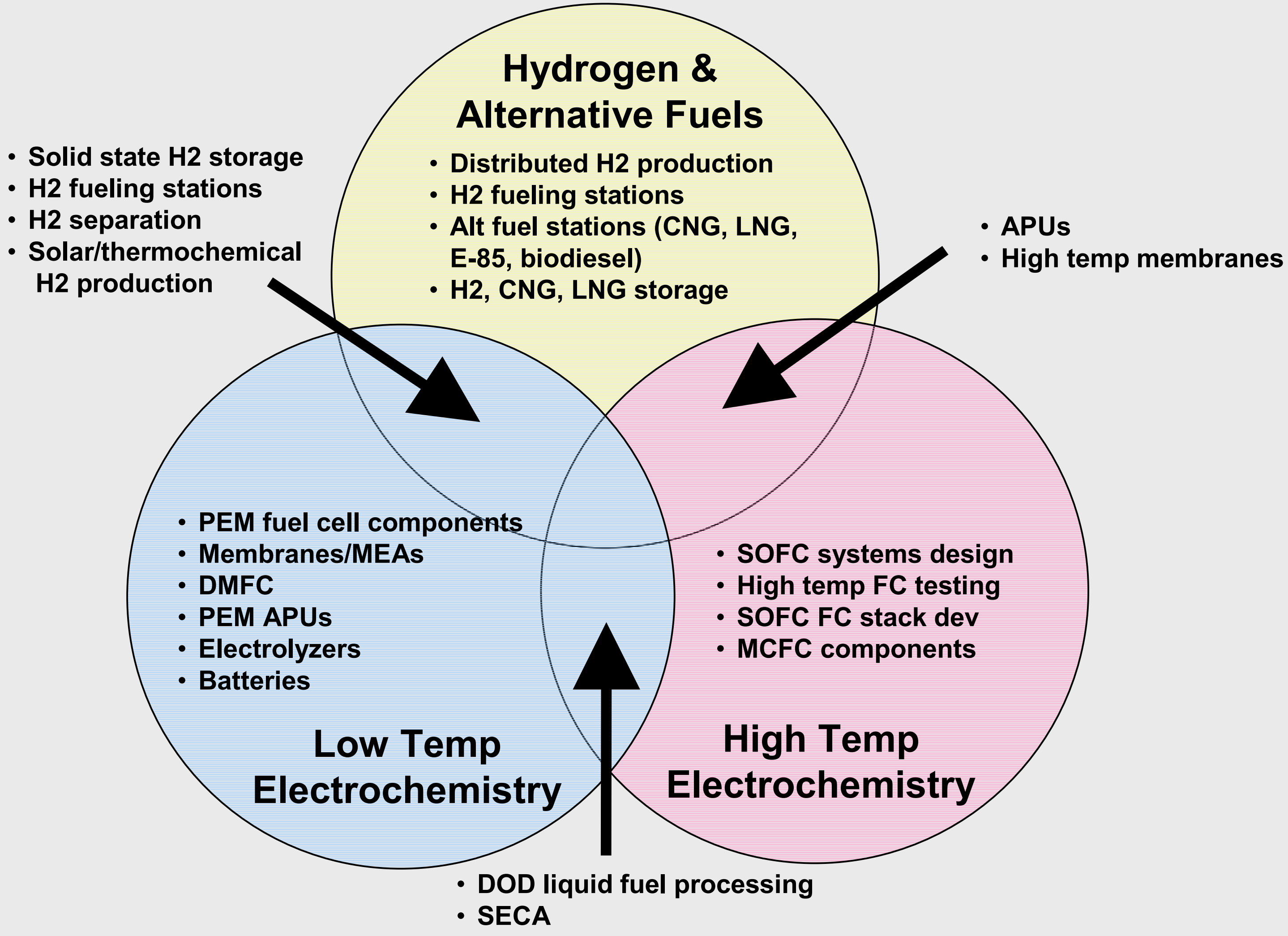
Hydrogen Energy Systems: Areas of Emphasis



Future Concerns and Hydrogen's Potential Role in U.S. Energy Portfolio

- Economic
  - Oil prices will eventually rise as conventional supplies diminish
  - Fuel cell economics will eventually compete with conventional propulsion technologies
- Energy security
  - 97 percent of fuels consumed in transportation are derived from crude oil in U.S.
  - >10 Million barrels per day of crude oil are imported
- Environmental
  - Transportation produces one third of anthropogenic greenhouse gases in U.S.

→ *Bush Administration's five-year, $1.7 billion FreedomCAR and FreedomFUEL Initiatives*

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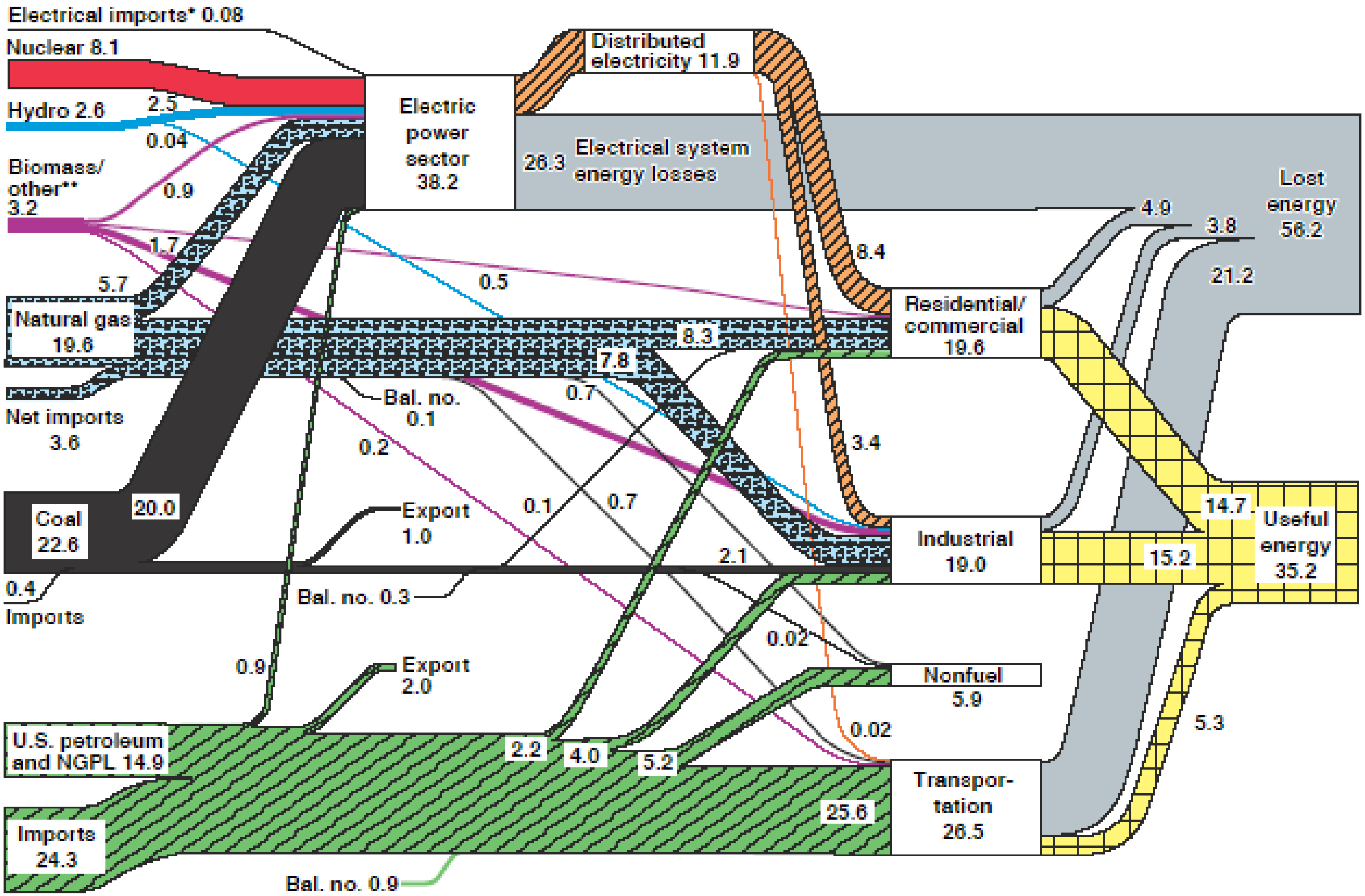
U.S. Energy Flow Trends – 2002
Net Primary Resource Consumption ~97 Quads



Source: Production and end-use data from Energy Information Administration, *Annual Energy Review 2002*.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.

June 2004
Lawrence Livermore
National Laboratory
http://eed.llnl.gov/flow

Why the Study?

- Premise:
  - The evolution of hydrogen energy systems could present new market opportunities and a hedging strategy for NG industry
  - Current analyses are flawed and lack NG industry input
- Objective: Identify business opportunities and valuation of strategic options for the NG industry as H2 energy systems evolve as a vehicle to encourage a strategic perspective regarding hydrogen and to encourage their engagement in policy development
- Methodology: Modified real options analysis – overlay of exploratory modeling (scenarios and economics) on real options lattice
- Focus: Stationary fuel cells in CHP applications; fueling stations

Why Real Options?

- Traditional analytic approaches insufficient for NG investment decisions
  - Focus on Chicken-and-Egg impasse for hydrogen infrastructure and end-use applications
  - Traditional "Big Bang" approach is dominant
    - Assumes that the only new application for hydrogen is in automotive sector
    - Assumes that consumers require "gasoline-like" convenience for refueling
    - Pilot-phase of government fleets, followed by well-timed, very steep ramp-up of infrastructure
  - Thus, enormous cost must be borne by society for years as underutilized infrastructure is built in expectation of emerging automotive applications
    - Has relegated hydrogen infrastructure debate to deep long-term possibility
    - NG and electric industry input has been insufficient

Recent Modeling Efforts

- "Well-to-wheels" studies of vehicle and fuel combinations
  - Useful for eliminating certain classes of technologies from consideration
- Global climate models with H2
  - Very different H2 results in scenarios may be useful
- Spatial Analysis of hydrogen distribution and refueling stations
  - Spatial visualization tools are a necessary step
  - However, focus on optimizing a low-cost infrastructure still relies on engineering approach, rather than economic incentives

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However, Recent Shift in Focus to Stationary Applications of Hydrogen

- National Academies Study (2004)
  - "The DOE has not developed a hydrogen RD&D strategy that systematically incorporates both the stationary and transportation sectors"
- Joseph Romm (Author of *The Hype About Hydrogen*)
  - Solid oxide fuel cell (SOFC) is best entry pathway
- H2 Highways Initiatives (California and Illinois)
  - Public-private partnerships that leverage heterogeneous local uses before transportation applications are mature
- Kammen and Lippman (UC Berkeley)
  - Stationary and mobile fuel cells offer potential benefits (lower spinning reserve, avoided T&D) to electric utilities

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Literature Conclusions

- Stationary fuel cell applications may emerge sooner than in transportation sector
- However, a definitive study has not been done either on national or utility level
- Natural gas and electric utilities stand to benefit from distributed power generation technologies penetrating the energy sector
  - However, what is the link with hydrogen?
- Is there any reason to separate hydrogen production away from the point-of-use to create an infrastructure?

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Where does Natural Gas Industry Fit?

- Owns and operates widespread transmission, distribution, and storage infrastructure
- Currently, natural gas reformer technology is the most mature and economical
- Industry has significant knowledge and experience in handling compressed gases, safety issues, billing, etc.
- High barriers to entry for other competitors
- Can be price-maker, not price-taker for hydrogen, can significantly influence industry at this early stage

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Risks and Opportunities on Horizon for Natural Gas Industry

- Market
  - Natural gas price risk
    - Price of natural gas relative to alternatives (e.g., oil)
  - Consumer preferences and adoption of new technologies?
- Regulatory/government policy
  - Climate change (e.g., power vs. transportation sector)
  - Environment (e.g., emissions)
  - Energy security (may entail different set of goals)
- Technological
  - Hydrogen fuel cell, reformer, storage costs
  - Will distributed power generation make an impact?

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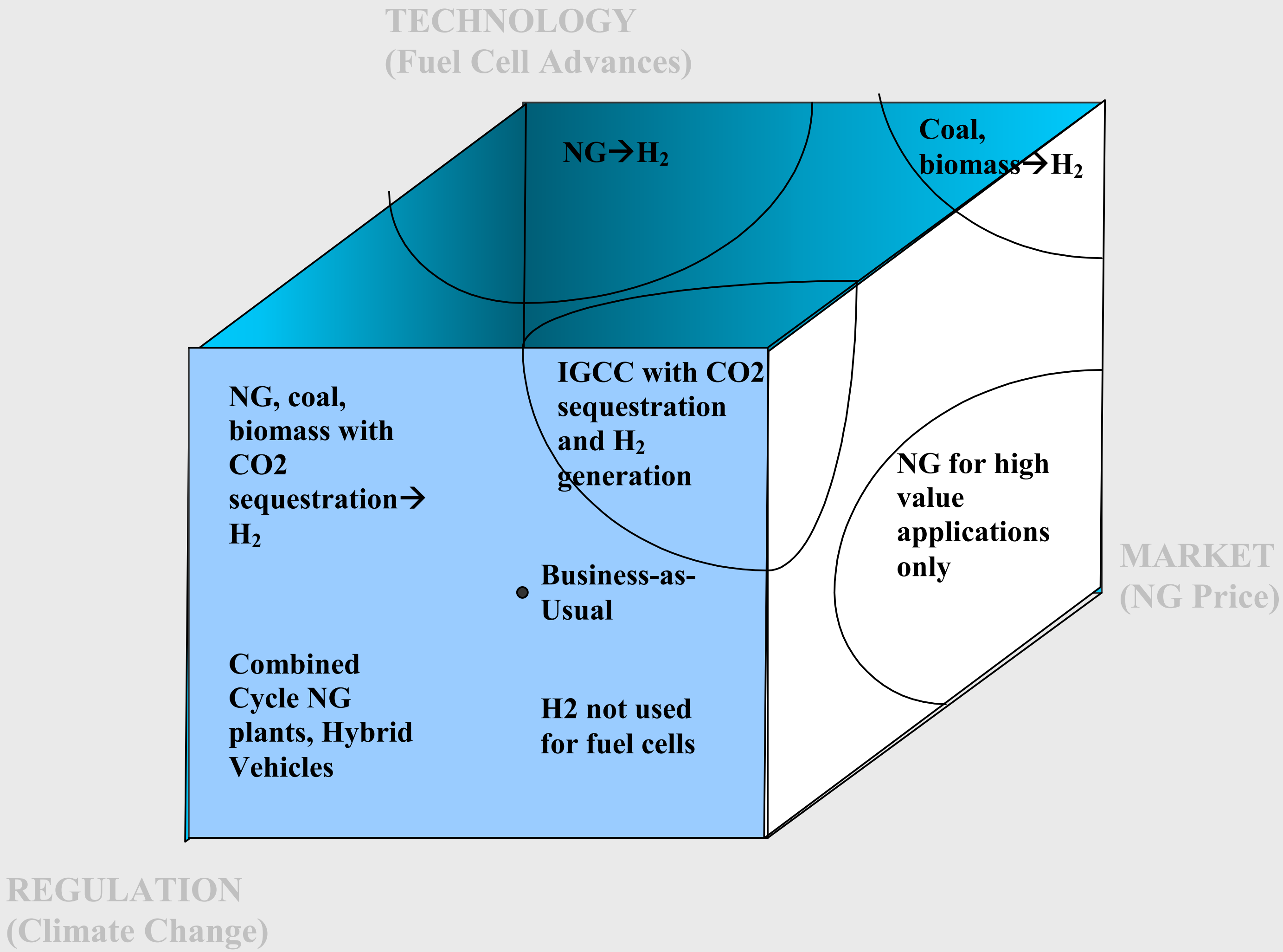
Potential Hydrogen Scenarios



Natural Gas Prices May Impact Infrastructure Plans

- NG industry plans major T&D investments
  - Mostly to keep up with demand for electric power
  - EIA estimates $40-80B needed in new NG pipelines and transmission infrastructure over next 2 decades
  - NPC forecasts $781B in capital investments through 2015 ($123B downstream, $658B upstream)
- How would a supply-side shock affect this investment scenario?
  - Stranded assets?
  - Is there a role for Hydrogen?

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Hydrogen as Insurance Against High Natural Gas Prices?

- Possibility of stranded assets?
  - T&D Investments must be planned years in advance
  - Markets fundamentals can change in shorter period of time
- Is there a role for hydrogen in hedging?
  - Creation of partial dual-use infrastructure during regular T&D investment cycle?
  - How much would it cost? Is it technically feasible? Where? How to choose?
- Is there a role for NG distribution companies to shift to being energy services providers?
  - Upstream H2 generation and distribution could eventually serve other lower-cost H2 producers

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Hydrogen for Distributed Power Generation

- The NG industry could jump-start distributed fuel cell applications
  - Microturbines and fuel cells can already be competitive, in theory, in some electricity T&D-constrained areas
  - NG industry has better access to capital than fuel cell companies and a greater interest than electric utilities
- However, electric utility industry dictates interconnection to grid and therefore DG market
  - Not all DG applications require interconnection, but it helps economics of DG significantly in most cases
  - Technologies (e.g., smart grids) may decrease interconnection costs and allow easier remote dispatch
  - Joint utilities (gas and electric), such as PG&E, may make regionally optimal investment decisions
- What is NG industry experience on customer side of meter?

A Case for a Hydrogen Distribution Network

- An H2 production and distribution network may have benefits to both industry and society at large
  - Efficiency
    - Fuel cell may potentially operate more efficiently
      - Exhaust heat could be used for productive purposes, rather than heating reformer
    - H2 can be made at more efficient scale further upstream
    - However, must be balanced against transportation costs
  - H2 distribution network allows multiple, lower-cost H2 producers to enter market
  - NG industry would own and manage infrastructure
  - Infrastructure would be poised to enter fuel cell vehicle refueling market eventually
- However, what type of coordination is needed to encourage upstream hydrogen production?
- Another idea: How to maximize value of existing infrastructure? (social planners perspective)

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Implementing a Hydrogen Network

- How does location of H2 conversion along NG industry value chain effect ability to participate in aggregate markets for technology, financing, and hydrogen services?
  - Spot, futures, derivatives market for H2?
- Is there a case for joint investment in hydrogen infrastructure and distributed power generation?
  - "Neighborhood cluster" concept
  - Critical infrastructure/homeland security applications
  - City or industry-wide load aggregation (e.g., "virtual municipalization")
  - Natural Gas and/or Electric Utility-financed DG penetration
- What should it look like?
  - National Distribution Grid? (unlikely, but perhaps long-term)
  - Micro-networks? Neighborhood hub and spoke?
  - Production at point-of-use? (i.e., no network)

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When do Traditional Methodologies Fail in Energy Policy?

- When there is radical architectural innovation
  - Direct cash flows may be insufficient
- When strategic and managerial options have value.
  - NPV calculation assumes now-or-never proposition, or that investment is reversible
- When technological choices involve different types of risk
  - WACC can lead to errors as projects vary significantly in their market-price risk

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Comparison of Valuation Techniques

> Discounted Cash Flow/NPV
  - Great first pass
  - But, subjective probabilities and discount rates are necessary
  - Assumes investment is static and/or reversible

> Decision Trees
  - Same discount rate used throughout tree even though risks change over time and branch-to-branch
  - Subjective valuation of risk added to risk-free discount rate typically

> Simulation

> Real Options Valuation

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Incorporating Timing and Uncertainty: Real Options Valuation

- What is a real option?
  - Technology that borrowed and extended from financial options theory
  - Used in pharmaceutical industry to evaluate drug R&D efforts
  - Used in the energy industry, but mostly for upstream oil and gas exploration and real-time power plant operation, rather than long-term investment strategies
- For H2 investment, enormous uncertainties in future energy commodity prices, technological development, environmental regulation, and consumer preferences
- Discounted cash flow (DCF) and traditional methods offer insufficient insight in identifying, assessing, and choosing among near-term actions that shape future options

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Financial Options

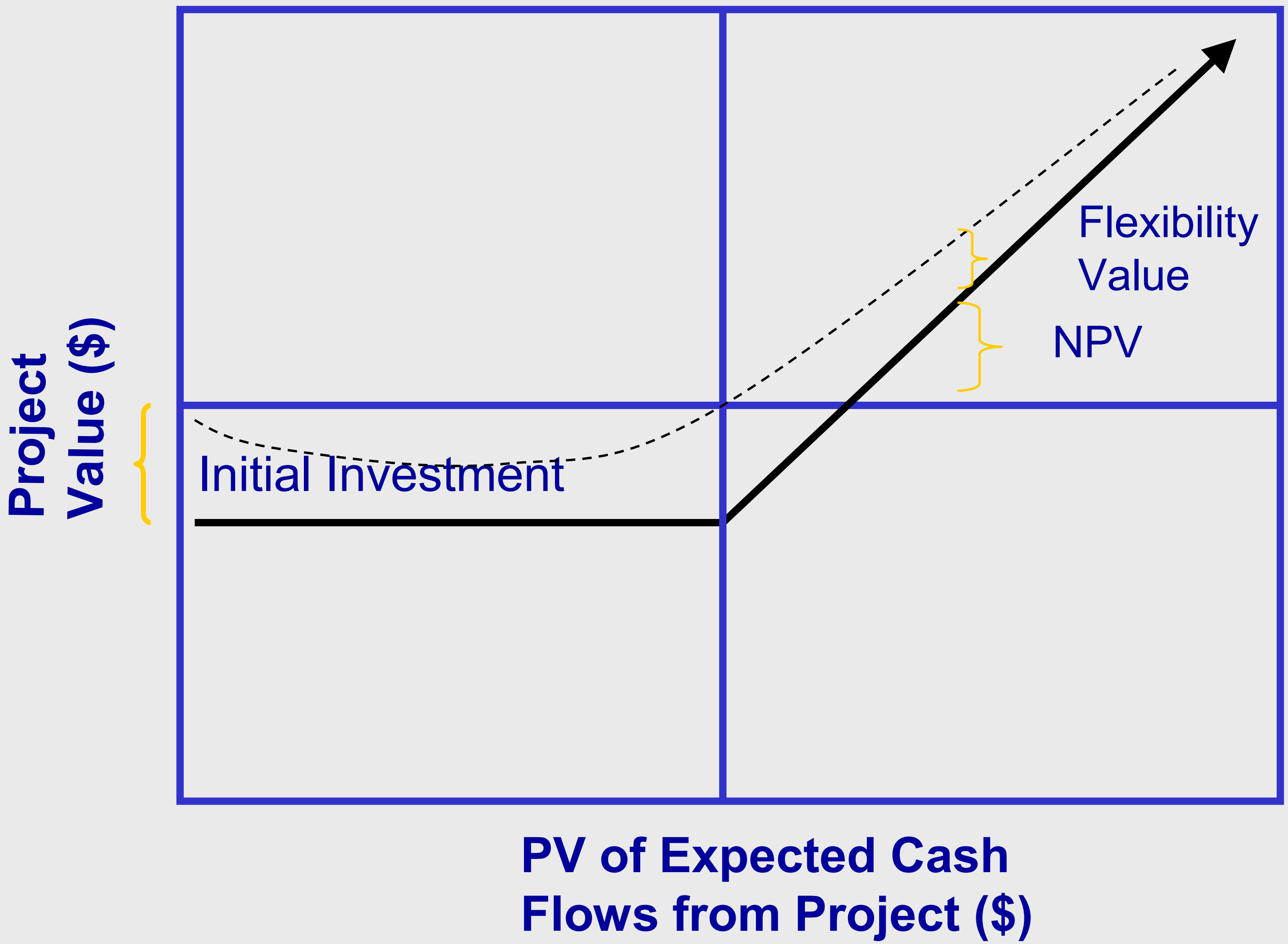
- An option is the right, but no the obligation, to buy an asset at a pre-specified price
- The option itself costs a premium
- The option can be exercised at expiration (European Option) or at any time during the contract (American Option)
- Financial options can limit downside potential without restricting upside potential (for a cost)

Projects as Call Options

> Opportunity to invest in a corporate project bears similarities to a financial option

Project	Call Option
Expenditure to Acquire Assets	Exercise Price
Value of the operating assets	Stock Price
Length of time decision may be deferred	Time to expiration
Riskiness of the underlying assets	Variance of stock returns
Time value of money	Risk-free rate

Value of a Real Option



Solving a Real Options Problem

- Practitioners typically use discrete time models (e.g., binomial model) rather than continuous (e.g., Black-Scholes)
  - With real options, early exercise is rule rather than exception
  - Underlying asset values are often discontinuous
  - Reduces mathematical complexity and increases transparency
- A binomial tree with outcomes at each node looks very similar to a decision tree
- However, the two approaches yield different estimates

Implications of a Real Options Approach

> Riskier investments will appear more valuable

> However, more projects will be abandoned during their investment cycle

> More importantly, project selection rankings can change

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Decision Trees and Real Options

- Decision trees and real options are closely related
- Tree represents all possible situations and the decisions that management can make in response
  - However, a decision tree calculated expected cash flows based on objective probability and then discounts by some rate
- Option valuation differs by calculating values in accordance with “no arbitrage principle”
  - Two different investment opportunities that produce same payoffs must be worth the same amount
  - In practice, this is equivalent to modifying the discount rate to reflect the actual riskiness in cash flows throughout the decision tree.
  - Call option is leveraged position and should be riskier than the asset
  - Fundamental question: when to exercise option? Can compare investment value ($Asset Value – $Investment Cost) versus option value (Replicating Portfolio Technique)

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Draft Real Options Cases for Analysis and Valuation

- Strategic growth and market power options in new markets?
  - Fuel cell DG and eventually vehicle refueling?
  - Price maker rather than price taker
  - Natural advantage of infrastructure
  - Preempt competition and jump start technology
- Prevent loss of market to competitors?
  - Existing market loss: e.g., CNG bus fleets → H2
  - New market loss: e.g., commercial building fuel cells
- Insurance option against price risk/volatility using dual use transmission and distribution
- Creating value through staged investment and incorporating new information over time
  - Climate, market, technological signals
  - Waiting, Growth, Exit strategies for upstream markets

Modeling Approach

- Customize to three geographic regions for case studies
  - H2 networks would be regional/local
  - So Cal Gas, NiSource, Keystone
- Real Options valuation
  - Identify relevant investments/options and stages
  - Identify variables and price formation process through the development of several scenarios
- Exploratory modeling and robust solutions
  - Explore parameter space (and structural form)
  - Goal is to find solutions that are robust against alternative world views
  - Rules of thumb, rather than optimal values, as output

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Likely Utility Input Requirements

> Current state of strategic plans as they relate to emerging energy technology and hydrogen (if any)

> Sufficient data to model service territory customer demand (customers, demand profiles, customer segments, etc.)

> Data to model distribution network and future capacity additions (if any)

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Kick off Meeting

- Proceeded with a set of questions to utility participants regarding system supply, demand, and infrastructure characteristics
- By end of meeting:
  - Consensus on approach
  - Consensus on scenarios
  - Clear requirements for initial data
  - Clear points of contact at each utility for follow up

Milestones

- Kick off meeting for all participants held in October in Chicago
  - Review overall work plan
  - Agree on scenarios to be evaluated
  - Determine input requirements
- Model completion and analysis phase – 6 months
  - Iterate early results with utility participants
  - Complete first draft of full report for review by select committee
  - Provide vetted draft to DOE for review and comment
- Finalize report and publicize
  - Agree on final report
  - Develop strategy with DOE to meet with other interested utilities