Economic, Environmental and Financial Analyses of Small-Scale Distributed Hydrogen Generation Alternatives

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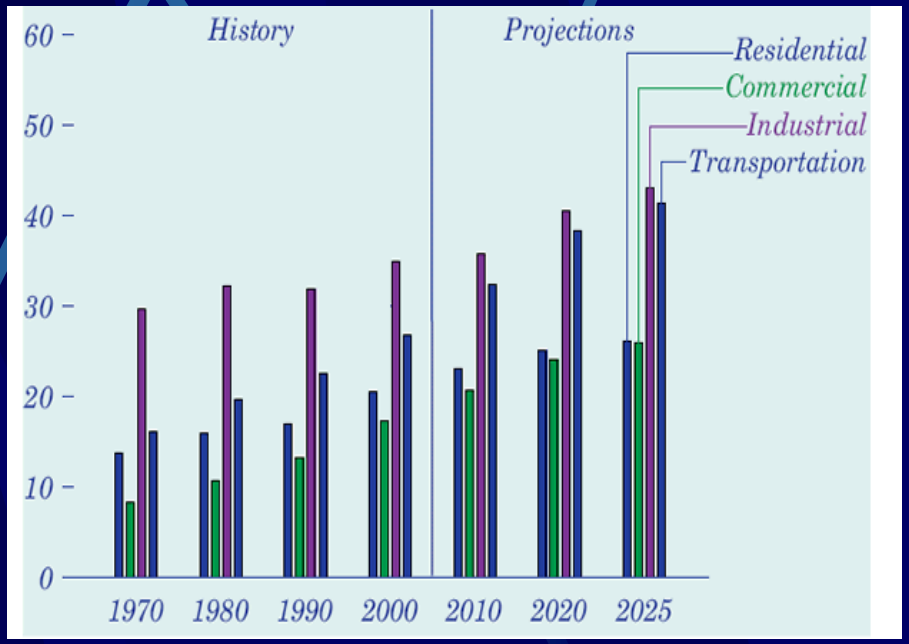
2004

Background (1/5)

- Urgent need to find a way to keep supplying energy to our homes and automobiles without jeopardizing our health and natural resources
- The most promising solution? Hydrogen: clean, efficient, and can be obtained from several sources



Primary Energy Consumption by Sector in quads
(Source: Energy Information Administration)

Background (2/5)

- Recent heavy investment in hydrogen technology by government, automobile manufacturers, petrochemical companies and others
- Hydrogen fueled vehicles being tested
- What is available now?
  - ❑Fuel cells for residential and light domestic applications
  - ❑Back-up power systems
  - ❑Other applications

GenSys stationary fuel cell
(Source: Plugpower Fuel Cell Systsms)

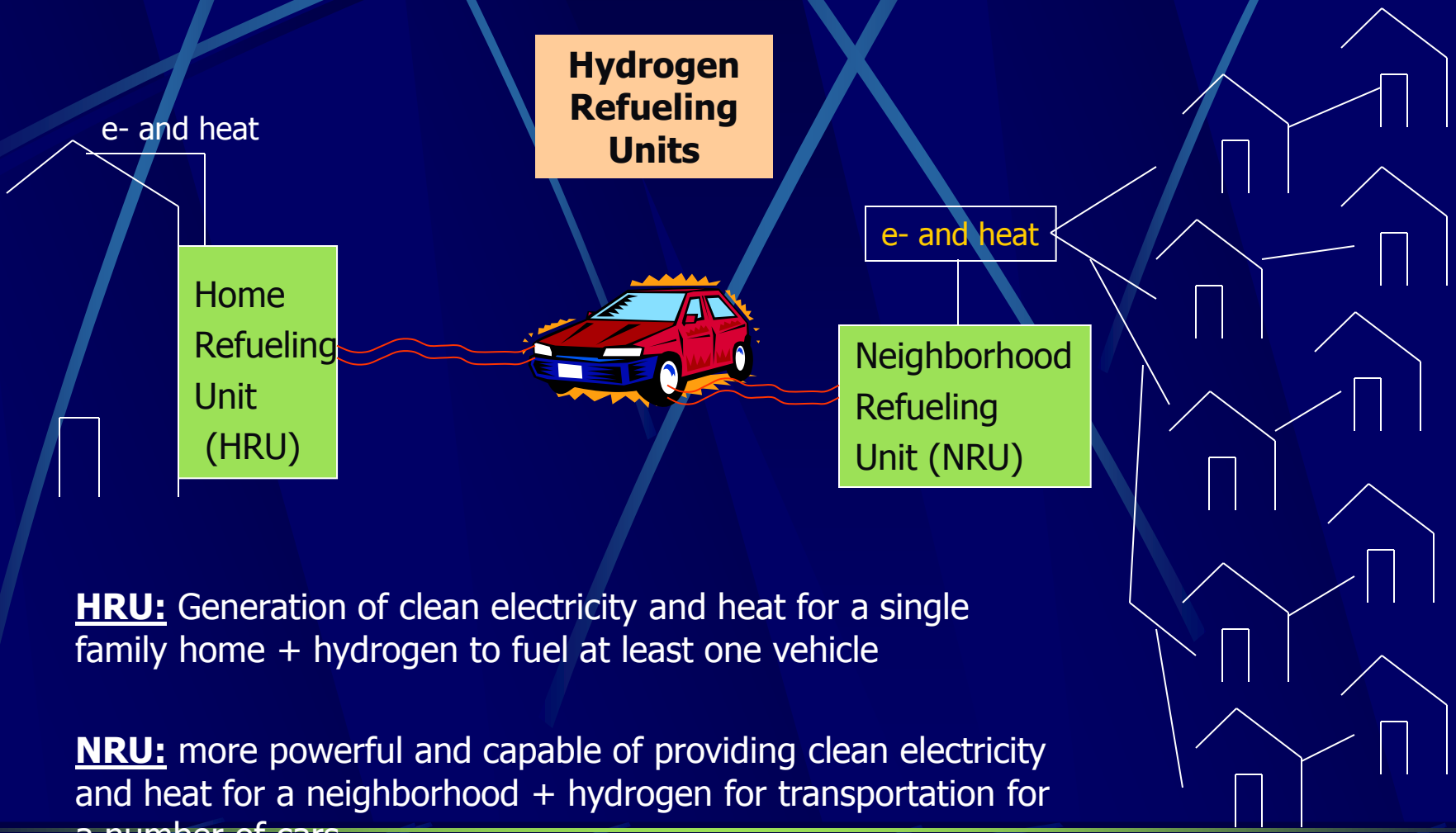
Background (3/5)

Home Energy Station Prototype

Solar powered water electrolyzing hydrogen station

Cogeneration station to meet the electricity, heating, and hot water needs of typical Japanese homes

Background (4/5)



HRU: Generation of clean electricity and heat for a single family home + hydrogen to fuel at least one vehicle

NRU: more powerful and capable of providing clean electricity and heat for a neighborhood + hydrogen for transportation for a number of cars

Background (5/5)

A Hydrogen Refueling Unit consists of:

- ✓ Power source: renewable / non-renewable
- ✓ Fuel processor: reforming / electrolysis
- ✓ Fuel cell stack: PEMFC / SOFC, etc.
- ✓ Air management system
- ✓ Water and thermal management system
- ✓ Storage system
- ✓ Ancillary components

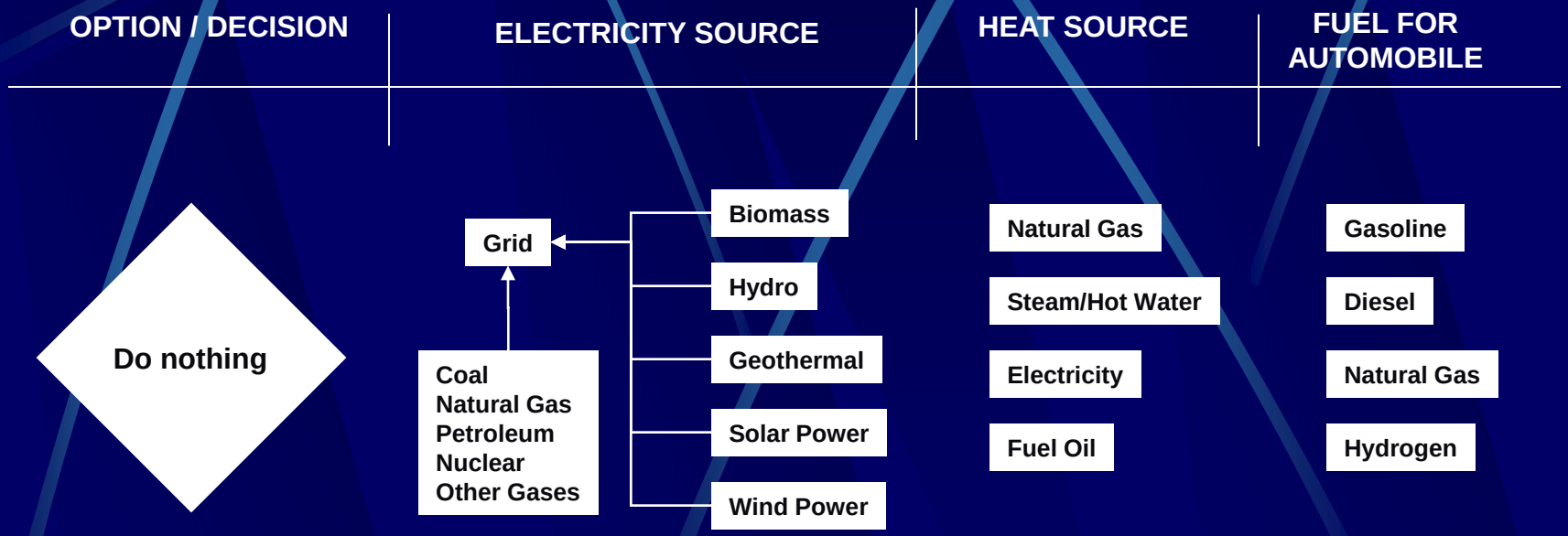
Problem Statement

- National Academy of Engineering (2004): "…in the committee's vision of a possible hydrogen future, the demand for hydrogen will likely be met using distributed production during the first couple of decades of transition."
- Chicken and egg problem:
  - Develop hydrogen demand facilities to pull demand?
  - Develop hydrogen infrastructure to encourage use?

Solution: Analysis of Small Scale Generation

- Start at small scale: residential units and distributed generation
- Engineering/economic analyses of three energy production alternatives:
  - Conventional (baseline)
  - Home Refueling Units
  - Neighborhood/Community Refueling Units

Alternative 1: Conventional Sources



OPTION ONE: CONVENTIONAL SOURCES OF ENERGY

FINANCIAL ANALYSIS

	2004	...	2024
ELECTRICITY:			
One tiem set-up fee	$ 20.00	$ -	$ -
Electricity cost	$ 1,200.00	$ 1,312.00	$ 1,338.00
TOTAL ELECTRICITY COST	*$ 1,220.00*	*$ 1,312.00*	*$ 1,338.00*
HEAT:			
Equipment cost	$ 2,000.00	$ -	$ -
Installation cost	$ 30.00	$ -	$ -
Operation and Maintenance	$ 66.00	$ 100.00	$ 150.00
Fuel cost	$ 850.00	$ 900.00	$ 960.00
TOTAL HEAT COST	*$ 2,946.00*	*$ 1,000.00*	*$ 1,110.00*
AUTOMOBILE FUEL:			
Cost of fuel	$ 720.00	$ 720.00	$ 720.00
TOTAL FUEL COST	*$ 720.00*	*$ 720.00*	*$ 720.00*
TOTAL	$ 4,166.00	$ 2,312.00	$ 2,448.00

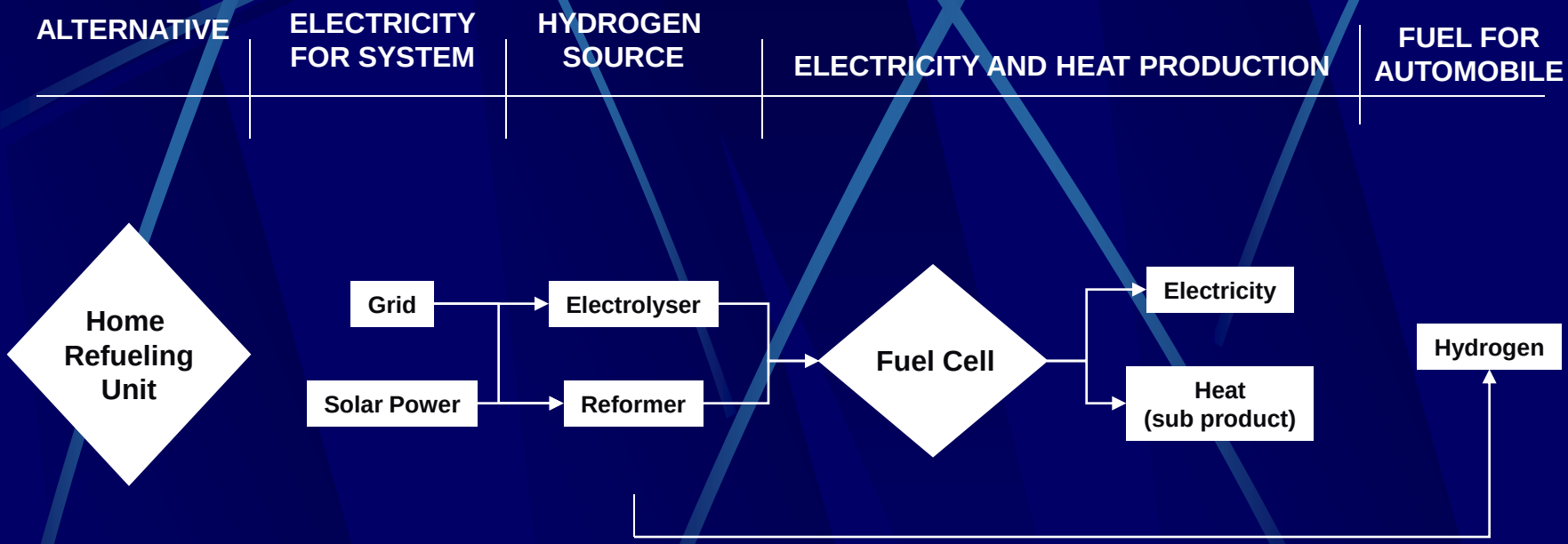
<---------NPV = $21,000 @ i= 6% and t=20 years

ECONOMIC ANALYSIS	
FINANCIAL ANALYSIS	$ 21,000.00
+ ENVIRONMENTAL ANALYSIS	$ 62,100.00
TOTAL NET PRESENT VALUE	$ 83,100.00

ENVIRONMENTAL ANALYSIS

EMISSIONS (tons)				COST TO SOCIETY (price paid for externalities)	
	2004	...	2024		
From residential power generation:					
SO2	0.75	0.85	0.65	$ 7,500.00	
NOX	0.9	1	0.8	$ 9,000.00	
CO2	1.2	1.3	1.1	$ 12,000.00	
From transportation:					
CH4	0.3	0.4	0.2	$ 3,000.00	
N20	0.11	0.21	0.01	$ 1,100.00	
CO	0.45	0.55	0.35	$ 4,500.00	
CO2	1.2	1.3	1.1	$ 12,000.00	
H20	1.3	1.4	1.2	$ 13,000.00	
				$ 62,100.00	<--- NPV = $62,100 @ i=6% and t=20 years

Alternative 2: Home Refueling Units



OPTION TWO: HOME REFUELING UNITS

FINANCIAL ANALYSIS

	2004	...	2024
Equipment cost	$ 6,500.00	$ -	$ -
Installation cost	$ 600.00	$ -	$ -
O&M ($/year)	*$ 200.00*	*$ 150.00*	*$ 100.00*
Fuel cost	$ 1,500.00	$ 1,600.00	$ 1,700.00
- Tax incentives	$ (500.00)	$ (100.00)	$ (75.00)
TOTAL	$ 8,300.00	$ 1,650.00	$ 1,725.00

<---------NPV = $45,000 @ i= 6% and t=20 years

ECONOMIC ANALYSIS

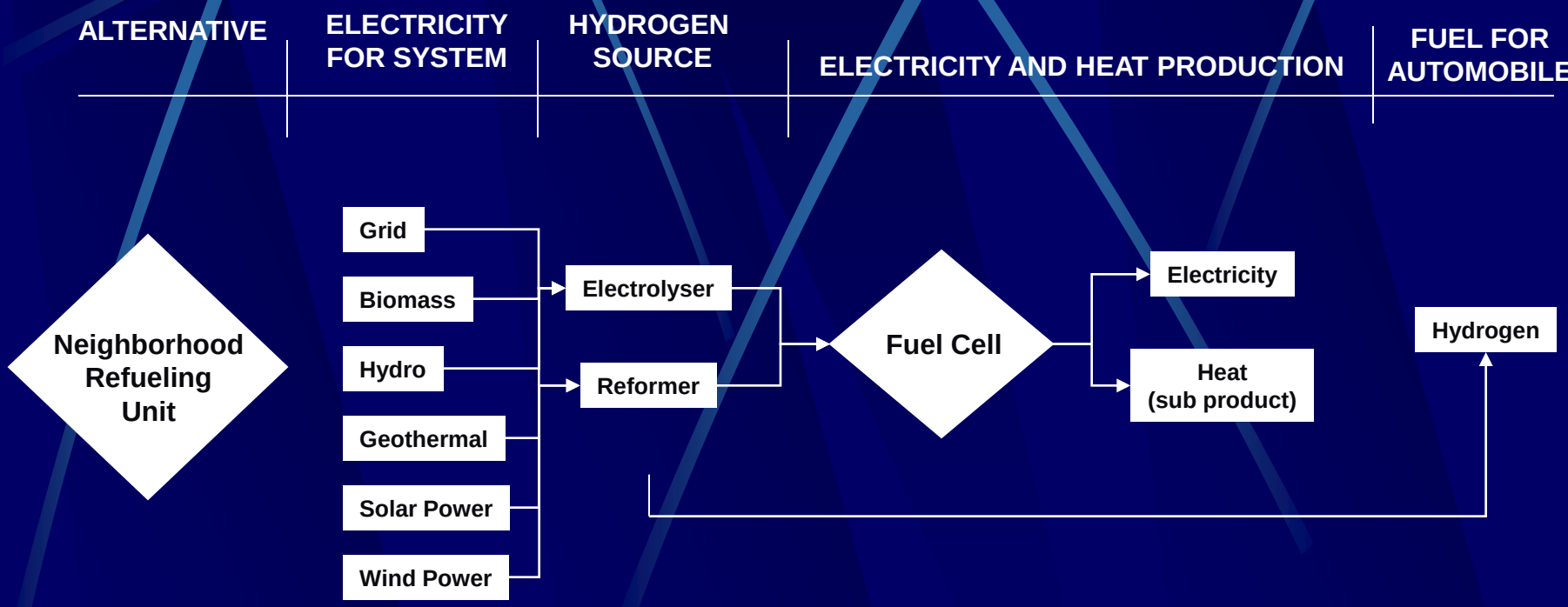
FINANCIAL ANALYSIS	$ 45,000.00
+ ENVIRONMENTAL ANALYSIS	$ 14,000.00
TOTAL NET PRESENT VALUE	$ 59,000.00

ENVIRONMENTAL ANALYSIS

EMISSIONS (tons)				COST TO SOCIETY (price paid for externalities)
	2004	...	2024	
From hydrogen generation:				
SO2	0.01	0.02	0.005	$ 1,000.00
NOX	0.07	0.08	0.065	$ 7,000.00
CO2	0.03	0.04	0.025	$ 3,000.00
H20	0.03	0.04	0.025	$ 3,000.00
				$ 14,000.00

<--- NPV = $14,000 @ i=6% and t=20 years

Alternative 3: Community Refueling Units



OPTION THREE: NEIGHBORHOOD REFUELING UNITS FOR 200 HOUSES

FINANCIAL ANALYSIS

	2004	...	2024
Equipment cost	$ 300,000.00	$ -	$ -
Installation cost	$ 7,000.00	$ -	$ -
O&M ($/year)	*$ 3,000.00*	*$ 3,200.00*	*$ 3,500.00*
Fuel cost	$ 100,000.00	$ 110,000.00	$ 110,000.00
- Tax incentives	$ 30,000.00	$ (100.00)	$ (75.00)
TOTAL	$ 440,000.00	$ 113,100.00	$ 113,425.00

<----------NPV = $4,500,000 @ i= 6% and t=20 years

PER HOUSE = $ 22,500.00

ECONOMIC ANALYSIS (PER HOUSE)

FINANCIAL ANALYSIS	$ 22,500.00
+ ENVIRONMENTAL ANALYSIS	$ 12,400.00
TOTAL NET PRESENT VALUE	$ 34,900.00

ENVIRONMENTAL ANALYSIS

EMISSIONS (tons)

	2004	...	2024
From hydrogen generation:			
SO2	1.2	3.2	0.2
NOX	13.2	15.2	12.2
CO2	5.2	7.2	4.2
H20	5.2	7.2	4.2

COST TO SOCIETY (price paid for externalities)

SO2	$ 120,000.00
NOX	$ 1,320,000.00
CO2	$ 520,000.00
H20	$ 520,000.00
	$ 2,480,000.00

<--- NPV = $14,000 @ i=6% and t=20 years

PER HOUSE= $12,400.00

Comparing the Results

NET PRESENT VALUES:	FINANCIAL ANALYSIS	ENVIRONMENTAL ANALYSIS	ECONOMIC ANALYSIS
OPTION ONE: CONVENTIONAL SOURCES	$21,000.00	$ 62,100.00	$ 83,100.00
OPTION TWO: HOME REFUELING	$45,000.00	$ 14,000.00	$ 59,000.00
OPTION THREE: NEIGHBORHOOD REFUELING	$22,500.00	$ 12,400.00	$ 34,900.00

Offer $1500 in tax credits?

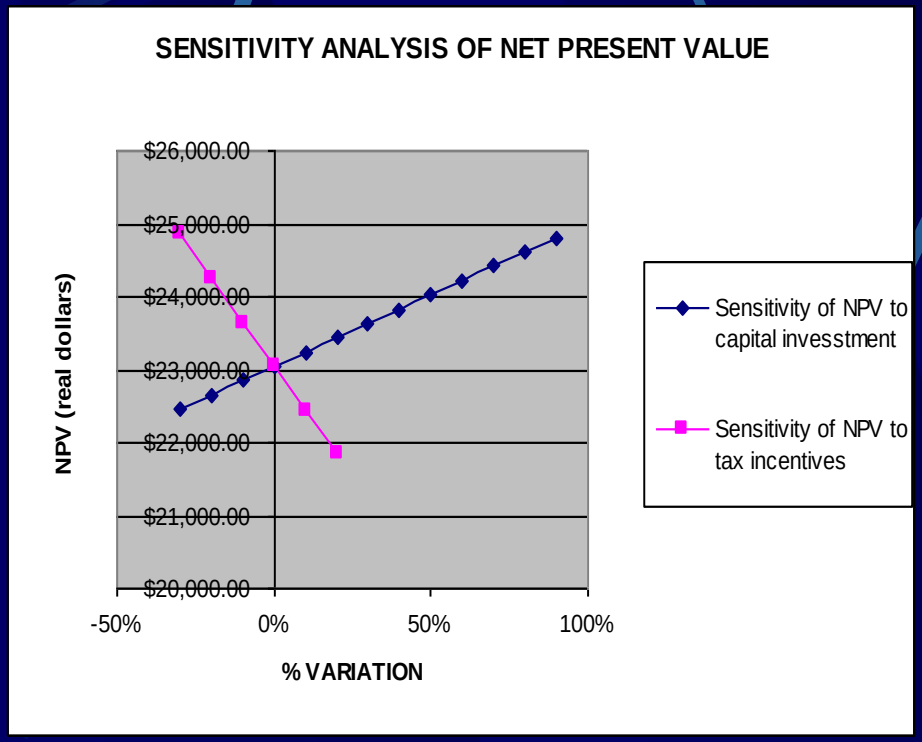
This is what the developer pays

How can we make options two and three more attractive for the developer?

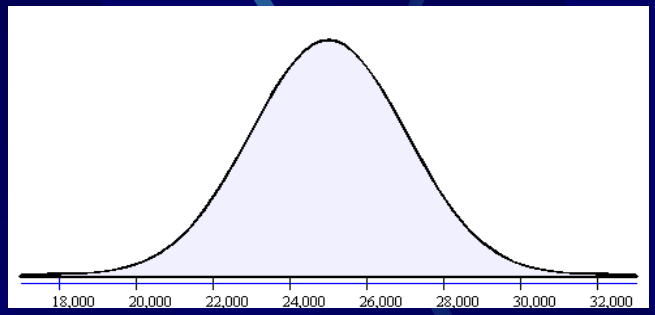
Economic incentives: tax credits, subsidies…

Sensitivity Analysis

Model the uncertainty of the critical variables

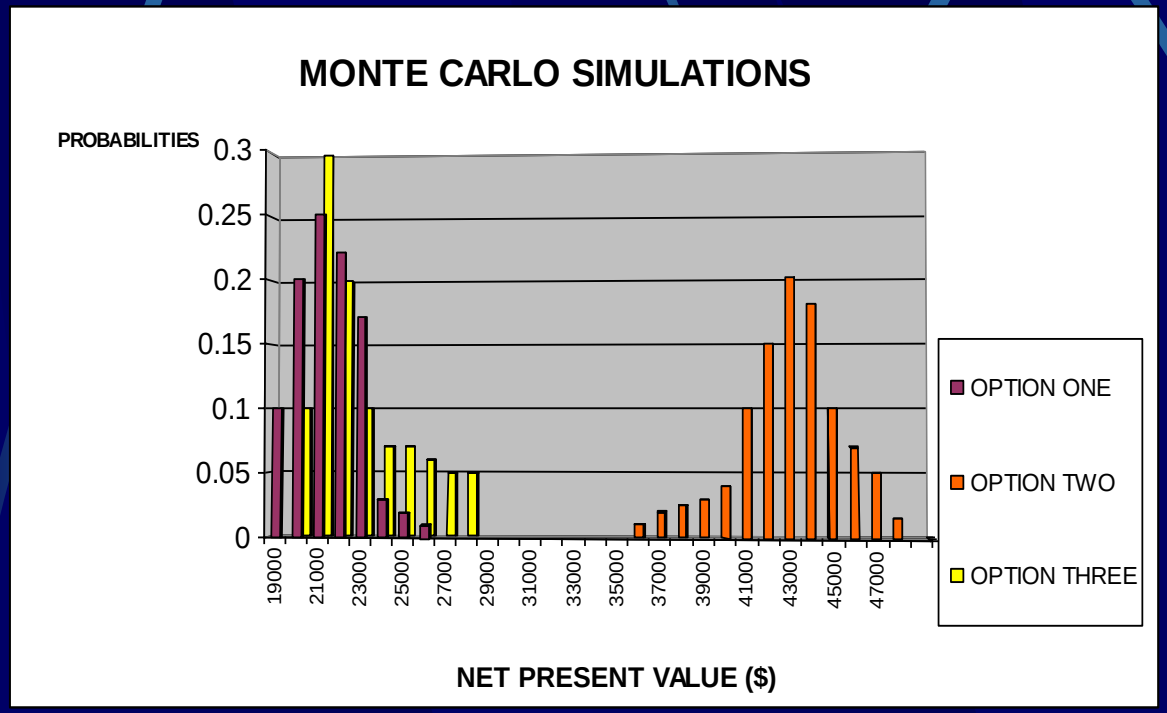


Capital Investment



Tax Incentives

Comparison of NPVs Using Simulation



Calculate multiple scenarios by repeatedly sampling values from the probability distributions

Value of the research

- To government: Will provide a solid basis for recommending financial schemes that encourage the utilization of cleaner technologies
- To automobile manufacturers: Will enable forecasting and evaluation of the financial viability of interconnections between hydrogen production and end use
- To developers: Will enable comparisons of present and projected net worth and financial parameters
- To all users: Will allow projections to be easily modified and refined in a user friendly way as new information becomes available

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