To Buy or Not to Buy?

Off-Grid Project Final Recommendations

Engineering 333

Calvin College Engineering Dept. Seminar

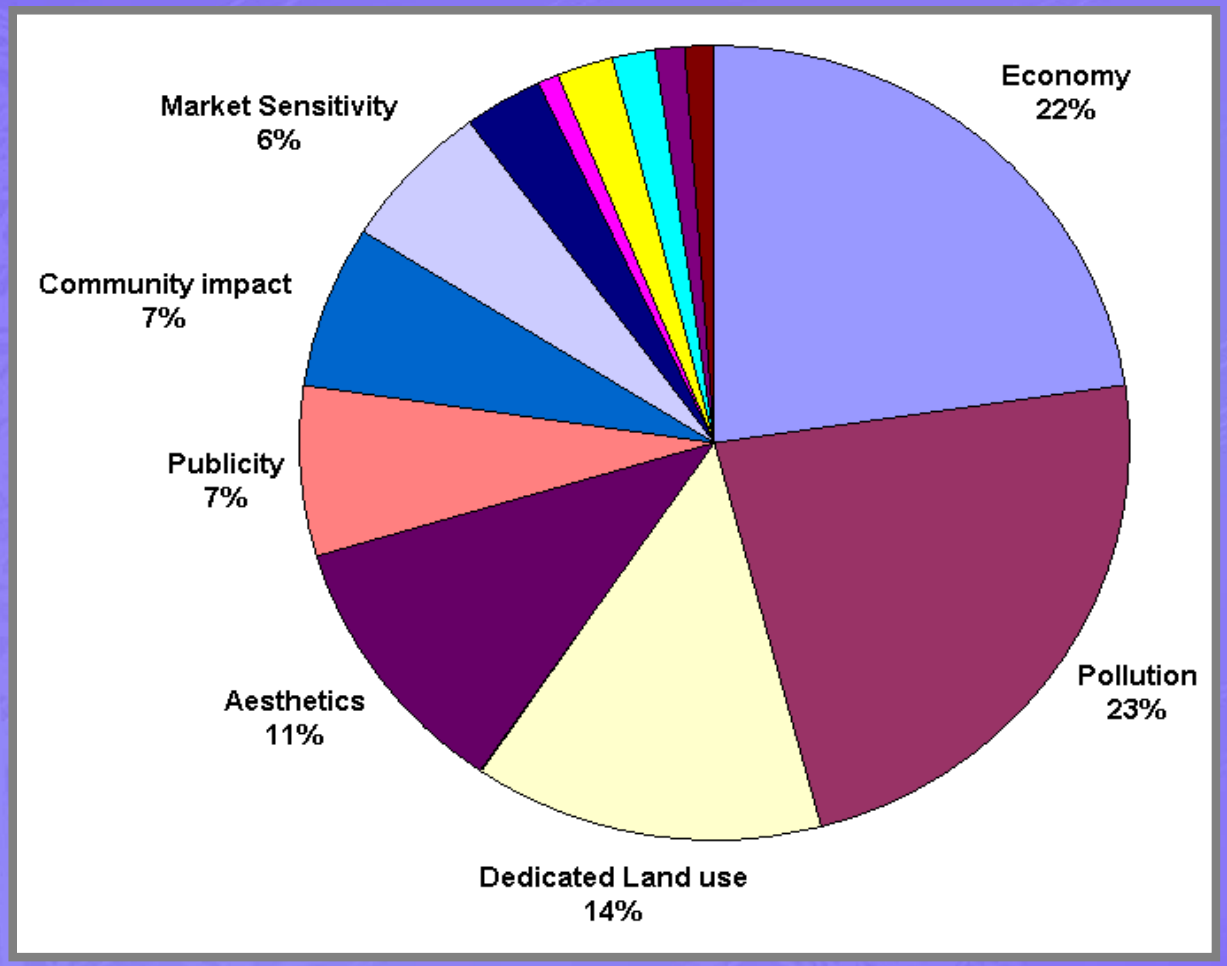
December 3, 2004

Advantages of Electrical Independence at Calvin

- Lower Electricity Cost
- Unaffected by Interruptions in Grid
- Opportunity to Generate Cleaner Energy
- Educational Opportunity
- Cutting-edge

Other Factors At Calvin

- Cost
- Pollution
- Land Use
- Aesthetics
- Community Impact
- Etc….



Context : Generation Options : Cogeneration : Wind Power : Energy Saving

What We've Done – In a Nutshell

- Current State of Energy Industry
- What about fuel cells and solar power?
- Cogeneration – What is it and can we use it?
- Wind at Calvin? Really?
- What can we do to reduce our usage?

Context : Generation Options : Cogeneration : Wind Power : Energy Saving

Current Natural Gas Prices Reflect a Bi-Layering Causation

Crude oil prices + Scarcity Premium

- Base level of natural gas prices determined by world crude oil price levels
- Scarcity premium reflects north American supply constraints

* This slide taken from *Natural Gas Price Instability: An Analysis of its Causes, Evolution, and Context within National and Global Energy Markets* by Robert Ozar.

Causes of Capital Flight From the U.S. By Majors

- Unattractive returns from mature and aging natural gas fields
- Have capital and technology to explore and develop untapped U.S. frontier areas:
  - blocked by environmental drilling moratoriums
- Concentrating on international frontier fields in low tax-rate areas (Kazakhstan, Nigeria, Angola, and Chad), Value Line 6/18/04 Chevron-Texaco

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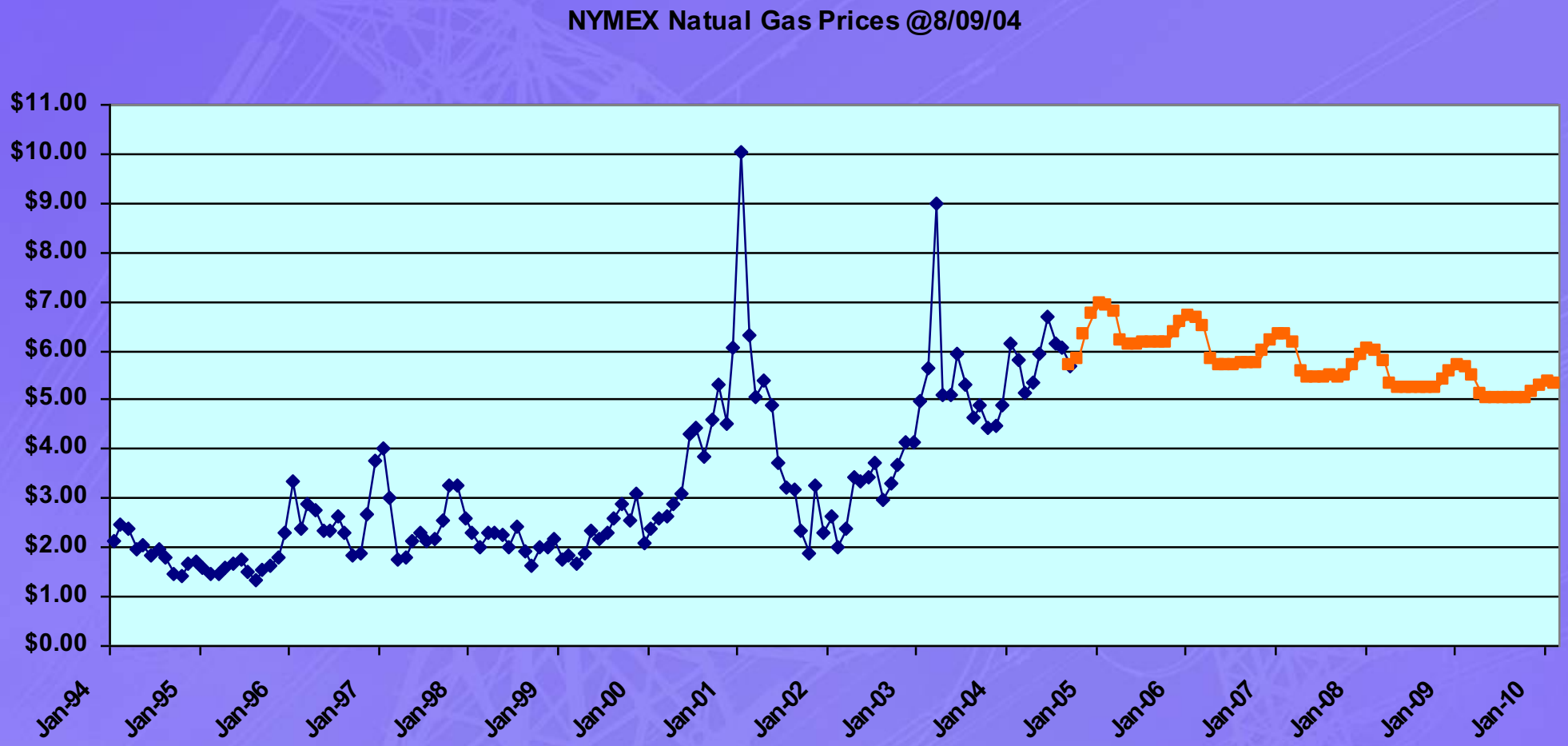
Price Volatility Masks the Nature of the Turbulent Transition Taking Place in U.S Natural Gas Markets



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Electricity Pricing

- Consumers Energy
  - Electricity Production:
    - 66.8% Coal/Oil
    - 6.6% Natural Gas
    - 11.9% Nuclear
  - Conclusion:
    - Overall electricity prices do not correlate with fluctuations in any particular market.
- Demand Rate
  - Purchased Power Surcharge
  - .0775 $/kW-h over past 5 years
  - .0814 $/kW-h this year
  - Reason: Fuel costs = “automatic pass through”

Electricity Pricing

- Rate Increases
  - Rate case in 2005 = rate increase in 2006.
  - Rate increase due to:
    - Increased emissions standards.
    - Increased cost of business operation.
    - Even distribution of electricity cost.
- Conclusion: Electricity prices are increasing, but at a constant unpredictable rate.
- Assumption for calculations: flat rate.

Solar P-V

- Utilizes energy from sun and converts it to electrical energy
  - 2 types:
    - Amorphous
      - Easy to install – adhesive
      - Capable of generating electricity at low light levels
      - Can be waked on
    - Crystalline
      - Generates more power per square foot
      - Must be mounted on a frame
  - Type used depends largely on installation location

Solar P-V Group Recommendation

- 75 kW system
  - –Sized to power the outdoor lighting system
- System doesn't actually power the lights directly
  - –Does peak shaving during daylight hours
- Recommended installation locations include:
  - –New Health and Wellness Center
  - –New Knollcrest Dining Hall
  - –Hekman Library
  - –North Hall

Solar P-V Group Recommendation

- Total Cost: **$1.45 million**
  - $1 million initial cost
  - $60,000 grant
  - 7 year loan @ 12%
- Total Savings: **$717,000 after 30 years**
  - this is how much Calvin would have spent on grid electricity without the PV cells
- To break even after 30 years, need electricity price to average twice what it is now
- Conclusion: NOT economically feasible

Solar P-V

- Non- Economic Advantages
  - Noise- quietest form of energy generation
  - Pollution free
  - Price stability
  - Long life- 20 year warranty, 30+ year life
  - Educational
  - Good public relations
- In the next 10 years, solar PV costs should come down

Fuel Cells

- Fuel Cells turn natural gas into electricity
- Fuel Cells convert hydrogen and oxygen into water, and in the process produce electricity
- Fuel cells are a relatively new way of generating electricity

Fuel Cells

Best Case Scenario (Fuel Cost = $ 7.00)	
Size	3 MW
Initial Cost	$12,000,000.00
Installation	$750,000.00
Annualized Initial Costs	$ 1 582 831.00 per year
Maintenance	$ 390 000.00 per year
Yearly “Savings”	$ -2,132,394.00 per year

Fuel Cells

- Advantages
  - Highly efficient and reliable – reduce waste
  - Quiet and produce constant voltage output
  - Much less pollution

- Disadvantages
  - They are very expensive
    * Costs are expected to reduce significantly (~50%) as their installed volume increases
  - Fuel source is natural gas

What is Co-gen?

- Cogeneration is a means of producing power in the form of electricity and heat. It is "the simultaneous production of heat and power in a single thermodynamic process. Almost all cogeneration utilizes hot air and steam for the process fluid."[1]

- Kinds of cogeneration systems:
  - Reciprocating engines
  - Microturbine (25-500 kW)
  - Combustion Turbine (500 kW-25 MW)
  - Stirling Engines
  - Fuel cells

1- http://www.energy.rochester.edu/cogen/

Cogeneration Systems

- Fuels used for cogeneration[1]:
  - Natural gas
  - Clean Oil
  - Coal
  - Biomass
  - Solar Concentrators
  - Hydrogen

1- http://uschpa.admgt.com/techapps.htm

Calvin's Cogeneration System

- 600 kW system.
- Reciprocating engine.
- Installed in 1990.
- Time to break even was 2.5 years.
- At time of installation gas prices were significantly less (~ $3.00/Mcf).
- Up front costs subsidized by gas company.
- Steam piped through campus for heating. Excess steam used to melt snow on sidewalks.

Other Factors Affecting Profitability

- Cost of electricity
  - Increased cost of electricity from grid makes co-gen more profitable
- Actual heating and cooling loads
  - Currently no monitoring of energy usage
  - Values used are calculated using sizes and approximate uptime of current heating and cooling systems
- Cost of capital
  - Assumed 12% for calculations but can vary

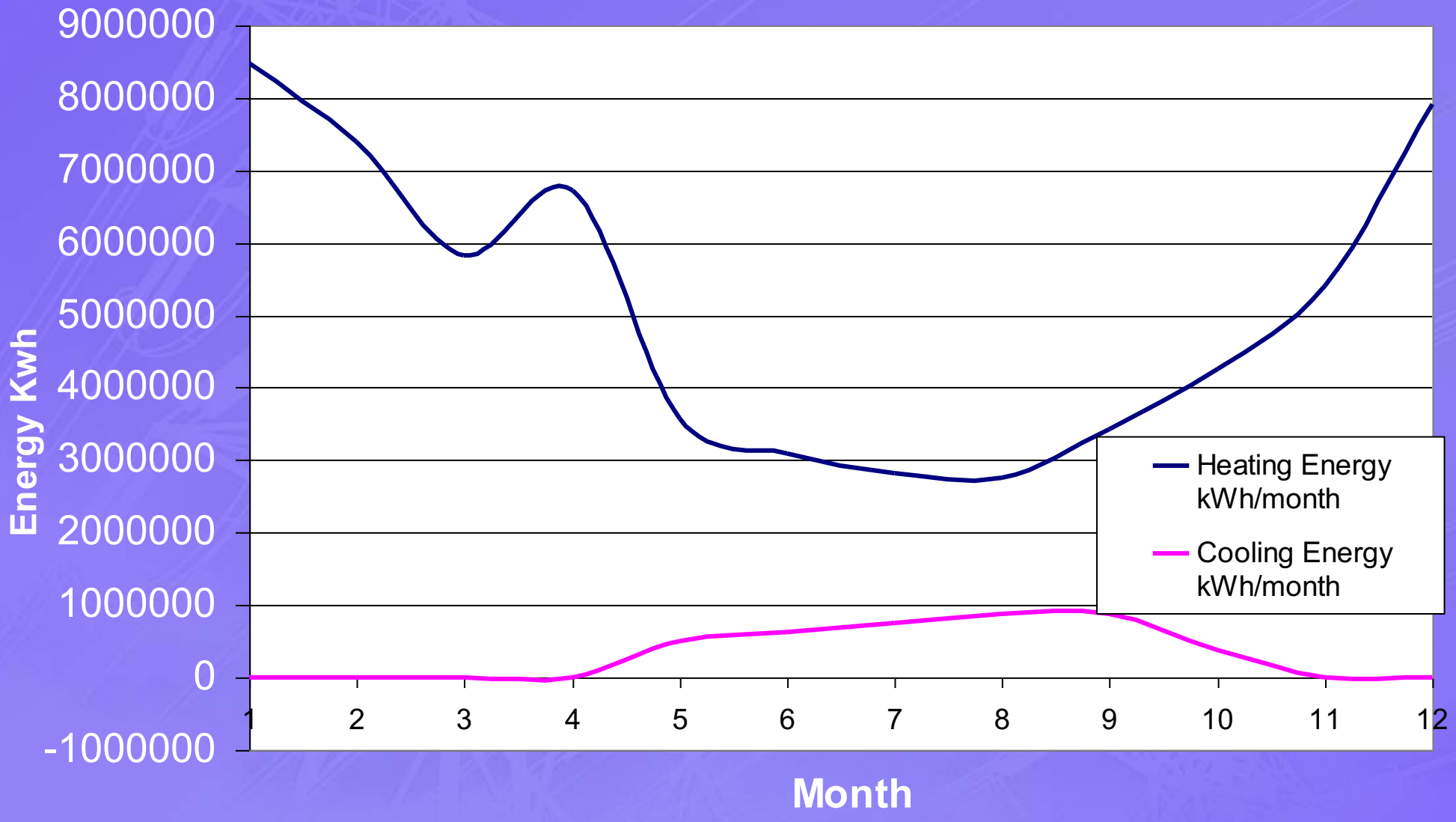
Co-gen: A Closer Look

- Outline of Cost Analysis Procedure
- Gas Turbine Economic Results
- Reciprocating Engine Economic Results
- Reasons for choosing Cogeneration systems.

Aspects Considered Within Cost Analysis

- Accurate and Conservative
- Energy usage sized on a monthly basis.
- Considered average air temperature and its effect on output energy
- Electricity cost savings -- used peak and off-peak rates
- Cost savings were based only on what can actually be utilized.

Calvin's Energy Usage per Month



Context : Generation Options : Cogeneration : Wind Power : Energy Saving

Baseline System Specifications

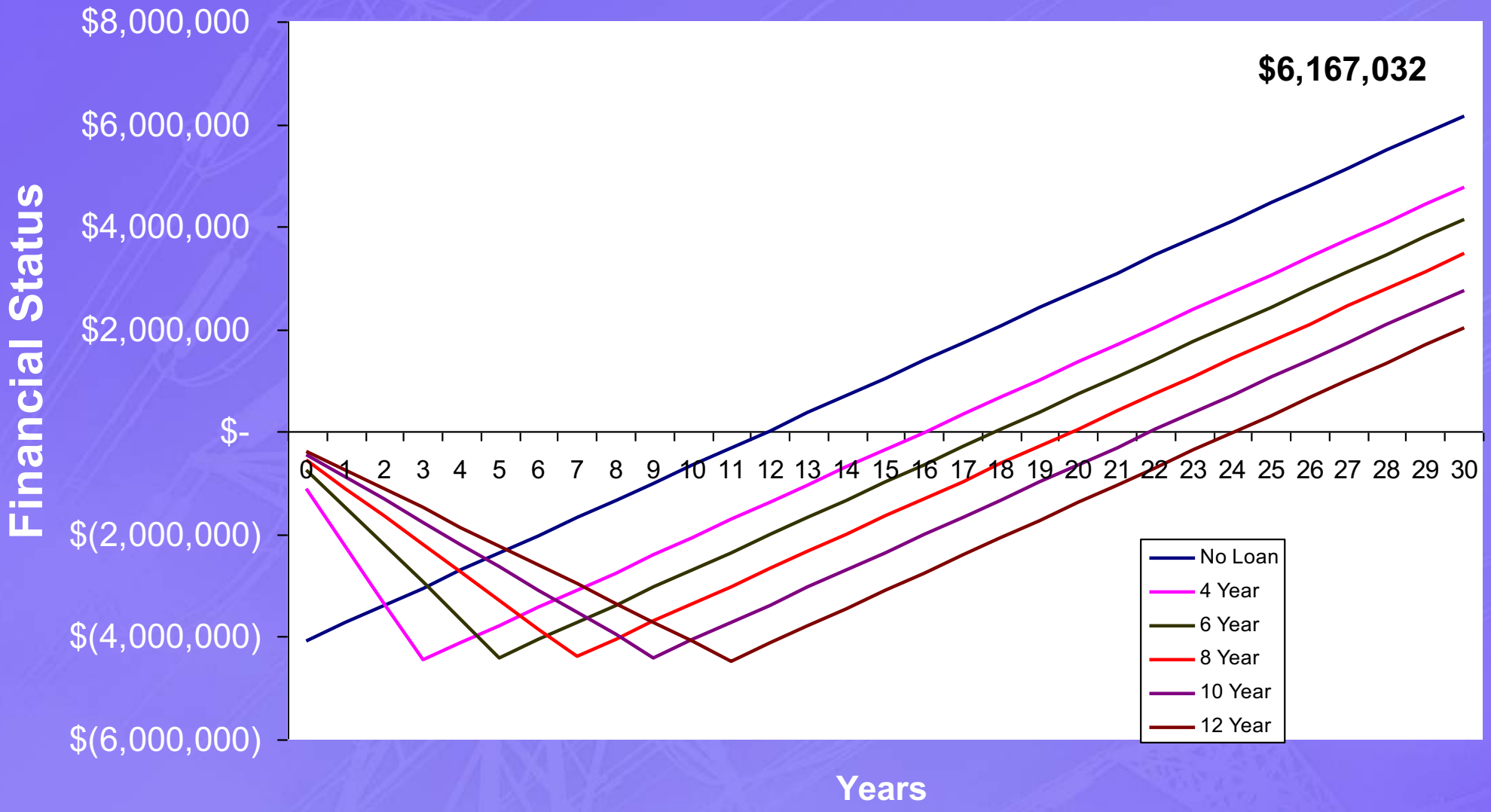
- Saturn 20 1.2MW -- $2.5 million installed
- 2 Absorption chillers $1.9 million installed

- Total upfront costs $4.4 million
- Annual savings in operating costs $580,000

Saturn 20 1.2MW

Financial Status For Next 30 Years

$8.00 For Gas



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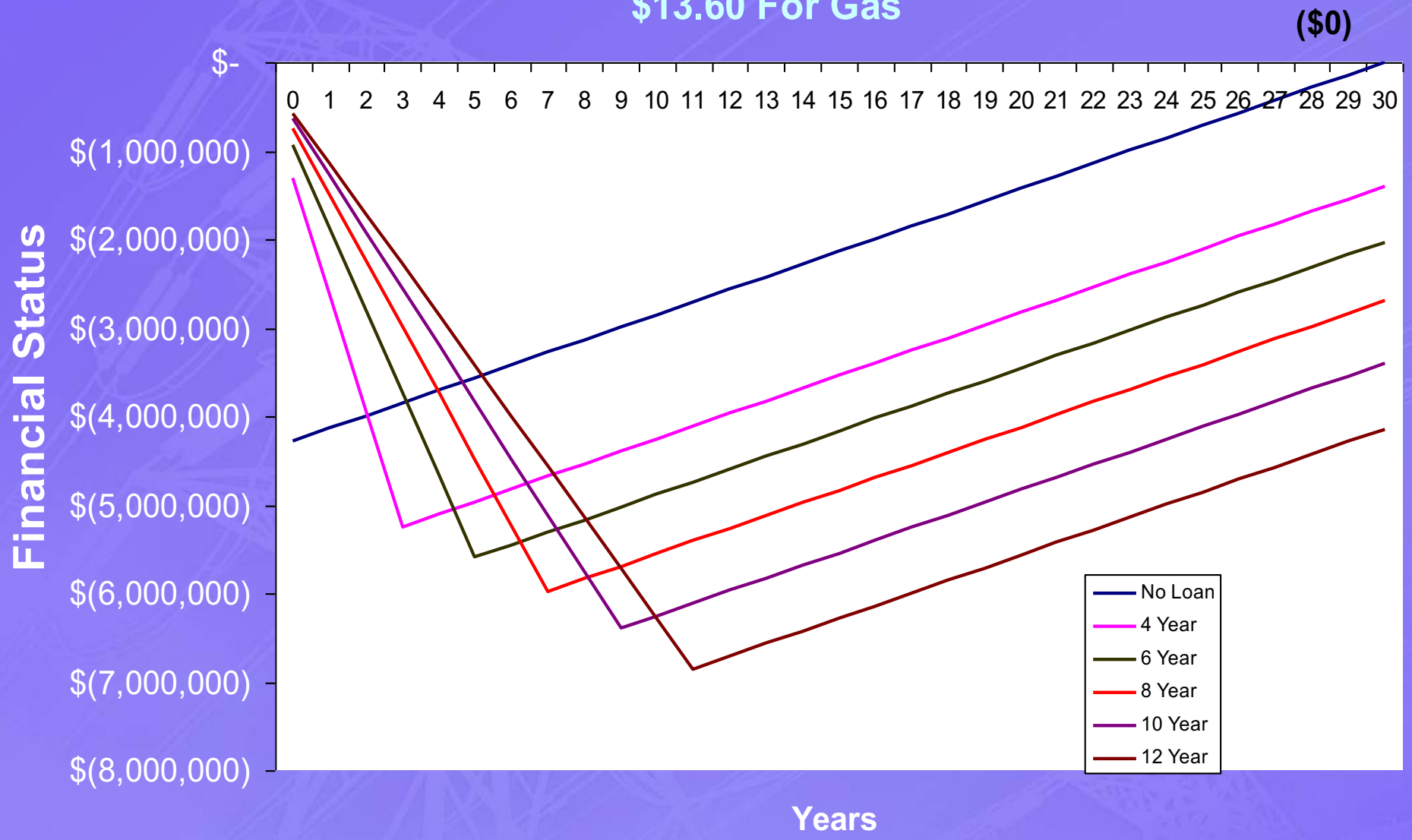
Saturn 20 1.2MW

Financial Status For Next 30 Years
$13.60 For Gas



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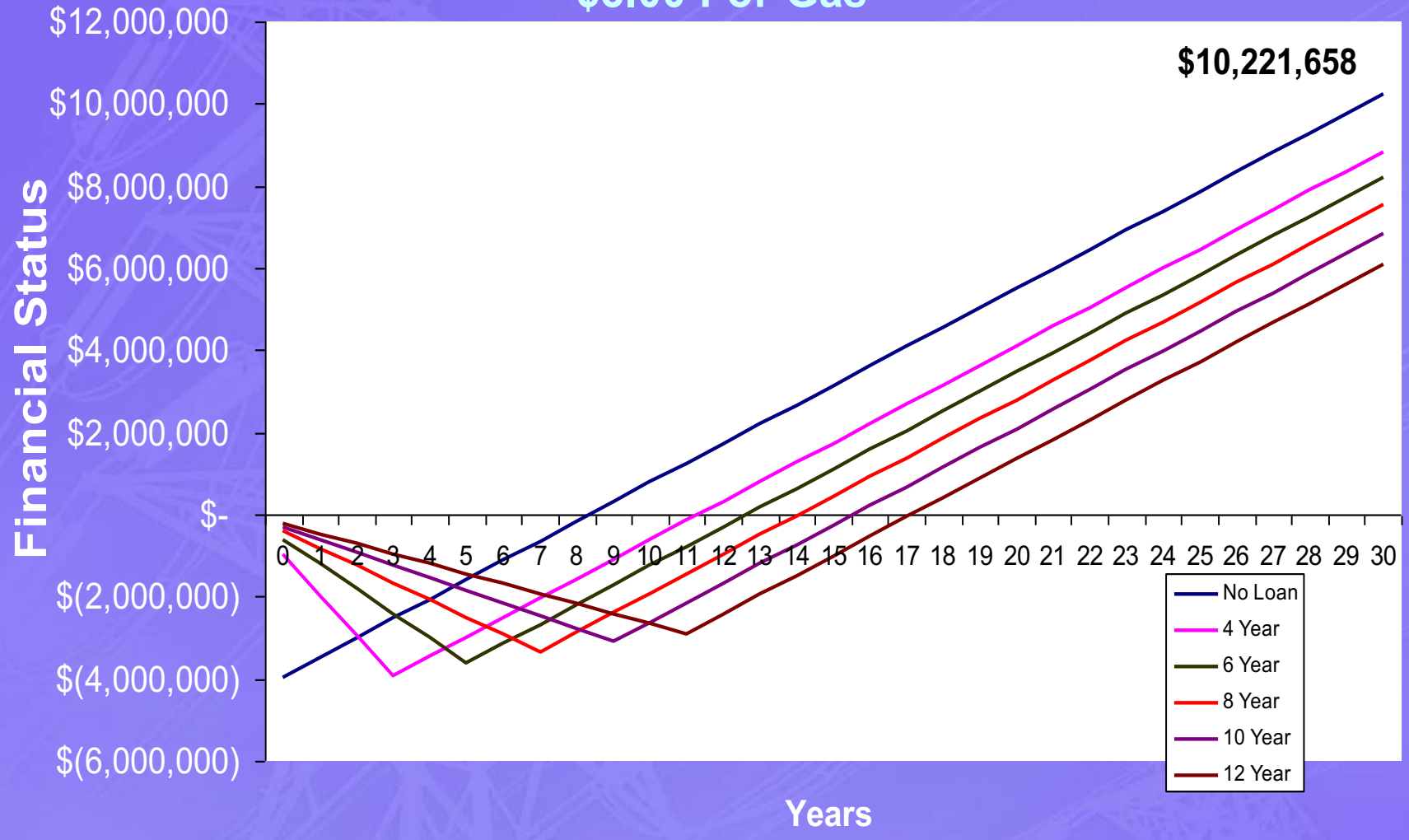
Calvin's Future Power Needs

- Calvin's energy needs are expected to grow in the next five years by about 60%
- These next cases model the economic value cogeneration systems might provide in the future.
- At this time Calvin's power needs will be near 5 MW

Single Saturn 1.2MW

Financial Status For Next 30 Years
$8.00 For Gas



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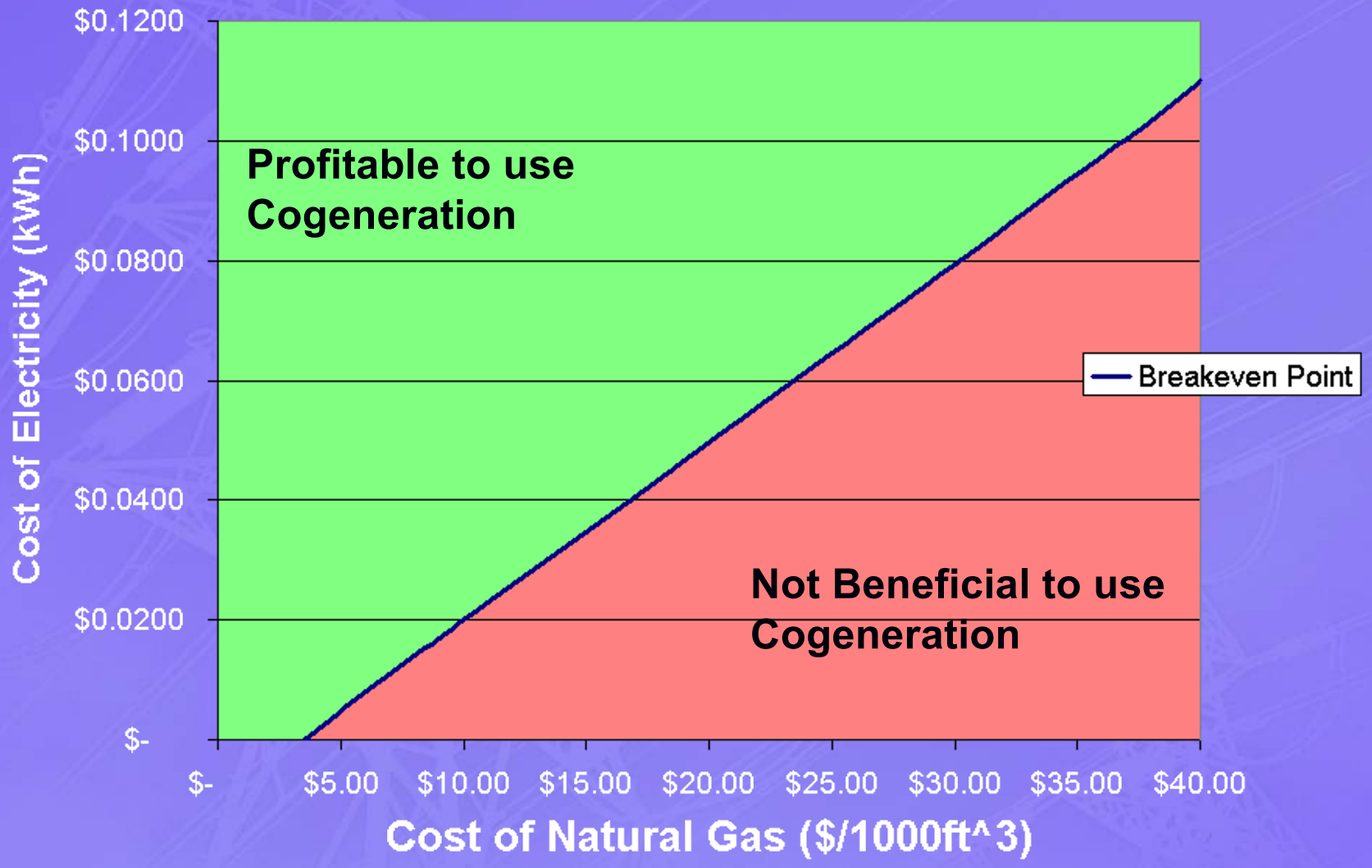
Breakeven Analysis Saturn 20 1.2MW



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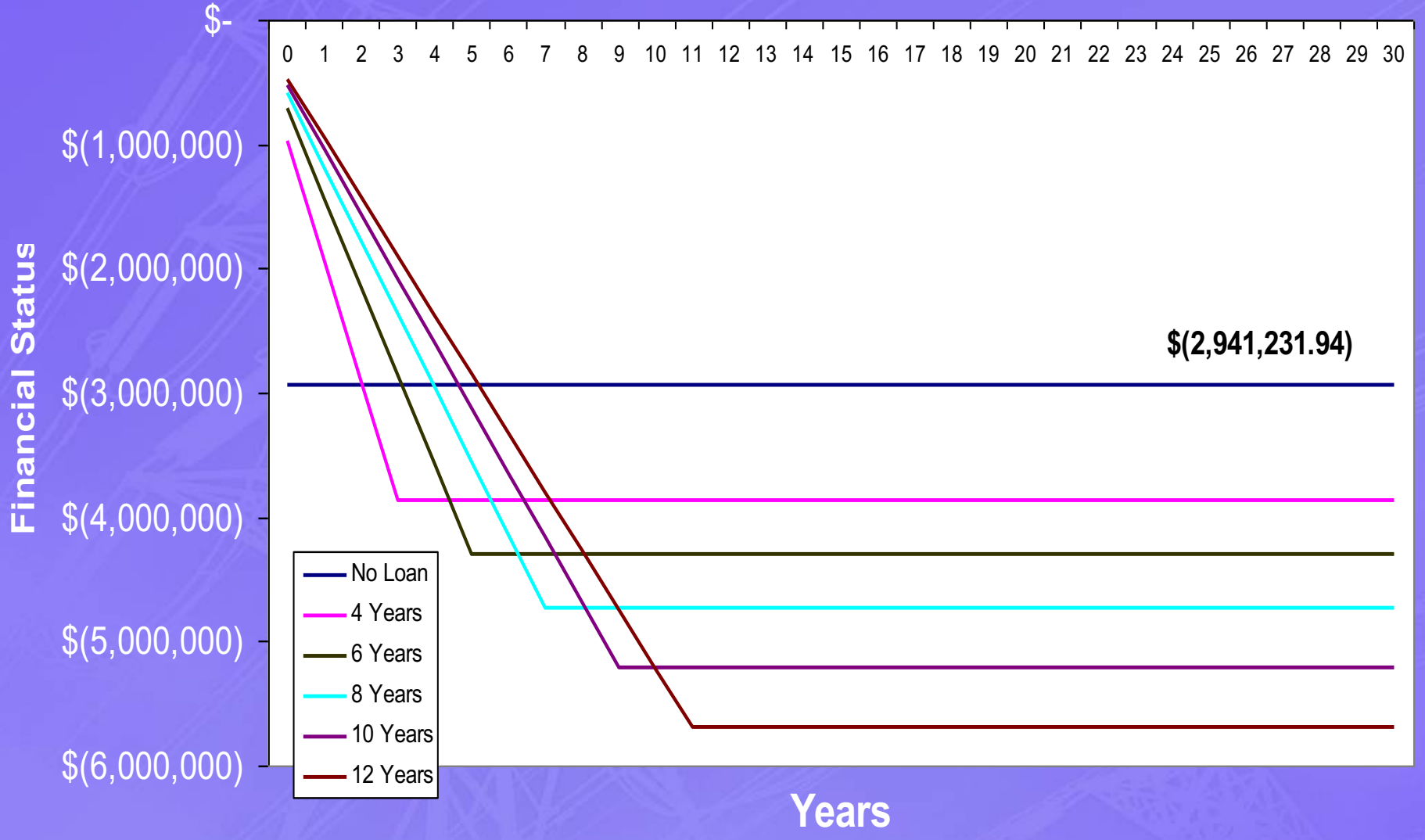
Special Cases and Considerations

- Further analysis was done to optimize the rate of fuel to be consumed by the turbine
  - Fuel increase will result in more steam output.
- In this case an optimum cost savings was found when additional fuel was added to the turbine.
- This supplemental firing saves an additional 1.5 million in energy costs.

Reciprocating Engine Cost Effectiveness

- Sensitivity to gas price.
- High maintenance costs.
- Breakeven point.

Financial Status For Calvin College For Next 30 Years
Reciprocating Engine
$7.74 Gas Price



Context : Generation Options : Cogeneration : Wind Power : Energy Saving

Additional Reasons for Reasons for Choosing Co-Gen

- Electricity from the grid although cheap is not green power.
  - Power companies operate in the 40% energy efficient range times more energy than they produce.
  - Co-Gen Systems operate between 80-95%
- Stewardship toward the Environment
- Great experience for new students.

Wind Power At Calvin

The Plan

Context : Generation Options : Cogeneration : Wind Power : Energy Saving

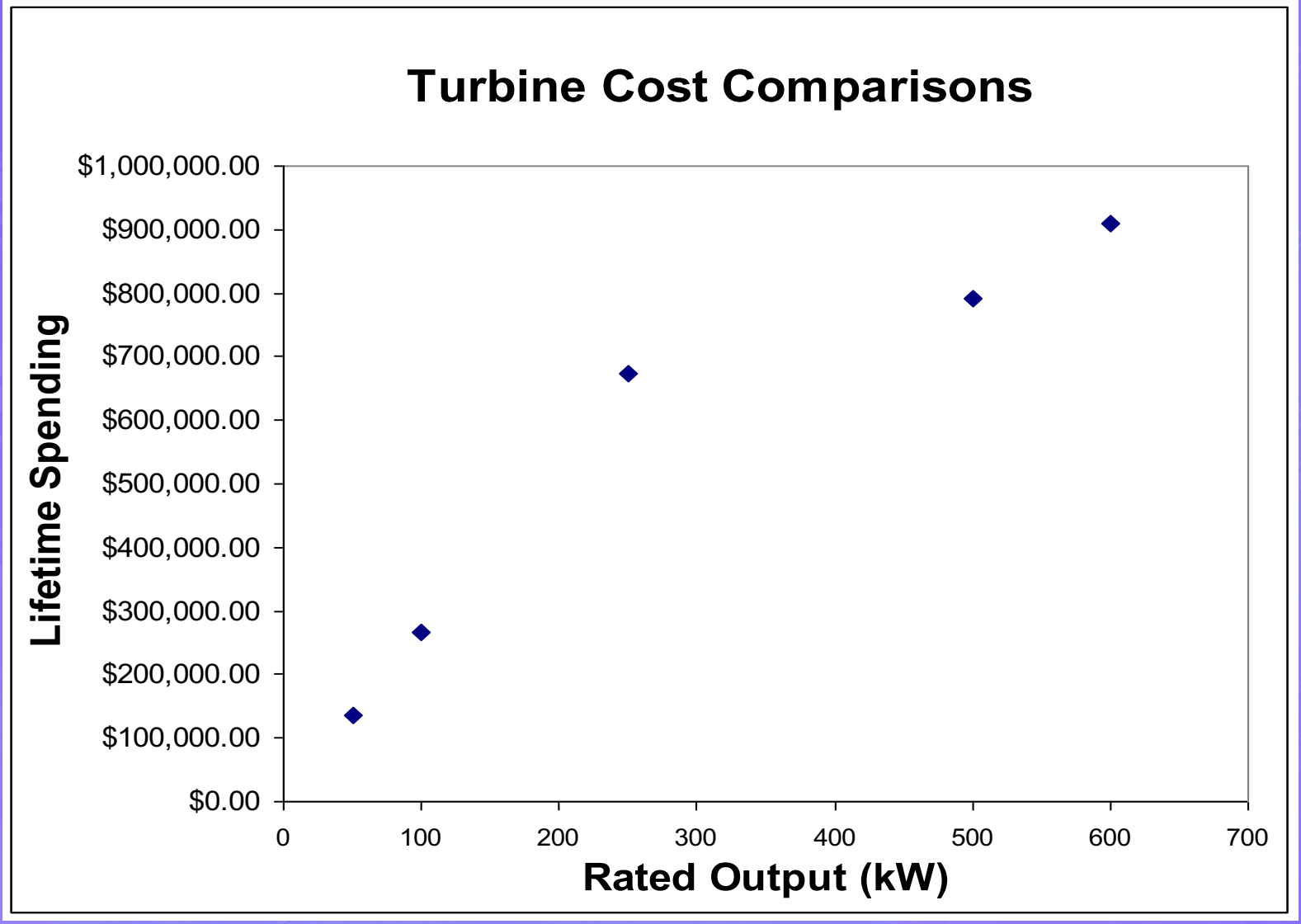
Considerations

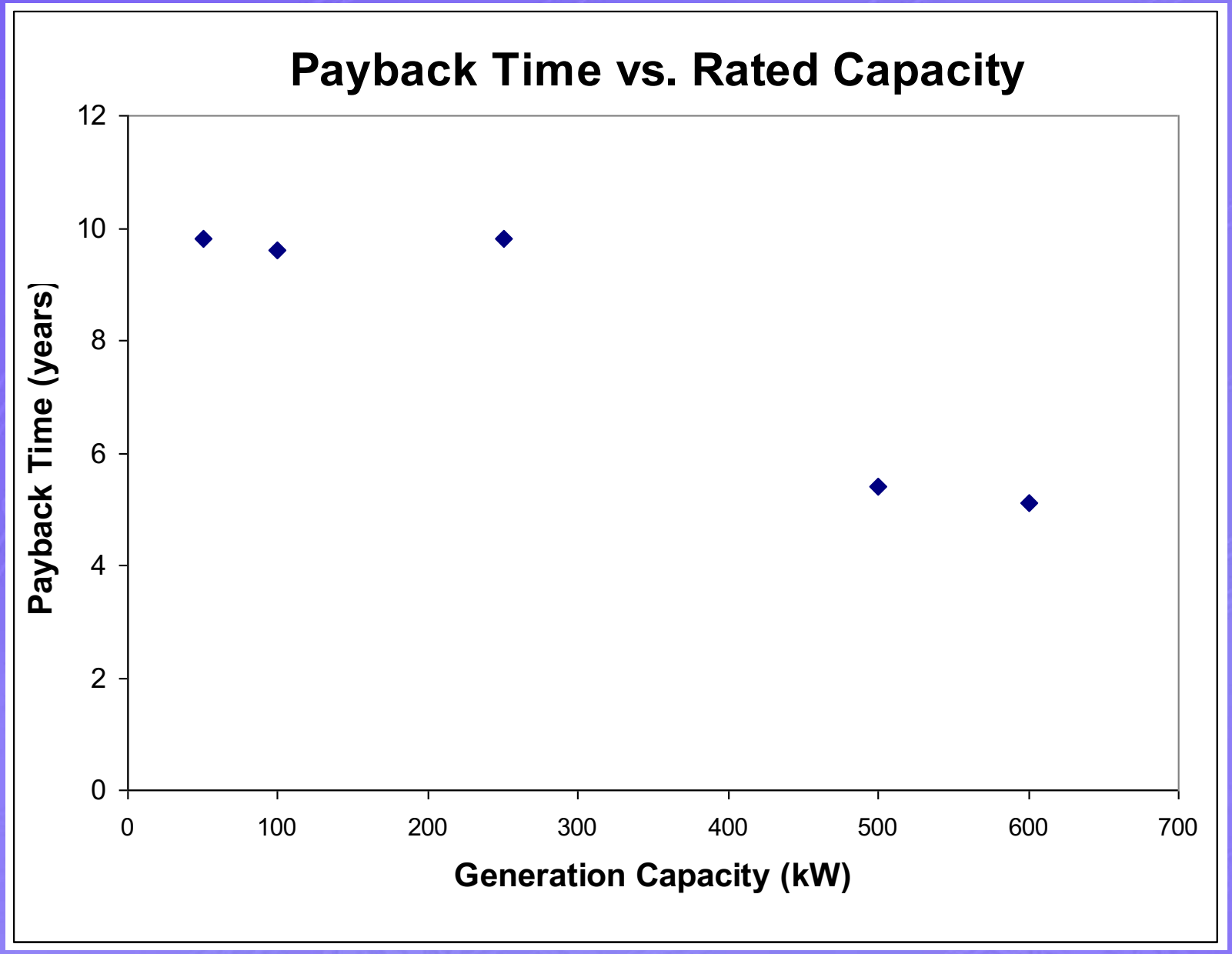
- Pilot program
- Height
- Space restrictions
- Aesthetics
- Community approval

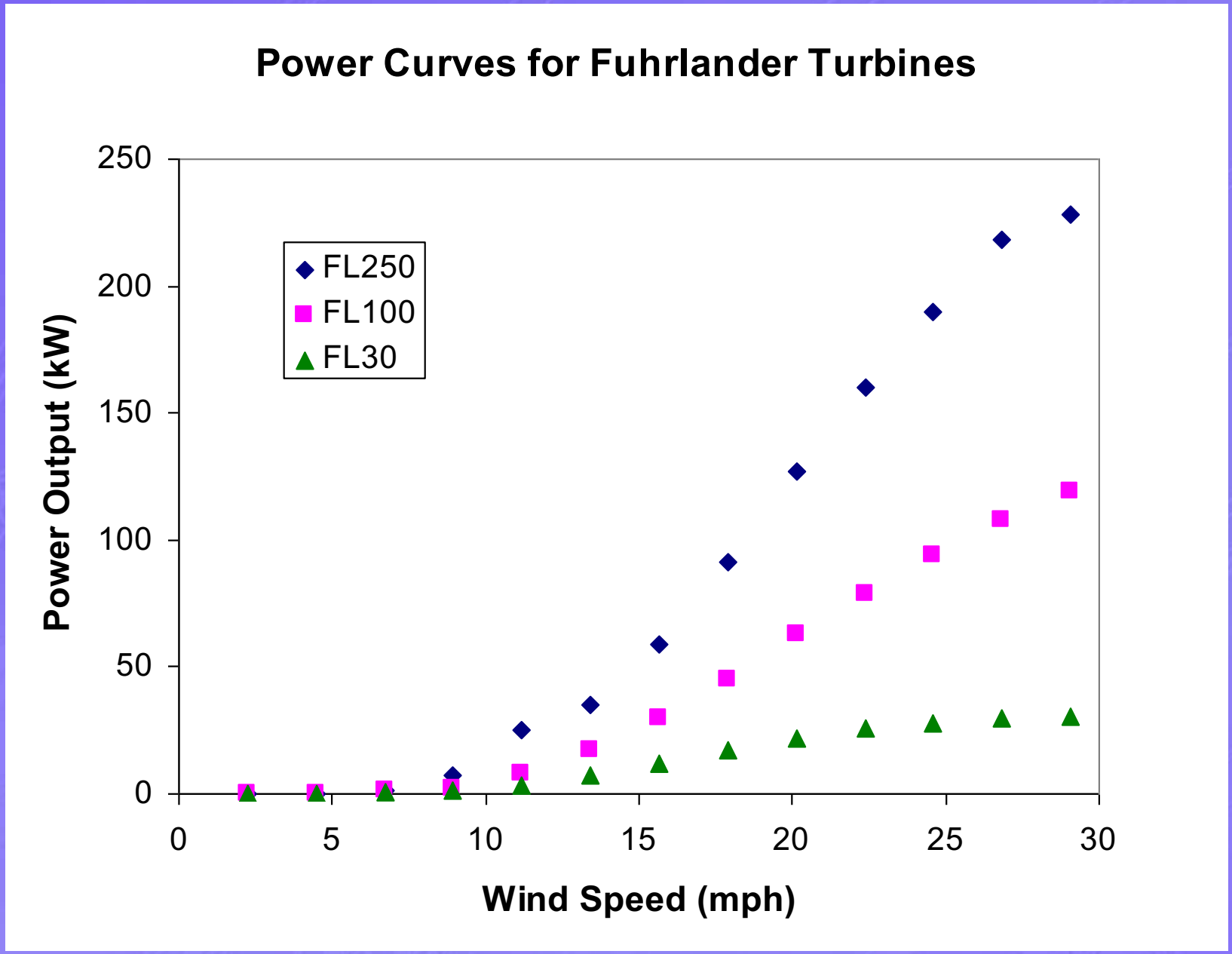
Recommendation 250kW

- Power Generation
- Total Investment
- Payback Period
- Rising Electricity Costs

Cost Analysis




Payback Time vs. Rated Capacity
Payback Time (years)
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
Generation Capacity (kW)


Power Curves for Fuhrlander Turbines
Power Output (kW)
250
200
150
100
50
0
FL250
FL100
FL30
0
5
10
15
20
25
30
Wind Speed (mph)

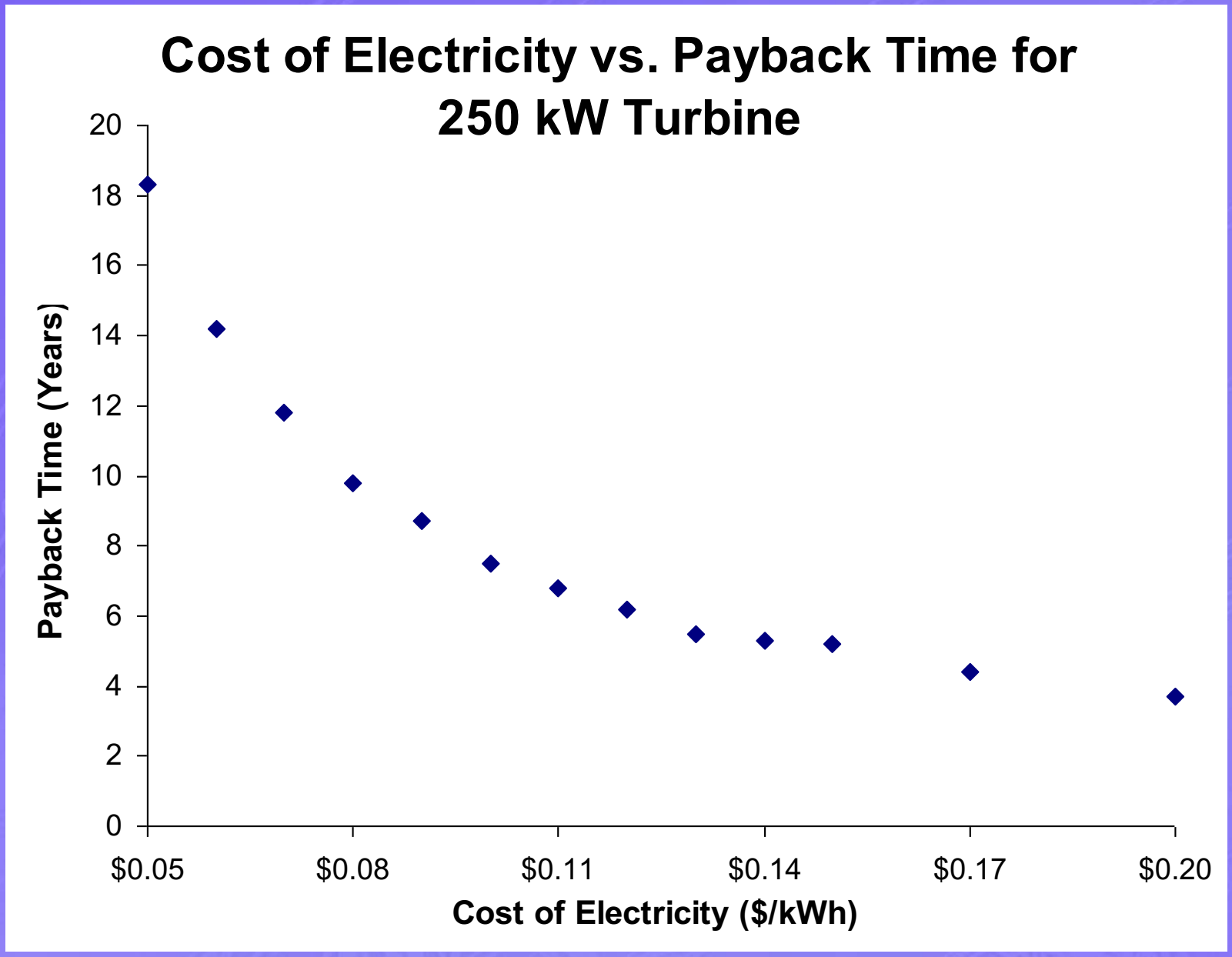
The FL250

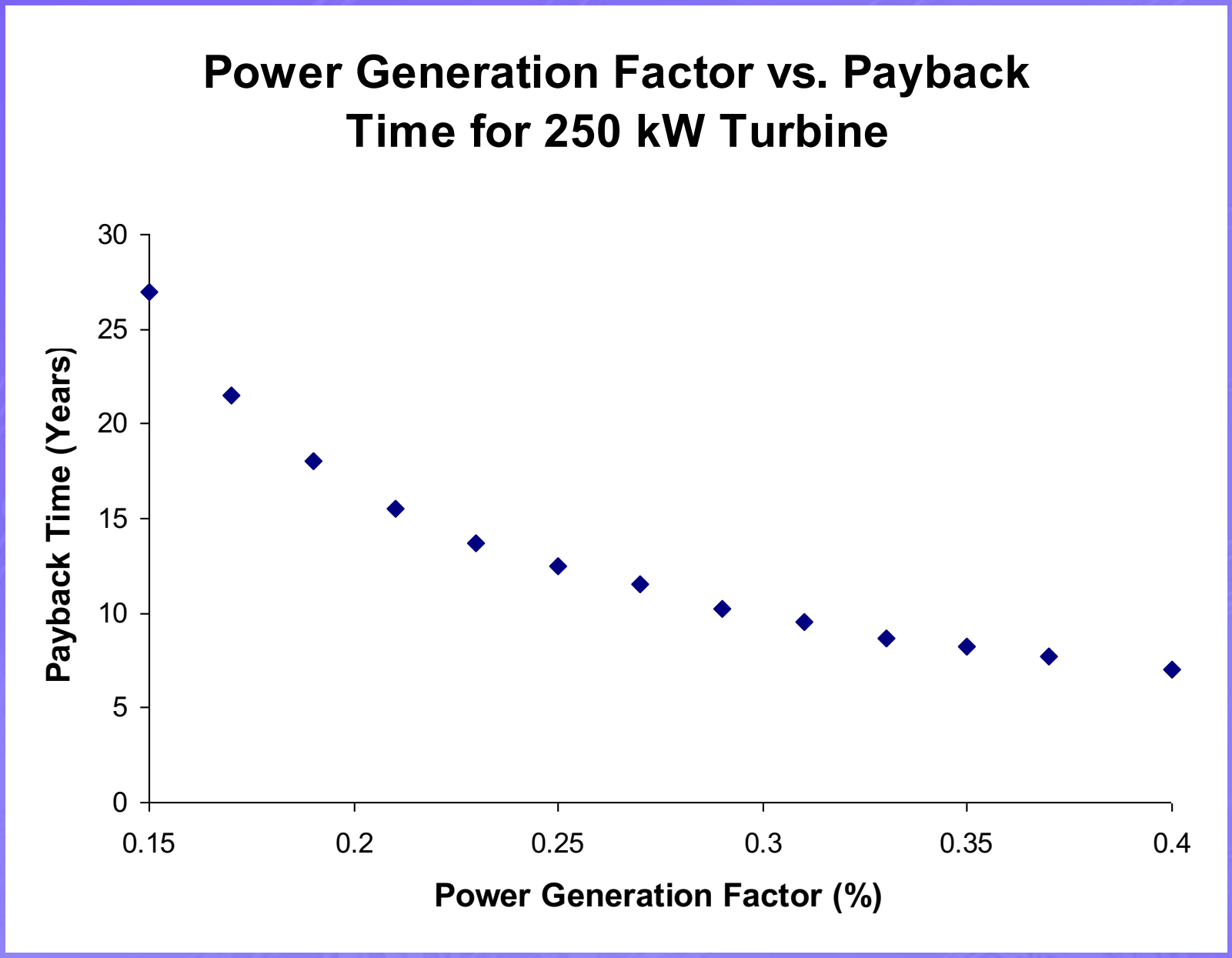
- Max Power 300 kW
- 138 ft. tall
- 94 ft. blade diameter
- 185 ft. total height
- 5.6 mph cut in wind speed
- 30 ft. X 30 ft. area required

Fuhrländer
AKTIENGESELLSCHAFT

Location

- GPS coordinates of:
  - N 42° 55.960 W. 85° 34.407 Elev. 800 ft


Cost of Electricity vs. Payback Time for 250 kW Turbine
Payback Time (Years)
20
18
16
14
12
10
8
6
4
2
0
$0.05
$0.08
$0.11
$0.14
$0.17
$0.20
Cost of Electricity ($/kWh)


Power Generation Factor vs. Payback Time for 250 kW Turbine
Payback Time (Years)
30
25
20
15
10
5
0
0.15
0.2
0.25
0.3
0.35
0.4
Power Generation Factor (%)

The Permitting Process

- Contacted City Planning Department
  - Wind systems not addressed by local ordinance
  - Permitted with approval
  - Required documents
    - Legal description of site
    - Site Plans
    - Wind Turbine Plans
    - Letter to Planning Commission

The Permitting Process

- Review applicable standards and restrictions
  - Setback
  - Noise Levels
  - Equipment
  - Code compliance
  - FAA requirements
- Notify the utility
- Notify neighbors
- Comply with permitting requirements

- Public Hearing Before Planning Commission

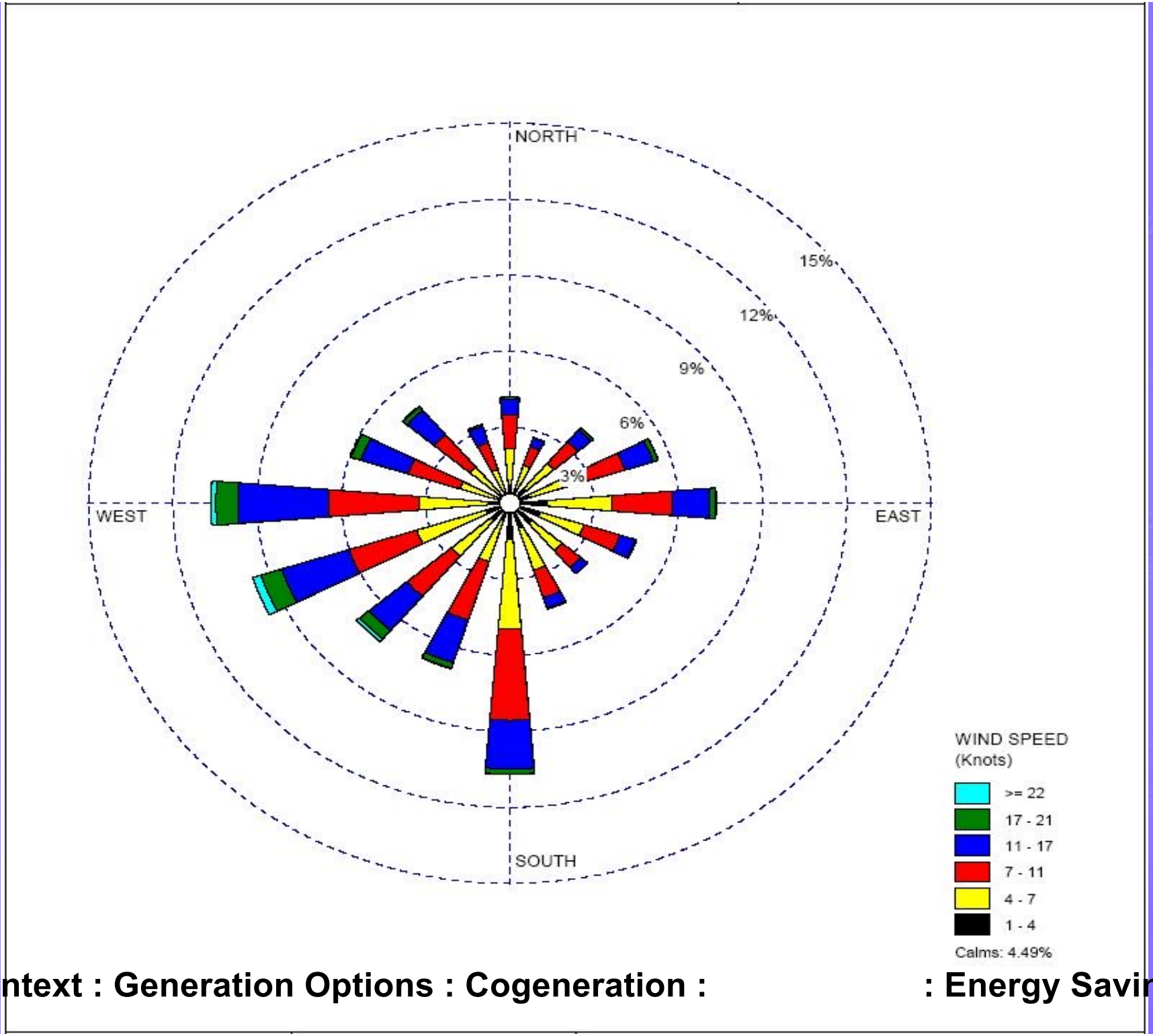
Possible Public Concerns

- Acoustics
- Aesthetics
- Property Values
- Electronic Interference
- Safety
- Avian Risk

Context : Generation Options : Cogeneration : Wind Power : Energy Saving

Non-economic Benefits

- No pollution, health effects, or global warming effects
- Not dependent on fuel costs
- Example for future expansion
- Contributes to goals of energy independence
- Stewardship



Context : Generation Options : Cogeneration : : Energy Saving

6. Address Siting and Project Feasibility
7. Understand Wind Energy's Economics
8. Obtain Zoning and Permitting Expertise
9. Establish Dialogue With Turbine Manufacturers and Project Developers
10. Secure Agreement to Meet Operation and Maintenance Needs

American Wind Energy Association

Wind Power Conclusion

- Wind power is feasible at Calvin College
- We recommend a 250 kW wind turbine
- The 10 steps to acquiring wind power have been considered
- Wind energy is becoming more economic every year

Reducing Calvin's Energy Usage

- Calvin can improve on "Being **Green**"
- Successful Case Study: Boulder University
- Energy Wasted in Dorms (Survey Results)

Energy Site Usage: Calvin vs. Yale

- Calvin's Usage: 380 kW-hr/m^2
- Yale's Usage: 620 kW-hr/m^2
- Typical Green Building: 250 kW-hr/m2
- Conventional University: 375 kW-hr/m2

VS

Context : Generation Options : Cogeneration : Wind Power : Energy Saving

Room for Improvement

- Many of the energy-saving strategies are being used on Calvin's campus already
  - Efficient lighting
  - EnergyStar replacement program
  - Automatic light switches
- Some areas can still be improved
  - Computers in academic buildings are left on at night
  - Computers in dorms are rarely turned off; night or day
  - Lights are left on all the time everywhere on campus

Total Quality Management Approach

- Improvement in “business” starts with empowering individual “employees”
- By making information available people are able to take a greater amount of ownership and responsibility.
- Equip people with the resources they need to make better choices and understand their effects.

Case Study: Boulder University

- Before, electricity usage increased by 5% yearly
- After one year of intensive programming, experienced a decrease of 1%
- Program included:
  - raising awareness of electricity consumption in dorms
  - using stickers on light switches on campus

Dorm Survey Results

109 RVD residents

- Most residents leave their computers on
  - 91% own computers
  - 71% don't turn it off at night
  - 94% don't turn it off during the day
- Some lights are being left on
  - 13% frequently leave room lights on
  - 14% leave bathroom lights on

Summary of Dorm Savings

Dorm Awareness	Yearly Savings
Computers off (day/night)	$6,326
Room Lights off	$3,062
Bathroom Lights off	$1,975
Participation Rate	0.5
Total	**$5,681**

Total Program Savings

Focus	Participation	Yearly Savings
Academic Computer Shut-off	100%	$1,034
Dorm Awareness	50%	$5,681
Save $ Stickers	20%	$1,313
Total	**57%**	**$8,028**

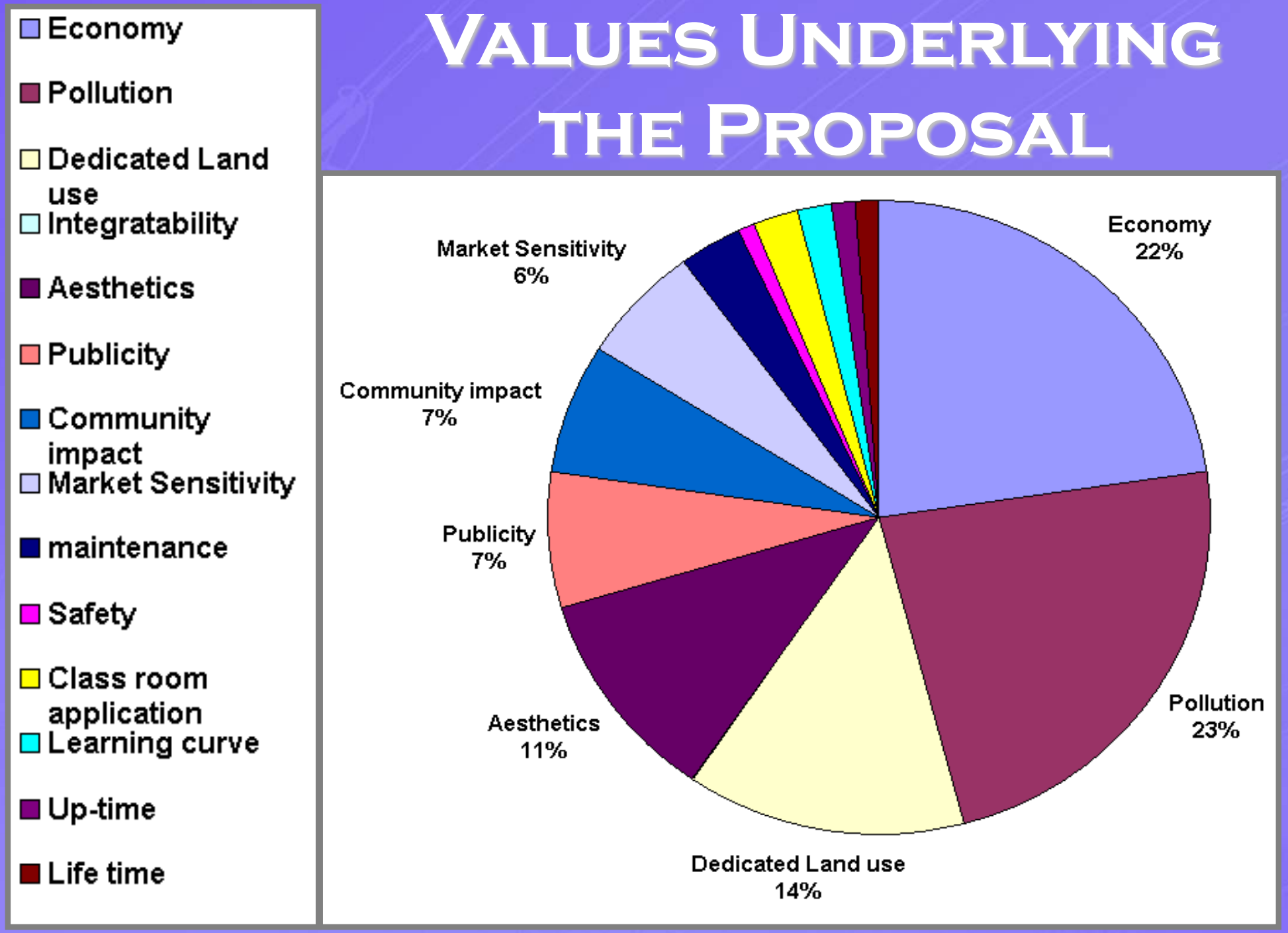
Concluding Remarks

- Appropriate action includes both production and reduction.
- Complicated Issues in an Uncertain Environment.
- As stewards, we must not be deterred from action.

Questions?

Location Options

Values Underlying the Proposal



Advantages of Electrical Independence

- Lower Electricity Cost
- Unaffected by Interruptions in Grid
- Opportunity to Generate Cleaner Energy
- Educational Opportunity
- Cutting-edge