ANALYSIS OF PRICING TRENDS AND GRID PARITY OF PHOTOVOLTAIC SYSTEMS

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Background

- Currently, the only incentive to use solar energy over traditional forms of energy are subsidies and discounts provided by either the government or a local energy provider.

- As of 2015, photovoltaic (PV) systems cost more than double that of natural gas or coal.

- Economic analysis:
  - **levelized cost of energy (LCOE)** of PV system has been lowering as the technology in PV modules develops and becomes cheaper.

$$\mathrm{LCOE} = \frac{Total\ cost\ over\ the\ lifetime}{Total\ energy\ generated\ over\ the\ lifetime}$$

  - **Grid parity** will occur when the price of solar energy stars to become competitive with existing energy resources.

Model Outline

- LCOE calculation:
  - Forecasting the solar GHI to calculate the total energy generated by the solar system over its life time.
- Economic Analysis:
  - Case 1) Grid parity analysis for integrated solar-storage and individual solar system in the next 10 years
  - Case 2) Installing solar system ignoring the storage

Neural Network For Solar GHI Forecasting

- Neural Network toolbox in MATLAB
  - x(t): Formatted time-date and solar zenith values
  - y(t): Normalized Global Horizontal Irradiance (GHI) values

- Data Preprocessing: Nighttime hours are removed and GHI is normalized.

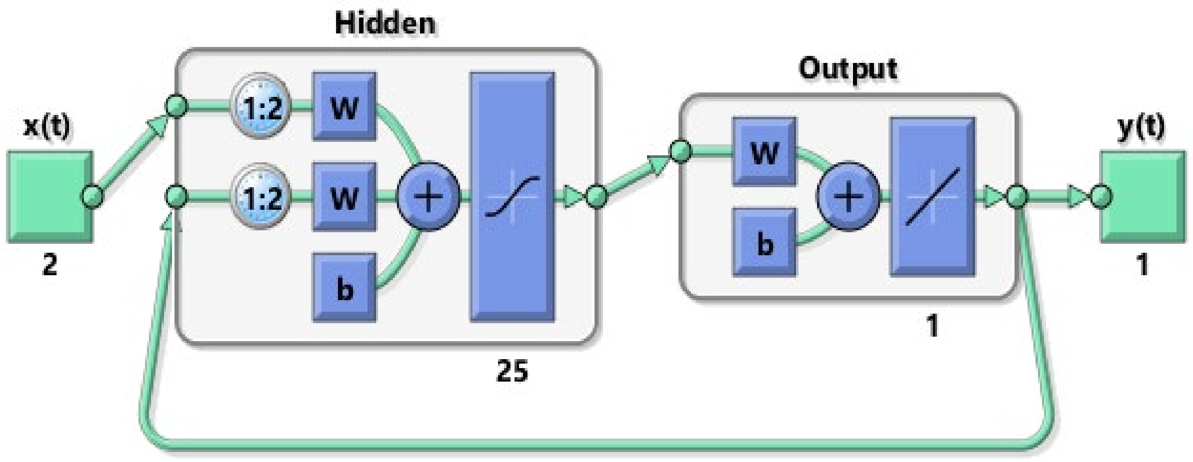


Figure 1: Neural Network Diagram

Neural Network Results

Mean square error (MSE)=**0.0786**

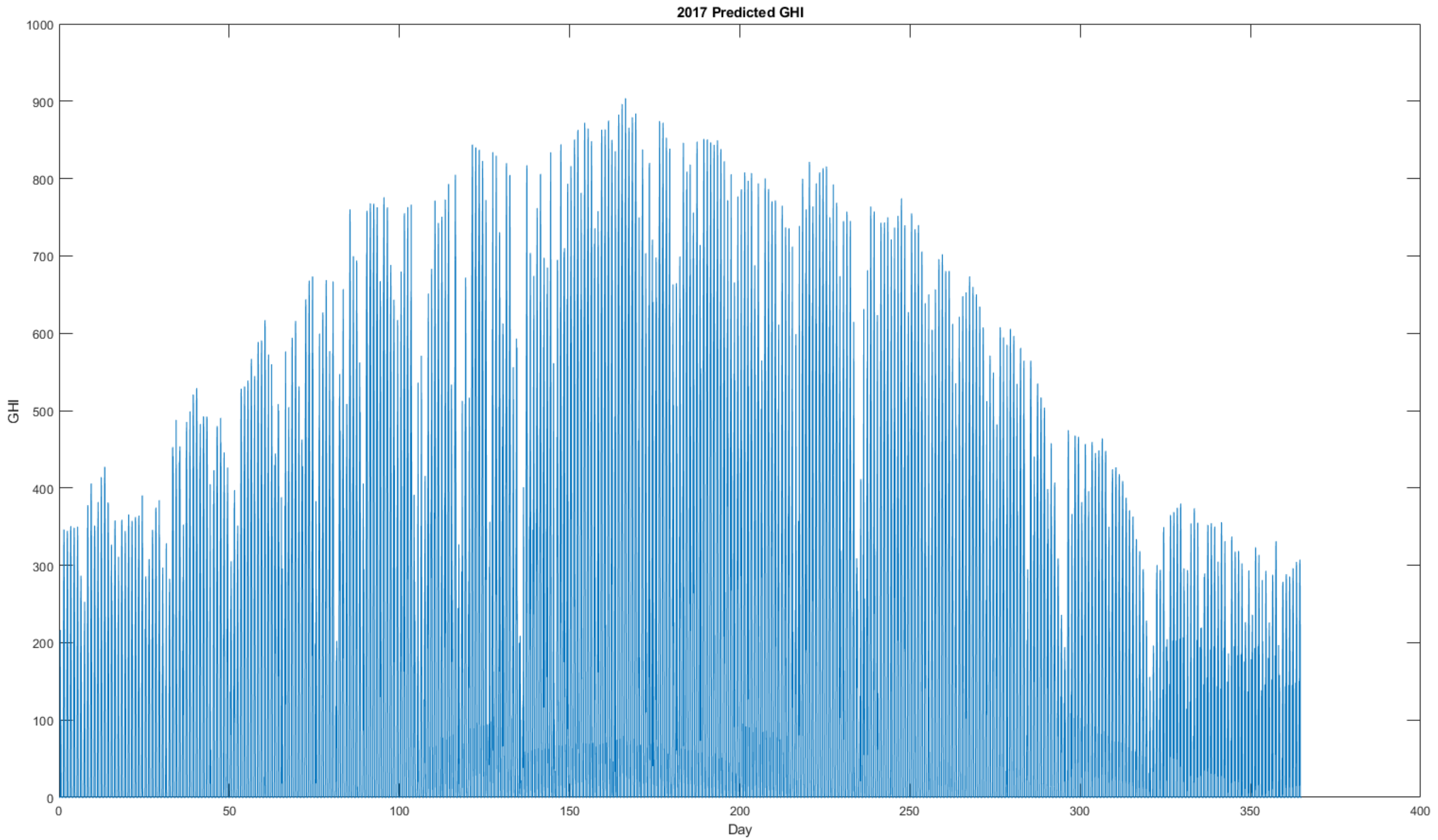


Figure 2: Predicted GHI for 2017

Case Study 1

- Grid parity analysis for integrated solar-storage and individual solar system in the next 10 years to find the optimal time to invest
  - First step: Choosing proper battery technology
  - Second step: finding the price trends of the battery and solar
  - Third step: using HOMER to check if it is economical?

First Step: Choosing Proper Battery Technology

- Batteries in residential PV systems allow the user to save excess power generated during peak hours for use later

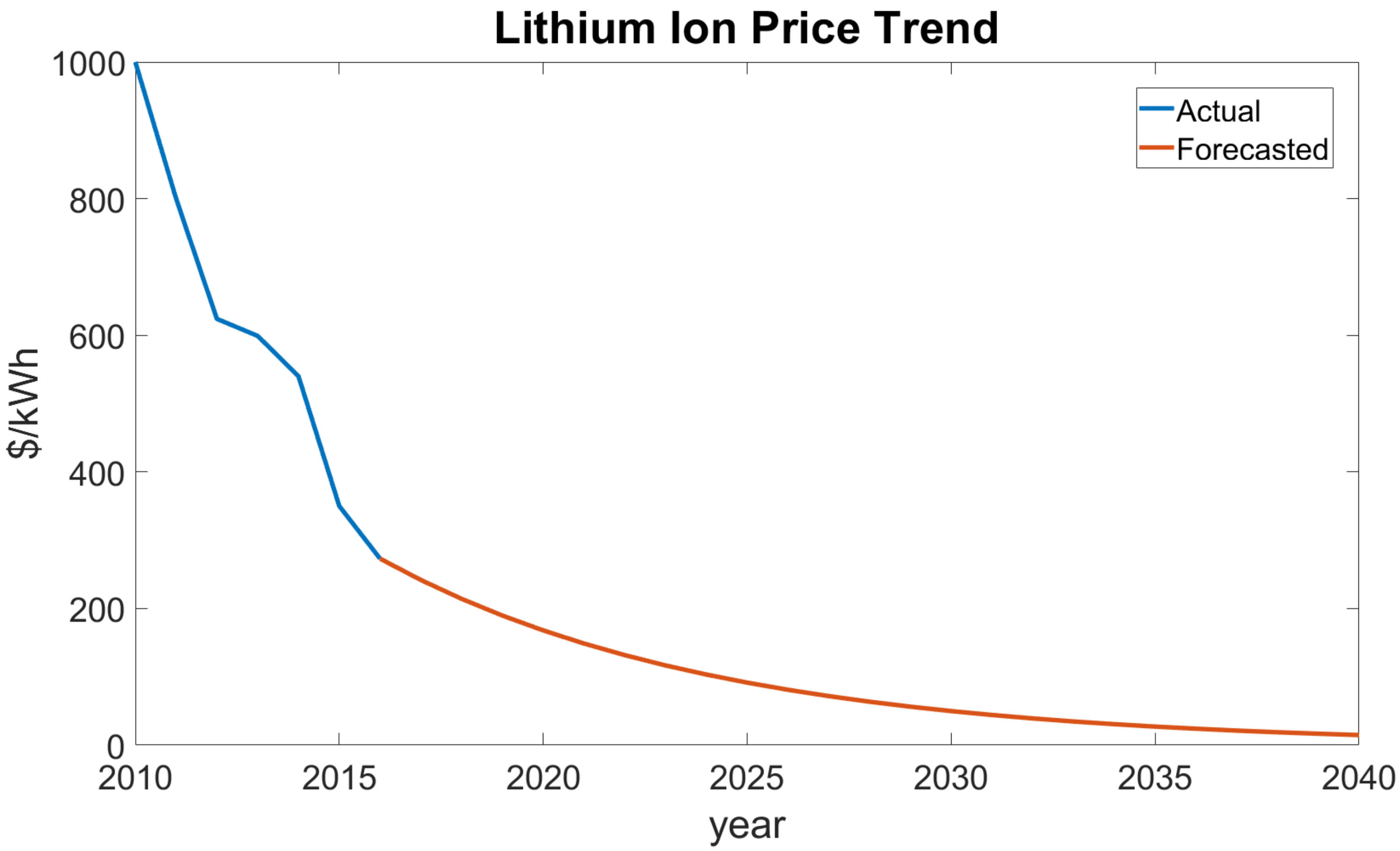
- Lithium Ion:
  - ✓ Long lasting
  - ✓ Low maintenance cost
  - ✓ High investment cost
  - ✓ Easier to install
  - ✓ Non-toxic

- Lead Acid:
  - ✓ More common in residential homes
  - ✓ Low investment cost
  - ✓ High maintenance cost

Lithium Ion is selected

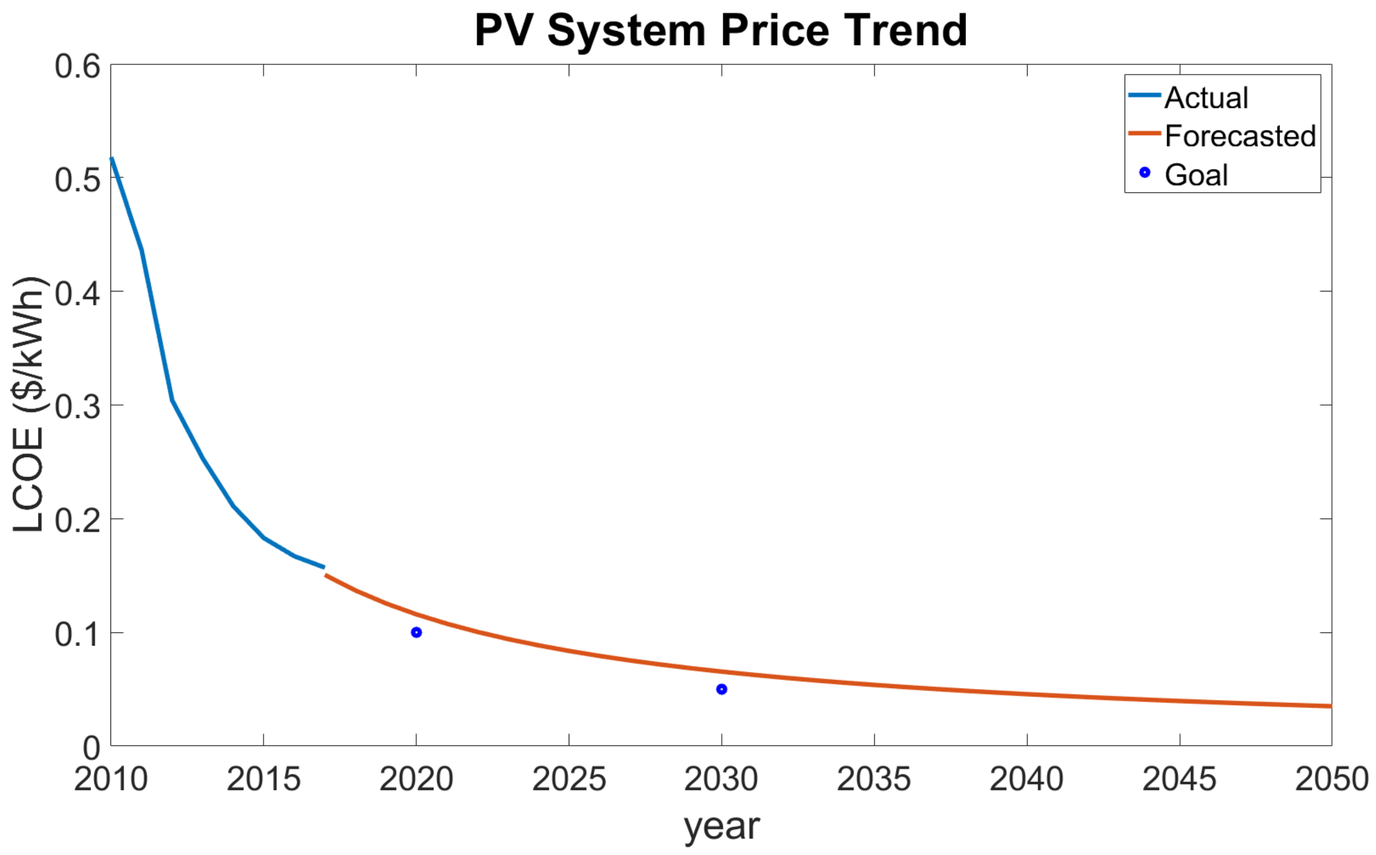
Second Step: Battery Pricing Trends

- Since 2010, the average price of Lithium Ion batteries has decreased at a rate of 11.43% from previous years.
- Battery prices are currently around $210 per kWh, which falls in line with the forecasted pricing.
- Even in the distant future, battery prices are still expensive per kWh



PV System Pricing Trends

- PV systems have been dropping in price as the technology progresses
- Polycrystalline PV module was considered (primary type used in residential PV systems)
- Fitted and plotted in MATLAB using a rational fitting equation
- As the price of PV systems fall, they will eventually reach grid parity



Grid Parity Analysis For Case 1 Using HOMER Pro

I. Economic analysis for installing integrated solar-storage for a residential customer in the next 10 years.

- Despite being allowed to have both types of batteries, the optimizer chose to use neither and opted for a PV only, grid-tied system.
- The grid parity does not happen for the integrated solar-storage system.

II. Economic analysis for installing solar ignoring storage for a residential customer in the next 10 years.

- For solar energy: **Grid parity is predicted to occur in 2025.**
- Predicted LCOE of $83.7 per MWh vs. Coal (30% CCS) at $84 per MWh

➢ When grid parity occurs, solar energy will no longer have to rely on incentives and subsidies to compete with other forms of energy.

➢ Any customer may still choose to invest in solar energy before this time depending on existing subsidies and incentives offered.

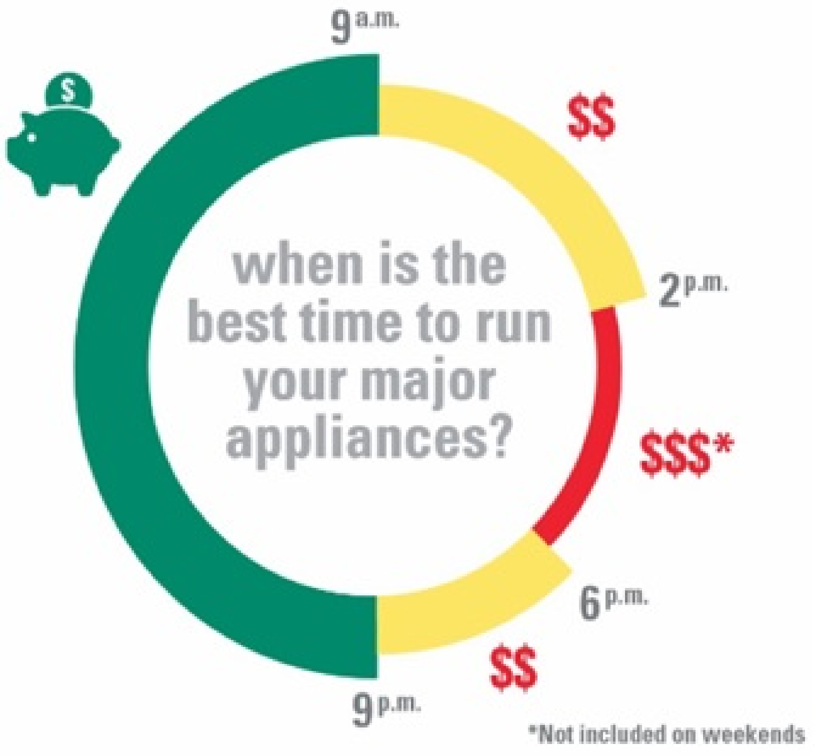
Case Study 2

- Economic analysis for the solar system ignoring the storage to compare two scenarios:
  - ✓ Scenario 1) Xcel energy’s Time of Use Plan
  - ✓ Scenario 2) Standard Purchase/Sellback Flat Rate Plan

- Using **HOMER Pro**

Scenario 1: Xcel Energy's Time of Use plan

- Xcel Energy's Time of Use plan: using "virtual bank" concept offered by the Excel energy in Colorado, to give the excess power to the grid and get the needed power at no charge, when the solar generation is insufficient.



Source: http://www.xcelenergy.com

Results for Scenario 1: Xcel Energy's Time of Use plan

- Optimal System:
  - ✓ 2.84 kW using a $250-275 W polycrystalline module
  - ✓ $2,800 initial investment

- Economics:
  - ✓ Return on Investment: 10.6%
  - ✓ Simple payback time: 6.73 years
  - ✓ LCOE: $0.0611 /MWh

Scenario 2: Standard Purchase/Sellback Flat Rate Plan

- Selling the excess power back to the utility grid at the current market price and buying the needed power at the market price of the time of use, when the solar generation is insufficient.
- The owner would be able to sell excess power during areas of peak production to make an income during times when generation exceeds load.
- The standard rate is selected based on the national average electricity price ($0.12 per kWh)

Results for Scenario 2: Standard Purchase/Sellback Flat Rate Plan

- Optimal System:
  - ✓ 12 kW using a $250, 275 W polycrystalline module
  - ✓ $11,000 initial investment

- Economics:
  - ✓ Return on Investment: 10.1%
  - ✓ Simple payback time: 6.83 years
  - ✓ LCOE: $-0.01988 /MWh

Comparison Between Two Scenarios

	Scenario 1	Scenario 2
Optimal Characteristics	$250-275 W	$250-275 W
	polycrystalline module	polycrystalline module
Optimal Capacity (kW)	2.84	**12**
Initial Investment Cost ($)	2,800	11,000
Return on Investment (%)	10.6	10.1
Simple Payback Time (year)	6.73	6.83
LCOE ($/MWh)	0.0611	**-0.01988**

- Considering the average PV module lifetime of 25 years, the initial investment in both scenarios can be made back within about **a quarter the lifetime** of the PV system.

- In scenario 2, a larger array would be the most economical, because the more energy that can be generated, the more money that can be actively made and sell back to the utility grid.

Conclusion

- In a typical residential case, using a battery at market price for the next 10 years is not cost effective as its capital cost is not enough reasonable to be invested in a residential case.
- For the typical homeowner, a grid-tied PV system is the simplest and most cost-effective way to convert to a solar powered home.
- PV is a viable option for homeowners because of existing subsidies and incentives that allow for solar to be competitive in today’s economy. However, those who do not want to rely on such subsidies have the option of waiting for grid parity to occur in 2025 to invest in a PV system.
- Considering the Standard Flat Rate Plan and a larger PV module, is more economical than the Xcel Energy’s Time of Use Plan, as the homeowner can make more benefit by selling more excess power back to the utility.
- For both plans, the initial investment will be about a quarter of the lifetime of the PV.

Thank you

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