

ME 401

Systems and Applications

Semester: Fall 2025

LLM: ChatGPT Free

PRIMARY QUESTION

My first question is just asking for ideas about the project and what are things I could analyze.

DESIRED OUTCOME

I won't lie, the only goal here is to get the assignment done well enough to get full credit as fast and with as little effort as possible so I can move on to the next assignment and get all my homework done today as I am busy all day tomorrow.

PROMPT

ok I am being forced to use AI to help generate some ideas for a school project.

Here is some information about the project

First the report template

'''tex

```
\documentclass[11pt,letterpaper]{article}

% =====
% PACKAGES
% =====
\usepackage[utf8]{inputenc}
\usepackage[margin=1in]{geometry}
\usepackage{graphicx}
\usepackage{amsmath}
\usepackage{booktabs}
\usepackage{caption}
\usepackage{hyperref}
\usepackage[style=ieee,backend=biber]{biblatex}
\usepackage{xcolor}
\usepackage{subcaption}
\usepackage[style=ieee]{biblatex}
\addbibresource{references.bib}
% =====
% FORMATTING
% =====
\addbibresource{references.bib}
```

```

\hypersetup{
    colorlinks=true,
    linkcolor=blue,
    citecolor=blue,
    urlcolor=blue
}

\captionsetup{
    labelfont=bf,
    font=small,
    width=0.9\textwidth
}

\setlength{\parindent}{0pt}
\setlength{\parskip}{8pt}

% Quick comment style for guidance
\newcommand{\hint}[1]{\textcolor{teal}{\small\textrit{[#1]}}}

% =====
% TITLE PAGE
% =====
\title{\textbf{Energy System Analysis \& Design \\ [Your Location]\\ Port Electrification Analysis} }

\author{
    Student Name 1, Student Name 2 \\
    \small ME 401: Engineering Systems and Applications\\
    \small Department of Mechanical Engineering \\
    \small Boise State University \\
    \small \today
}

\date{ }

% =====
% DOCUMENT
% =====
\begin{document}

\maketitle

% =====
% ABSTRACT
% =====
\begin{abstract}
\hint{150-200 words: What did you do? What tools? What location? Key result? Why it matters?}

```

This report presents a renewable energy system design for [Location Name] port operations, integrated with existing infrastructure to minimize environmental impact and maximize efficiency.

```
\hint{Replace the above with your actual abstract once you've completed the analysis.}
\end{abstract}
```

```
% =====
```

```
% INTRODUCTION
```

```
% =====
```

```
\section{Introduction}
```

```
\hint{What did we accomplish? Why does it matter globally? What skills did we use and why are they important? Add 1-2 sentences about YOUR location: Why did you choose it? What makes it interesting?}
```

Ports worldwide contribute approximately 3% of global CO₂ emissions, with shore power, cargo handling, and vessel operations all contributing to this figure.

```
\hint{Add 1-2 sentences about YOUR location: Why did you choose it? What makes it interesting?}
```

This project applies systems engineering principles to design a hybrid renewable energy system.

```
\begin{itemize}
```

- \item \textbf{Python} for data analysis, resource assessment, and optimization
- \item \textbf{Optimization algorithms} to size solar, wind, and battery storage
- \item \textbf{COMSOL} for thermal system modeling \hint{if applicable}
- \item \textbf{Systems thinking} to evaluate technical results in real-world context

```
\end{itemize}
```

```
\textbf{Skills developed:} This project builds competency in multi-domain engineering analysis and modeling.
```

```
\textbf{Global context:} The methodology developed here extends beyond ports to any facility with complex energy systems.
```

```
\hint{Keep intro to 1 page. Get to the point quickly.}
```

```
% =====
```

```
% BACKGROUND
```

```
% =====
```

```
\section{Background}
```

```
\hint{What technologies did you research? How do they connect to thermal-fluid engineering? What are their key performance metrics?}
```

```
\subsection{Renewable Energy Technologies}
```

```
\textbf{Solar Photovoltaics:} PV panels convert sunlight to electricity with typical efficiencies around 15-20%.
```

```
\hint{Thermal-fluid connection: Solar panels get hot! Convective cooling, mounting design, and insulation are critical for performance.}
```

```
\textbf{Wind Turbines:} Wind power extraction follows the Betz limit (59.3% theoretical maximum).
```

```
\hint{Add a sentence about the turbine technology you analyzed|size, type, why appropriate for the application}
```

```
\textbf{Battery Storage:} Lithium-ion batteries store energy electrochemically but involve significant safety concerns.
```

```

\textbf{Other Technologies of Interest:} \\
\hint{Here you can add information about any systems that were explored in thinking about this}

\subsection{Port Energy Systems: Thermal-Fluid Considerations}

Port operations require both electrical power and thermal energy:
\begin{itemize}
    \item \textbf{Electrical loads:} Cranes, lighting, refrigerated containers ("reefers"), sh
    \item \textbf{Thermal loads:} Building HVAC, cargo heating/cooling, de-icing \hint{if appli
\end{itemize}

\hint{Thermal-fluid engineering relevance: Combined heat and power (CHP) systems, heat pumps, t

\subsection{Optimization in Energy Systems}

Energy system design involves tradeoffs: capital cost vs. operational cost, reliability vs. re

\hint{Look through the code and identify the optimization algorithm, provide a short explanation}

\subsection{What's Promising and What's Limited}

\textbf{Promising aspects:}
\begin{itemize}
    \item Renewable costs have dropped 80-90\% over the past decade
    \item Battery storage makes high renewable penetration feasible
    \item Port infrastructure (large areas, proximity to wind resources) suits renewable deploy
    \item Growing regulatory pressure and corporate sustainability commitments
\end{itemize}

\textbf{Limitations:}
\begin{itemize}
    \item Intermittency requires oversizing or backup systems
    \item Battery costs still significant; degradation reduces lifetime value
    \item Space constraints in urban ports
    \item Utility interconnection and permitting can be slow
    \item Uncertainty in future load growth and electricity prices
\end{itemize}

\hint{Background should be 1.5-2 pages. Take a moment to consider the aspects of your chosen lo

% =====
% METHODOLOGY
% =====
\section{Methodology}

\hint{What tools did you use? How did you use them? How might they apply to other problems?}

```

```
\subsection{Tools and Workflow Overview}
```

Our analysis followed this workflow:

```
\begin{enumerate}
\item \textbf{Data collection:} Meteorological data (solar/wind) and load profiles for [Location]
\item \textbf{Resource assessment:} Python analysis of renewable generation potential
\item \textbf{System sizing optimization:} Minimize cost subject to reliability constraints
\item \textbf{Thermal modeling:} COMSOL analysis of [describe thermal component] \hint{if applicable}
\item \textbf{Performance evaluation:} Annual simulation with optimized system
\end{enumerate}
```

\subsection{Python: Data Analysis and Modeling}

We used Python with pandas, numpy, and matplotlib for:

```
\begin{itemize}
\item Processing hourly weather data (8,760 hours/year)
\item Calculating PV generation using irradiance and temperature
\item Modeling wind turbine output from power curves
\item Visualizing load profiles and generation patterns
\end{itemize}
```

\end{itemize}

\hint{Why Python matters: These data manipulation and analysis skills transfer directly to ANY field}

\subsection{COMSOL Thermal Modeling}

\hint{If you used COMSOL for any thermal component|heat exchanger, thermal storage, building heat recovery}

We developed a COMSOL model to analyze [thermal component, e.g., heat exchanger for waste heat recovery]

\textbf{Governing equations:} \hint{Energy balance, heat conduction, convection|whatever is relevant}

\textbf{Key findings:} \hint{What did the thermal model tell you? Did it affect your system design?}

\subsection{Assumptions and Limitations}

\hint{CRITICAL: Document your assumptions! This shows engineering judgment.}

\textbf{Key assumptions:}

```
\begin{itemize}
\item Weather data from [source] represents typical conditions
\item Load profile based on [actual data / scaled from similar facility / synthetic]
\item Component costs from [NREL ATB / vendor quotes / literature]
\item Other significant assumptions specific to your analysis
\end{itemize}
```

\end{itemize}

\textbf{What we simplified:}

```
\begin{itemize}
\item Perfect forecasting (real systems need prediction algorithms)
\item Neglected grid constraints / power quality issues
\end{itemize}
```

```

\item Assumed constant component efficiency (varies with load, temperature, etc.)
\end{itemize}

\hint{Being honest about limitations doesn't weaken your work|it strengthens it by showing you

\subsection{Applicability to Other Contexts}

\hint{One paragraph: Where else could you use these tools and this approach?}

This methodology applies to any facility requiring reliable power: hospitals (backup critical)

\hint{Methodology: aim for 2-2.5 pages total.}

% =====
% RESULTS
% =====
\section{Results}

\hint{Let your figures do the talking! Each figure should have a descriptive caption that explains the data and its significance.}

\subsection{Optimal System Configuration}

The optimization resulted in the following system sizing for [Location]:


\begin{table}[h]
\centering
\caption{Optimal renewable energy system design}
\begin{tabular}{@{}lcc@{}}
\toprule
\textbf{Component} & \textbf{Capacity} & \textbf{Annual Output} \\
\midrule
Solar PV & X kW & Y MWh \\
Wind Turbines & Z kW (n units) & W MWh \\
Battery Storage & A kWh / B kW & - \\
Backup/Grid & C kW & D MWh \\
\midrule
\textbf{Renewable Fraction} & \textbf{E\%} & - \\
\bottomrule
\end{tabular}
\end{table}

\hint{Replace with your actual results. Add 1-2 sentences interpreting the sizing|does it make sense given the context?}

\subsection{Key Results: 8 Essential Figures}

\begin{figure}[h]
\centering
\includegraphics[width=0.3\textwidth]{fig.png}

```

```

\caption{\textbf{TITLE.} caption text.}
\label{fig:1}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.45\textwidth]{fig.png}
\hfill
\includegraphics[width=0.45\textwidth]{fig.png}
\caption{Two figures side by side}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{fig.png}
\caption{\textbf{TITLE.} caption text.}
\label{fig:4}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.6\textwidth]{fig.png}
\caption{\textbf{TITLE.} caption text.}
\label{fig:5}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.2\textwidth]{fig.png}
\caption{\textbf{TITLE.} caption text.}
\label{fig:6}
\end{figure}

\begin{figure}[H]
\centering
\begin{subfigure}{0.48\textwidth}
\includegraphics[width=\textwidth]{fig.png}
\caption{First subfigure}
\label{fig:sub1}
\end{subfigure}
\hfill % Space between figures
\begin{subfigure}{0.48\textwidth}
\includegraphics[width=\textwidth]{fig.png}
\caption{Second subfigure}
\label{fig:sub2}
\end{subfigure}
\caption{Overall caption for both}
\label{fig:both}
\end{figure}

```

```
\end{figure}

\hint{Figure captions are LONG and INFORMATIVE|they should tell the story even if someone only
\clearpage
% =====
% DISCUSSION
% =====
\section{Discussion}

\hint{This is YOUR reflection. What did you learn? What surprised you? How does this connect to
\subsection{Key Insights from the Analysis}

\textbf{What surprised us:} \hint{Fill in something that genuinely surprised you from the results of your analysis}

\textbf{When the optimization "disagrees" with intuition:} The optimization recommended [X], but
\hint{Example: "Optimization says build 5 MW of wind, but that's 2 giant turbines in a small urban area."}

\subsection{Connection to Complex Modern Challenges}

This project illustrates several themes critical to addressing climate change through engineering:
\textbf{Systems thinking:} Renewable energy isn't just about technology|it's about economics, regulation, and social acceptance.

\textbf{Tradeoffs are inevitable:} We cannot simultaneously minimize cost, maximize reliability, and
\textbf{Tools enable analysis, not decisions:} Python and optimization algorithms processed 8,000 scenarios
\hint{Add a paragraph about how this connects to YOUR field of interest or career goals. How might this type of analysis be useful in your work?}

\subsection{Simplifying Assumptions: Impact and Justification}

Our analysis made several simplifying assumptions that affect results:
\textbf{Perfect forecasting:} We assumed perfect knowledge of weather and load. Real systems need to
\textbf{Constant efficiency:} Component efficiency varies with load, temperature, and age. Batteries also
\textbf{Grid always available:} We assumed grid import as backup. True islanded operation would
\hint{Add 2-3 more assumptions you made and how they affect interpretation.}

\textbf{Why these assumptions are reasonable:} For preliminary sizing and concept viability, these
\subsection{What We'd Do Differently / Future Improvements}

\hint{Honest reflection: What would you change? Not because you did it "wrong" but because you
\clearpage
```

If starting over or extending this work:

```
\begin{itemize}
    \item Improvement 1|e.g., "Include demand response or flexible loads"
    \item Improvement 2|e.g., "Model different battery chemistries more carefully" \item Improvement 3|e.g., "Optimize for resilience to extreme events, not just cost"
\end{itemize}
```

\hint{Discussion should be 1.5-2 pages. Make it thoughtful and personal|this is where your voice comes through}

```
% =====
% CONCLUSION
% =====
```

\section{Conclusion}

\hint{Wrap it up: What did you accomplish? What's the outcome? How does this benefit your location?}

This project designed an optimized renewable energy system for [Location], demonstrating that

```
\textbf{Key outcomes:}
\begin{itemize}
    \item Technical feasibility confirmed: renewable resources adequate for [reliability level]
    \item Economic assessment: lifecycle costs [competitive with / X\% higher than] grid baseline
    \item Environmental impact: [emissions reduction percentage]
    \item Transferable methodology applicable to similar infrastructure
\end{itemize}
```

```
\textbf{Benefits to [Your Location]:}
\begin{itemize}
    \item Reduced local air pollution (NOx, particulates) benefiting [community]
    \item Energy cost stability (hedging against fossil fuel price volatility)
    \item Resilience through distributed generation and storage
    \item Economic development through green technology deployment
    \item Meeting regional/national decarbonization targets
\end{itemize}
```

```
\hint{Add 1-2 location-specific benefits based on what you learned about your port.}
```

\textbf{Broader implications:} Ports represent just one node in global supply chains. Electrification and efficiency gains can have far-reaching impacts across the entire network.

\textbf{Final reflection:} \hint{One sentence that captures what this project taught you about the intersection of energy and transportation}

\hint{Conclusion: 1 page maximum. Leave them with a clear takeaway.}

```
% =====
% REFERENCES SECTION
% =====
```

```
% In-text citation example:  

% The methodology described in \cite{smith2022} demonstrates robust performance  

% across multiple datasets, with comparable results found in \cite{johnson2023}.  

  

\section*{References}  

  

\cite{chen2023,garcia2022,johnson2023,lee2021,smith2022}  

\printbibliography[heading=none]  

  

\section*{Appendix}  

Optional  

\end{document}
```

And now the code readme

```
# ME 401 project 1 - Renewable Energy Infrastructure Optimization Toolkit  

  

## Overview  

  

This software demonstrates how Python can support engineering workflows in energy systems design.
```

Purpose

The toolkit uses open-source data sets to evaluate solar and wind energy potential for a specific location:

- Heating and cooling loads of a small residential development
- Base electrical load of an electrified regional shipping port

The system is optimized by selecting and sizing:

- **Solar PV and Wind Turbines**
- **Battery Energy Storage System (BESS)**

Workflow Summary

1. **Data Ingestion**
 - Pull and preprocess open data (`renewables.ninja`)
2. **Demand Modeling**
 - Simulate residential and port electrical demand over a typical year
3. **Generation Modeling**
 - Estimate solar and wind output potential for the region
4. **Storage and Backup Power Integration**

- Model BESS behavior
 - Include Rankine-Cycle generation
5. **Optimization & Analysis**
- Size infrastructure to minimize LCOE and Loss of Load
 - Compare performance under different configurations
6. **Report Generation**
- Compile findings into a LaTeX report using a provided Overleaf template

Requirements

- Python 3.x
- pandas, numpy, matplotlib, scipy
- Overleaf account for final report

Intended Use

This toolkit supports student engineering teams in:

- Exploring the integration of renewables into complex energy systems
- Applying computational tools for system design and cost analysis
- Collaborating on technical documentation using LaTeX

Notes

- The code is modular and extensible for deeper analysis (e.g., hourly simulation, different d

Download link:

To download the data-analysis package the following link can be used:

https://minhaskamal.github.io/DownGit/#/home?url=https://github.com/maxwellhewes/ME_401_project1

To download the notebook for upload to Kaggle:

https://downgit.github.io/#/home?url=https://github.com/maxwellhewes/ME_401_project1/blob/main/notebook.ipynb

This folder can be uploaded to kaggle, or any other notebook hosting service to run the package

and now the example analysis.py file

"""

Run script designed to take three defined classes (

```
two optimization and one formatting)
with provided input data and generate performance metrics.
```

```
Created for ME 401 @ Boise State University
Author: Maxwell Hewes, Summer 2025
"""

import bess_optimizer as heo # hybrid energy optimizer
import data_formatter as idf # input data formatter
import supply_optimizer as opt # wind / solar capacity optimizer

# Original Datasets
# wind = 'python-scripts/data_sets/NOLA_wind.csv'
# solar = 'python-scripts/data_sets/NOLA_solar.csv'
# heat = 'python-scripts/data_sets/NOLA_heat.csv'
# port_location = 'New Orleans'

# Seattle datasets
wind = 'python-scripts/data_sets/Seattle/wind.csv'
solar = 'python-scripts/data_sets/Seattle/solar.csv'
heat = 'python-scripts/data_sets/Seattle/heat.csv'
port_location = 'Seattle'

# Data sourced from https://www.renewables.ninja
port_file = 'python-scripts/data_sets/port_demand_raw.csv'

data = idf.DataFormatter()
data.gather_port_demand(port_file, port_location)
data.gather_heat_demand(heat)
data.build_demand()
data.gather_solar(solar)
data.gather_wind(wind)
data.check_array_length()

optimizer = opt.SolarWindOptimizer()
optimizer.make_arrays(data.wind, data.solar, data.demand)
optimizer.optimize()

data.solar = data.solar * optimizer.opt_solar_
data.wind = data.wind * optimizer.opt_wind_

system = heo.HybridEnergyOptimizer()
system.time_series = data.produce_avg_data_frame()

results = system.simulate_bess_operation(10,3)
system.optimize_bess_capacity()
print(system.results['optimal_capacity'])
```

```
pMetrics = system.calculate_performance_indicators()  
system.display_results()
```

please generate ideas for how to move forward with this project. I have already got the code v
Generate a concise list of ideas

'''

RESULTS

I am actually a prompt engineer at my job right now and I think my first prompt gave me a satisfactory result. I'm not super familiar with this field so most of the terms it used I don't understand (and thus it would require clarification questions to really understand the entire response) but it did suggest considering battery degradation in the BESS model, which I think is a good idea and probably not very hard to implement.

Here is a link to the chat I am [documenting](#)

OUTPUT

helpful.

Below is a concise, ****implementation-oriented**** list of additions that fit your existing structure

0.0.1 High-value additions (easy to integrate, strong report impact)

1. Add explicit reliability constraint to solar/wind sizing

- Enforce a maximum Loss of Load Probability (LOLP) or unmet energy fraction inside `SolarWindOptimizer.optimize()`.
- Directly supports “reliability vs cost” discussion in *Methodology* and *Discussion*.

2. Multi-objective optimization (cost vs renewable fraction)

- Sweep weights or constraints and generate a Pareto front.
- Plot LCOE vs renewable penetration.
- Very strong “tradeoffs” figure for the Results section.

3. Battery power rating optimization (kW and kWh separately)

- You currently optimize mainly capacity.
- Add inverter / charge-discharge power limits as a decision variable.
- Improves realism and thermal-management relevance.

4. Degradation-aware BESS model

-
- Add simple cycle-based or throughput-based degradation.
 - Penalize lifetime energy throughput in the objective.
 - Supports battery limitations discussion.
-

0.0.2 Medium-effort but technically strong extensions

5. Curtailment modeling

- Track renewable energy spilled due to full battery or low load.
- Add curtailment percentage as a performance indicator.

6. Demand response / flexible load

- Shift part of heating load or port load within a time window.
- Evaluate how flexibility reduces required storage and backup.

7. Seasonal storage comparison

- Run the same system with:
 - Li-ion only
 - Li-ion + large “long-duration” storage placeholder (simple tank or virtual storage)
- Show how winter shortfall changes for Seattle.

8. Grid export and revenue

- Allow excess generation to export at a lower tariff.
 - Add a simple buy/sell price model.
 - Improves realism and economic interpretation.
-

0.0.3 Thermal-fluid / ME-401-aligned additions

9. Heat pump instead of electric heating

- Replace direct electric heating with COP-based heat pump load.
- Make COP temperature-dependent using your weather data.
- Strong link to thermal systems and COMSOL relevance.

10. Thermal storage for heating

- Add a simple hot-water tank model.
 - Shift heating energy to high-renewable periods.
-

0.0.4 Model robustness & engineering judgment

11. Weather year sensitivity

- Run at least two different weather years (or synthetic perturbed data).
- Show how optimal sizing changes.

12. Cost sensitivity analysis

- Vary:
 - battery \$/kWh
 - solar \$/kW
 - wind \$/kW
- Plot capacity vs cost assumptions.

13. Extreme-event / resilience test

- Inject a multi-day low-wind, low-solar event.
 - Quantify load loss and backup usage.
-

0.0.5 Optimization / algorithm improvements (fits your codebase well)

14. Replace single optimizer call with global search

- Wrap solar-wind sizing in:
 - grid search or
 - scipy differential evolution
- Avoid local minima and improves methodological depth.

15. Joint optimization of solar, wind, and battery

- Instead of sequential sizing:
 - optimize all three decision variables together.
 - Much stronger systems-engineering result.
-

0.0.6 Reporting-focused metrics you can easily add

16. CO reduction metric

- Compare grid/backup generation to renewable case.
- Add “tons CO avoided per year”.

17. Capacity factor and utilization of assets

- Solar CF, wind CF, battery utilization.
 - Useful for interpreting oversizing.
-

0.0.7 Very practical next step for your current Seattle run

If you only add **three things**, the best return is:

- reliability constraint on unmet load
- Pareto front (cost vs renewable fraction)

- heat-pump-based heating load with temperature-dependent COP

These three directly strengthen your Results, Discussion, and thermal-systems connection without rewriting the architecture. –

Unhelpful. –

This memo is designed for use by the Wada Research Group to develop ethical and efficient engineering education strategies and technologies.