Final project: ELECTRA

Using smart charging to reduce carbon emissions caused energy losses in Electric Vehicle charging

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Computational Entrepreneurship

1. **Introduction**

The problem identified is the carbon emissions offset by inefficient Electronic Vehicle charging are contributing to climate change. Our charging systems are inefficient.

And it's impacting our planet. Conventional EV charging in the UK relies on a grid that sources fossil fuel-based, solar, wind, etc. energy. This means we are ultimately charging out electronic vehicles with fossil fuels. Negative impact on the environment:

- **Higher Carbon Footprint:** Charging EVs with electricity derived from fossil fuels increases overall carbon emissions, undermining the environmental benefits of EVs.
- **Energy Source:** The conventional UK grid relies on fossil fuels for around 33% of electricity (as per UK Energy Trends March 2024)

Negative impact on EV owners:

- **Battery Health:** Deterioration caused by overcharging reduces battery lifespan.
- **Wasted time:** Inefficient charging systems lead to prolonged charging times

Our proposed solution is software that shifts to smart charging with dynamic programming uses less current, keeps the system at a reduced load, and adjusts charging plans with real-time data. This solution has the following impact metrics:

- **Reduces Energy losses:** By charging at lower currents (optimal speed), balancing loads between stations, and making real-time adjustments as vehicles come in
- **Reduced Carbon emissions linked to energy losses**: Minimizes losses by reducing charging power and calculating losses using real-time data.
- **Increase battery longevity**: By preventing overcharging.
- **Decrease wait times:** Ensures vehicles are ready and charged by the time the user needs to drive off

Within the scope of the project, the first metric has been fully developed and included in the MVP. The other three metrics have an initial development but will be developed fully in the next product prototype.

2. **Body of Research**

The process behind the problem definition

Before selecting the final problem statement, I led the group in conducting in-depth research and brainstorming sessions on potential problems to address to contribute to less climate change. The following list contains all the other ideas we discussed as a team:

- Create a tool for sustainable farming to reduce pollution from the agroindustry

- Create a system to assign/limit energy to reduce energy use and light pollution in Canary Wharf
- Reduce the harm of AI by proposing a clean data center (reducing the amount of energy used)
- Using AI/ML to reduce the carbon footprint of the fashion or construction industry
- Use hardware to simulate electronic vehicle charging and reduce the energy being utilized

Annex 1 contains evidence of the in-depth research of each idea, the 5 Why's brainstorming exercise, the 5 W's, and the 1 H brainstorming exercise, amongst others.

Research and Realisation

While researching, we encountered a lot of information on the sustainability of electronic vehicles being less than expected so decided to tackle this problem. Our main insight was discovering that more renewable energy does not necessarily mean less carbon emissions because this reduction depends on the grid the energy is interacting with, not the source of the energy itself. That notion of a "clean" energy not being as clean as we might think, led us to formulate our next hypothesis. If EVs in the UK are being charged on a grid heavily reliant on fossil fuels, then we are not even using renewable energy. Please see Annex 2 for notes on the key research conducted on this topic.

In the next stage of our research, we concentrated on the following points of research:

- How the energy grid in the UK works (charging in peak times, etc.)
- Effects of balancing an energy grid (UK or international case studies) - how it reduces carbon footprints, negative effects of having an imbalanced energy grid
- ML approaches to energy loss reduction in the world - What has already been done! What have researchers already discovered?
- Things that have been done to reduce energy consumption (via charging) in the UK
- How energy consumption translates into emissions in the UK

As a team, we also conducted additional research covering up to 12 academic studies of how computing can be harnessed to reduce energy losses while charging. Please see Annex 3 to access the group Google Docs where both of these research exercises are found.

Creative Computational Exercise

The software developed uses the research previously mentioned to hit the four impact metrics described in the introduction in the following manner:

- **Optimal Charging Speed:** The algorithm uses an optimal charging speed for each vehicle instead of the maximum charging speed. Charging at optimal speeds can reduce energy losses, as losses are often proportional to the square of the current. By charging at lower currents (optimal speed), the algorithm reduces these losses.
- **Energy Loss Calculation:** Energy losses are calculated using a simplified model where losses are proportional to the square of the power (Ohm's Law). By reducing the charging power, the algorithm minimizes these losses.

- **Efficient Use of Time:** The algorithm allocates charging tasks based on the available time for each vehicle. It ensures that the vehicle charges within the available time frame, preventing overcharging and unnecessary energy consumption.
- **Balanced Load Distribution:** By checking the current load and maximum load of each station, the algorithm ensures that no station is overloaded. This balanced distribution of load helps in maintaining efficient energy use across all stations.
- **Real-time Adjustment:** The algorithm takes real-time data into account (e.g., current battery levels, available time, and current station load), allowing for dynamic adjustments and avoiding fixed schedules that might not be energy efficient.

3. **Technical implementation (project management, development, and deployment)**

Now, to develop software that could achieve hitting the 4 metrics in a simple yet reliable way. We developed a main charging algorithm (algorithm.py) developed in python to optimize charging and allocate charging tasks between stations. The following list details the step-by-step functioning of our software:

a) **User Inputs**:

- Battery Level: Current battery level of the EV.
- Car Type: Specific type of EV, as charging capabilities and battery sizes vary.
- Current Location: The user's current location is used to find the nearest charging stations.
- Maximum Duration: The number of hours the user has to finish charging their car.

b) **Finding Closest Charging Stations**:

- Google Maps API: The software uses the Google Maps API to locate the nearest charging stations based on the user's current location and preferences.

c) **Charging Station Assignment**:

- Data Analysis: The software analyzes the data to select the most suitable charging station considering factors like distance, availability, and charging speed.
- Optimal Station: Assign the EV to the nearest charging station that can charge the car within the user's maximum duration.

d) **Charging Process**:

- Optimal Speed Charging: The software controls the charging rate to optimize energy efficiency, charging the EV up to a maximum battery level of 80% to minimize energy loss.
- Random Charging for Comparison: Uses a random assignment and charging rate for comparative purposes to highlight the efficiency of the optimized process.

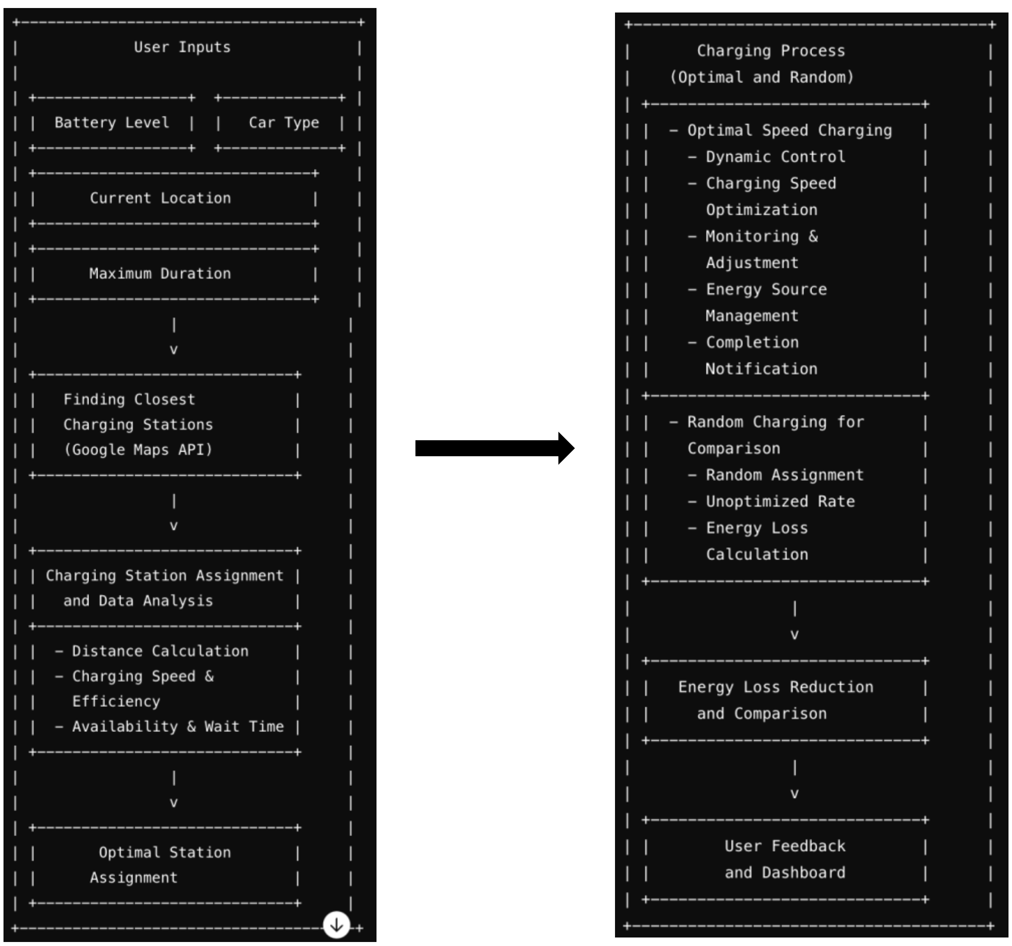
e) **Energy Loss Reduction**:

- Efficiency Calculation: The software calculates energy loss for both the optimized and random processes.
- Comparison: Compares the energy loss between the two methods, demonstrating the benefits of the optimized process.

f) **User Feedback (using flask)**:

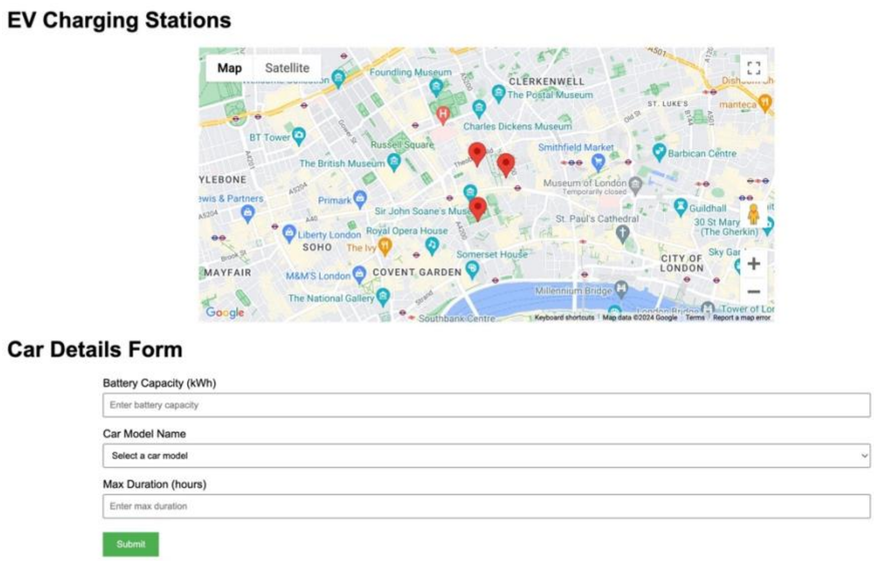
- Dashboard: Users can view the charging status, energy savings, and efficiency comparisons.
- Notifications: Sends alerts and updates about the charging process and results.

The following diagram illustrates how this main algorithm is structured:

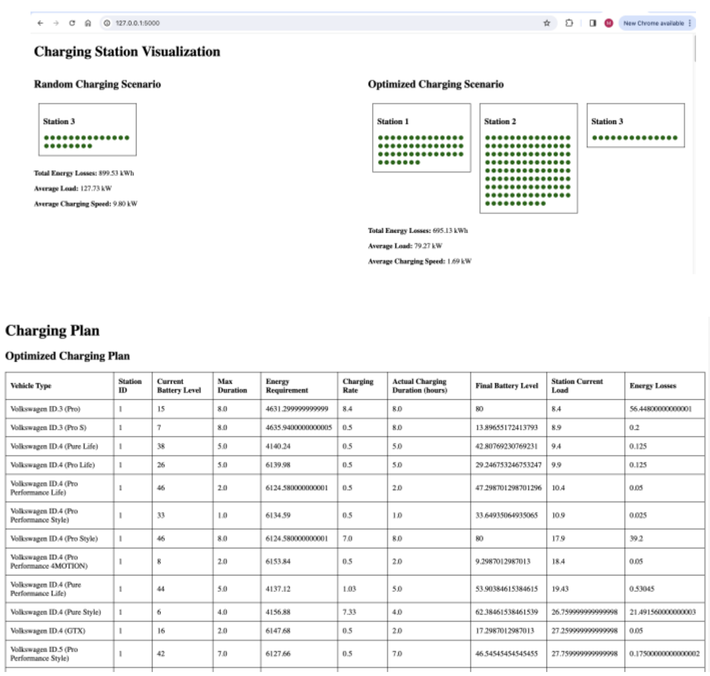


The next step was to develop the GUI and user interface. This part is split in two for this project: 1) the interface the user (EV owner looking to charge their car) sees and interacts with and 2) the GUI with the dashboard that our actual client (government or station owners) would see with all of their result metrics. Both parts were developed in JavaScript/HTML and were locally hosted on our laptops.

This is the user interface mentioned above:



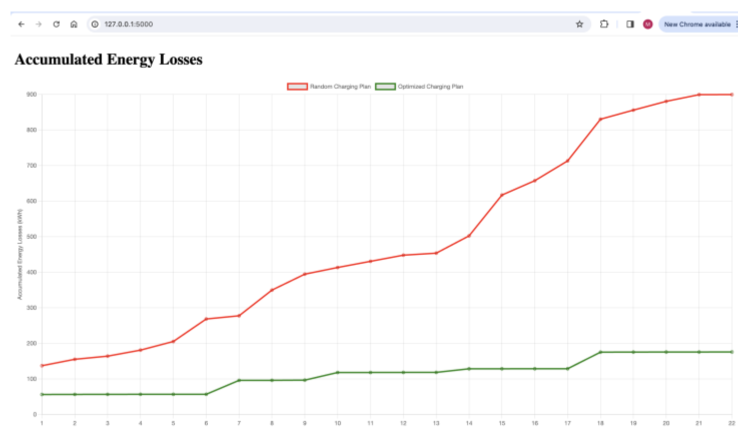
This is the dashboard available to station owners /governments



Charging Plan

Optimized Charging Plan

Vehicle Type	Station ID	Current Battery Level	Max Duration	Energy Requirement	Charging Rate	Actual Charging Duration (hours)	Final Battery Level	Station Current Load	Energy Losses
Volkswagen ID.3 (Pro)	1	15	8.0	4631.299999999999	8.4	8.0	80	8.4	56.44800000000001
Volkswagen ID.3 (Pro S)	1	7	8.0	4635.9400000000005	0.5	8.0	13.89655172413793	8.9	0.2
Volkswagen ID.4 (Pure Life)	1	38	5.0	4140.24	0.5	5.0	42.80769230769231	9.4	0.125
Volkswagen ID.4 (Pro Life)	1	26	5.0	6139.98	0.5	5.0	29.246753246753247	9.9	0.125
Volkswagen ID.4 (Pro Performance Life)	1	46	2.0	6124.580000000001	0.5	2.0	47.298701298701296	10.4	0.05
Volkswagen ID.4 (Pro Performance Style)	1	33	1.0	6134.59	0.5	1.0	33.64935064935065	10.9	0.025
Volkswagen ID.4 (Pro Style)	1	46	8.0	6124.580000000001	7.0	8.0	80	17.9	39.2
Volkswagen ID.4 (Pro Performance 4MOTION)	1	8	2.0	6153.84	0.5	2.0	9.2987012987013	18.4	0.05
Volkswagen ID.4 (Pure Performance Life)	1	44	5.0	4137.12	1.03	5.0	53.90384615384615	19.43	0.53045
Volkswagen ID.4 (Pure Style)	1	6	4.0	4156.88	7.33	4.0	62.38461538461539	26.759999999999998	21.491560000000003
Volkswagen ID.4 (GTX)	1	16	2.0	6147.68	0.5	2.0	17.2987012987013	27.259999999999998	0.05
Volkswagen ID.5 (Pro Performance Style)	1	42	7.0	6127.66	0.5	7.0	46.54545454545455	27.759999999999998	0.17500000000000002



In terms of project management, the team worked together in weekly meetings as well as separately on specific pieces of the work that had been split up. We shared a selection of collaborative project documents and tools including a Miro board for brainstorming, a selection of Google docs and spreadsheets, and a shared repository on Git Hub.

4. Entrepreneurship

Our innovative software aims to revolutionize the efficiency and environmental impact of electric vehicle (EV) charging systems by leveraging advanced computational technologies. By aligning with the societal goal of reducing energy loss and optimizing resource use, this software serves both economic and environmental needs. We intend to create a win-win situation by providing governments and EV station owners with a tool that not only enhances the operational efficiency of charging stations but also minimizes their carbon footprint. Through a Business Model Canvas (BMC) approach, we will clearly outline the value proposition, key activities, resources, and customer relationships to ensure transparency and mutual benefit. Our negotiation strategy will focus on demonstrating the tangible benefits of the software, such as cost savings and sustainability improvements, to secure partnerships that drive widespread adoption and societal impact. The following outlines a summary of our BMC:

Key Partners

- Governments
- EV Station Owners
- Google Maps API providers
- Renewable energy suppliers

Key Activities

- Software development and maintenance
- Real-time data integration
- Customer support and training
- Marketing and sales

Key Resources

- Advanced algorithms for dynamic programming
- Real-time data integration systems
- Load balancing technology
- Skilled development and support team

Value Propositions

- Reduced energy loss and optimized charging efficiency
- Real-time adjustments based on dynamic data
- Improved load balancing across charging networks
- Scalable solutions for small to large deployments

Customer Relationships

- Dedicated support for all packages
- Customization options for unique requirements
- Regular updates and improvements

Channels

- Direct sales to governments and EV station owners
- Online marketing and webinars
- Partnerships with renewable energy suppliers

Customer Segments

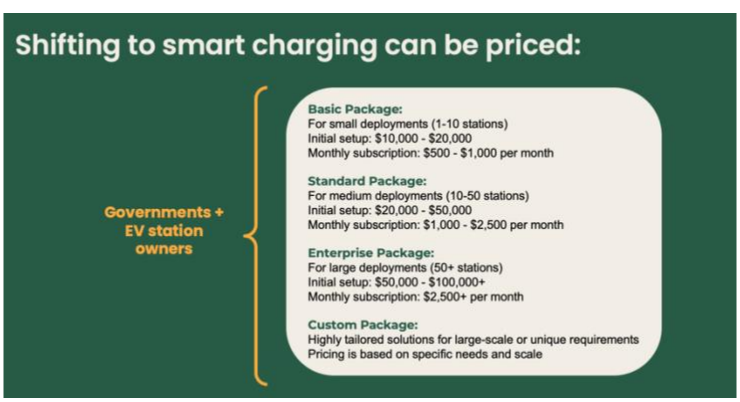
- Small EV station owners (1-10 stations)
- Medium EV station networks (10-50 stations)
- Large EV station networks (50+ stations)
- Custom solutions for unique or large-scale deployments

Cost Structure

- Initial setup costs
- Monthly subscription fees
- Maintenance and support costs
- Marketing and sales expenses

Revenue Streams

- Initial setup fees (ranging from $10,000 to $100,000+)
- Monthly subscription fees (ranging from $500 to $2,500+ per month)
- Custom package pricing based on specific needs



Taking into account this business model, we would expect to reach a revenue of 2.4million dollars per year by year five and recover the initial investment of $500,000 by year two:

Financial Model:

Projections Year 5

Revenue: $2,402,102

Operational profit: $1,732,391

Active packages: 52

Assumptions

Total Market: over 40k stations

Capturable Market Share: 3%

Year 1 will sell 5 basic, 3 standard and 2 enterprise packages.

Operational costs increase 25%, 20%, 15% and 10% in years 1-4.

CapEx of $50,000 annually for upgrades and maintenance.

Initial investment of $500,000 for tech infrastructure and initial operation.

View commercial model spreadsheet

5. **Accessibility, Inclusion, and Ethics: Ensuring Privacy and Security**

Attention to Stakeholder Impacts and Ethical Considerations

Our software, Electra, places a high priority on addressing stakeholder impacts and maintaining ethical standards, particularly regarding user privacy and data security. We understand the critical importance of these aspects in building trust and ensuring the responsible use of technology.

User Privacy and Data Security

- **Data Storage and Privacy**: Electra uses state-of-the-art encryption and secure cloud storage to protect user data. All data collected is anonymized to prevent any potential misuse of personally identifiable information. We comply with global data protection regulations, such as GDPR and CCPA, ensuring that user privacy is maintained at all stages.
- **Security Measures**: Our software employs robust security protocols, including end-to-end encryption, regular security audits, and real-time monitoring for unauthorized access. We also have a dedicated security team to address vulnerabilities promptly and ensure the highest level of data protection.

Ethical Considerations

- **Informed Consent**: Users are fully informed about what data is being collected, how it is used, and the measures taken to protect their privacy. Consent is obtained explicitly, ensuring transparency and user control over their data.
- **Impact on Marginalized Communities**: Electra is designed to be inclusive and accessible to all users, including marginalized communities. By optimizing charging

efficiency and reducing costs, we make EV charging more affordable and accessible, promoting broader adoption of sustainable transportation options.
- **Digital Inclusion**: We provide support in multiple languages and ensure our software is accessible to users with disabilities, following WCAG (Web Content Accessibility Guidelines) standards. We aim to make Electra a tool that benefits a diverse user base, regardless of socioeconomic status or technical proficiency.

Societal Impact and Ethical Technology Development

- **Balancing Innovation and Accessibility**: While Electra leverages advanced technologies like dynamic programming and real-time data integration, we ensure these innovations are accessible to a wide range of users. Our tiered pricing model accommodates various deployment scales, making it feasible for small businesses and large enterprises alike.
- **Environmental Benefits**: By reducing energy loss and optimizing resource use, Electra contributes to environmental sustainability. This aligns with global efforts to combat climate change and promotes the adoption of cleaner technologies.
- **Continuous Ethical Review**: We have established an ethics committee to continually review our practices and ensure they align with our commitment to social responsibility. This includes evaluating the societal impact of our software and making adjustments as necessary to uphold our ethical standards.

In conclusion, Electra is developed with a deep commitment to ethical considerations, user privacy, and data security. We strive to create a positive societal impact by making EV charging more efficient, accessible, and inclusive, ensuring our technology benefits all users while protecting their rights and interests.

6. Reflection/Discussion

Teamwork, individual contributions, and key learnings

Throughout this project, I took on a wide range of responsibilities and made significant contributions that were essential for its success. Here's a comprehensive list of my contributions:

- Designed and coded our main charging algorithm (algorithm.py), ensuring its efficiency and effectiveness in optimizing charging processes.
- Developed the graphical user interface (GUI) for our clients, including energy-saving graphs, metrics, and detailed charging plan tables, enhancing user experience and accessibility.
- Developed the full financial model, ensuring accuracy and feasibility in our projections.
- Designed and structured the PowerPoint presentation, creating a compelling narrative and visually engaging slides.
- Developed Electra's brand identity, ensuring consistency and alignment with our project goals.
- Crafted the final and refined problem statement, incorporating inputs from the team for clarity and precision.
- Led brainstorming sessions to generate innovative ideas and solutions, fostering collaboration and creativity among team members.

- Conducted in-depth research on all topics mentioned in the document, providing valuable insights and data to support our proposals.
- Practiced and delivered the pitch, refining it to effectively communicate our project's value proposition and key features.

These contributions required meticulous attention to detail, extensive research, and a significant time investment. By taking ownership of these tasks, I ensured that our project was comprehensive, well-executed, and aligned with our objectives.

Although not all team members were equally engaged and actively collaborated, this project taught me invaluable lessons about the importance of effective collaboration, division of labor, and integration of individual contributions. I realized that successful teamwork hinges on clear communication channels and open dialogue, ensuring everyone is informed and aligned with the project's objectives. Moreover, I gained insights into the deceptive nature of greenwashing and the importance of critically evaluating sustainability claims. It became apparent that what is marketed as sustainable isn't always so, particularly concerning renewable energy and electric vehicles, which may inadvertently contribute to climate change. This experience underscored the necessity of thorough research and critical thinking to address complex environmental challenges effectively.

Limitations and future work

- **Scalability Concerns:** While Electra's software appears scalable, ensuring seamless scalability as the number of users and charging stations grows needs careful planning and infrastructure development.
- **Data Accuracy Assurance:** Dependency on external data sources like Google Maps API raises concerns about data accuracy and real-time updates. Ensuring data integrity is crucial for reliable service.
- **Thorough User Testing:** Conducting extensive user testing during development could have provided deeper insights into user preferences and potential usability issues specific to Electra's target market.
- **Fully develop all key metrics mentioned throughout this report:** Fully develop metrics beyond the calculation of energy loss linked to optimized vs random charging algorithms.
- **Enhanced Data Analysis:** Incorporating more comprehensive data analysis techniques could further optimize Electra's charging algorithm and decision-making processes.
- **Partnership Expansion:** Exploring partnerships beyond governments and EV station owners, such as automotive manufacturers or energy companies, could expand Electra's reach and offerings.
- **Customer Education:** Provide comprehensive training and support resources to ensure customers can maximize the benefits of Electra's software and understand its capabilities fully.

7. Sources used throughout the project:

GitHub Repositories:

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Note: The unavailable SagePub article (https://journals.sagepub.com/doi/10.1177/25148486231159628) should be cited with the available information you have. If you can provide any additional details (like authors, article title), it would be helpful for citation.

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Annex 1.

Notes taken during the teams first brainstorming meeting:

Loose brainstorming ideas:

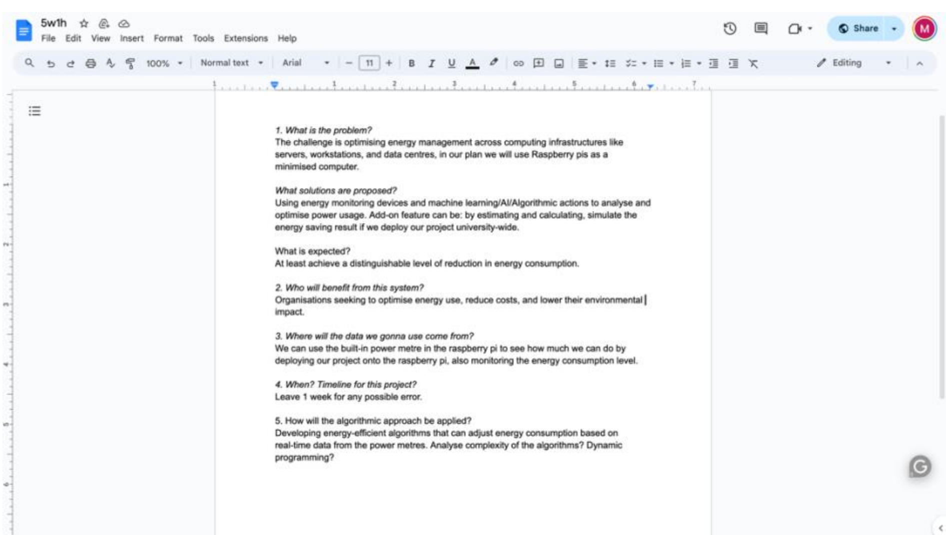
- India has a main fertile region for agricultural activities just above the capital city. Farming in this region is generational. People in this region are illiterate. US company was supposed to “educate” farmers in exchange for providing the farmers with seeds, fertilizers, and everything. Now this is the most polluted region in India because they are growing the wrong crops in the wrong seasons with the wrong fertilizers, and they are burning crops. This coincides with air that is flowing through the mountains so all the smoke flows down to the capital. The proposal: Tool for farmers to decide what to grow in what season and how to reduce emissions, to fight against improper seed practices
- Light pollution in Canary Wharf, servers, and computers are probably 24/7, create a system that collects peak usage times in offices, and then with ML create a model to predict when these will be used and assign energy “budgets” or booking computers somehow

Two potential problem statements:

1) Inefficient supply chains in the [Fashion/Construction/Agriculture] industry generate excessive greenhouse gas emissions and therefore contribute to climate change

2) Fragmented data systems and a lack of an interdisciplinary approach lead to inefficient natural resource management and cause environmental damage (for example deforestation, and overfishing).

(5WHYS are in the pictures on the next page!)



1. What is the problem?
The challenge is optimising energy management across computing infrastructures like servers, workstations, and data centres, in our plan we will use Raspberry pis as a minimised computer.

What solutions are proposed?
Using energy monitoring devices and machine learning/AI/Algorithmic actions to analyse and optimise power usage. Add-on feature can be: by estimating and calculating, simulate the energy saving result if we deploy our project university-wide.

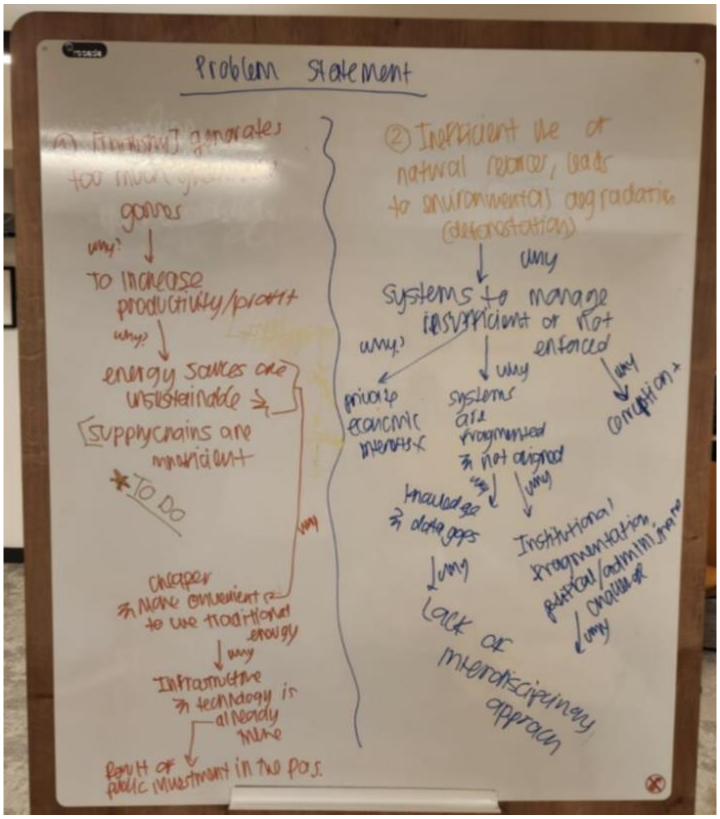
What is expected?
At least achieve a distinguishable level of reduction in energy consumption.

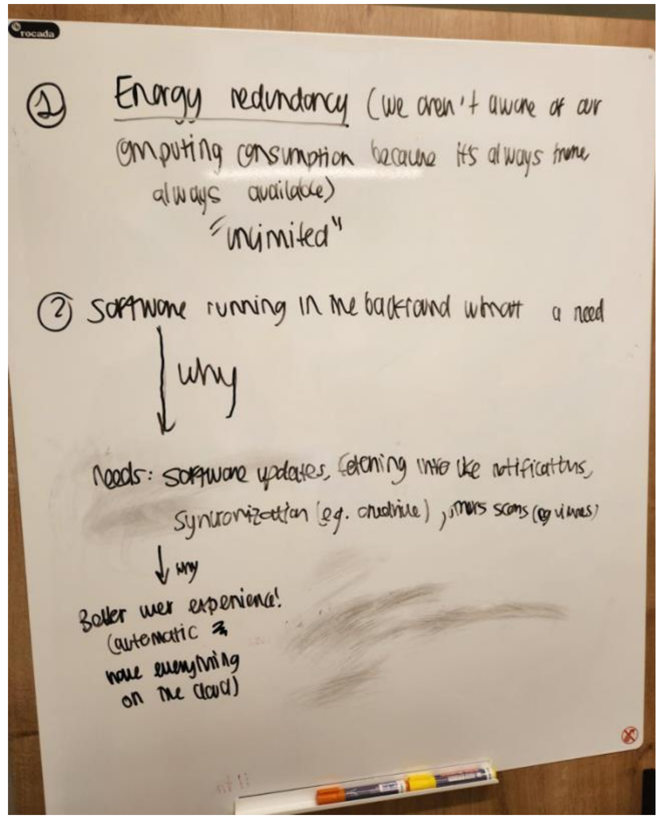
2. Who will benefit from this system?
Organisations seeking to optimise energy use, reduce costs, and lower their environmental impact.

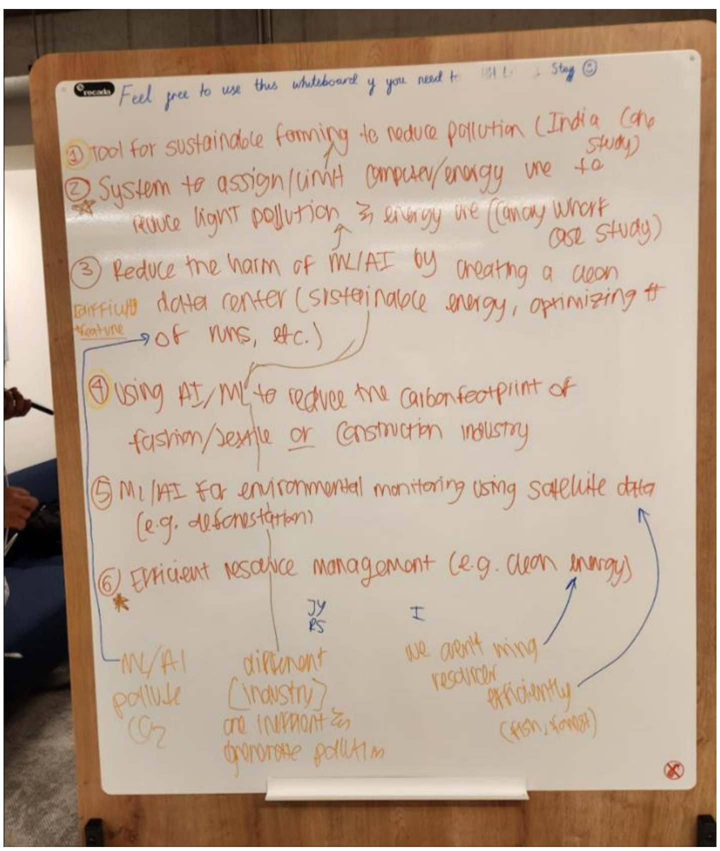
3. Where will the data we gonna use come from?
We can use the built-in power metre in the raspberry pi to see how much we can do by deploying our project onto the raspberry pi, also monitoring the energy consumption level.

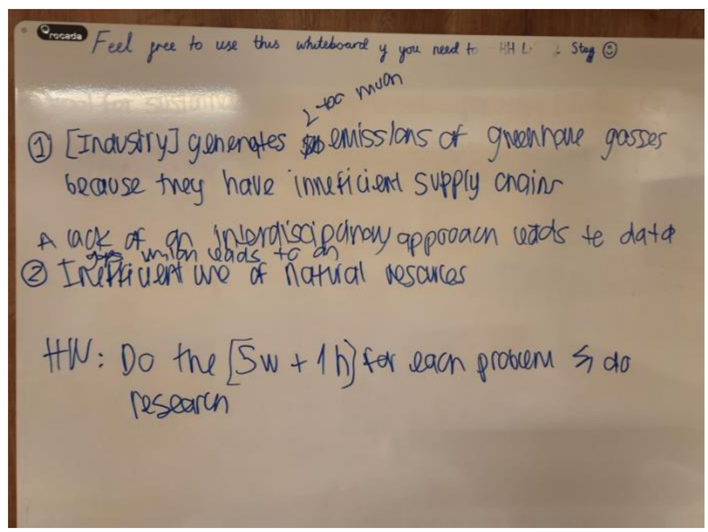
4. When? Timeline for this project?
Leave 1 week for any possible error.

5. How will the algorithmic approach be applied?
Developing energy-efficient algorithms that can adjust energy consumption based on real-time data from the power metres. Analyse complexity of the algorithms? Dynamic programming?


Problem Statement
gasses
why?
To increase productivity/profit
why?
energy sources are unsustainable &
[supplychains are innefficient
*TO DO
why
cheaper
& More convenient to use traditional energy
why
Infrastructure & technology is already there
Result of public investment in the past
② Inefficient use of natural resources, leads to environmental degradation (deforestation)
why
systems to manage insufficient or not enforced
why?
why
why
private economic interests
systems are fragmented & not aligned
corruption
why
why
knowledge & data gaps
Institutional fragmentation political/administrative challenges
why
why
Lack of interdisciplinary approach


① Energy redundancy (we aren't aware of our computing consumption because it's always there always available) "unlimited"
② Software running in the backround without a need
why
Needs: software updates, fetching info like notifications, synchronization (eg. onedrive), virus scans (eg viruses)
why
Better user experience! (automatic & have everything on the cloud)


Feel free to use this whiteboard if you need to
① Tool for sustainable farming to reduce pollution (India (case study)
② System to assign/limit computer/energy use to reduce light pollution & energy use (canary wharf case study)
③ Reduce the harm of ML/AI by creating a clean data center (sustainable energy, optimizing # of runs, etc.)
Difficult
feature
④ Using AI/ML to reduce the carbon footprint of fashion/textile or construction industry
⑤ ML/AI for environmental monitoring using satellite data (e.g. deforestation)
⑥ Efficient resource management (e.g. clean energy)
JY
RS
I
ML/AI pollute CO_2
different [industry] are inefficient & generate pollution
we aren't using resources efficiently (fish, forest)


Feel free to use this whiteboard if you need to
① [Industry] generates too much emissions of greenhouse gasses because they have inneficient supply chains
A lack of an interdisciplinary approach leads to data gaps which leads to an
② Inefficient use of natural resources
HW: Do the [5w + 1h] for each problem & do research

Annex 2.

MORE **RENEWABLE ENERGY DOES NOT NECCESARILY MEAN LESS CARBON EMISSIONS.** THIS REDUCTION DEPENDS ON THE GRID, NOT THE ENERGY SOURCE.

- To guarantee 100 percent emissions reductions from renewable energy, power consumption needs to be matched with renewable generation on an hourly basis, this depends on the type of grid that the country has, not the source of the energy
- Averages of the carbon dioxide associated with grid power is **valid only when fluctuations in renewable generation are small, or when all excess renewables can be stored.** Some European countries experience large fluctuations in carbon content due to existing renewables and do not yet have enough storage capacity to capture all excess electricity.
- Ultimately, the environmental value of renewable energy used for charging devices like EV's depends on the grid they interact with

https://sustainability.stanford.edu/news/when-100-renewable-energy-doesnt-mean-zero-carbon

- One study estimates that renewable energy sources typically emit about 50g or less of CO_2 emissions per kWh over their lifetime, compared to about 1000 g CO_2/kWh for coal and 475 g CO_2/kWh for natural gas.

https://www.wri.org/insights/setting-record-straight-about-renewable-energy

THE MAIN PROBLEM WITH RENEWABLES IS THAT THEY LEAD TO VARIABILITY, THIS IS BEING MANAGED VIA FORECASTING, ETC.

- Wind farms produce electricity when it's windy and solar farms produce power when there's sun, leading to variability in the supply of energy. However, this can be — and is being — managed by utilities and grid operators through operational practices, forecasting, responsive loads and infrastructure such as storage and transmission.

https://www.wri.org/insights/setting-record-straight-about-renewable-energy

SMART CHARGING MAKES ENERGY CHEAPER, NOT MORE SUSTAINABLE

- Data analytics and machine learning algorithms are used to analyze historical charging data and grid conditions to make informed charging decisions. By learning from past behavior and predicting future demand patterns, these algorithms can optimize charging schedules to minimize emissions by maximizing the use of renewable energy and avoiding peak periods of grid carbon intensity.
- The reinforcement learning in the algorithm works by incorporating feedback from positive results, like an EV having the desired amount of charge at the designated departure time. It also incorporates negative results, like having to draw power past a certain peak threshold. **Based on this data, the charge scheduling algorithm can make more intelligent decisions about which cars to charge when.**
- **"Smart charge scheduling is really an optimization problem," Harper said. "In real-time, the charging station is constantly having to make tradeoffs to make sure that each car is being charged as efficiently as possible."**

https://news.uchicago.edu/story/using-machine-learning-improve-management-electric-vehicle-charging

https://www.researchgate.net/publication/286726772_Smart_charging_of_electric_vehicles_using_reinforcement_learning

Annex 3.

Miro board:

https://miro.com/app/board/uXjVKSuGyjE=/

General research:
https://docs.google.com/document/d/1Bhkq8BEoOwcCPOoiiiDje1GgVcrBjtaH9fYyupn-Z2A/edit

https://docs.google.com/document/d/13AWnUWvUpG6Dnvm6h7TCJYHrzY4N6q55jUl0iDDxieI/edit

https://onedrive.live.com/view.aspx?resid=3434BABBBD7C8123%211006&authkey=!AKcMbOznxXGreng

Research on academic studies:

https://docs.google.com/spreadsheets/d/1w02swT_p1l1lQ2NcY6oW9GstdOGzw1QIlfML3cqRig0/edit?gid=0#gid=0

https://docs.google.com/document/d/1AjwV8daEpeDDpp9ntmcp8aHCrBuGKkxHb0E-de-QAOM/edit