Electri-Cache

Electric grid storage solution using electric vehicle batteries – saving carbon emissions

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1 Introduction

In this section we will introduce the key concepts.

1.1 Overview

The average electric vehicle battery can store 90 kwh (kilowatt-hour). The average household uses 30kwh per day. Thus, an average electric vehicle can supply 6 hours of electricity to an average household for under 10 percent of the vehicle battery. Our idea is to create a platform that enables electric vehicle owners to help the electric grid store and consume excess energy. Allowing electric vehicle owners to set a percentage of their vehicle's battery for the electric grid. Thus, when generation is higher than electricity consumption the system can use the vehicle batteries to save energy from waste. Then, when grid consumption is above production, the batteries can be used instead of Peaker plants. This process will reduce carbon emissions and create revenue for the vehicle owner.

1.2 Problem Description and Motivation

The main problem is the instability of the electric grid, the asynchronous timing between peak demand and energy production. Supply and demand on the electric grid can vary; supply can increase or decrease, and demand can rise or fall these do not inherently coincide. Electricity production is achieved through different means. Some of which are highly polluting (Peaker plants), others produce varying amounts of electricity throughout the day or even by the hour (solar panels, wind turbines). A main way in which supply can differ from demand is with what is known as the Duck Curve. The execs energy can be stored instead of wasted.

1.3 Goals

- Reduce carbon emissions
- Save money for users
- Increase awareness of the renewable energy problems:
- Stabilize duck curve
- Find A solution for the lack of electricity storage
- Decrease the use of Peaker plants

1.4 Scope

- Sustainability
- Electric grid
- Electricity storage solutions

1.5 Glossary

- **Average use of electricity** – Household VS car; The average electric vehicle battery can store 90kwh. The average household uses 30kwh per day. Thus, an average electric vehicle can supply 6 hours of electricity to an average household for under 10 percent of the vehicle battery.
- **Bidirectional chargers** [9] – Bidirectional charging makes it possible to charge the batteries of electric vehicles and discharge energy stored in the vehicle batteries into the power grid. Can be used to help balance momentary spikes in electricity demand.

- **Carbon emissions** [6] – Carbon dioxide emissions or CO2 emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring.
- **Consumption fluctuations** – increase and decrease in electricity use due to changes in weather, economic situation, political situation.
- **Duck curve** [7] – The duck curve is a graph of power production over the course of a day that shows the timing imbalance between peak demand and renewable energy production.

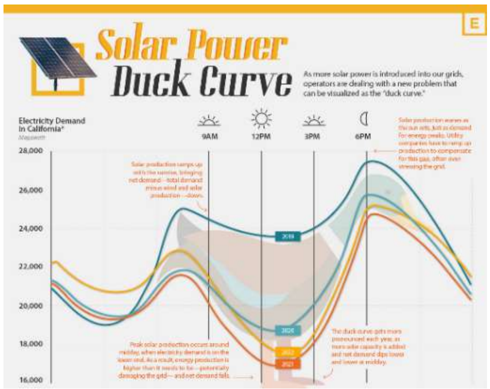


Figure 1 - Graph that shows and describes the Duck Curve. [2]

- **Electric grid** [5] – An electrical grid is an interconnected network for electricity delivery from producers to consumers. Electrical grids vary in size and can cover whole countries or continents.
- **Electricity price fluctuations** [8] – The price of electricity does not rise or fall arbitrarily. The time of day, the time of year, fuel prices and the weather are the variables by which the price of electricity may rise or fall.
- **Grid battery –** The amount of the vehicle battery storage allotted for use by the electrical grid.
- **KWH -** kilowatt-hour unit of energy measurement. One kilowatt for one hour.
- **MoSCoW** – Is a technique for organizing and prioritizing requirements. Prioritized by Must, Should, Can and Will not.
- **Peak demand** – Peak demand refers to the times of day when our electricity consumption is at its highest.
- **Peaker plant** [4] – Peaking power plants, also known as “peaker plants”, and occasionally just “peakers”, are power plants that generally run only when there is a high demand, known as peak demand, for electricity. Because they supply power only occasionally, the power supplied commands a much higher price per kilowatt hour than base load power.


Figure 2 - Peaker plant

- **Private user** – An individual or household that owns their own vehicle or vehicles.
- **Stability of the electric grid** – Balance between production and consumption of electricity.
- **V2G –** Vehicle to grid electricity transportation.

2 General description

In this section we will give a general description of Electri-Cache.

2.1 User Characteristic

In the user characteristics section, we will define the distinct types of characters that will be a part of Electri-Cache.

2.1.1 Client Description

In the client description we will depict the client.

"Electric Ireland is the retail division of ESB (Electricity Supply Board). ESB was established in 1927 as a statutory corporation in the Republic of Ireland and the majority of shares are held by the Irish Government. Previously known as ESB Customer Supply and ESB Independent Energy, the retail division of ESB has been rebranded to Electric Ireland in 2012. Recognized as Ireland's leading energy provider, Electric Ireland supplies electricity, gas and energy services to over 1.2 million households and 95,000 businesses in the Republic of Ireland and Northern Ireland." Electric Ireland [1].

Figure 3 - Electric Ireland logo [1]

2.1.2 End-User's Description and Scenarios

In the end-user's description and scenarios, we will relate the different end users and their circumstances.

Advanced user:

Fraida is married and has a cat. Is the logistics manager at Egged and has many electric buses under her watch that sit idle at certain times, part of her job requirements is to offset costs and as well as make sure the company is meeting their sustainability goals. Freida is an expert at logistics, has excellent technological capabilities and uses a desktop at work.

Figure 4

Scenario:

Fraida has buses numbered 10 through 20 sitting idle at the bus depot between 10:00 and 16:00. The battery usage for the grid on these buses needs to be raised to 100% at these hours. Fraida connects all the buses to the Electri-Cache, then presses the Advanced button. She then creates a new template, configures it to those hours and battery percentages. She then adds the buses to that template. In this way the company saves money and reduces their total emissions.

Average user:

Yosef, married +3, collage graduate, owns an electric car, and understands the implications of our fragile climate and that running a household is expensive. Yosef would like to reap the most out of the system.

Figure 5

Scenario:

Yosef works at a full-time job, stays at his office for long hours. While rushing to work after dropping his kids off at school, he forgets to plug in his vehicle when he gets to work. The system sends Yosef a notification to his phone reminding him to plug-in his vehicle. Yosef pushes on the notification and gets a map with plug-in locations. Yosef chooses a location and presses navigate to open the navigation app of choice.

Naive user:

Bailey, 87, widow +3, High School educated, worked as a typist, her grandkids bought her an electric car, because she cares for the environment.


Figure 6

Scenario:

Bailey receives a notification "Save power – set your vehicle to the recommended amount", Pushes it and her vehicle will automatically charge and discharge relative to the grid market.

2.2 System Perspective

In this section we will describe the different system perspectives.

2.2.1 Software

- User-side app
- Desktop broad control app
- Website
- Server-side operations
- Data analytics

2.2.2 Hardware

- Electric cars
- Electric vehicle bidirectional chargers
- Home and around it - electric connection
- Smartphones
- Desktops
- Servers

2.2.3 Data and Information

- User data
- Vehicle data
- Location data
- Electricity price data
- Historical weather data
- Historical electricity price data

2.2.4 Processes

Defined in the processes are several types of actions a user can interact with Electri-Cache.

1. Notification for the best time for the user to leave their vehicle plugged in:
   a. Notification pops up.

   b. Once the users push on the notification a map with plug-in locations is displayed.
   c. The user can choose a location on the map and press “Navigate” to open their navigation app of choice.
2. History graphs of the user's usage of battery as well as the carbon saving the user have contributed, and how much money the user saved.
   a. Go to the graphs page
   b. The user chooses the graph they want
   c. The user holds their finger for specific times
   d. A message pops up "Do you want to optimize?" If yes go to recommended.
3. Battery control menu - set the amount of battery for the grid or pause it when the user wants their full battery use.
   a. In the interface go to the ‘Home’ page press the plug symbol
   b. Charge the battery only, pause the battery associated for the grid use
   c. Alternatively, set the amount of battery percentage or see it in kwh
4. Advanced - click the advanced button and create templates for use. These templates can be applied to multiple vehicles.
   a. Click the advanced button
   b. Create template
   c. Assign vehicles to template
5. History
   a. A list of prior charging locations
   b. Click on the locations to see how the user's stats at that place
   c. Click to navigate opens Waze
6. Recommended - based on the user's usage to set aside more or less of the user's battery.
   a. The “Recommend” will be a bar that pops up on the ‘Home page’ as a notification, or via other processes
   b. Under it will have the option to “Set to the recommended” or “Choose your own”
   c. "Set to recommended" will set aside a recommended amount battery for the grid based on the user's usage
   d. "Choose your own" will open the battery control menu

(There is a log-in and a sign-up process, as well as the ability to share the user's achievements)

2.2.5 People

People will outline those who need to be associated with Electri-Cache for it to function.

- Electric vehicle owners
- Fleet managers
- System developers
- Marketers
- Electric companies

2.3 Market Survey

A system that will motivate and guide users with one or many electric cars, to store power by charging at renewable energy peak production time and discharging at low. The system will connect the vehicle charging system to the user's smartphone, desktop or tablet and therefore control the vehicle’s battery.

Companies with similar ideas:

- **IO-Techa -** The US-based startup specializes in finding solutions for eVehicle smart charging and powerline communications. Their focus is the design and production of EV chargers. https://www.iotecha.com

Figure 8 - IO-Techa logo

Figure 7 - IO-Techa bidirectional charger

- **V2G EVSE** - This is a growing UK-based startup that produces and distributes bi-directional electric vehicle charging stations. https://www.v2g-evse.com

Figure 9

- **Fuergy** - "Our goal is to shift from conventional electricity consumers to innovative green power prosumers who produce, consume and share energy effectively." Products: BraIn – smart battery storage solution, MAInchart – dispatch system for electricity suppliers. https://fuergy.com/about-us

Figure 10 - Fuergy logo

Figure 12

Figure 11

Company	Advantages	Disadvantages
IO-Techa	The company produces a suitable charger which contributes to energy transportation process from vehicle to grid.	Lack of a user-friendly interface.
V2G EVSE	Bi-directional charging stations are a good way for vehicle owners to be able to consume and dispatch electricity at any given time.	Lack of a visual interface that saves previous visited locations and contains map.
Fuergy	A smart battery and a dispatch system are necessary so that the vehicle owner will control how much electricity it set aside for vehicle or for grid.	A multifunctional system that transmits and cycles electricity for both battery and grid.

Electri-Cache will grant the client both hardware (e.g. - bidirectional chargers, V2G charger stations, smart batteries, and a smart dispatch system for electricity suppliers.), and software (e.g. - a location and navigation system) access whilst maintaining a user-friendly interface, and obtaining the foundational ideas offered by the companies mentioned above.

2.4 The approach

Electri-Cache will create a platform that will guide the user to save money and carbon emissions. The system is based on the idea that a proper solution for grid instability is storage of power by a battery that is accessible and capable to it as an electric vehicle battery. Our system will contribute to grid stability and will reduce carbon emissions by concentrating data regarding the best time to charge and discharge the vehicle’s battery, and by easing the user that needs to manually change the process from charging to discharging, to automatic conversion.

2.5 Constraints

The constraints for Electri-Cache will be outlined next.

- The bidirectional charger must have an internet connection during charging and discharging.
- The user must have an electric vehicle with a bidirectional charger.
- The user is not using their vehicle during renewable energy peak production time.
- The user does not need the full electric vehicle battery.

2.6 Assumptions and Dependencies

The assumptions and dependencies section will focus on key things that are needed for Electri-Cache to operate.

- Electric grid
- Internet
- Electric vehicles and owners
- Servers
- Bidirectional electric vehicle chargers
- Major assumption is that the electricity grid can be predicted based on the weather

3 Functional requirements

The Functional requirements will be defined as follows according to the type of requirement and prioritized by MoSCoW.

Functions:

- **Location page [S]**
  a. A map with plug-in locations is displayed.
  b. The user chooses a location.
  c. The external navigation app opens.

- **Reminder to plug-in [C]**
  a. Reminder sent to user - "Renewable energy is high!".
    I. The user pushes the notification.
    II. The user is sent to the location page.

- **Battery control menu [M] - On Home page**
  a. “Set battery percentage for the grid”
    I. A battery (to use for grid) / km (how much is left for driving) range is displayed.
    II. The user can drag the percentage scale to the wanted amount
    III. The user can press Save.

- **Pause battery usage [M]**

  The battery will charge only while plugged in until the next time plugged-in, set in the template.

- **Optimization [M]**

  a. A rubric with the following text - “Set recommended” is displayed.
  b. A click on “Set recommended” will initiate the “The Predictive model” algorithm.
  c. The result will provide the user with the correct time and percentage data for charging and discharging the vehicle.
  d. The accurate schedule will be displayed on screen.
  e. A precalculated three-day grid battery schedule will be displayed on screen.
  f. Graphs which will show the next three days of total carbon emissions savings and monetary brake down will be displayed on screen.

- **History [S] –** On Home page
  a. The user clicks check previous locations.
     I. A list of prior charging station locations opens.
     II. Click on the location feature opens Waze.
  b. A click on the history feature opens user stats.
     I. Opens usage history graphs and total saved amount of carbon emissions and expenses.
  c. Optimize your charging and discharging schedule and percentage analysis (goes to "optimization" process).

- **Sign in/Sign up [C] –** On Home page
  a. The message "Sign in/ Sign up" message is displayed
     I. Sign-up requirements:
        i. Full name
        ii. ID
        iii. Vehicle number – if the owner has more than one, they could "add car"
        iv. Password
        v. Email
        vi. Display a message "Allow the app to set a recommended charging and discharging schedule"
        vii. “Set recommended" process is activated
     II. Sign-in requirements:
        i. Email or ID
        ii. Password
     III. Forgot password
        i. Sends email
        ii. The email contains a link to a password initialization process.

Advanced button[M]: Electri-Cache will have options for the advanced user in the Advanced section.

b. Create template

I. Set charging time:

i. "Start time" and "End time" titles are displayed.

ii. "Start time" will set the time that the vehicle will be charging in.

iii. "End time" will set the time that the vehicle will stop charging.

II. Set discharging time:

i. A "Start time" and "End time" titles are displayed

ii. "Start time" will set the time that the vehicle will be discharging in

iii. "End time" to set the time that the vehicle will stop discharging

III. “Set grid battery level” will allow the user to set a battery percent for the grid.

i. "Start time" will set the time that the vehicle will be at the selected grid battery level.

ii. "End time" will set the time that the vehicle will return to the default battery level.

IV. Max kilometers – choose max kilometers per day that the user wants to set aside battery for – this will also show the percentage level of battery that the user needs for driving

V. “Save template” will save the "Template" for further use.

c. Assign vehicle to template

I. A list of vehicles is displayed by their names.

i. "Select a vehicle" will be displayed

II. “Choose a template” will open a list of templates.

i. "Select a template" message is displayed

ii. The user chooses the wanted template

d. The template is assigned to the vehicle, which will operate consecutively

The predictive model [S]: The predictive model will attempt to predict the price of electricity using the predictive model, when best to sell or to buy electricity. Electri-Cache will achieve this by comparing the weather forecast to the historical data gathered. In its most basic form, it will find times with similar weather and see the median price change.

- **Building the data set** (The builder)
  a. The builder will gather historical prices of the electrical grid and store the change in price by date and time.
  b. The builder will gather two distinct types of historical weather data, the sunlight, and the wind speed by date and time.
- **Categorizing the data set into types** (The categorizer)
  a. The categorizer will create a dataset of all the different weather patterns of wind speed and sunlight.
  b. The categorizer will then include the date and time of every time that weather pattern happened.
  c. At each pattern, the categorizer will measure the median electricity price change and store it with the pattern.
- When the predictive model is called it will find the pattern that matches the given weather forecast and return the median or in other words the prediction.

Life cycle:

PRI:

1 Electri-Cache must have the ability to know the vehicle battery level.

2 Electri-Cache will run the "Predictive Model" consecutively

3 When the "Predictive Model" will receive results that show that renewable energy production is high, the system will inform the user

IN:

1 Electri-Cache will learn the user's average time and percentage level of charging and discharging

2 The system will perform calculation of how the user can optimize their charging and discharging schedule

3 The system will hold data of the user’s vehicle current location and nearby charging stations location data

4 The predictive model will consecutively store the weather data and the price changes.

5 The predictive model will be called by the system which will show the results in the "Set Recommended" process.

POST:

1 The system will save for further use new charging locations

2 The system will initiate the chosen template charging and discharging commends

Subsystem:
Electri-Cache will communicate with the bidirectional charger to instruct it and to receive the battery state.

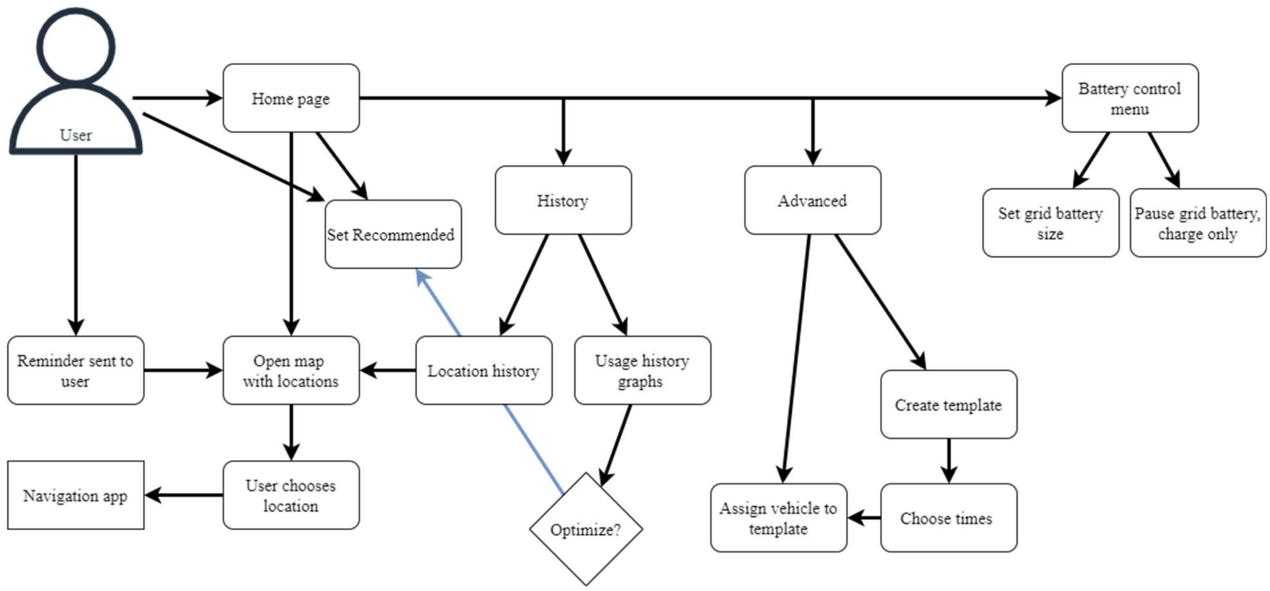
4 Non-Functional requirements

The Non-functional define concepts that are not key parts of this project however must be addressed.

- **Reliability** - Electri-Cache must have secure sign-up and sign-in processes.
- **Storage** - Electri-Cache must have cloud storage.
- **Security** - Electri-Cache must have a secure web host.
- **Interaction with other apps -** Electri-Cache must connect to a maps program.
- **Data acquirement -** Electri-Cache must learn the user's expected schedule of charging and discharging their vehicle or vehicles.

5 System flow

The system flow is the diagram that represents the user interactions with the system.



6 Risk management

In the risk management section will analyze the different risks and the different solutions to them.

- **Risk** – The system may not hold enough data to predict and analyze the user's charging and discharging habit (in the case of a new user), therefore the system would not be able to display the user's average amount of carbon emissions and expenses savings.

  Action to be taken – The system will create a default template, which will automatically operate on the vehicle from the moment the user is added.

- **Risk** – If the vehicle is turned off, how would the system work and control the electricity flow from vehicle to grid and vice versa.

  Action to be taken – The process of creating and assigning a template will occur on the app itself. Whenever the vehicle is turned on, the app will automatically set the chosen template and the settings will be defined for the vehicle and the smart charger.

- **Risk** – Physical problems while charging and discharging may occur.

  Action to be taken – While the process (charging/discharging) ongoing, check for errors in the process consecutively, if an error occurs, send a reminder to the user's smartphone/desktop.

- **Risk** – The user may forget to plug-in the vehicle.

  Action to be taken – Electri-Cache will notify the user to plug-in.

7 System main screen specifications

System screen specifications define the screen sizes and the associated device types.

- Smartphone – Small screen portrait orientation handheld
- Desktop – Large screen landscape orientation positioned on a desk or lap

8 Non-goals

- Changing the electricity supplier method of electricity production
- Finding other resources for electricity production
- Support the market of bidirectional chargers and electric vehicles

9 Open issues

Open issues are problems that we do not have solutions to.

- Price of bidirectional chargers
- Not enough solar panel fields
- The lack of available renewable energy
- The bidirectional chargers, and the smart battery market is not highly developed

10 References

The references section will hold the references.

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