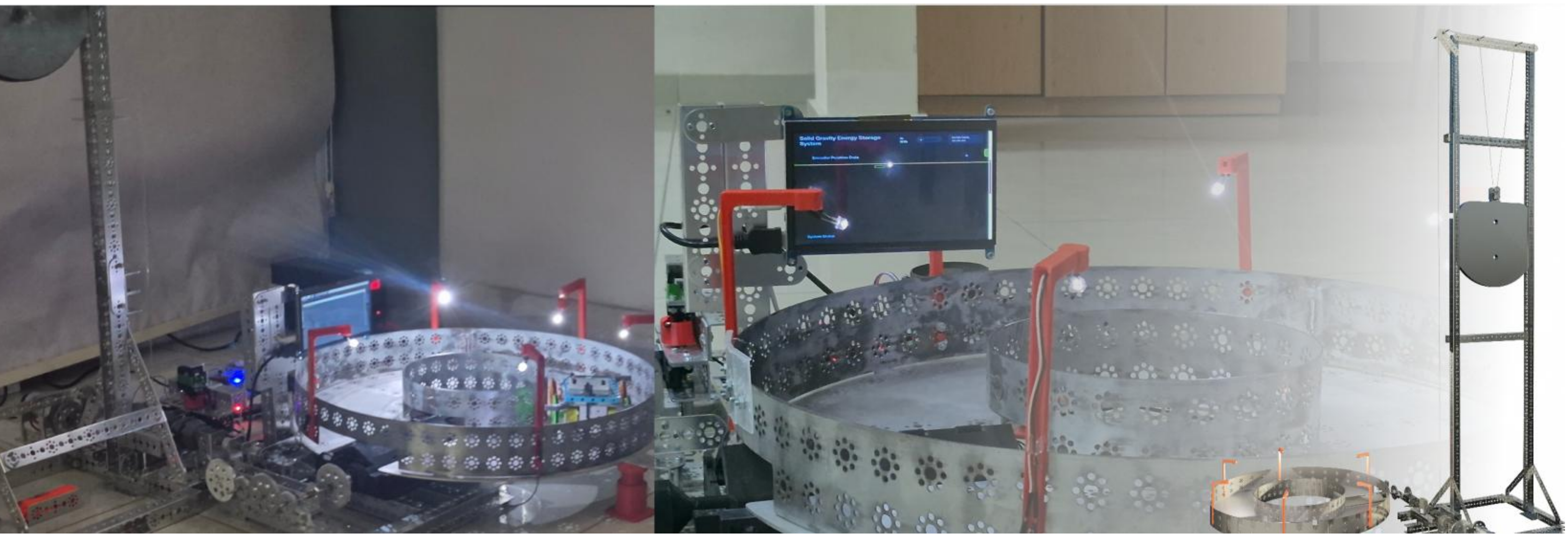
Senior

VLNs

GraviPower

Syria



GraviPower… Stored by the Hour

TABLE OF CONTENTS

TEAM PRESENTATION 2
EXECUTIVE SUMMARY 3
ROBOTIC SOLUTION 4
3.1 EVOLUTION OF PROJECT IDEA DURING THE PREPARATION 4
3.2 RESEARCH INTO SIMILAR IDEAS 4
3.3 MECHANISMS DESIGN 5
3.3.1 Pseudo-Bump: 5
3.2.2 Motion Transmission and Torque Amplification Mechanism: 6
3.3.3 Lifting System: 6
3.3.4 Connecting and Disconnecting Mechanism (C&D): 7
3.3.5 Motor Gearbox: 8
3.3.6 Electrical Circuit & Load Management: 8
3.3.7 Field Design: 8
3.3.8 Tower Design: 9
3.3.9 Prototype Scaling and Dynamic Calculations: 10
3.4 CODING OF THE SOLUTION 11
3.4.1 System Logic and ROS Integration: 11
3.4.2 PID Control Algorithm: 14
3.5 CHALLENGES DURING DEVELOPMENT PROCESS 15
SOCIAL IMPACT AND INNOVATION 16
4.1 THE NEED FOR OUR PROJECT 16
4.2 ON-GROUND EFFECTS OF THE PROJECT 16
4.3 CONCRETE (REAL-WORLD) EXAMPLE 16
4.4 EXTRA ELEMENT OF ENTREPRENEURSHIP 18
4.5 AI MODEL OF GRAVIPOWER 18
4.5 STARTUP IDEA - NEXT STEPS & PROTOTYPE DEVELOPMENT 19
4.6 KEY INNOVATION 19
CONCLUSION 19
LIST OF RESOURCES 20
APPENDIX 20

TEAM PRESENTATION

We are the **VLNs**, a team of three passionate students from the **National Center for the Distinguished (NCD).** Over the past three years, we have participated in major competitions, earning valuable experience and insight along the way. After working together for so long, we ’ve become more than just teammates, we ’ve become a small family. Now, we aim for the gold! During our time at the NCD, we lived, studied, and grew together. Each of us has improved his skills and learned to overcome challenges, and now we complement one another perfectly. Interestingly, our team ’s name, VLNs, comes from a game we love, but it also stands for Vertical Lifting Newtons, which gives a little description of our project.

Figure 1: Team’s photo

Meet the Team:

- **Ghadir Ahmad (18 years old):** With a strong foundation in mechanics and CATIA V5, Ghadir played a crucial role in construction and 3D designing. His innovative thinking and helpful nature contributed to many creative ideas along the way.

- **Shady Al-Hasan (19 years old):** Played an important role in developing the project mechanically also using CATIA V5, in addition to being the best coder in the team. Shady provided us with cutting-edge solutions and worked tirelessly through tough times to ensure the success of our project.

- **Zain Alfai (19 years old):** Zain was a major contributor to the mechanical and physical foundations on which our project is built. In addition to being our circuit designer, he supported the team with his hands-on skills and contributed valuable ideas throughout the project.

- **Salman Daher - Coach (21 years old):** Salman graduated from the National Center for Distinguished and now studies robotics engineering at Manara University. Salman gave us a lot of advice. His passion for learning and sharing knowledge inspires everyone around him. In addition, he was in the first place our Mathematical Modelling trainer.

EXECUTIVE SUMMARY

In our modern world, renewable and non-renewable energy sources are diverse, from solar energy to wind and wave energy etc. The high availability of energy and the instability of its generation, such as solar and wind energy, makes the biggest problem today lies in energy storage rather than its generation. Hence the importance of our solution, which provides a sustainable, effective, durable, and high-capacity way to store energy, which is **Solid Gravity Energy Storage** [1].

The idea is to raise a large mass to a high altitude above the ground. It can be lifted inside a high tower or inside mines and wells. When the potential energy stored in this mass is needed, the mass is left to fall and rotate a generator while falling to produce electricity with high efficiency (80% - 90%) [2]. Thus, the mass plays the role of a battery [3].

And one fascinating thing is that our system does not use electricity for charging. but provides free electricity, by raising the mass purely mechanically.

One promising source of untapped energy suitable to do this is all around us - something we experience every day: the movement of vehicles. We designed a clean **car pseudo-bump** that transmits the power of the movement of vehicles and utilizes it to raise a huge mass. But how can a car raise such a massive weight? We implemented a one-way gearbox to solve this issue; this gearbox increases the torque of the car so it can raise the mass. Our solution falls under the first area of the competition theme for this year. Specifically, the second sub-area (Robots Helping to Save Resources) as it has helped save city resources and protect the environment.

But of course, the mass falls at an accelerated rate due to the acceleration of gravity, and the generator rotating at an accelerated speed will cause unstable and inefficient generation. We can resort to breaking the mass in order to slow it down, but that is not the ideal solution because it causes energy loss. Here comes the role of our robotic solution, which operates an **electric brake** to slow down the mass 's fall and regulate its descending speed. We use controllers and sensors to increase the electrical load on the generator when the falling speed increases, which leads to its slowing down. In this case, there is no wasted energy, because the energy is used to operate the excess load, which may be represented by several useful devices.

Providing a solution to one of the major problems of today 's world, which is energy storage, our project presents an innovative idea that, if applied in real life, could represent a significant step towards a cleaner and more sustainable future. Our project 's efficient use and harvesting of energy reinforces its importance in saving city resources by making use of different forms of energy around us [4].

What did we get in our prototype with 11.2 Kg mass and 1.2m tower height?

1) 6 Street Lights
2) 2 DC Motors Overload
3) 3.5 watt/s ~ 1Kwatt/h
4) 35s Operation Time

ROBOTIC SOLUTION

3.1 EVOLUTION OF PROJECT IDEA DURING THE PREPARATION

The Base of The Idea:

At the beginning of thinking about an innovative idea, our team met with **Dr. Almohannad Makki**, the former manager of the National Center for the Distinguished in Syria, to discuss some different and new ideas that could contribute to solving a problem in an environmentally clean way. After a while of discussion and searching, we settled on the idea of storing energy using solid gravity. This idea seemed to us to be an appropriate and strong basis for launching our project, due to its benefits on various social, economic, and environmental levels. Few other research has been made, before we settled on the idea of raising a mass from the ground, thus, storing its potential energy, and when the energy is needed, the mass is left to fall and rotate a motor as it is falling, to retrieve the energy back.

Figure 2: VLNs Team with the Former Head of the National Center for Distinguished - Dr. Almohannad Makki

Efficiency Enhancement:

After a period of testing this idea and studying its details, we found that investing energy from the falling mass can be greatly improved if we can control the mass to fall at a constant speed. Controlling the speed of the mass is possible using brakes, but the enhancement we found is that we can cancel the use of brakes by increasing the electrical load on the motor, which will slow it down and form a brake to control the speed of the mass, and that is how the energy is utilized and not wasted like in a normal mechanical brake, this idea is the key innovation of our project.

Energy Accumulation:

After that, and in the context of our attempt to make the project more renewable and environmentally friendly, we thought of ways to lift the suspended mass on a tower.

We tested several types of energy for the lifting process until we arrived at the idea of taking advantage of the cars ’ movement. When considering the heavy traffic congestion. This idea is excellent as a large and stable energy source.

3.2 RESEARCH INTO SIMILAR IDEAS

We conducted extensive research into existing gravity-based energy storage systems and found several projects with concepts like ours. Companies like Energy Vault and Gravitricity have developed systems that lift heavy weights to store potential energy, which is later converted into electricity when the weights descend. Energy Vault uses cranes to lift large concrete blocks [5], while Gravitricity employs winches to raise weights in mines shafts [6]. Additionally, regenerative braking systems in electric vehicles, which capture energy from braking, are like our method of harnessing energy from car movement [7].

Our project is distinct primarily due to the high efficiency of our energy accumulation process by taking the energy from the cars purely mechanically. We have developed a smart method of controlling the descent of the mass by adjusting the electrical load on the motor to act as a brake [8], maximizing energy generation during the falling phase. This makes our power retrieval more efficient compared to other systems. Additionally, we combine this with an innovative energy generation approach, where car movement over pseudo-bumps helps lift the mass. This integration of energy storage and generation provides a

3.3 MECHANISMS DESIGN

sustainable, dual-function system that sets our design apart.

The mechanics in our prototype are basically the hardware of each of the **charging** phase (when the mass rises) and the **discharging** phase (when the mass descends), we will break down and explain the mechanics of both phases, starting with the charge one.

3.3.1 Pseudo-Bump:

In our project, the pseudo bump serves as the initial point for the accumulation of kinetic energy. This bump is 3D printed using PLA filament and consists of several main sections:

Fixed Joint: this joint is fixed in place, allowing the bump to rotate around a specific axis by 25 degrees, which represents the maximum angle to ensure it does not disturb vehicles passing over it. The rotation of this joint transfers motion to the Bearing, which then passes it on to the rest of the system. [9]

Movable Joint: This is the highest point of the bump, with a height of 2 cm above ground level. When the bump is pressed by a passing vehicle, the triangular-shaped bump opens up and flattens to align with the road surface. The rotation of this joint increases the opening angle to achieve alignment with the ground.

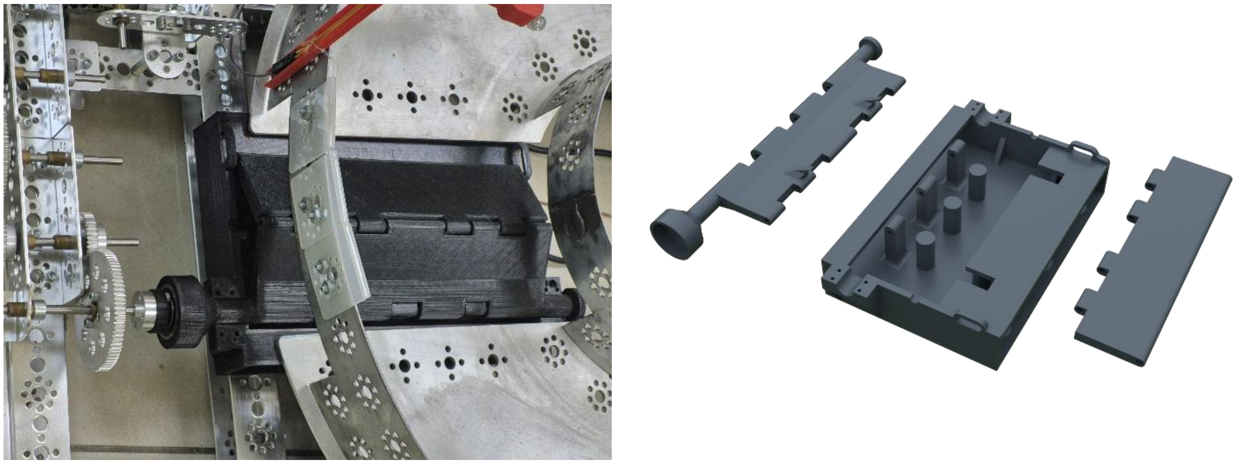


Figure 3: Car Pseudo-Bump

Springs: The springs compress when a vehicle presses down the bump. Once the pressure is relieved, the springs return to their original shape due to their elasticity, returning the bump back to its initial height.

To ensure that the pseudo-bump doesn 't accumulate energy more than the system could store (maximum charge phase) we added a servo motor to flatten the bump (lock it to the ground level). our choice of the bump 's angle and height value is suitable for the small-scaled prototype. These values ensure comfort pressing of the bump by the passing car (the small robot in our prototype) because of the low height (2 cm), while making sure not to reduce the amount of accumulated energy due to the large angle (25 degree) compared to standard bump designs in real life scales.

3.3.2 Motion Transmission and Torque Amplification Mechanism:

After gathering kinetic energy from the pseudo bump, the motion transfers to the second phase through three steps:

First Stage: A clutch or Bearing (one-way gear) prevents reverse motion in the system when the pseudo bump returns to its initial position (because of the springs) after being compressed, allowing the motion to be transmitted in only one rotational direction (the bearing used in the prototype) [10].

Second Stage: The motion then passes through a gearbox with a speed amplification ratio of 4.

Third Stage: This involves a worm gear that transmits motion in one direction (only towards the lifting system) and prevents reverse rotation and the falling of the mass, amplifying torque by a factor of 40. Thus, till this point, the torque of the lifting stage is increased by a factor of 20 (for more details, check the calculations here).

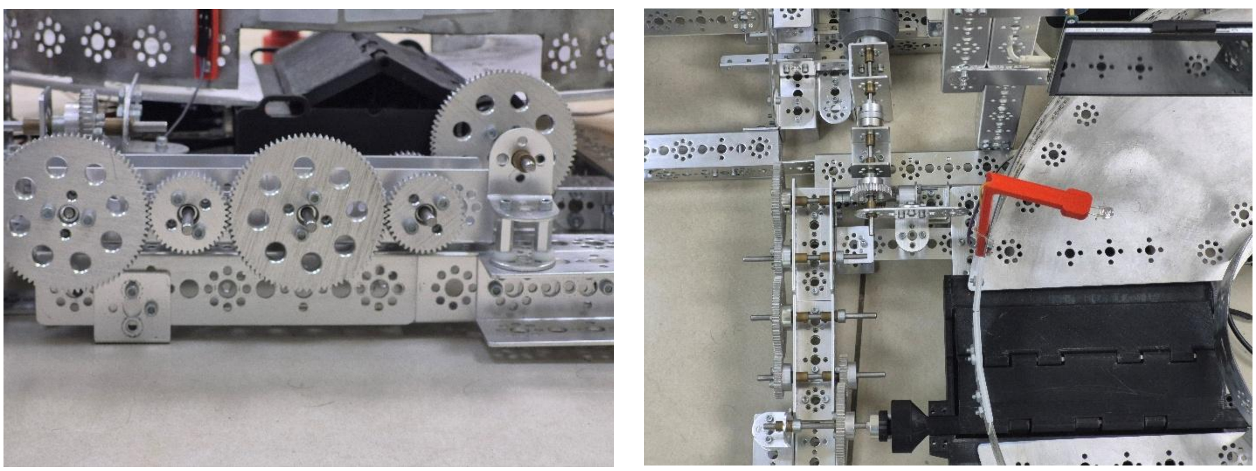


Figure 4: Bump to Mass Gearbox

3.3.3 Lifting System:

This is a pulley system that contains multiple pulleys responsible for the mass-raising operation. These pulleys are set as follows:

- **Main Pulley (Spool):** a pulley with a radius of 1.75 cm (for more details, check the calculations here), which in its turn amplifies the torque by its arm **(1.75cm)**.
- **Guiding Pulleys:** Two guiding pulleys are located at the top of the tower. Their main function is to direct the rope along the correct path, ensuring that it stays properly aligned throughout the lifting process.

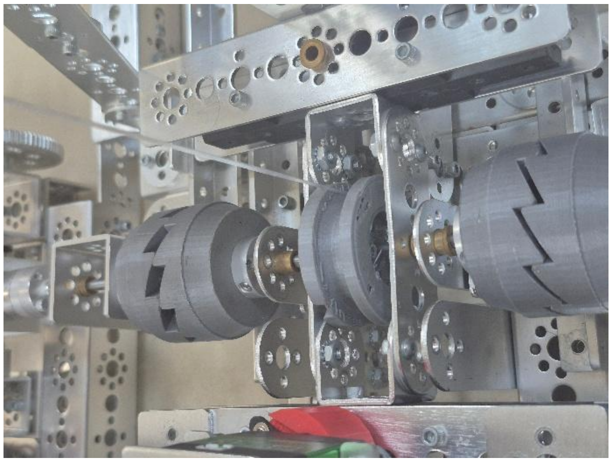


Figure 5: Main Spool

Figure 6: Guiding Pullies

- **Mass Pulley:** Lastly, there is a pulley on the mass directly. This pulley serves many purposes: it protects the rope, increases the stability of the mass movement, and finally, multiplies the torque by a factor of 2 when raising the mass. This makes the overall torque amplification of the lifting process 20 **(1/4 for the first stage * 40 from the worm gear * 2 from the mass pulley)**. This pulley plays a crucial role in our pulley system by adding these benefits and helping to reach the appropriate discharging time.

3.3.4 Connecting and Disconnecting Mechanism (C&D):

After the mass is raised to its highest point, the system stores energy to its full capacity. Now the system is in the maximum charge phase, and it should be locked (the pseudo-bump should be flattened). Then the system will be ready to discharge whenever the sunlight fades, which is determined by a light sensor. First of all, we need to disconnect the main pulley from the gearbox and connect it to the energy generation system (the motor and its own gearbox). Here comes the need for the connecting and disconnecting mechanism. The key component is a 3D-printed PLA parts shaped like a circular chainsaw tooth, designed to transfer energy in one direction. When the main pulley is pushed to the gearbox direction, two of these parts match and the gearbox transfers motion to the pulley, but when the pulley is pushed the other way, the parts in the gearbox side mismatch, and another two of these parts match so that the motion from the pulley is transferred to the motor side gearbox. To move the main pulley between these two phases, we used an HTS-35H Servo motor with a torque of 35KG/CM, connected with a rack and pinion mechanism to convert rotational motion into linear motion. This servo needs a controller that consists of an ESP32 core board and a multi-functional extension board.

Figure 7: Connecting and Disconnecting Mechanism

3.3.5 Motor Gearbox:

Because of the high weight of the mass that could be utilized, and in order to increase the discharge time of our prototype, the generator is not connected directly to the main pulley, which rotates due to the fall of the mass. There is a speed amplification factor formed by the pulley on the mass increasing the speed (on the generator 's side) by two, and a gearbox between the motor and the main pulley with speed amplification factor of 1.5, 3 in total (for more details, check the calculations here).

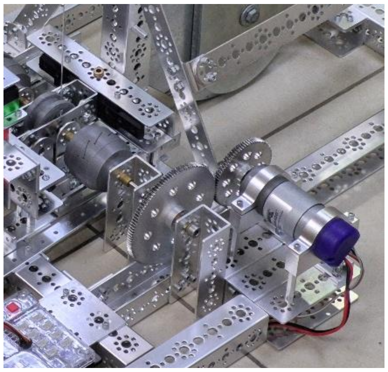


Figure 8: Motor Gearbox

3.3.6 Electrical Circuit & Load Management:

The main electrical load in our prototype consists of 6 white 0.5-watt 8 mm LEDs powered by the energy from the falling mass during discharging. The motor generates around 6 V. To make it suitable for lighting the LEDs, we use a step-down converter regulating the voltage at 3.3 V. To manage the increasing voltage caused by the accelerating mass, we use an automated system with an ESP32 controller (the same ESP we used for C&D servo), relay board, and sensors like the encoder of the TorqueNADO motor. This system adds an extra load, a fan (DC Motor) with another DC Motor Controlled by BTS motor driver driven by a **pwm** signal, which converts excess voltage (extra speed) to a beneficial use. The total discharge time is about 35 seconds. The full schematic diagram is shown in figure 24 in appendix 2.

3.3.7 Field Design:

The field is the part of our prototype that is supposed to represent the road with cars on it, to present how our idea will work in real life, we made a circular path for the road, with a car to represent the traffic, the path contains walls on the sides with a distance of **17 cm** between them (the width of the path), and a determined place to put the pseudo bump. The car has a shape of **18 x 16 cm^2** and a room on its top to provide the ability for modifying the weight of the car. The car drives on the path blocked by the walls on both sides, with a simple manner of going forward, relying on the smooth rotation of the walls to turn and run in the circular path.

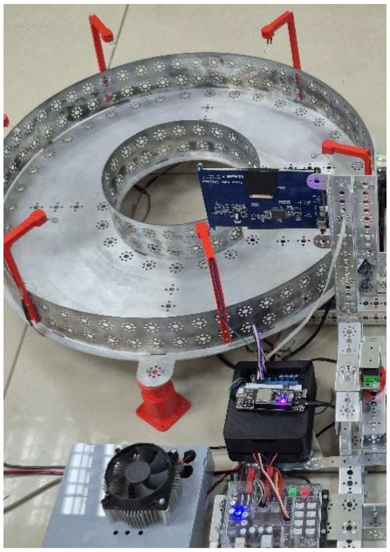


Figure 9: Field Design

3.3.8 Tower Design:

Given the weight of the mass in our prototype and the required lifting height, we designed a compact, efficient tower. After testing various designs and making improvements based on engineering concepts, we arrived at the final structure, capable of steadily supporting the mass. The tower stands 120 cm tall, with a functional height of 105 cm. It is built entirely from Tetrix Kit parts, using channels, flat pieces, and L brackets. The tower consists of two main columns that hold the mass (which helps stabilize the structure). A strong and fixed base supports the weight and is designed for easy maintenance and assembly. Our studies indicate the need for a mass of approximately 11.2 KG (for more details, check the calculations here); its two ends are blocked from the sides by the channels of the tower 's columns, so that the mass fits in place. This gives us more control over the mass descent.

Calculating the weight of the mass needed was done using these equations, knowing the height of the tower and the power requirements to ensure the demo reaches a runtime of 35 seconds:

Figure 10: Tower Design

$$\eta \cdot E_{\{mech\}} = E_{\{elec\}} \quad (1)$$

$$\Rightarrow m \cdot g \cdot h = P_{load} \cdot t \cdot \frac{1}{\eta} \quad (2)$$

$$\Rightarrow m = \frac{P_{load} \cdot t}{\eta \cdot g \cdot h} \quad (3)$$

SYMBOL	DESCRIPTION
$E_{\{mech\}}$	Mechanical Potential Energy (Joules)
$E_{\{elec\}}$	Electrical Energy (Joules)
P_{load}	Electrical Load (Watt)
η	Efficiency Factor
m	Calculated Mass (kilograms)
g	Gravitational Acceleration Constant (m/s^2)
h	Efficient Height of the Tower (meters)
t	Operating Time (seconds)

Table 1: Energy Calculation and their Definitions

3.3.9 Prototype Scaling and Dynamic Calculations:

Equations (4) and (6) represent the final differential equations of the current in the generator and load circuit, describing their dynamic behavior. By modeling these equations, we determined the optimal system parameters, including the mass, motor gearbox ratio, and the radius of the main pulley. Moreover, by considering the angle of the speed bump and the length of its arm (specified in the bump section), we derived the torque amplification ratio required to be applied to the main gearbox to effectively lift the mass by the car.

$$\dot{i}' = \frac{k\omega - (R_m + R_l)i}{L_m + L_l} \quad (4)$$

$$I_{eq} = I_m + I_{gears} + \frac{I_{mass} + I_{pulley}}{K_1^2} \quad (5)$$

$$ki - \frac{mg}{K_1} = \left(I_{eq} + \frac{mr}{K_1^2}\right)\ddot{\theta} \quad (6)$$

SYMBOL	DESCRIPTION
i	Motor Current
r	Radius of the Spool (Main Pulley)
$\ddot{\theta}$	Angular Acceleration of the Motor Shaft
$\dot{i}'$	Rate of change of current
$\omega = \dot{\theta}$	Angular speed of the motor shaft
k	Back EMF constant of the motor
R_m	Internal resistance of the motor
R_l	Load resistance
L_m	Inductance of the Motor
L_l	Inductance of the Load
I_{eq}	Equivalent moment of inertia of the system
I_m	Moment of inertia of the motor
I_{gears}	Moment of inertia of the gearbox
I_{mass}	Equivalent inertia of the lifted mass
I_{pulley}	Moment of inertia of the pulley
K_1	Motor gearbox ratio
m	Calculated Mass (kilograms)
g	Gravitational Acceleration Constant (m/s^2)

Table 2: Dynamics Calculation and their Definitions

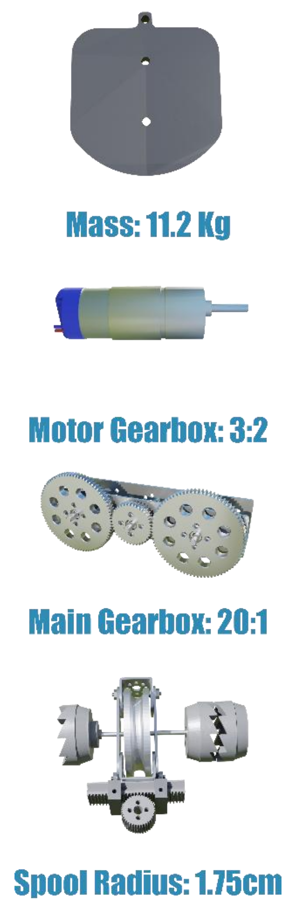


Figure 11: Final Results

3.4 CODING OF THE SOLUTION

3.4.1 System Logic and ROS Integration:

The control logic of our project is based on a state-driven system that manages all operations automatically. The code defines several modes that represent the system 's different working states, such as charging, discharging, and fast charging. Each mode activates specific components and deactivates others to ensure smooth transitions and prevent conflicts between actions.

The operation of our project is based on ROS, which facilitates the communication between the system components and the management of the overall process. We used a **raspberrypi 4 model B** device as the brain of our system, on this device the **ROS Master** runs and the other controllers connect to it via **Serial** or **Wi-Fi**. There are four nodes communicating with each other to dictate the behavior of the system by setting its state to a specific Mode. The modes are:

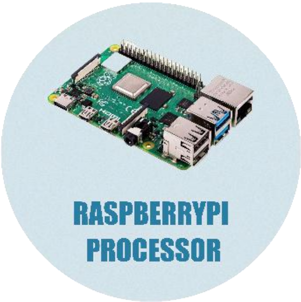


Figure 12: Raspberrypi

- **Charging**: By connecting the C&D (Connecting and Disconnecting) mechanism to the gearbox and activating the pseudo-bump, this mode is called Charging because the mass is raised by passing cars and the system is charging.

- **Discharging**: By connecting the C&D mechanism to the motor, and deactivating the pseudo-bump, the system enters the discharging mode.

- **Fast Charge**: This mode is designed only for the prototype. To clearly present the demo, we needed a way to lift the mass quickly. Therefore, the Fast Charge mode was added to lift the mass using the motor. It is activated by connecting the C&D mechanism to the motor and powering the motor to lift the mass and charge the system.

The ROS nodes responsible for activating the various modes:

1) Python Node (Main Control):

The Python code serves as the main node in the system. It organizes the distribution of commands to the other nodes and handles workflow cases. This node changes the current mode of the system based on sensor readings or commands from the web page node (system dashboard) by publishing the mode to the ESP - Servo node and the PRIZM controller node. The Python node ensures that the operating of all system components is integrated and synchronized.

2) Web Interface Node:

A user-friendly web page that is an essential component for tracking the system values and controlling it. The interface displays the motor voltage and encoder position in real time. It also shows when a car passes over the pseudo-bump. The system can be controlled from the interface through buttons designated to set the different modes. For example, when the **Charge** button is clicked, the interface node sends a service request to the python node to change the mode being published to **Charge**. For implementing It, we used the **rosnodejs** JavaScript library so that it connects locally with the ROS master. We associated an IP address and a port to make it reachable from other devices.

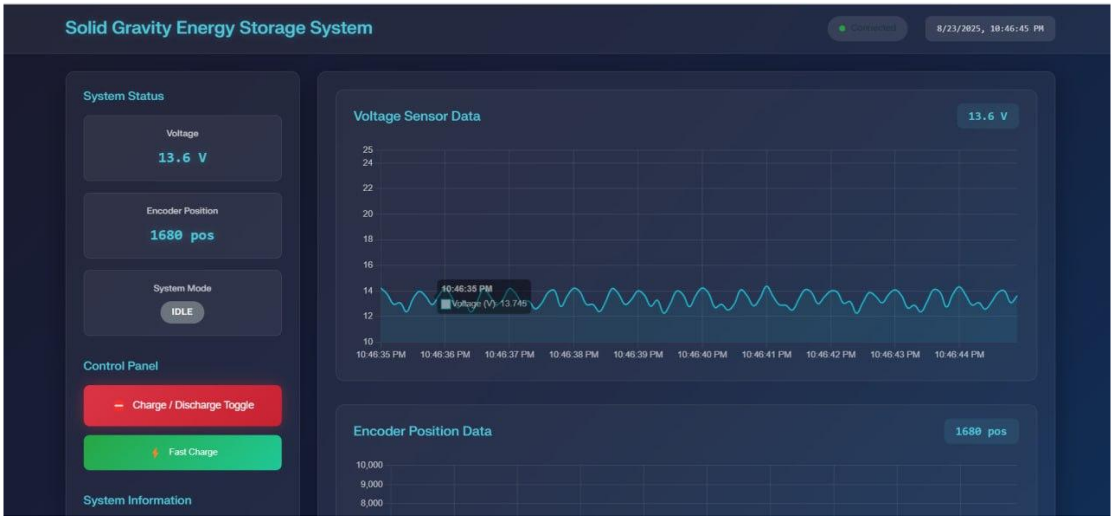


Figure 13: Web Dashboard of the System

3) PRIZM Controller Node:

The PRIZM controller contains a part of the Arduino code, which reads the values of some sensors and controls the motor and servo motor responsible for the pseudo-bump state (activated or deactivated). This code continuously publishes the readings of the encoder and the voltage values, so that this information can be used in the other nodes. It reads the mode value published by the python node and act accordingly. In addition to determining whether it is night or day using a light sensor and sending this value to the main control node to choose the appropriate mode for the system.

Figure 14: PRIZM Controller

4) ESP Node:

The HTS-35H Servo motor we used for the stability of the C&D mechanism needs control from an ESP32 controller. This board contains another part of our Arduino code that controls the C&D Servo beside the relay to supply the load in the discharging mode. This node publishes when a car passes over the pseudo-bump by reading values from its limit switch. It also reads the mode value published by the Python node and acts accordingly. One more, it controls the pwm signal sent to the BTS driver to control the overload.

Figure 15: ESP32 Sheild

You can explore our GitHub repository by pressing this link here, or pressing on the following icon to get more details about the packages and the codes.

Python Node

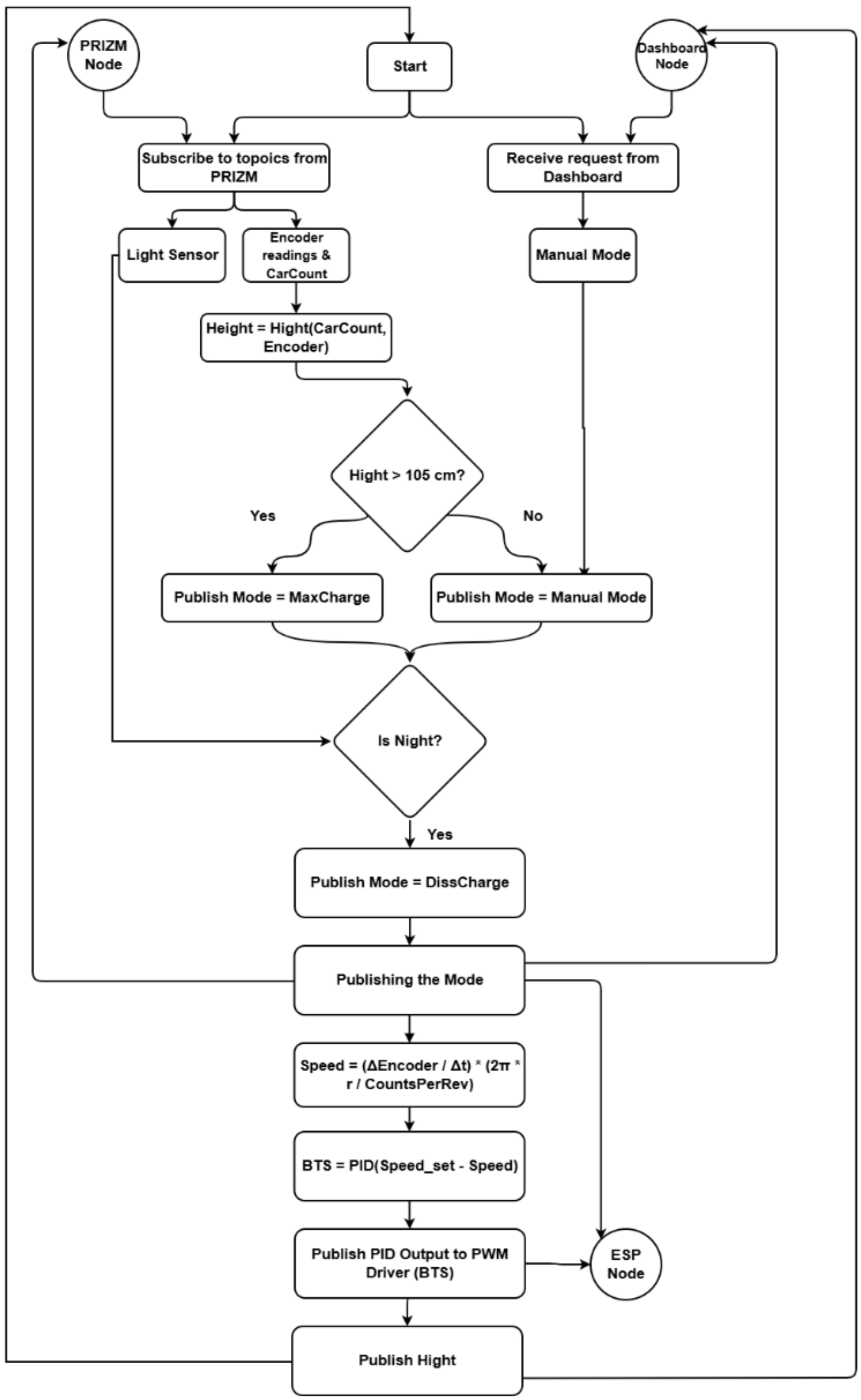


Figure 16: Flow works of the Main Control Node

3.4.2 PID Control Algorithm:

For the control algorithm, we have a variable additional load on the generator (represented by two DC motors). The power allowed to reach this excess load is controlled by a BTS motor driver using the PWM pin. In the Python node, we use the encoder readings and apply a PID algorithm to keep the mass descending speed at the right point on the efficiency graph (6V operating voltage) [13] , thus generating electricity with the maximum efficiency possible. The Python node calculates a value between 0–255 and sends it to the ESP node, which adjusts the PWM value on the BTS.

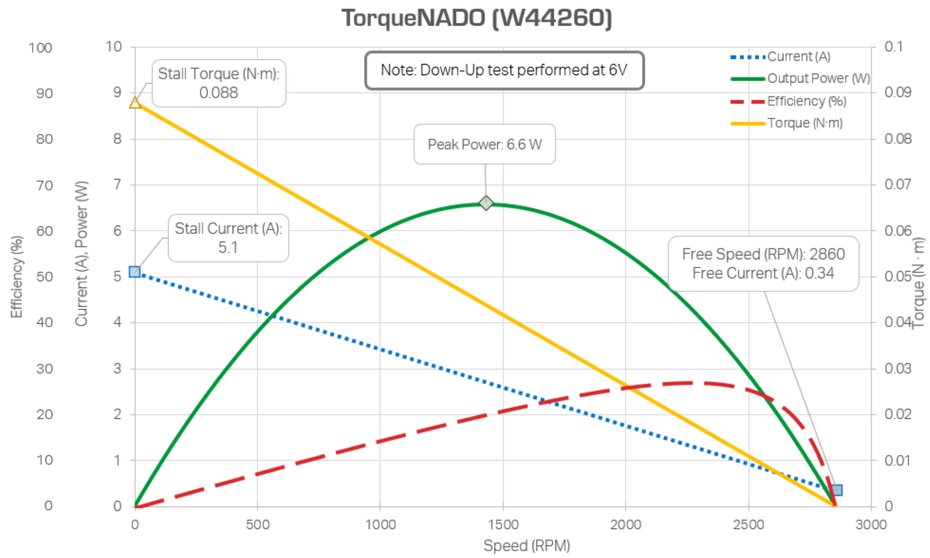


Figure 17: TorqueNado Motor Efficiency Diagram

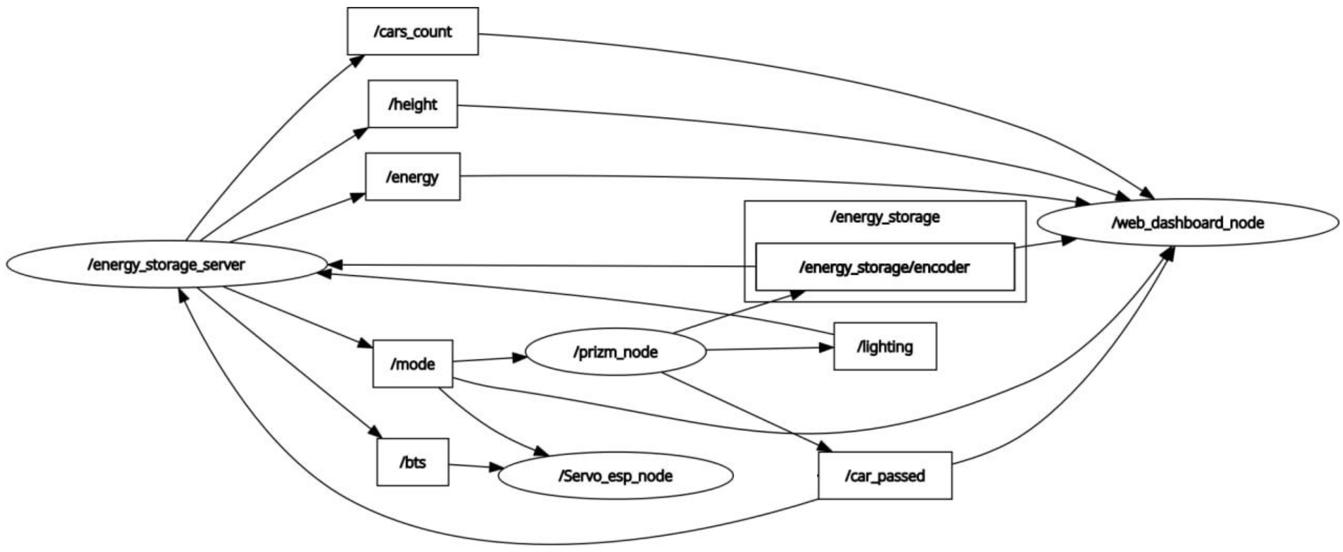


Figure 18: RQT Graph showing how different ROS nodes of the system are connected

3.5 CHALLENGES DURING DEVELOPMENT PROCESS

- **Challenges during tower construction:**

  The first version of the tower was somehow steady, but to increase its stability according to engineering concepts, we removed the straight beams that connect every two adjacent channels and replaced them with triangular connections, to increase stability and efficiency [11]. It seemed to work well at first, but we faced some problems with sitting it without tilting, it also costs too many Tetrix parts, which made us think of a solution for this problem leading us again to the third and final version of the tower, having a strong base to correct tilting, and high efficiency using fewer Tetrix parts, the final version met our requirements perfectly. Images of the different versions are included on our **GitHub** repository.

- **Challenges during developing the Disconnecting and Connecting Mechanism:**

  The connecting and disconnecting process carries a significant risk, because it involves moving the main pulley while the mass is hanging in the air. This process needs to be swift and precise to ensure the matching of the couplers safely, which caused us to face many challenges to reach the current stable mechanism. At first, we used a stepper motor. The problem we faced with it was that the motor has quite a high torque but a low speed. For this process, we need both high speed and torque to guarantee safety and efficiency, so we implemented another method: we used a servo motor with a torque of 35 kg/cm. The new powerful servo was able to safely lock the mechanism to a fixed position. It also had enough speed to switch the position correctly and smoothly.

- **Challenges with 3D-printed parts:**
  In the first pulleys we printed, we faced a challenge. When the pulley was used many times, it started to crack and break eventually, because of the tension caused by the weight of the mass. This problem is caused by the 3D printer setting; we had to test many models to reach the most efficient infill and thickness. Also, some parts, like the C&D coupler, faced a problem with the smoothness of the edges, which caused issues in the mechanism. Thus, we tested many models of each 3D printed part to find the most efficient version of each, and to determine how to choose the settings of the printer.

SOCIAL IMPACT AND INNOVATION

4.1 THE NEED FOR OUR PROJECT

Modern cities consume huge amounts of energy every day, while the demand for cleaner and more reliable power continues to rise. However, many renewable energy sources such as solar and wind are intermittent. They depend on weather, making energy storage a critical challenge. Traditional batteries, although widely used, are expensive to maintain, have limited lifespans, and create environmental and disposal problems. At the same time, cities are full of constant movement - especially road traffic - which produces mechanical energy that is completely wasted. Our project addresses both issues by capturing a portion of this everyday mechanical motion and storing it as gravitational potential energy, which can later be released as electrical power when needed. This approach provides a sustainable, low-maintenance, and long-life alternative to chemical batteries, using a system that can be integrated directly into urban infrastructure and scaled to support community-level energy needs.

4.2 ON-GROUND EFFECTS OF THE PROJECT

- Enables energy independence for large companies by allowing them to generate and store their daily energy needs.

- Environmentally friendly, reducing pollution and emissions compared to traditional storage methods.

- While individuals or small entities may not directly use the pseudo bumps due to installation challenges, they can benefit from the storage system in different sizes for various uses.

- This project directly contributes to global sustainability efforts, particularly SDG 7, SDG 9, SDG 11, and SDG 13, by enabling cities to generate and store clean energy using their own everyday motion.

Figure 19: Sustainable Development Goals our Project Covers

4.3 CONCRETE (REAL-WORLD) EXAMPLE

We studied a case where we can light the city center (Homs City - Syria) as a concrete example of our prototype. We first Scheduled a meeting with Homs City Traffic Department Manager **Eng. Bashar Alsebaai**, we discussed the possibility of scaling our prototype to a real-world project where we can benefit the city. He was very excited about the project and provided us with needed data for calculating and designing the bigger-scale project.

This map shows the real place where we chose to light the streets:

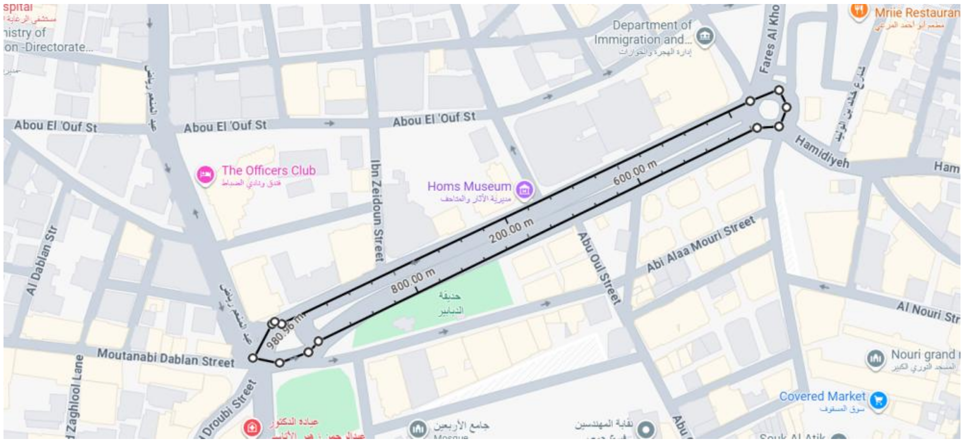


Figure 20: Main Road Chosen for the Study

Table 3 shows the estimations we built [12]:

Item	Estimation	Notes
Distance of Lightening (m)	850	
Number of LEDs	17	According to spacing distance (50 m) according to Syrian code
Power of each LED ($Watt$)	40	link
Lighting Time ($hours$)	6	
Traffic Density ($Cars/day$)	15000	According to the City Police Command Cente
Average Car Weight (ton)	1.3	According to the most owned cars in Syria
Tower Height (m)	20	
Mass Needed (ton)	75	
Torque Amplification ($Bump/Mass$)	144	
Vertical Displacement of Mass ($Cycle/m$)	0.0013	
Cable Diameter (mm)	22	link The load is divided by 2 due to the pulley system design
Cable Length (m)	80	
Cable Cost ($\$$)	56	link
Gearbox Cost ($\$$)	268	link
Mass & Tower Cost ($\$$)	4000	
Total Cost ($\$$)	~9000	Elements costs + Installation Costs

Table 3: Estimations for the Case Study

4.4 EXTRA ELEMENT OF ENTREPRENEURSHIP - PARTNERS

To bring this solution into real urban environments, collaboration with key partners is essential. Municipal authorities and city planning departments are needed to integrate the system into streets and public spaces, ensuring safety and compliance with road infrastructure standards. Energy distribution agencies and local utility companies are important partners to connect the generated power to the lighting network and manage stored energy release. Engineering and manufacturing partners can support the production of durable mechanical components at scale. In addition, universities and research centers can assist in continuous improvement, data monitoring, and system optimization. By working with these partners, the project can move efficiently from prototype to full deployment, ensuring technical reliability, economic feasibility, and long-term positive impact on the city.

4.5 AI MODEL OF GRAVIPOWER

Choosing the best place to install our system is a comprehensive process, as it requires careful evaluation of efficiency, benefits, and long-term impact. To solve this issue, we developed an AI tool that analyzes data using some parameters **(traffic density (30% weight)**, infrastructure **(20% weight)**, and population density **(25% weight)** These weights reflect the importance of each factor) and rates all suitable places in the city. The AI model combines data from: traffic and transport agencies for traffic density, OpenStreetMap, and municipal GIS layers for infrastructure, and census and demographic databases for population. In addition to that, we implemented this model into a web page, we used a **Random Forest Regressor** model. The model is trained on a composite score that combines these factors with defined weights. so, the user can choose a city, and the model will show a comparison between the suitable place and their rate, and pin the locations on a map, so the user will be able to detect the address. Also, the user can adjust the classification setting based on the importance of each parameter.

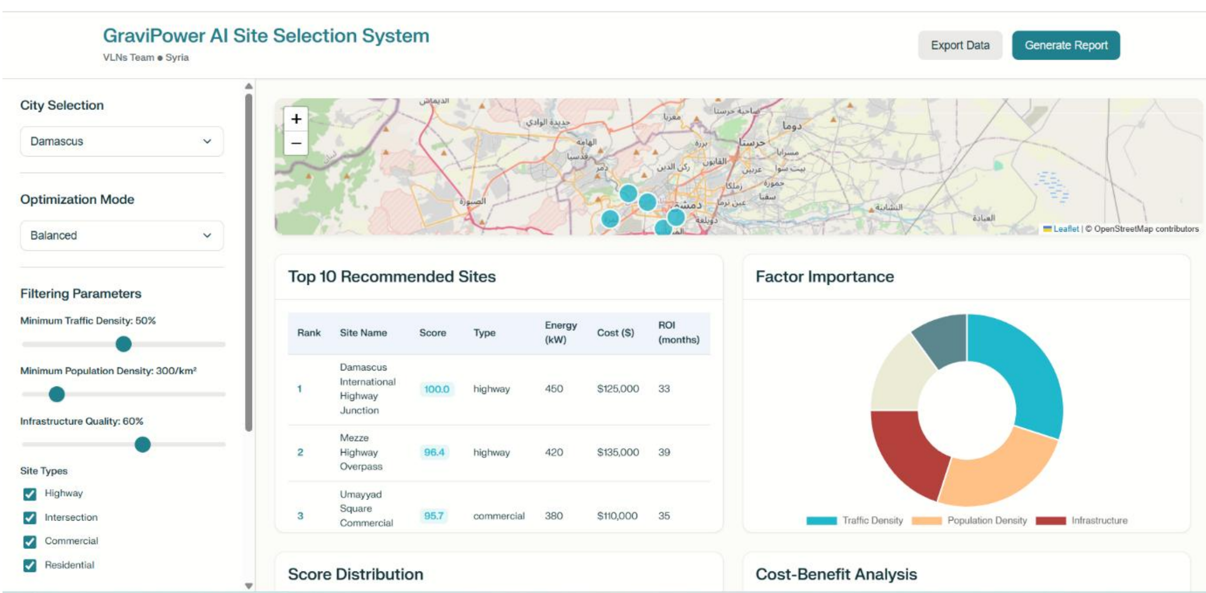


Figure 21: GraviPower AI Site Detector

4.5 STARTUP IDEA - NEXT STEPS & PROTOTYPE DEVELOPMENT

The next step for our project is expanding usability to individuals. While currently focused on large companies and governments, we aim to offer residential versions of our system. Homeowners could integrate a storage-only system with renewable sources like solar panels, using solar power to lift the mass for energy storage. This expands access and promotes clean energy use.

Figure 22: Meeting with the head of EvoTech Incubator Dr. Workozek

We had the chance to meet the Founder & Manager of **EvoTech** Incubator in Syria, Damascus **Dr. Ghaith Workozek** who helped us figuring out the aspects of adapting the project and upscaling it. Dr. Workozek showed his acceptance for the project, and he said that he liked the idea. After presenting our project, we met some business experts in the incubator, and there we presented our study for Homs city center and they provided us with the important sheets to make a full business.

We also discussed following a **Lean Startup** roadmap to move from prototype to deployment as follows:

Prototype Refinement → **Pilot Implementation** → **Cost Optimization & Production Planning** → **Limited Deployment and Evaluation**

Months 1–3 | Months 4–9 | Months 9–14 | Months 14–18

Figure 23: Time Plan for the Deployment of the Project

4.6 KEY INNOVATION

Our project offers a groundbreaking approach to energy storage by using the potential energy of a suspended mass. Unlike traditional systems, we maximize energy efficiency by precisely controlling the mass 's descent without relying on brakes, minimizing friction and heat loss. Smart controllers manage the electrical load to optimize energy generation, making the system more sustainable and efficient. To add, our energy accumulation mechanisms are purely mechanical; that means more efficiency at power transfer.

Additionally, we harness kinetic energy from everyday activities, like cars driving over bumps, and can adapt the system to other sources like waves or wind, providing flexible and innovative clean energy solutions.

CONCLUSION

Our project focuses on developing an innovative energy storage system using gravity, where we harness the kinetic energy generated by vehicles. This clean and renewable system converts the mechanical energy produced by cars into stored potential energy, which is used then to generate electricity when needed. What makes our system unique is its high efficiency and innovative method of energy retrieval. We control the speed of the descending mass to generate as much energy as possible, without relying on traditional brakes that waste energy, our project will significantly impact by providing sustainable energy storage solutions for large companies, especially in areas with heavy traffic. Our system also offers the potential for energy independence and environmental benefits by reducing reliance on traditional energy storage methods that harm the environment. We aim to expand our project to include harnessing other energy sources like wind and wave motion, making the system more versatile and effective in different regions.

And that is our: **GRAVIPOWER STORED BY THE HOUR**

LIST OF RESOURCES

[1] K. Chen, "Types, applications and future developments of gravity energy," MSMEE, 2022.

[2] J. D. Hunter, "Underground Gravity Energy Storage: A Solution for," MDPI, 2023.

[3] W. Tong, "Solid Gravity Energy Storage: A review," North China Researchgate, July 2022.

[4] "How To Read DC Motor & Gear Motor Performance Curves," Isproducts, 2024. [Online]. Available: https://lsproducts.com/design-note/how-to-read-dc-motor-gear-motorperformance-curves/

[5] D. R. Gupta, "Gravity Based Energy Storage System: A Technological Review," ISSN, 2020.

[6] A. C. Ruoco, "Storage Gravitational Energy for Small Scale Industrial and Residential Applications,"MDPI, 2019.

[7] M. H.-E. Haider, "Analysis of Speed Breaker Mechanism for More Effective Electricity Generation,"ResearchGate, 2015.

[8] E. E. P. special, "Why speed of the induction motor decreases with an increase in load? — Effect of loading on I.M.," YouTube, Jan. 1, 2023. [Online]. Available: https://youtu.be/jshQqLYmIPw?si= SwQvD8aXgKFG_UD.

[9] S. Ibrahim and M. El-Gindy, "Dynamic Characteristics of Vehicles Passing Over Speed Humps,"International Journal of Vehicle Systems Modelling and Testing, vol. 5, no. 1, pp. 18–35, 2010.

[10] "CSK12PP One Way Clutch Bearing 12x32x10mm," bearingstreet, 2024. [Online]. Available: https: //bearingstreet.com/csk12pp-one-way-clutch-bearing-12x32x10mm/

[11] "Running a Brushed DC Motor as a Generator," Portescap, 2021. [Online]. Available:https://www.portescap.com/en/newsroom/whitepapers/2021/12/running-a-brusheddc-motor-as-a-generator

[12] M. Zeeshan, "Exploring the Strongest Structural Material Shapes in Building Construction," Alsyedconstruction, 2024. [Online]. Available: https://alsyedconstruction.com/exploring-thestrongest-structural-material-shapes-in-building-construction/#the-superiorityof-the-triangle-in-structural-design

[13] [Online]. Available: https://motors.vex.com/other-motors/torquenado

Organizations that helped us:

DISTINCTION AND CREATIVITY AGENCY
هيئة التميز و الإبداع

المركز الوطني للمتميزين
NATIONAL CENTER FOR THE DISTINGUISHED

الأولمبياد العلمي السوري
THE SYRIAN SCIENCE OLYMPIAD

EVOTECH INCUBATOR
حاضنة نمو التقنية

Appendix 1: Business Model Canvas

<table>
<tr>
<td rowspan="2">Key Partners

Suppliers of sensors, controllers, DC motors, and batteries.

Infrastructure companies.

Local academic and research collaborators for technical expertise and innovation.</td>
<td>Key Activities

System installation and maintenance at client sites.
Demonstrating system capabilities and performance.
Ongoing calibration and optimization of energy capture and storage mechanisms.
Developing, updating, and monitoring system software and web interface.
Technical support and troubleshooting.</td>
<td rowspan="2">Value Propositions

Providing sustainable, low-carbon energy solutions to communities and businesses.
Enabling energy independence by allowing entities to generate and store electricity using clean energy sources.
Delivering large-scale energy capacity based on vehicle traffic density.</td>
<td>Customer Relationships

Product website for easy communication and support.
Troubleshooting guides for common issues.
Direct contact with specialized support teams for assistance and maintenance</td>
<td rowspan="2">Customer Segments

Factories and large businesses seeking energy independence and cost savings.
Organizations focused on reducing carbon footprints, including companies and non-profits.
High-traffic centers such as transport hubs, parking facilities, toll booths, and highways.</td>
</tr>
<tr>
<td>Key Resources

Technical equipment: DC motors, pulleys, ropes, sensors, controllers.
Specialized infrastructure: Car bumps, gear systems.
Skilled team: Mechanical, coding, and circuit design expertise. Digital tools: Web interface and ROS-based software for system monitoring and control.</td>
<td>Channels

Direct sales through the team's headquarters and communication lines.
Demonstrations at industry and technology events to showcase the system.
Networking and collaboration with energy companies and local government bodies for deployments.</td>
</tr>
<tr>
<td colspan="2">Cost Structure

Monitoring and software maintenance expenses. Construction costs including tower building=4000$, installation of pseudo-bumps, and infrastructure=324$. The total cost = 8648$</td>
<td colspan="3">Revenue Streams

Asset sales: Selling the energy storage system hardware and maintenance tools.
Energy sales: Income from electricity generated
Service contracts: Recurring fees from customers
Total revenue = 721$ annual</td>
</tr>
</table>

Table 4: Business Model Canvas of GraviPower

Appendix 2: Full Schematic of the Circuit

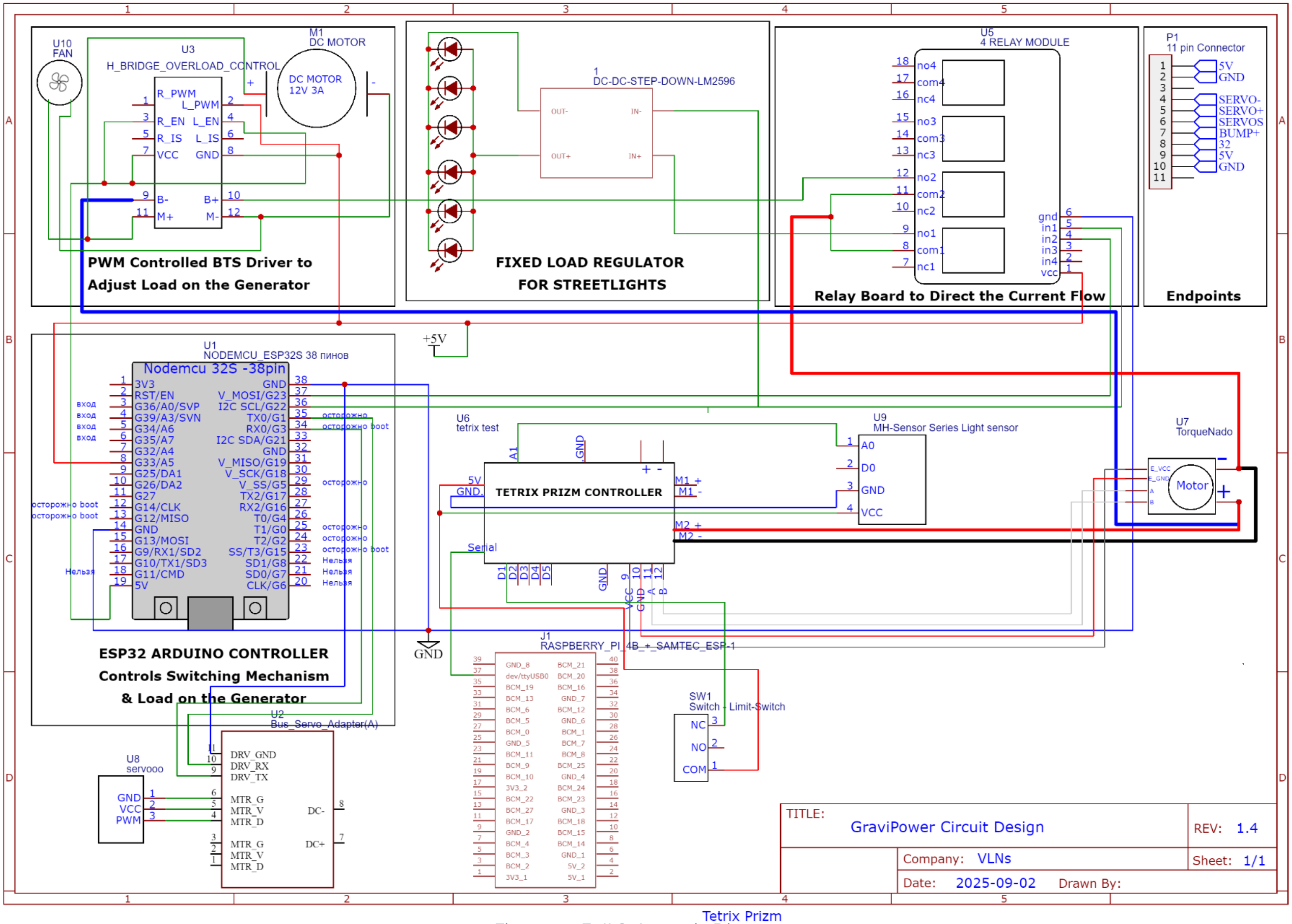


Figure 24: Full Schematic Diagram