January 6th, 2021

E-Clipse
InnovationProject

Deliverable 6

—

Final report

TEAM C

E-Clipse
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1. Summary

In this section, the reader is reminded of the context of the project as well as the work that was already achieved in the previous deliverables.

1.1. Context of the project

1.1.1. Presentation

The innovation project is part of the final year of the ECAM Engineering program. It is a transversal project which purpose is to cover multiple disciplinary fields while allowing students to develop their project management skills. The main objective is to drive the design of an innovative product from A to Z. The project was therefore divided into two parts:

- Opportunity analysis (expression of a need, definition of a target market, definition of product specifications).
- Technical development (technical design and testing).

Throughout the semester, methodological tools were provided by external speakers while specific teachers were assigned as supervisors for each group.

1.1.2. Team

For the project, students were randomly assigned to teams while ensuring that each time had a balanced representation of students from each of the three concentrations in the ECAM Engineering program (mechanical engineering, robotics, and systemic design). Team C is presented in the following figure:

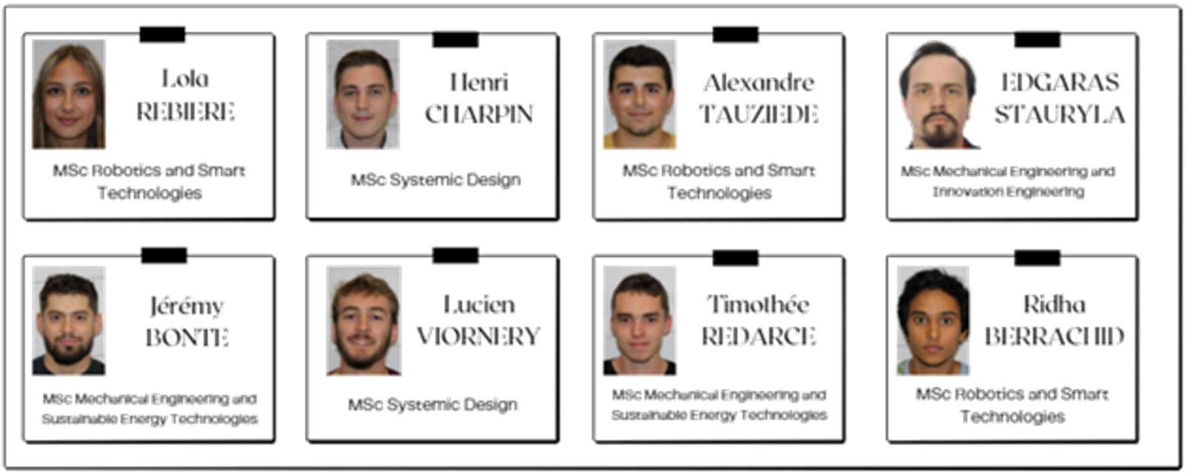


Figure 1: Team C organisation chart

The team's supervisors are presented in the following organisation chart:

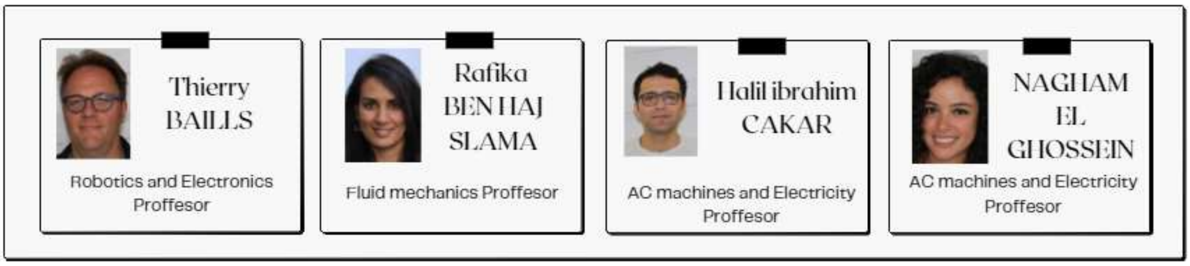


Figure 2: Supervisors organisation chart

1.1.3. Schedule and organisation

To ensure its smooth running, several milestones corresponding to the different parts of the project were established along with intermediate deliverables. They allowed the supervisors to follow the project as it was progressing and are reminded below:

- Project formulation (definition of the subject).
- Needs analysis (market requirements and uses).
- Product specifications (functional and interactional requirements).
- Technical product architecture (definition of the product architecture and commitments).
- Technical development of the product.
- Results (summary, critical analysis, and feedback).

The schedule which the group was tasked with following is presented in Figure 3.

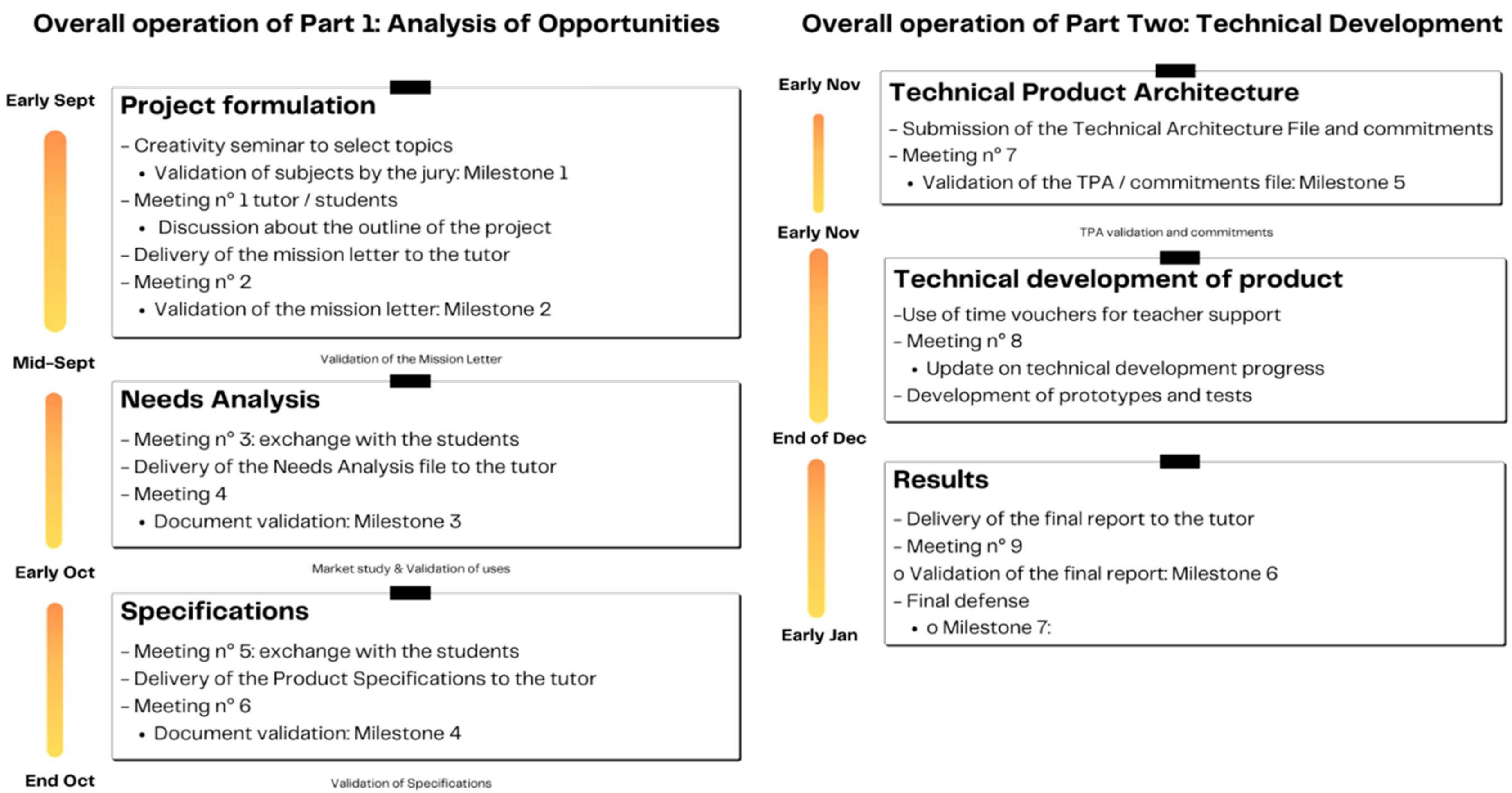


Figure 3: Project schedule

1.2. Project formulation

The preliminary creativity seminar which was attended at the beginning of the project helped with the selection of a topic related to the design of the innovative product. During that seminar, several tools were used which led the team to settle on working on a product that would be related to the use of renewable energies.

The idea of adding solar panels to everyday objects and enhancing them was quickly presented, with some special attention to windows blinds.

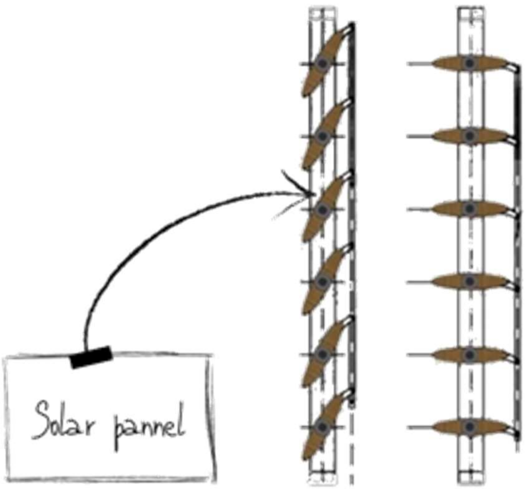


Figure 4: Concept of solar panels covered blinds

The product idea which was therefore pitched to the supervisors is a concept of an intelligent outdoor blind with integrated solar panels, which can follow the course of the sun, and fold or unfold depending on the amount of outside light.

1.3. Needs analysis

The goal of the needs analysis was to highlight a specific need for specific targets to check for the existence of a potential market for the product.

The problem of clean energy generation and consumption, especially for office buildings, was first investigated. It was determined that there is room for improvement as well as an increasing demand for innovative solutions that help implement renewable energy sources in the energy mix. With ever-increasing electricity needs as well as a global increase in environmental awareness, an opportunity on the market for solar panels covered blinds was found. Using tools such as the severity of need formula or the product key success factors strengthened that idea.

The proposed solution was therefore more accurately defined as:

- An intelligent outdoor blind with integrated solar panels.

- A product with a dual function of shade and electricity generation.
- A product which is set to function automatically and be self-sufficient.

The product concept was branded as “E-Clipse” to highlight its “smart” aspect and its light shading function.

For such a product, French cities such as Paris or Lyon are markets which present potential thanks to the steady growth of the demand and their market value. The market was segmented into three different strategic business units:

- Sunlight shading and isolating.
- Space optimization for electricity generation.
- Reduction of the electric bill.

The value proposition for the product was therefore defined as follows:

“We make you save money & energy in your office building by proposing intelligent solar panel covered blinds for a unique way of producing clean electricity.”

There is some indirect competition for the E-Clipse product in each specific business unit. However, there is only one direct competitor on all three combined: SolarGaps. The analysis of that competitor and a competition mapping highlighted that E-Clipse could stand out and differentiate itself from SolarGaps with its additional features and the expected quality of service provided.

A user analysis was performed to characterize the different types of users on the targeted market segment (office buildings and public institutions such as schools):

- Office workers/students.
- Teachers.
- Building managers.

Surveys were then conducted to obtain a clear definition of the users’ expectations and pain points to specify a context of use. It was highlighted that the targeted audience was highly motivated by the alternative proposed by the product. However, it was made clear that using the product should not add any effort for the user.

1.4. Product specifications

Conducting a functional and an interactional analysis in parallel led to the definition of a list of quantitative and qualitative specifications that the product must fulfil to satisfy the future customer.

The functional product requirements stood out when considering the objective of limiting the amount of interaction between the user and the product. The office worker must be able to enjoy the automatic shading adjustment function without getting disturbed in their work. For the office manager, the product is only attractive if it can effectively reduce the office’s electric bill or at very least not imply any extra costs. Three quantitative criteria were therefore expressed:

- The position of the system must be as precise and accurate as possible.
- The system’s automated function must respond as fast as possible.
- The system must at the very least be self-sufficient energy-wise.

For the qualitative criteria, the comfort of the user was the main point:

- The system must be adapted to the incoming light so that minimum action is required
- from the user.
- The system must provide a comfortable environment regarding internal luminosity.
- The system needs an intuitive human-machine interface (HMI).
- The system must resist external conditions (wind, debris, dust…).

1.5. Product Architecture

From the main functions identified in the functional analysis, the following key functions were determined:

- The system must provide a comfortable luminosity in the internal area for the user.
- The system must convert solar energy into electrical energy.
- The system must regulate the lighting of the internal area based on sunlight or the user.

Using creativity sessions and creativity tools, ideas of technical solutions to fulfil each of the key functions were presented. Finally, using several criteria, the best combination of solutions was highlighted. To fulfil its requirement, the product must be automatic external blinds with photovoltaic panels, as well as the possibility of being manually commanded.

The architecture of the product is therefore made of three different modules:

- External blinds.
- Photovoltaic panel.
- Manual+Automatic feature.

Precise technological solutions were discussed using the FAST method to fulfil the products' key functions. A list of commitments for the technical development of the product was then written. They concern six different topics:

- Mechanism (kinematic diagram, sizing, technical drawings).
- Electrical connection (automation logic, sensor analysis, electrical analysis).
- Motor (motor analysis, motor integration).
- Blade (architecture design, material analysis, lifecycle analysis).
- Photovoltaic panels (conversion analysis, efficiency analysis, integration analysis).
- HMI (coding, user interface design).

2. Technical developments

In this section, the technical developments that were performed by the team are presented.

2.1. Design of the blinds

2.1.1. Kinematic diagram and functioning

The kinematic scheme for the “E-Clipse” blinds is shown in Figure 5.

The mechanism of the blinds has been analyzed by visual inspection of external blinds at ECAM as well as the blinds at the “CROUS Alix” student housing. These blinds were selected for analysis since they already fulfilled the minimum requirement for the blinds.

The analyzed blinds only require a button press from the user to operate the blinds (referred in this project as manual blinds). After reviewing the blinds at ECAM as well as at the student residence the optimal size definition and the shape of the panels themselves were selected. After selecting the shape and analyzing the operating principle the kinematic diagram was drawn.

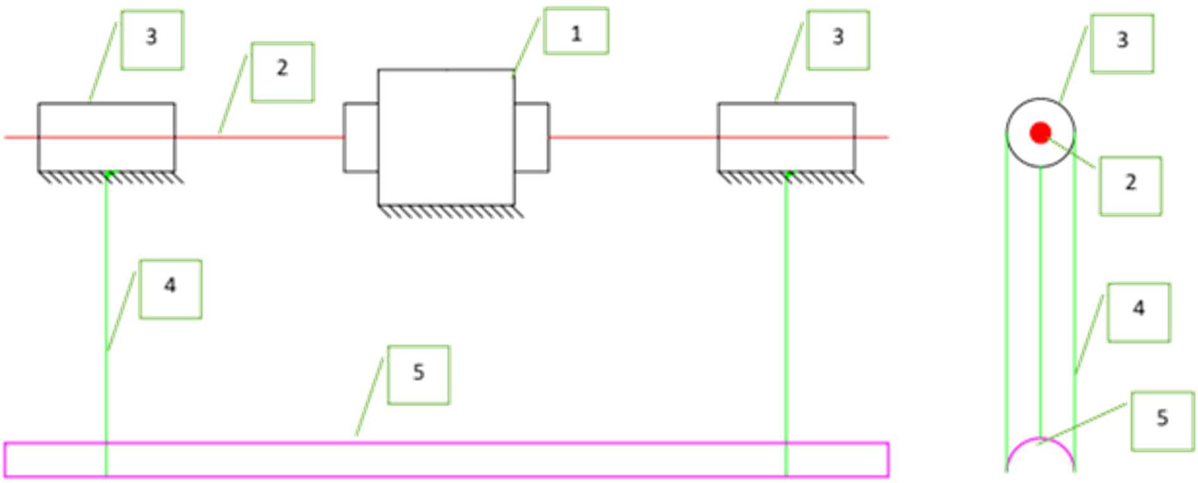


Figure 5: Kinematic diagram of the “E-Clipse” blinds (1 – Reversible DC motor; 2 – Main shaft; 3 – Couplings; 4 – wires; 5 blind panels)

The mechanism of the blinds is quite simple: the reversible Dc motor (1) rotates the shaft (2). The shaft then rotates the couplings (3) which in turn winds or unwind the wires (4). This creates a translational movement for the wires along the vertical axis of the blinds.

The wires (4) are grouped by 3 (Figure 5, right projection) and are connected to the panels of the blinds (5) via 3 points. The middle point is only connected the lowest panel and has a clearness hole for it on the others. These 3 points are separated by the width of the panel and since the wires are wounded and unwounded in 3 different points along the diameter of the coupling, wires can be used to achieve both rotational and linear motion for the blind panels. The middle wire is used to control the height of the blinds since its main purpose is to lift the lowest blinds for them to stack.

The left and right wire are used to control the rotation of the panel. This is achieved via distance between them and their different contact point. As the right is more tensed than the left one during the winding of the wires a see-saw mechanism is achieved. This allows the panels to rotate up to 90°. To lift the blinds, the rotation of the shaft (2) is reversed so now the opposite wire is more intense which then rotate the panels in the opposite direction till it achieves the equilibrium which is the open position. In the open position, the panels are now ready to be raised by the middle wire.

2.1.2. CAD and technical drawings

A CAD model as well as technical drawings of the product were created using the Solidworks software. A preview is presented below. The motor was not detailed in this model.

The 3D model is presented in Figure 7. Figure 7, Figure 8, and Figure 9 show the blinds in their working environment. Figure 9 presents a zoomed in view of the frame's lower fixation to the wall.

Figure 10 and Figure 11 are the technical drawings of the assembly and the transmission system, respectively.

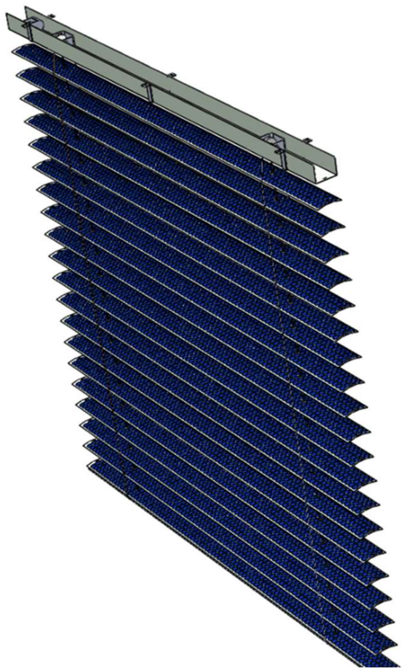


Figure 6: E-Clipse blinds

Figure 7: E-Clipse blinds in their environment (1)

Figure 8: E-Clipse blinds in their environment (2)

Figure 9: E-Clipse blinds in their environment (3)

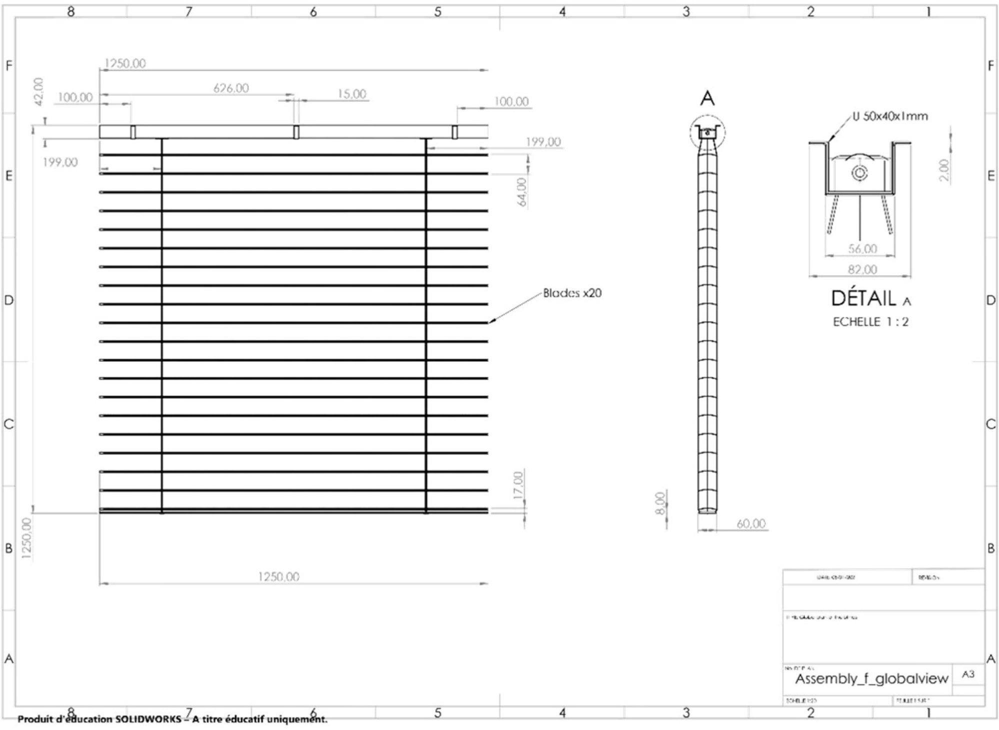


Figure 10: Technical drawing of the assembly

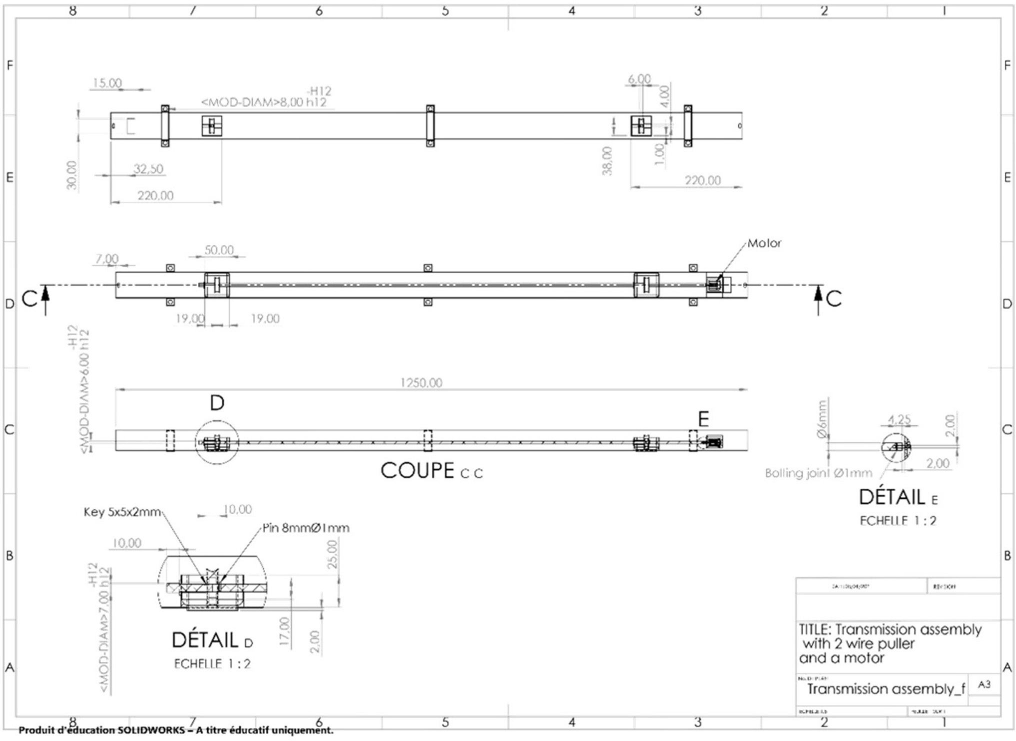


Figure 11: Technical drawing of the transmission

2.2. Materials analysis

Material selection is a key part of a design engineer's job as all characteristics and properties of a product are dictated by the materials it is made of. Materials determine the properties of the object, its weight, cost, ductility, fatigue limit, tensile strength and so on… Because of that, the material selection process should not be overlooked given its importance in the result. They must therefore guarantee durability and sustainability.

2.2.1. Blades

To help on the selection of the material, the software GRANTA EduPack 2020 was used. It allows the comparison of several thousands of materials (and composites) following the properties most relevant to the project. The materials can be sorted into charts and graphs or eliminated by setting limits. Limits can be a range to respect for certain properties, or, for unquantifiable characteristics, a Boolean function (true/false) or one of two scales: "Unacceptable, Limited Use, Acceptable, Excellent" or "Poor, Fair, Good, Excellent". In graphs, different colours represent different families of materials (metals, polymers, ceramics…) and grey materials mean they were discarded by the selection process.

The E-Clipse blinds are set outside of buildings, therefore they must sustain external conditions. The aim of the product being commercialization, the price must also be considered. The following parameters were chosen:

- Resistance to freshwater: acceptable, excellent.
- Resistance to saltwater: limited use, acceptable, excellent.
- Resistance to weak acids: limited use, acceptable, excellent.
- Resistance to UV radiations: good, excellent.
- Recyclability: yes.
- Price: maximum 10€/kg.
- Density: maximum 3000kg/m^3.

After initially removing certain classes of materials (ceramics, glasses, liquids, and gases), this step reduced the possibility from 3897 to 387 materials.

GRANTA EduPack allows the creation of composites. Aluminium-SiC (silicon carbide) foam of density 410kg/m^3 seemed to be an interesting material to work with. However, it is mostly used in an aluminium foam "sandwich", where two dense metallic sheets are put around the foam. To simulate this, 3 composite materials were created using this foam and 3 other metals which also showed promising results: Magnesium of commercial purity (9980A), Aluminium alloy 2014A and Aluminium alloy 518.0. Each composite followed the same ratio of two layers of 1mm thick of dense metal separated by a foam core of 3mm.

To make an appropriate decision, 4 graphs were made:

- Flexural strength vs Density
- Fracture toughness vs Density
- Price vs Density
- CO_2 footprint of primary production vs Price

Flexural strength is the strength of a material loaded in bending. It is relevant when selecting materials for strength-limited designs loaded in bending.

Fracture toughness measures the resistance of a material to crack propagation. Brittle materials have low fracture toughness values, whereas ductile materials have higher fracture toughness values and are less susceptible to crack propagation and sudden failure.

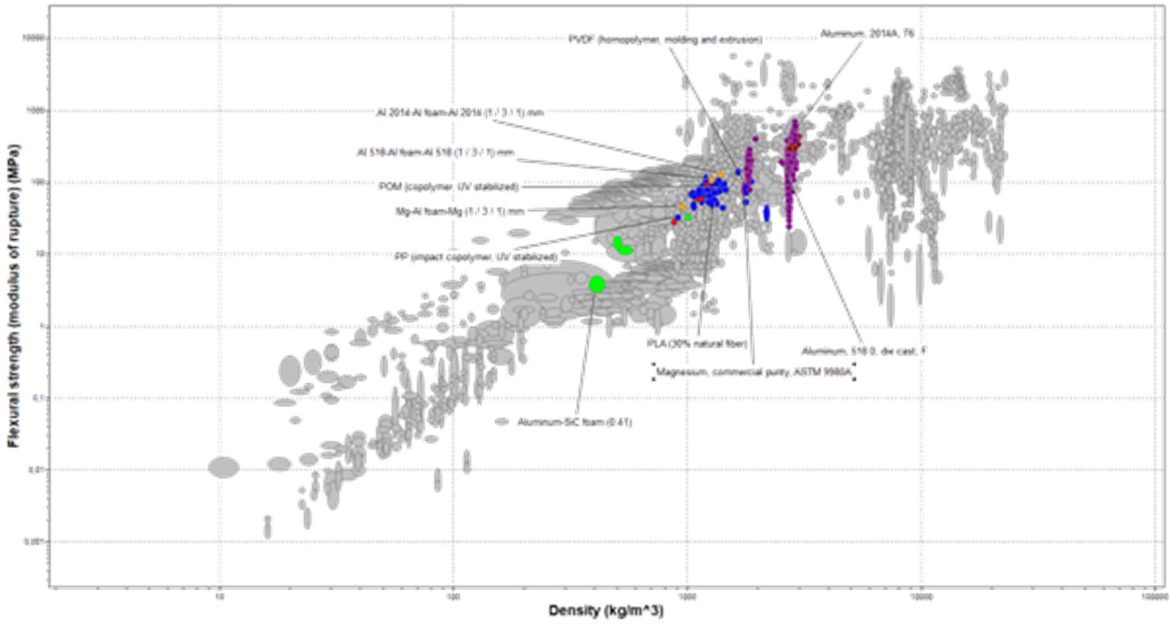


Figure 12: Flexural strength vs Density

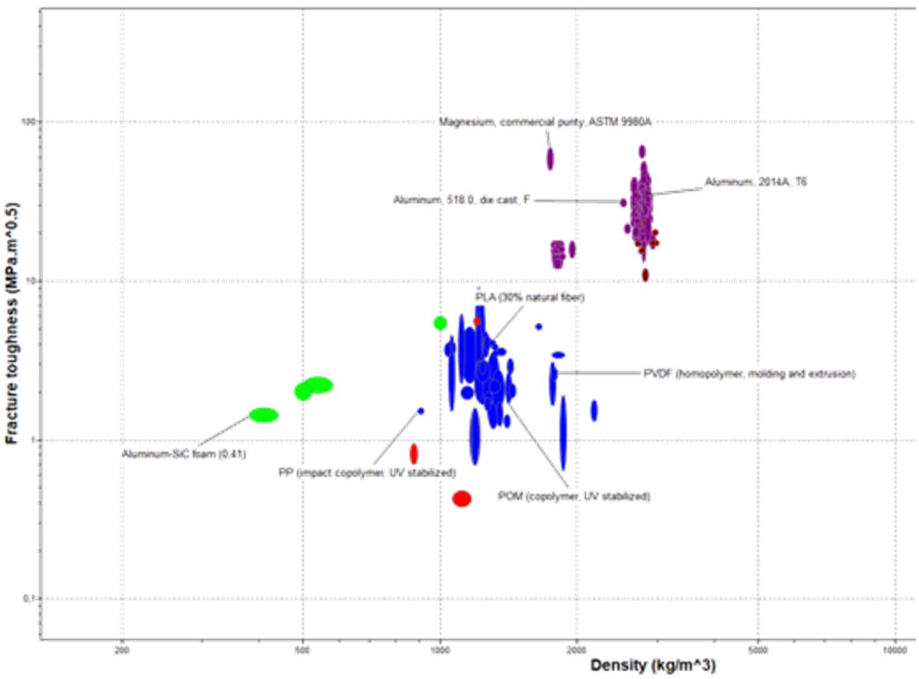


Figure 13: Fracture toughness vs Density

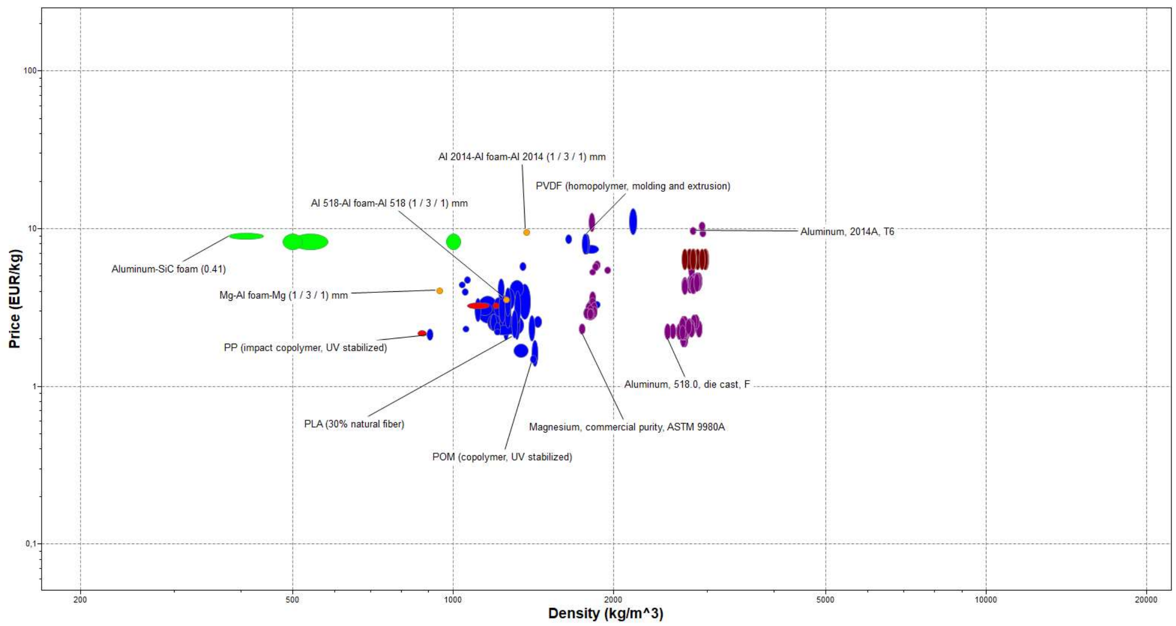


Figure 14: Price vs Density

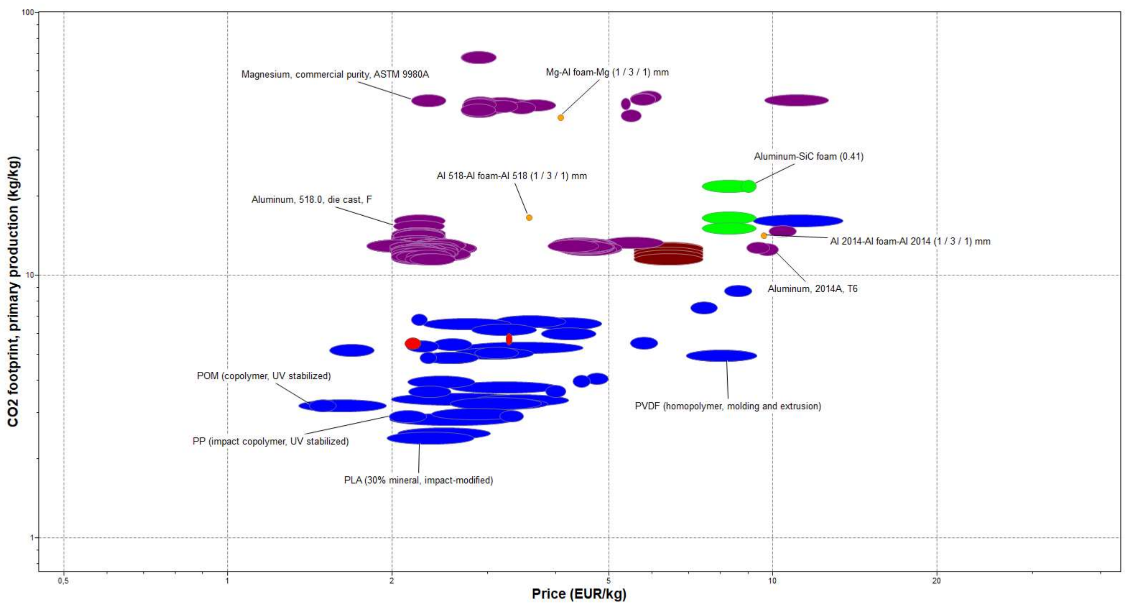


Figure 15: CO_2 footprint vs Price

Figure 12 revealed that the three new composites were able to keep a good flexural strength while significantly decreasing the density of their layer materials, thus ensuring structural integrity, and reducing the weight of the final product.

Other materials that were kept in mind at this stage were Polyoxymethylene (POM), Polyvinylidene Fluoride (PVDF), Polylactide with 30% natural fibre (PLA) and Polypropylene (PP).

Erreur ! Source du renvoi introuvable. showed metals to be most resistant to fractures, PLA also displaying better properties than other materials. The prices of the composites displayed in Erreur ! Source du renvoi introuvable. are only an estimation. However, they do not include the cost of assembling the three layers, their actual price would be much higher than what is shown.

The analysis of the materials was carried out to determine possible candidates for this project. At this stage, considering performance but also price, the best materials seem to be Aluminium 518.0, Magnesium 9980A and PLA. Once the physical constraints had been respected, the environmental axis emerged. Using figure 5, for a more ecological product, Magnesium 9980A was discarded. PLA has the least impact, but another comparison should be made with Aluminium 518.0.

Both materials are recyclable, and one is even biodegradable. Looking at these materials one by one, PLA offers better environmental performance in terms of CO2 footprint, particularly regarding primary production (2.39 Vs 14.7) but also recycling (0.8 Vs 2.6). In addition, the end of life of PLA offers more possibilities as shown in the table below.

	Aluminium 518.0	PLA
Recyclable	Yes	Yes
CO_2 footprint, primary production	14.7 kg/kg	2.39 kg/kg
Embodied energy, recycling	33,1 MJ/kg	15,1 MJ/kg
CO_2 footprint, recycling	2,6 kg/kg	0,8 kg/kg
Recycle fraction in current supply	40,5%	0,1%
Downcyclable	Yes	Yes
Combust for energy recovery	No	Yes
Safely Depositable in a Landfill	Yes	Yes
Biodegradable	No	Yes

Despite the many advantages of the biodegradable material, the final choice went to the aluminium alloy, which is more durable outdoors and is not flammable, which is a very important point when it comes to safety and new construction. Moreover, while the CO_2 footprint of the aluminium for primary production is about 6 times the footprint of PLA, a much larger portion of it in the current supply is being recycled, considerably reducing its impact.

	Aluminium 518.0	PLA
Water (fresh)	Excellent	Acceptable
Water (salt)	Acceptable	Acceptable
Weak acids	Excellent	Acceptable
Weak alkalis	Acceptable	Acceptable
UV radiation (sunlight)	Excellent	Good
Flammability	Non-flammable	Highly flammable

In the end, it is the use phase that determines the final material, thus highlighting the importance of each phase of a product's life cycle.

To model the environmental impacts, ADEME's Bilan Produit was used. This tool allows the selection of the different materials used, their quantity, the associated manufacturing processes, and details on the packaging. The important transport phase, from the extraction of raw materials to transport to the waste treatment plants is considered. Finally, the end of life is chosen for each component of the product and some specific recycling methods can be considered depending on the components.

The Bilan Produit tool enables the entire process to be considered by focusing on each stage of an object's life cycle. However, the limits of the tool can quickly be reached when working with complex products incorporating new technologies. Thus, it has been necessary to simplify certain components by retaining only the main materials of these, such as the motors, the various sensors or even the photovoltaic panels. Moreover, some data concerning transport (kilometres) have also been approximated, as the exact location of the production, assembly or recycling sites is not known.

Catégorie d'impact	Classification	Total	Unité
Changement climatique - Biogénique; Impact potentiel	I	-1.2e-3	kg éq. CO2
Changement climatique - Fossile; Impact potentiel	I	1.6e+2	kg éq. CO2
Changement climatique - Usage des sols; Impact potentiel	I	0.0e+0	kg éq. CO2
Utilisation de ressources fossiles; Impact potentiel	III	7.0e+2	MJ
Utilisation de ressources minérales et métalliques; Impact potentiel	III	4.0e-3	kg éq. Sb
Utilisation des sols; Impact potentiel	III	-1.2e+1	sans dimension (pt)
Changement climatique; Impact potentiel	I	1.6e+2	kg éq. CO2
Eutrophisation eaux douces; Impact potentiel	II	-6.9e-3	kg éq. P
Particules; Impact potentiel	I	3.5e-5	incidence de maladie
Formation d'ozone photochimique; Impact potentiel	II	6.6e-1	kg éq. COVNM
Acidification; Impact potentiel	II	2.0e+0	mol éq. H+
Eutrophisation terrestre; Impact potentiel	II	2.2e+0	mol éq. N
Eutrophisation marine; Impact potentiel	II	2.1e-1	kg éq. N
Appauvrissement de la couche d'ozone; Impact potentiel	I	1.2e-6	kg éq. CFC 11
Radiations ionisantes; Impact potentiel	II	-1.7e+3	éq. kBq U235

Figure 16: Impact on the environment

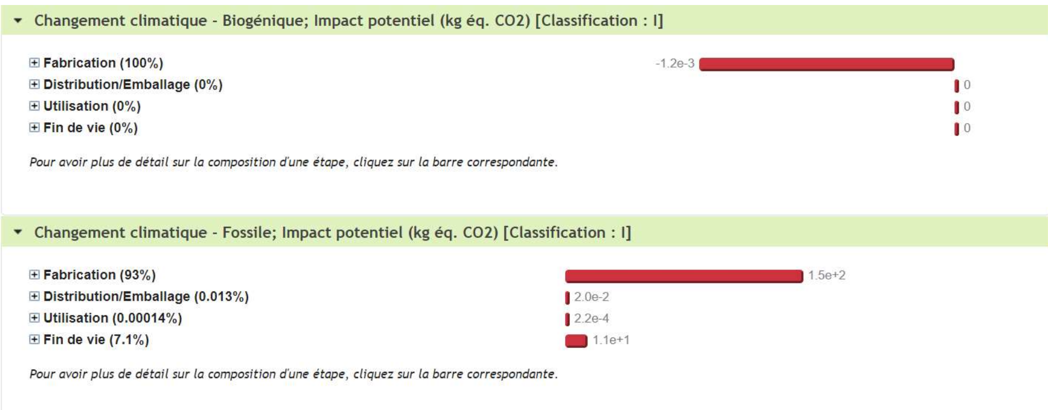


Figure 17: Impact on climate change

2.2.2. Photovoltaics selection

The main selling point of the E-Clipse blinds, which differentiates them from regular automatic blinds, is its ability to generate electricity using photovoltaics. The choice of the right photovoltaic technological solution is therefore of the utmost importance for the design of the product. When talking about innovative products, this is especially true because solar cell technology is a field of study which is continuously improving. This is further supported by the data presented in figure 18.

There are three types of solar cells:

- Crystalline silicon
- Thin film
- Multijunction & Emerging PV

Crystalline silicon cells (1st generation cells) are the most common and known technology. They are based around the concept of a p-n junction. Due to Silicon being the second most abundant element in the Earth's crust (after Oxygen), crystalline silicon cells can be easily manufactured.

Thin film cells (2nd generation cells) are comprised of active material (Silicon, Cadmium Telluride or Copper Indium Gallium Diselenide) sandwiched between glass panels. As they are semi-transparent, they can be laminated into windows or used in building integrated photovoltaics. Their flexibility and lowered weight compared to 1st generation cells also lead to additional applications.

Multijunction cells and emerging PVs are considered as 3rd generation cells and can exhibit the highest efficiencies. Multijunction cells consist of multiple thin film layers (composed of Gallium or Germanium) with different band gap energies. Usually developed for spatial applications, they are nowadays being investigated for terrestrial ones.

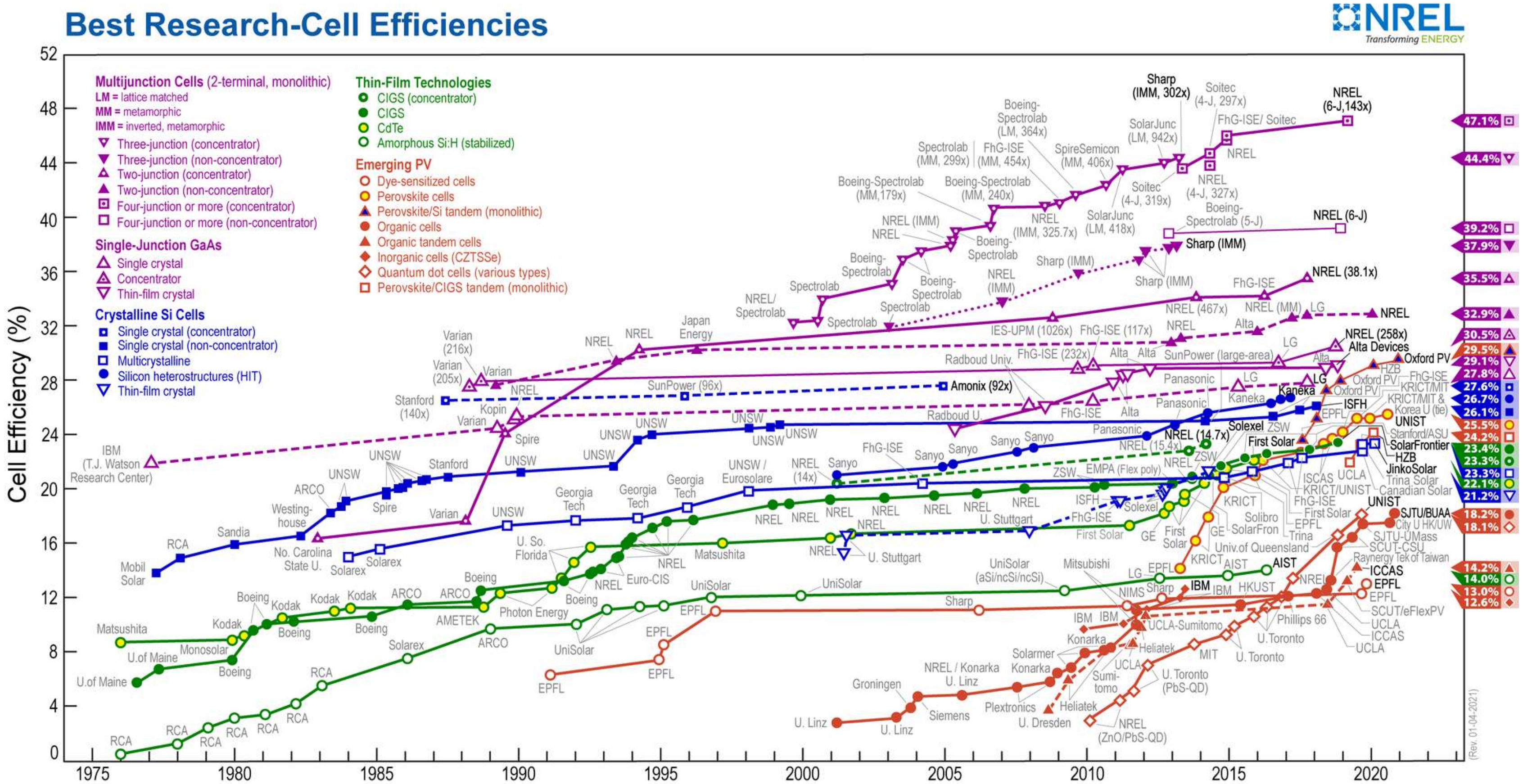


Figure 18: Best research-cell efficiencies

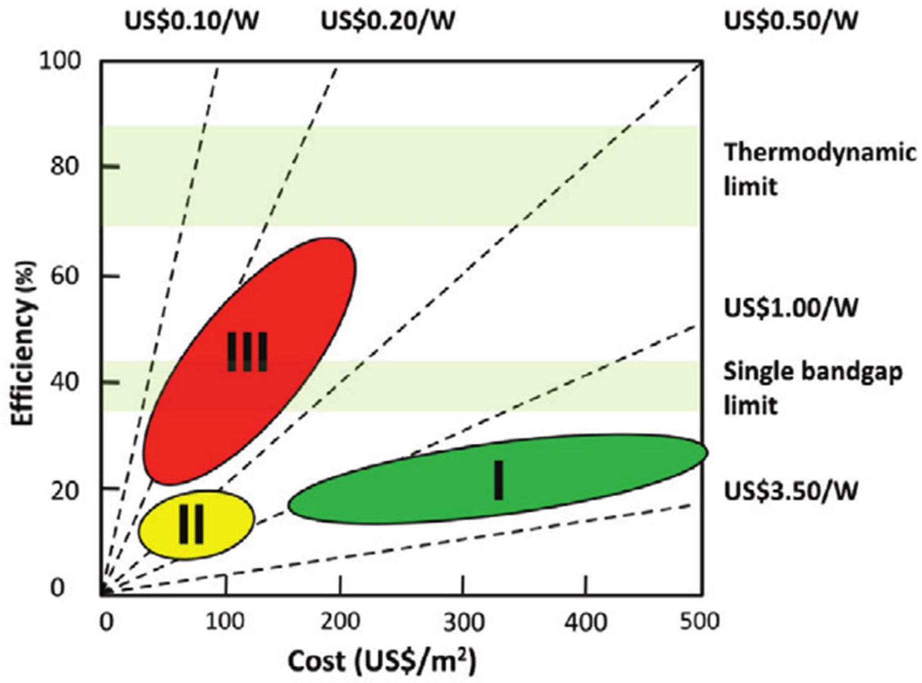


Figure 19: Efficiency vs price per watt for the 3 generations

From a point of view purely focused on the efficiency, 3rd generation solar cells are straight winners. On top of their high efficiency, most of them are built from more abundant, non-toxic, and more durable materials than 2nd generation solar cells. Their efficiency vs their cost per Watt as displayed in Figure 19 would also encourage their use and will make them the photovoltaics technology to use for a cleaner energy mix in the future. However, Figure 19 does not consider manufacturing costs which are still exceptionally high for 3rd generation solar cells, which explains why they have been exclusively used for spatial applications and are currently not commercially available in the industry. Finally, the efficiencies obtained for 3rd generation solar cells were mostly obtained in laboratories, which means that they might not be so high when used in practical applications.

Thin film solar cells have the advantage of their lightweightness, which could fit especially well to cover blind blades (since it would require a lesser amount of energy to wind or unwind them). The main issue is that the most efficient 2nd generation solar cells are made of Tellurium, a rare and toxic material. They also tend to damage at a rate which is currently too fast to be used in commercial applications.

The option which is currently the most techno-economically viable is 1st generation solar cells, especially monocrystalline silicone cells. Their broad spectral absorption range and their high carrier mobility are well suited for applications such as covering blind blades. They are also a technology which is well known, and mass manufactured, which results in lowered costs. Their efficiency and price per performance are also expected to keep decreasing, as showcased in Figure 21.

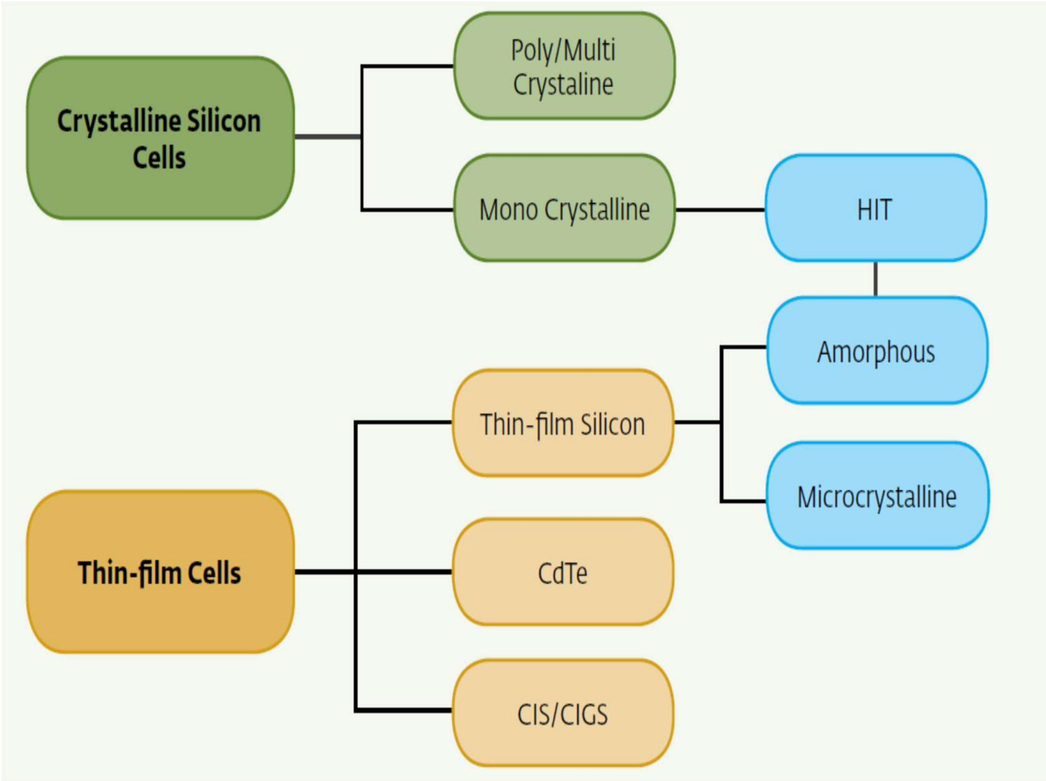


Figure 20: Different types of commercially available PV cells

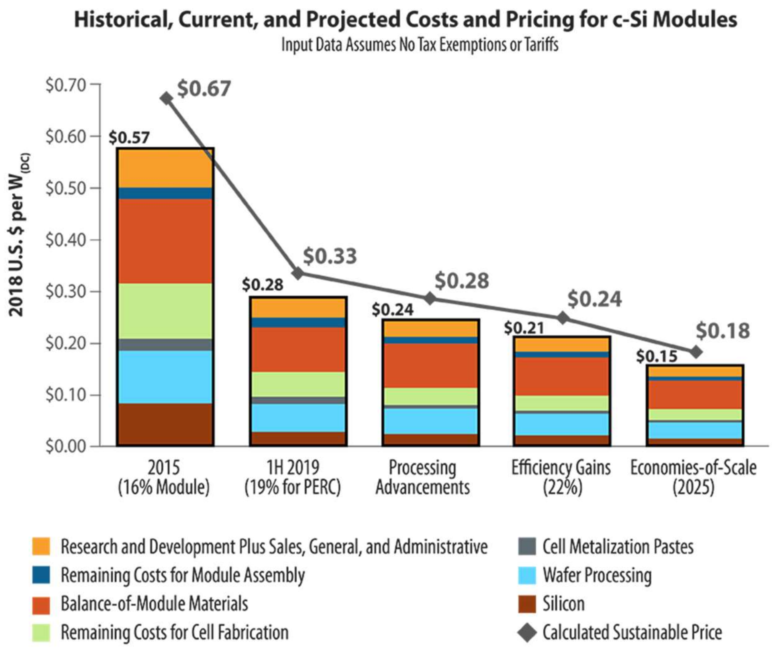


Figure 21: Historical, current, and projected costs and pricing for c-Si modules

The E-Clipse team believes that, as the product is innovative and must be first introduced to and adopted by its users, an attractive price must be ensured. While thin film and multijunction solar cells will probably be used in future models if the product knows success and if both technologies are getting developed by researchers, monocrystalline silicon cells are preferred for now. Perovskite organic solar cells (PSC, 2nd generation) are worth mentioning as a potential contender because they are simple and cheap to manufacture. Researchers are developing PSC with efficiencies as high as 29% and are slowly becoming commercially viable.

The E-Clipse blinds would therefore be covered by arrays of monocrystalline silicon solar cells such as the SunPower c50 cells (data found in annex). Ethylene tetrafluoroethylene (ETFE) is expected to be used as a protective and self-cleaning material (as they SunPower c50 are already coated for radiation protection) due to its outstanding corrosion resistance and strength over a wide temperature range and its ability to let light pass through.

2.3. Electrical connections

This section presents the developments made regarding the automation logic, the electrical circuits as well as a study of the sensors used.

2.3.1. Automation logic

2.3.1.1. Controllable parameters

The two parameters that change are the height and the tilt of the panels. A height of 0% means that the blinds are closed, 100% they are completely opened. The tilt corresponds to the angle between the panel and an imaginary vertical line. 0° is completely closed and 90° means that panels are horizontal and let light through.

These two parameters are the ones that the user can change manually but they are also the parameters that are managed during the automatic mode.

2.3.1.2. Algorithmic challenge

The algorithm of the E-Clipse blinds is responsible for controlling its height and angle at any given time. The objective is to have the best lighting inside the room while maximising energy creation through the photovoltaic panels. The challenge is that nothing should be installed inside the room, so it is difficult to know the actual luminosity inside the room. The reasons behind that are that it would require too much adaptability, as every room is different. It would require many sensors to have a good overview of what is happening. Sensors are therefore kept outside with the blinds. Further details about the actual solution are given in the next section.

2.3.1.3. Types of user

There are two types of users:

- The user that cannot access the general settings. This user is the type of user that is impacted by the blinds by working next to them for instance. His interaction with the blind should be minimal. When this interaction occurs, it should mainly be to control the parameters of the blind.
- The system manager, who has access to the settings of all the blinds under his control. The settings can be specific to each blind or generic for a single or group of buildings. These users can also need to control a specific blind

2.3.1.4. Settings

The following list is not exhaustive and has for purpose to give an idea of the possible features that the E-Clipse blinds will be capable of. These settings would be managed through a web application. This web app is presented in section 2.4. These settings remain at the state of ideas since the backend of the web application has not been developed.

- Set times at which blinds are set to a specific position (ex: blinds close at 7 in the evening and go back in automatic mode at 7 in the morning)
- Create events that trigger when desired and cause the blinds to perform a certain action (ex: completely open the blinds whenever there is a fire emergency)
- Presentation mode: switch between automatic mode and a set position
- Manage access to certain windows (ex: people must be connected to a verified account, only people that work in the specific room, everyone that flashes the QR code even without an account)
- Users with an account can see the previous blinds they controlled, this feature can be disabled or limited in time/number (ex: only verified accounts can have up to ten windows that disappear after one week)

2.3.2. Electrical circuitry and sensors

2.3.2.1. Manual override of the blinds for a presentation

The first step in the robotics development concerns building the circuit for the manual use of the blinds. Indeed, even though they are autonomous, there can always be manual override to go up and down. This is because the user may want to have the blinds go down for a specific reason (ex: presentation), but the automation is not in tune with this action.

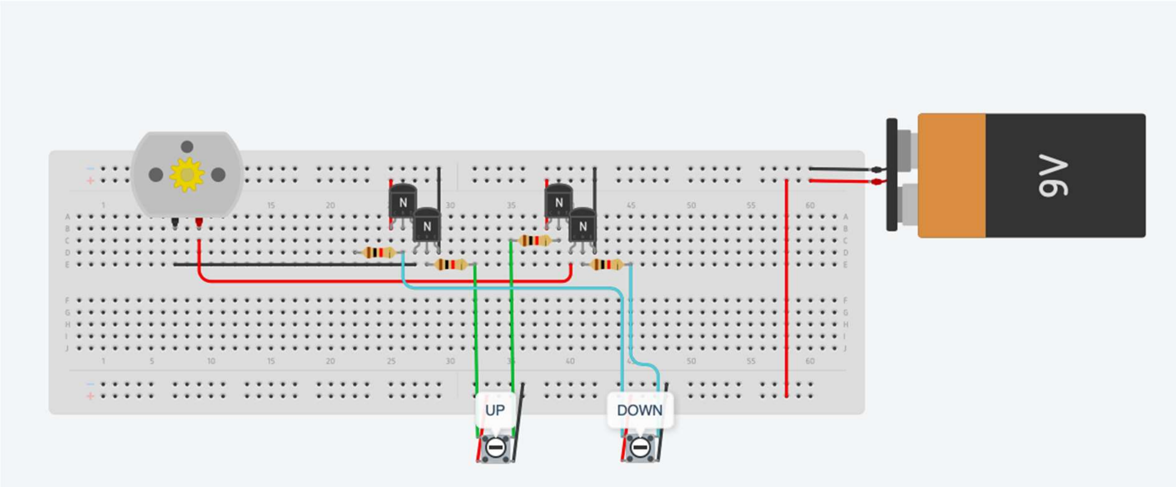
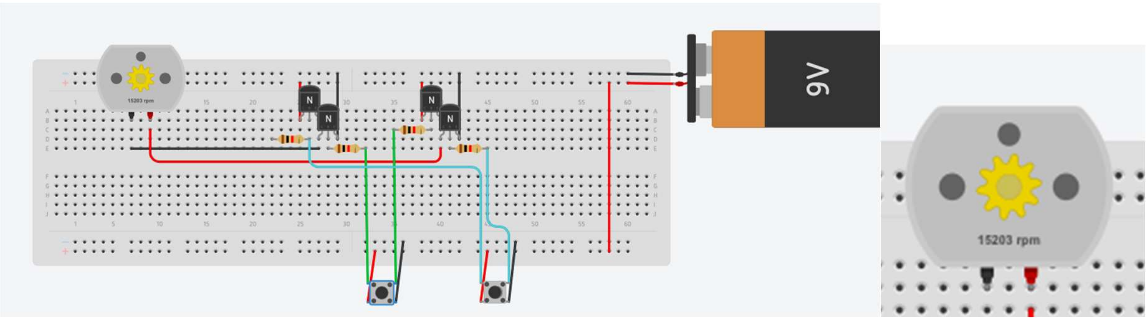
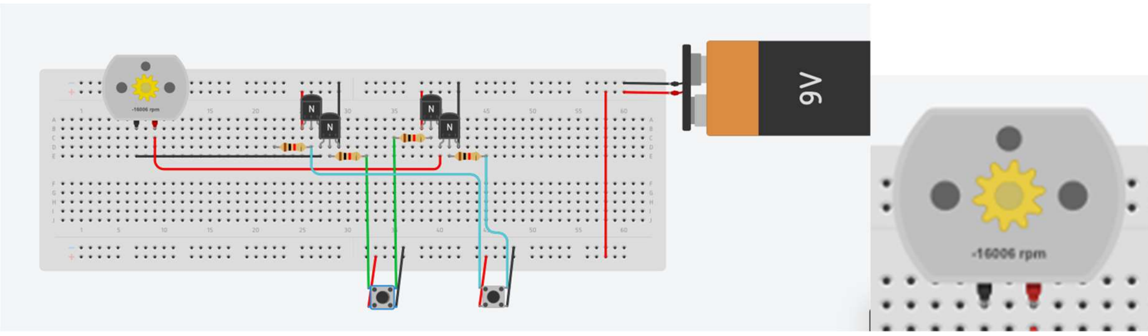


Figure 22: Electrical circuitry

Figure 22 shows what the circuit looks like. It is composed of two push and hold buttons that will control the height of the blinds. It is only a simulation of the real product. Indeed, the power will come from the wall outlet in a real-life situation.



When the UP button is held the motor runs clockwise to pull the blinds up. Once the button is released, the blinds will stop, allowing the user to have the desired height.



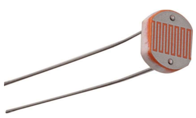
When the DOWN button is held the motor runs anti-clockwise to pull the blinds down. Once the button is released, the blinds will stop.

2.3.2.2. Sensors

To create a smart product as there is a wish to do for the E-Clipse blinds, one of the first tasks is to define which sensor will be used. This has the purpose of measuring data that will then be exploited to allow the program to decide on an action for the product.

As the goal of the blinds is to provide shading, the data that is interesting to measure is the amount of light. This will help to decide whether the room is illuminated enough and if there is a need to move the blinds.

A light sensor is then the best choice for this application. It is composed of semiconductor materials and works on the purpose of the PN junction. The following table presents the 3 main types of light sensors that are existing on the market.

Type of light sensor	Working Process	Applications
Photodiodes 	Convert light into photocurrent 3 terminals: base, emitter, collector Basic light sensor	• Detection of light rays • Used in logic circuit • Optical fibre communication system
Phototransistor 	Convert light into photocurrent 3 terminals: base, emitter, collector Transparent container to enhance the light More accurate than Photodiode	• Counting system • Ambient light detection • Remote controller
Photoresistors (CDS cell) 	Light dependant resistor 2 terminals Current flow increases when light increases	• On and off streetlight • Compare relative light level • Infrared detectors

In the present case, the best fit is the photoresistor. This is because it is commonly used for outside purposes. Moreover, the input value is easily obtainable with Arduino and an analogical port.

There exists a wide range of sensors using this technology as presented in the following table. A doing a comparison between them helps determine which sensor will be used while producing the blinds. There is a need to be able to detect at least between 10 and 1000 lux as the recommended enlightenment of a room is 400 Lux. This will be used as a limit in the further development for controlling the height of the blinds.

Light Sensor	Lux Range	Temperature	Communication Interface	Power Consumption
Simple CDS photoresistor	18 and 50 KΩ at 10 Lux	–30 to 75 °C	one branch at 5V one branch at analogical input	0,1 mA average current
Adafruit TSL2591	0,1 to 40 Klux	–30 to 80 °C	I2C Serial communication	0,5mA average current 15 µA standby current
SI1145	1 to 128 Klux dynamic range	–40 to +85 °C	I2C Serial communication Up to 3.4 Mbps data rate	9 µA average current < 500 nA standby current

The final choice before going any further is the light sensor TSL2591. This is the best fit because the range of lux is enough with the limit stated above. Furthermore, the power consumption is interesting, as well as the temperatures that the sensor can withstand. Finally, it works very well with a controller, which makes it easy to program to obtain a final smart product.

Once this has been decided, the next step is to define how these sensors are going to be used and what is the logic behind it. As stated previously, the goal here is to control the height and the orientation of the blinds. To do so, a programmable controller is going to be used. In this case, it will be an Arduino Uno. It will receive information from the sensors and then transmit the action to the DC Motor.

The toughest decision was on how to place the sensors to get the desired amount of data. The most difficult was for the control of the tilt of the blinds. The desired feature was that depending on the ray of light, the blind will tilt or not to provide more shading. The solution found was to put inclined sensors at the top of the frame of the blinds. Then other sensors are going to be put on either side of the frame at different heights to control the height of the blinds.

Thanks to these decisions, a block diagram of the logic could be generated (see Figure 23) as well as an Arduino code. The code will be implemented directly on the Arduino controller. The resulting circuit board for these autonomous features can be found in the Test section, along with a Tinkercad simulation of the code.

The block diagram represents the different components involved in the overall development for the control of the blinds. It represents at the same time the manual and the autonomous use of the blinds and how the different components interact with one another.

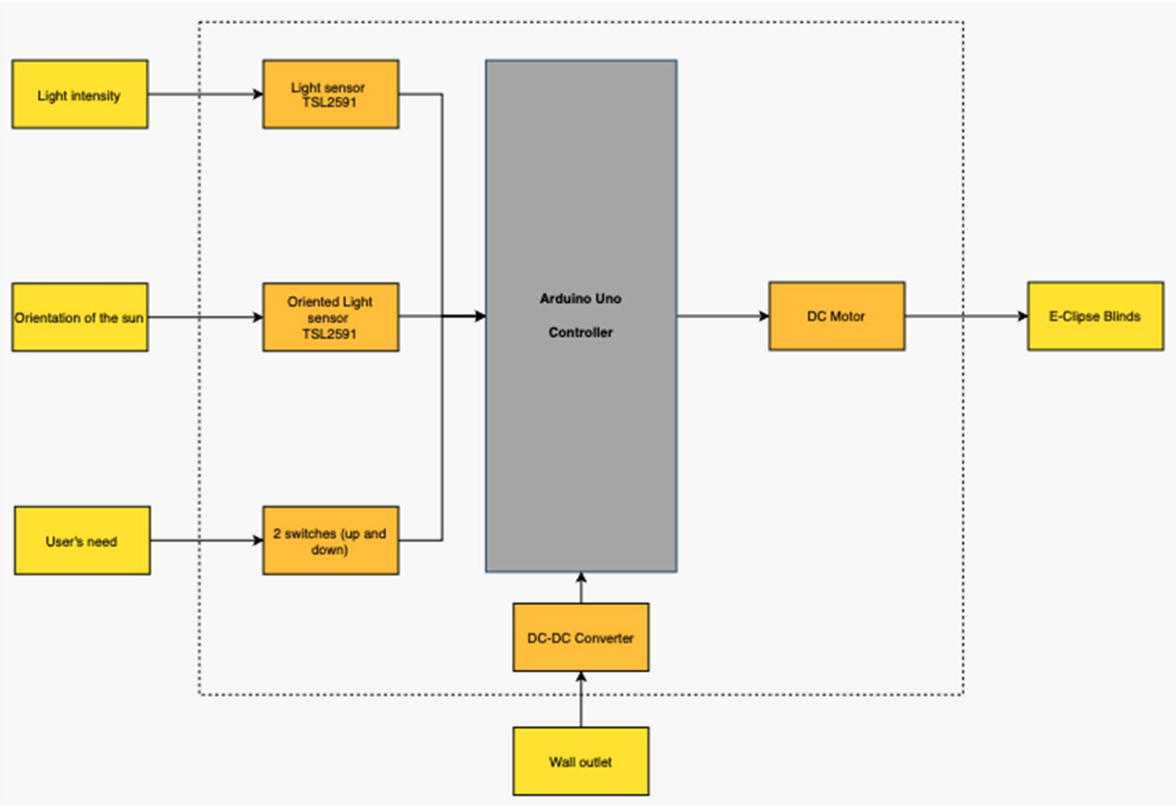


Figure 23: Block diagram

2.3.2.3. Development of the programming

To have a good functioning product some programming is required. The first attempt at coding the algorithm managing the blinds gives the following: The code is composed of different if statements for different scenarios that will help manage the positioning of the blinds. First, it is initialized with putting the motor at zero and assigning the outputs of the sensors as variables. These variables will be used as conditions to whether the blinds should go up or down. As stated previously, the best luminance is 400 Lux. There are different scenarios because the sensors are not at the same height. Depending on where the sensor is located on the frame, the blinds will not go completely down or up.

Figure 24 shows how the code is written when the sensors that are down of the frame are in use.

```
//Scenario 1: The lower sensors are exposed, the blinds needs to go all the way down
if (ML==6 && MR==6 && HL==6 && HR==6) //neglect other sensors
{
  if (LL>=400 && LR>=400) // there is too much luminosity, the blinds need to go down
  {
    while (Height>0) //Loop runs until the blinds are completely down
    {
      analogWrite(enA, 255);  // run motor at maximum speed
      digitalWrite(in1, HIGH); // Motor is anticlokwise
      digitalWrite(in2, LOW); //Blinds goes down
      Height[17]=Height[17]-1;
    }

  }
  if (LL<=400 && LR<=400) //there is not enough luminosity, the blinds need to go up
  {
    while (Height<80) //Loop runs until the blinds are up mid lenght
    {
      analogWrite(enA, 255);// run motor at maximum speed
      digitalWrite(in1, LOW); //Motor is clockwise
      digitalWrite(in2, HIGH); // Blinds goes up
      Height[17]=Height[17]+1;
    }
  }
  else
  {
    digitalWrite(in1, LOW); //Only one sensor is above limit
    digitalWrite(in2, LOW);//Nothing happens
    delay (2000);
  }
}
```

Figure 24: Down frame sensors in use

One can see that the sensors of each side are considered. When both are under 400 Lux, it means that there is not enough luminosity, so the motor is activated clockwise to pull the blinds up.

When both are over 400 Lux, the reverse action happens.

Finally, if only one is above, the blind does not need to move so the motor stops. This scenario is repeated for each pair of sensors that are at different heights.

The same procedure is done regarding the sensors used for the tilt as they are just positioned in a different orientation.

The complete code can be found in the appendix.

2.3.2.4. Future development

The previously introduced code is the first attempt, it does not respond to all the needs the best way it could. Despite being simple it gives an appreciation of the desired outcome. The next step is to answer the problem of internal lighting. For that, a neural network could be trained to move the blinds prior to the input given by the sensors. This can be implemented by training a neural network prior installation with a unity script. The idea would be to model the place where the window will be installed and simulate sun lighting. By knowing what the light intensity is inside the room and what it should be, blinds can be adjusted and feed the neural network with a set of input/output pairs. The neural network can then be tested using the same unity environment. To achieve even better performance, the neural network would also be learning from the user inputs, adding new pairs every time the user acts manually on the system.

2.3.2.5. *Method of communication*

To continue the development, there is a need to choose the correct network that the smart E-Clipse product will use. In this case, the goal is to have one that can pass a signal at a rate of 1Mps. Choosing the correct network is important as if a wrong choice is made, it can lead to unable to use the product, higher costs, and reduced autonomy.

Networks can be classified into two categories, Long-range networks and Short-range networks. The range represents the distance within the communication is possible. The following figure shows what are the different networks available on the market in terms of rate and range.

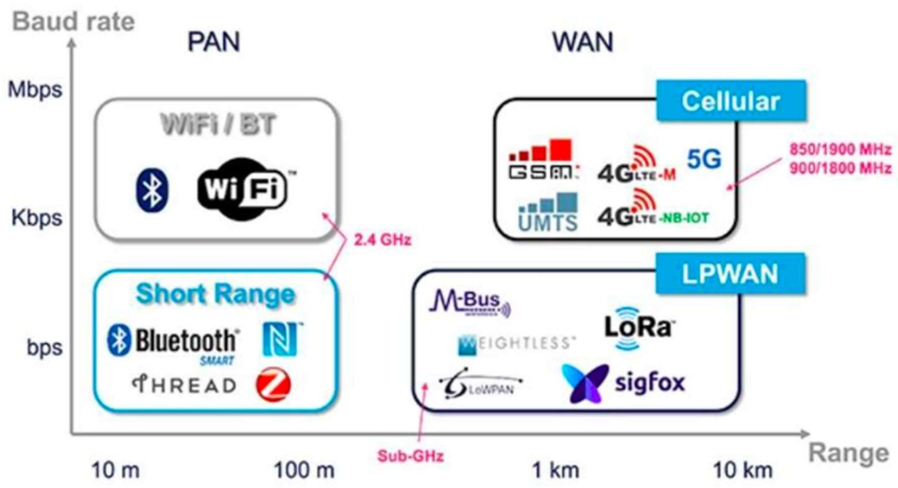


Figure 25: Network mapping

In the case of E-Clipse blind, a short-range communication is enough. This is because it is created for office purposes which does not require a very long range to pass the data. The following table proposes a comparison between the three main types of short-range networks.

	Bluetooth	Zigbee	WIFI
Range	20 m	70-300m	100 m
Hardware Cost	1-3$	2-6$	1-4$
Baud Rate	1Mbps	10kbps-250kbps	>1Mbps
Consumption	Very Low	Low	Medium
Frequencies	2,4 GHz	2,4 GHz	2,4 GHz and 5 GHz

Here the WIFI is the best fit. Indeed, it has enough band rate to transport all the data needed, the biggest bit being the software upgrades that will come down the line. It is also easier to install as many offices are already provided with WIFI, there will be only a need to add an interface that will communicate with the device designed.

2.3.2.6. Interface of communication

As stated in the previous part, the network used is going to be the WIFI. To connect the E-Clipse device for the control, a network card directly implemented on the administrator's computer can be used as it will avoid adding external modules. This choice has been done as a computer will always be available in the office for the card to be added. An internal antenna will communicate with the Arduino board to allow control, communication, and interaction.

The card used is the TPLINK TG-3468. It is a typical LAN card with different baud rate range possible (10/100/1000 Mbps). It provides a high performance for communication. Finally, there is an LED indicator for state and operation which allows the user to see if the card is well functioning or needs maintenance. The datasheet for this component can be found in the appendix.

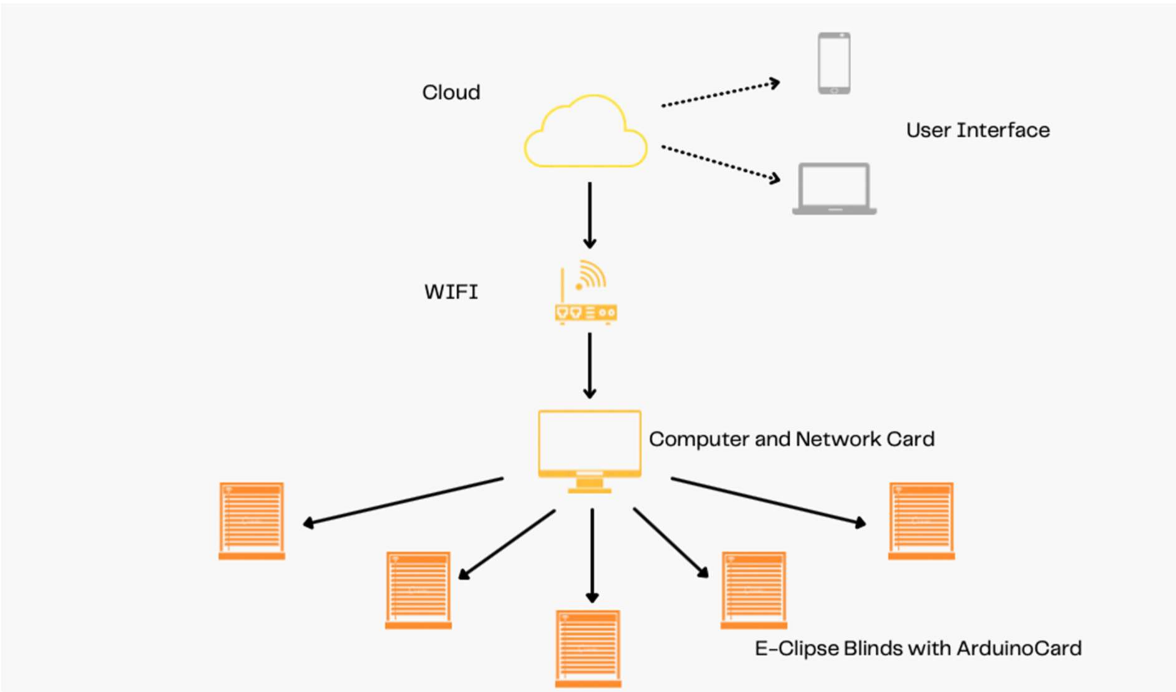


Figure 26: Data transmission system

Figure 26 shows the different components involved and how the different data are transmitted.

2.3.2.7. From Solar Energy to Electricity

One of the features of the E-Clipse product is to produce energy thanks to the photovoltaic cells present on the blades of the blinds. The photovoltaic cells will have a DC current as an output. To use the energy generated, there is a need to use a DC-AC converter. Thanks to this conversion, the produced AC current can be sent to an electrical grid and be either reused directly (ex: for powering the blind or charging a phone) or be stored for future use (electrical companies provide a bonus if the energy is sent back).

There are specialized DC-AC converters for solar panels. The following table shows the three different types that are on the market.

String Inverter	Power Optimizer- String Inverter	Micro-Inverter
· Reliable and efficient · Easier system maintenance · Cheapest solution	· Each output is optimized independently and then send to a centralized inverter · Provides level monitoring of system and panel	· Each output is inverted independently · Can easily expand the system size · Good solution for complicated installation (angles/ different directions)

For the blinds, the best DC-AC converter is the Micro-Inverter. This is because each window will be equipped with blinds and they will not always be facing the same direction. Using this type of DC-AC converter will prevent any impact on the lot if one window is in the shade. Finally, it is the easiest to install and to maintain. Figure 27 shows the block diagram of a Micro-inverter.

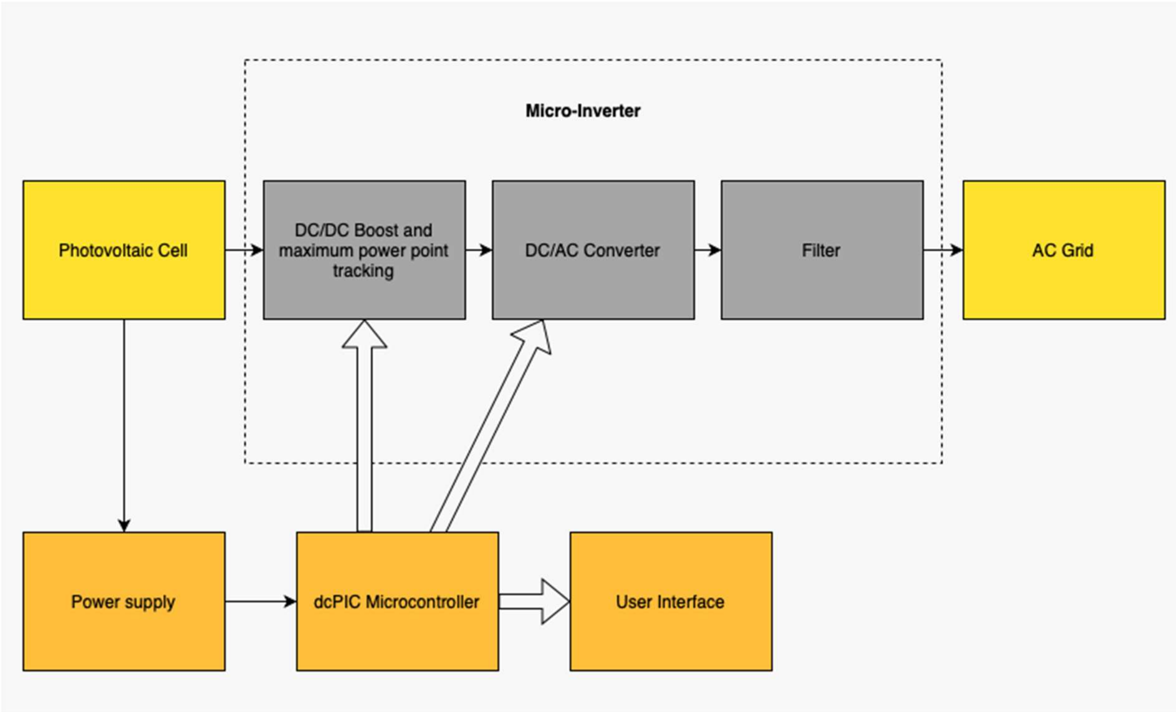


Figure 27: Block diagram for the micro-inverter

2.4. Human-machine interface

This section will introduce the reader to the prototype of the E-Clipse web application. It has several functions for different end users. The most common use of the web app is to access a control panel for the blinds. The other function of this web app is to control all the settings that go with the E-Clipse product. To separate the two use cases, users will be managed with different access authorisations. The structure and the design of the prototype will be discussed here. If the reader is not familiar with application prototyping, there is this little explanation about prototype development in annex.

2.4.1. Structure

The feature of the web app allowing the user to control the blind is at the centre of the web application. This is because it is going to be the main use of this tool. The feature allowing to control the settings must be hidden to users that cannot access it. The idea is that a user that enters the application to control a specific blind will be able to do so without tweaking and playing too much with it. For the structure, users that will only control a few blinds are likely to use the phone version, as opposed to the web version being more likely used by the few that manage the settings. However, bear in mind that both platforms can be used for both use cases.

2.4.2. Mobile version

This type of user will basically have two choices to connect to the web app. The first is to scan the QR code that is next to the blinds and that will bring him directly to the controller for this blind. The other, maybe for users that will need to access it more often, is to directly open it from the web by accessing E-Clipse's website. Either way, when this user connects, they will see the controller for a specific window and be able to change the window he is controlling without having to scan the specific QR code. However, limitations can be installed for limiting where you must be to access a panel, who you must be, etc. Figure 28 shows the controller for the window 3 in I101 as the blinds are fully closed.

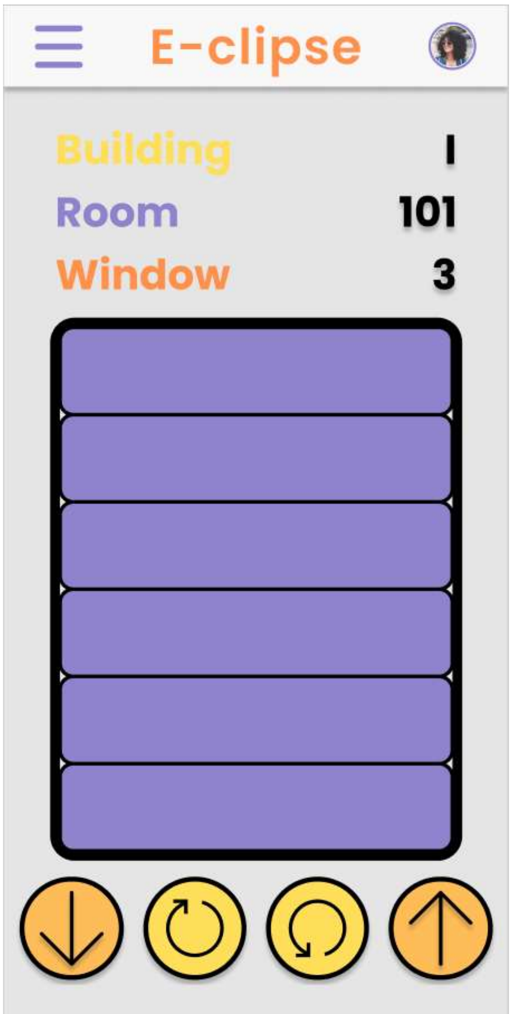


Figure 28: E-Clipse controller for a window, mobile version

The prototype for the limited access user can be found here, or by flashing the QR code presented in Figure 29 (obviously it is better to use the QR code to experience the application on mobile):

Figure 29: WebApp QR code

2.4.3. Web version

The few product managers will access the same application, but they are less likely to do so with the QR code and thus less likely to use it on the phone. However, even if it is possible, the prototype only shows a laptop version of the settings. The main difference for this version is the access to both the settings of the window itself and the settings of the whole building. Considering that some users might have to manage different buildings (for instance if it were to be installed in a school), each building will have its own settings. Finally, the settings include a page giving the stats of the building/window in terms of power generated and consumed.

The prototype for the system manager can be found by clicking here.

2.4.4. Design

The design of the web app is made so that the main feature is at the centre of everything. It is also important to have a simple and understandable design. The direct feedback of the impact the buttons of the controller have on the blinds is a good way to help people understand what is happening even if they do not directly see the blinds they are acting on. A secondary features of the app is the account part. It is possible for the user to customize it a little, but it is mainly a tool for the system manager to control access rights. Finally, it is a design that allows future feature to be integrated easily through the menus without interfering with the main feature that is controlling the blinds.

3. Tests, analysis, and discussion

In this section, the performance tests which were carried out to ensure that the product would fit the requirements are presented. Their critical analysis and a discussion can be found at the end of the section.

3.1. Sensor testing

The major test that can be performed regarding the sensors and the electrical circuit concerns the functioning of the motor in function of the light on the sensors. To create a simulation of what could be the real-life scenario, the website Tinkercad has been used. This allows to use an Arduino card and to program it as if it were in the actual situation, as well as the different electrical components needed. The only drawback of the website is that not all sensors are available for use. In this case, the sensor TSL2591 was not accessible. To perform the simulation, a simple photoresistor was used as it has the same working principle as the sensor chosen.

The code created during the technical development is implemented on the simulated Arduino and the electrical circuit is connected as shown in the following figure.

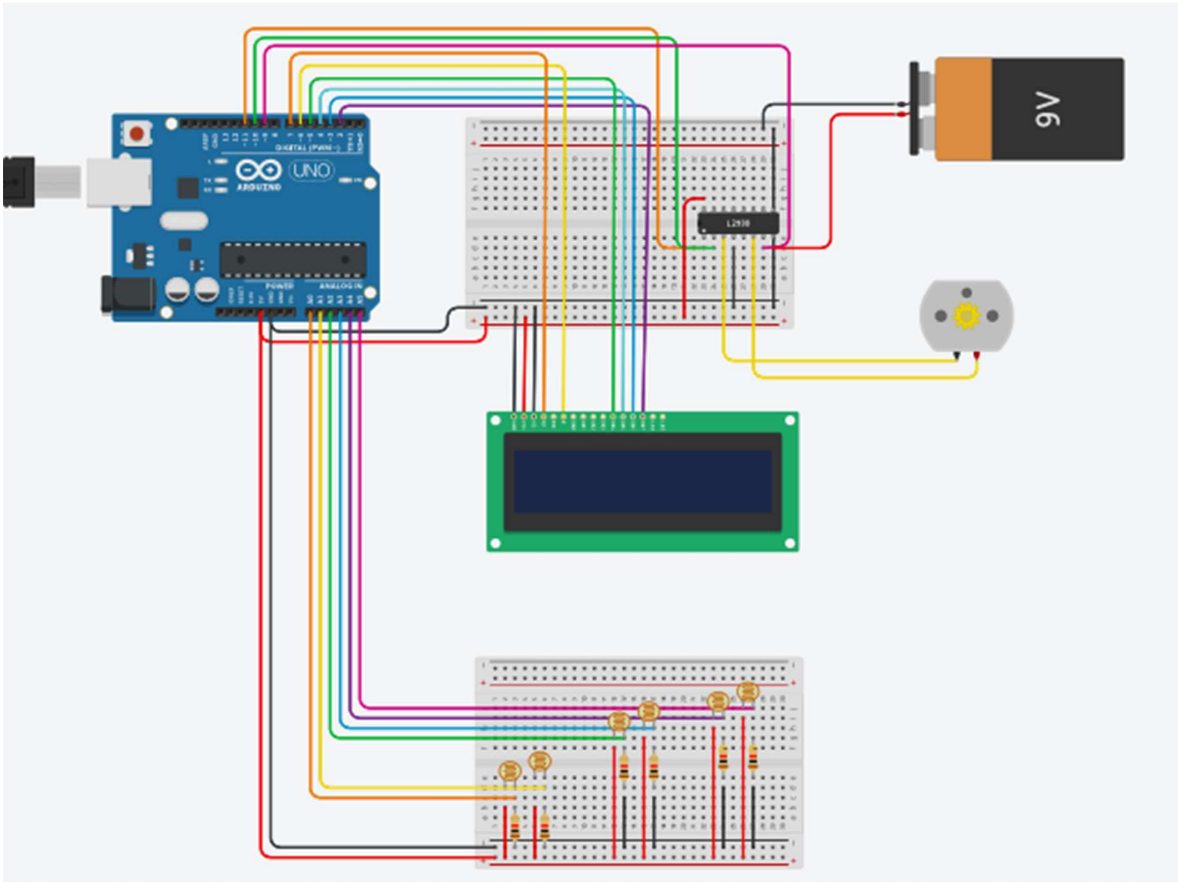


Figure 30: Test circuit for the code

The procedure of this testing follows three times the same steps. This is so because there are three sets of sensors and they all need to be tested. The following points represent the procedure:

- Note which sensors are being tested.
- Launch the simulation and verify that the code is compiling correctly.
- Check the state of the motor.
- Puts the two sensors at a certain value and check the state of the motor.
- Repeats with other values.
- Either test is validated and can perform the next set or test is not validated and modify code/circuit.

There is a set of three times two sensors. Each pair represent a sensor of each side of the frame positioned at different heights. The ones at the left represents the one based at the lowest point of the frame, the middle ones are the ones for the middle of the frame and finally, the ones at the left are the ones for the higher point.

A L293D bridge is also used to connect the DC motor to the output of the Arduino, and an LCD screen is used for the testing to display the value of the sensors to see how the motor speed depends on it.

To symbolize whether the blinds are going all the way down or not, the DC motor will run at different speeds. This is done because this simulation is not connected directly to the blinds. Here are the different statements:

Speed	Action on the blinds
The motor goes at maximum speed	goes up to mid height.
	goes all the way down.
The motor goes at mid speed	goes all the way up.
	goes down to mid height.
The motor goes slowly	tilts up to 90°.
	tilts up to 0°.

The first testing concerns the lower sensors. The simulation is done in two different situations two demonstrate how the motor will behave when changing the values of the photoresistors.

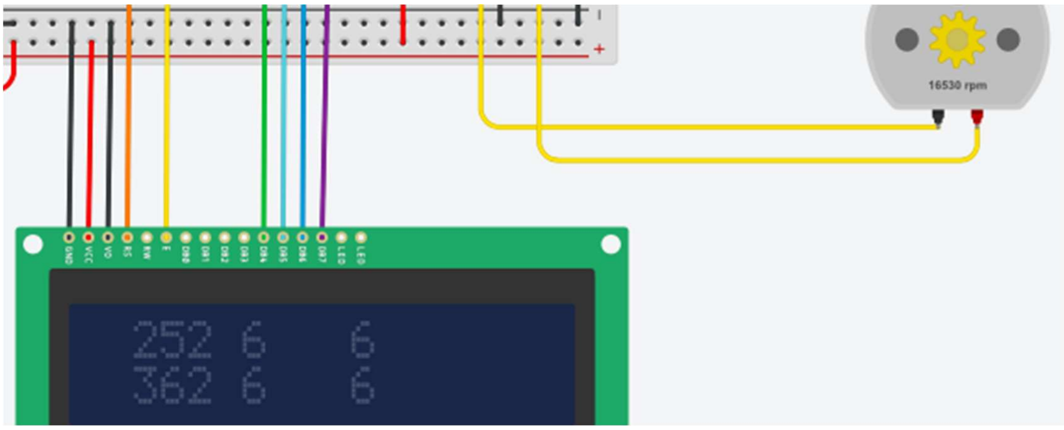


Figure 31: Electrical circuit test 1

Figure 31 shows that when the two values of the sensor are below 400 Lux, the DC motor runs with a positive speed (clockwise). This means that the blinds will go up because there is not enough luminosity.

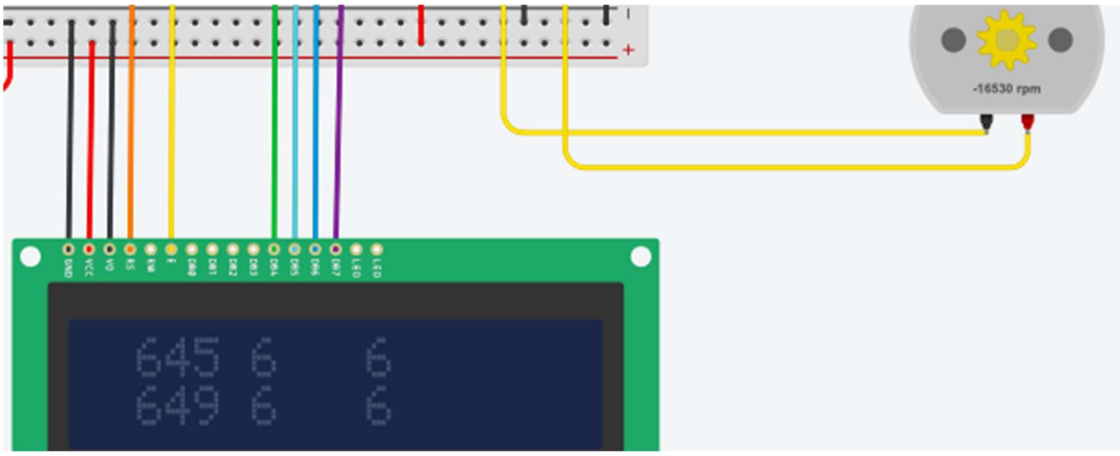


Figure 32: Electrical circuit test 2

Figure 32 shows that when the two values of the sensor are below 400 Lux, the DC motor runs with a negative speed (anti-clockwise). This means that the blinds will go down because there is too much luminosity.

The second testing concerns the second set of sensors. They are the ones that are positioned mid-height of the frame of the blinds. The two figures represent the same conditions on the sensors than in the first testing.

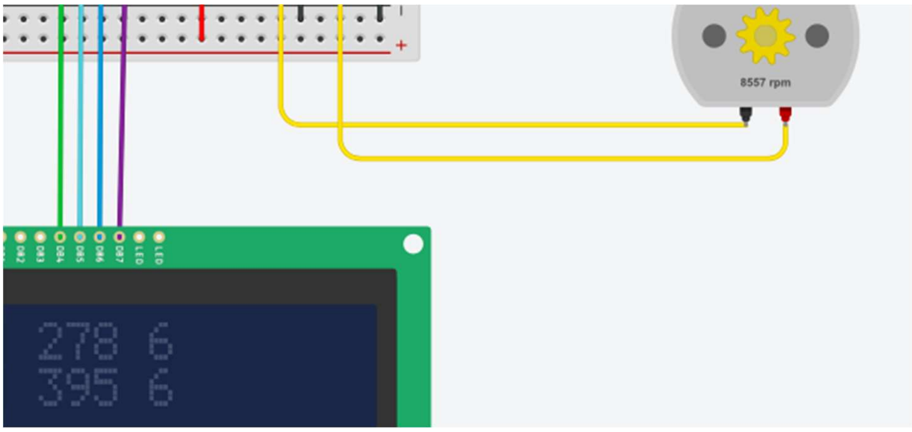


Figure 33: Electrical circuit test 3

Figure 33 shows that if there is not enough luminosity, the motor runs clockwise and will make the blinds go up.

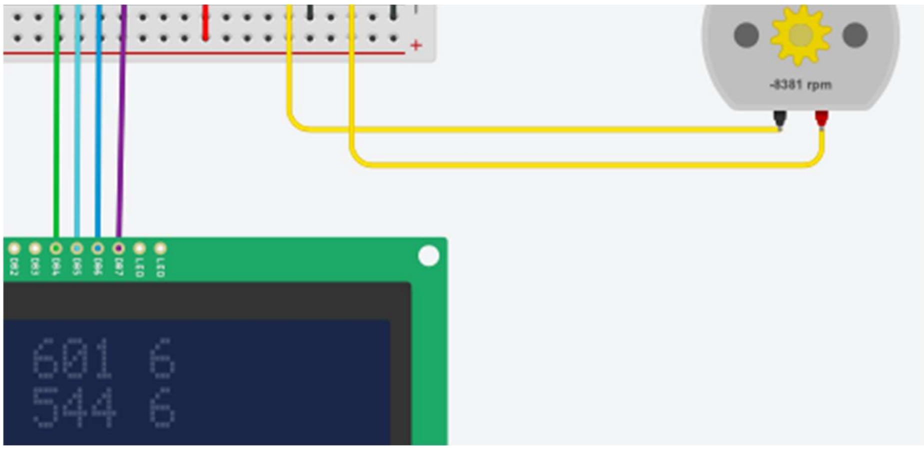


Figure 34: Electrical circuit test 4

Figure 34 shows that if there is enough luminosity, the motor runs anti-clockwise and will make the blinds go down.

The last testing is about the last set of sensors. These are the ones that will be oriented to control the tilt of the blinds. The two following figures are obtained thanks to the same procedure as stated below.

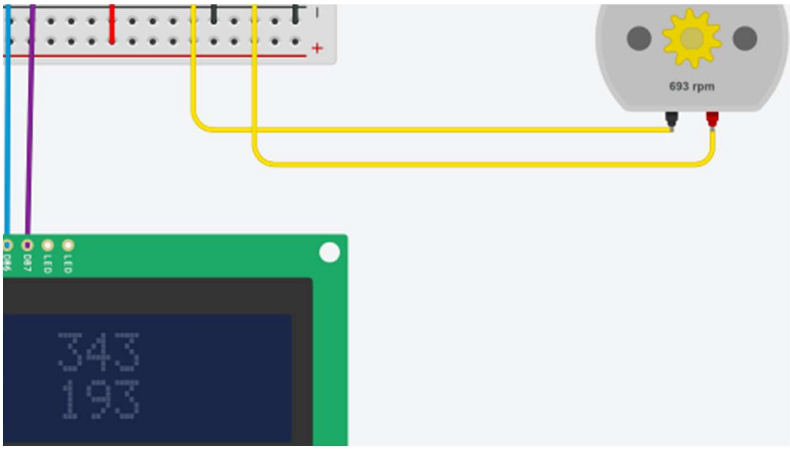


Figure 35: Electrical circuit test 5

Figure 35 shows that if there is not enough luminosity, the motor runs clockwise and will make the blinds tilt up to 0°.

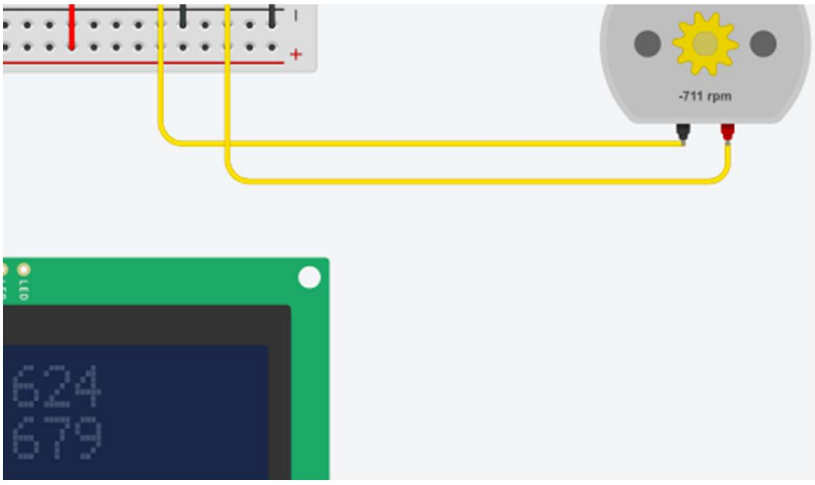


Figure 36: Electrical circuit test 6

Figure 36 shows that if there is enough luminosity, the motor runs anti-clockwise and will make the blinds tilt up to 90°.

This sums up all the testing performed on the sensors and their impact on the blinds' functions. With the procedure put in place, each sensor could be tested. Thanks to Tinkercad, the simulation was made possible and the sensors could be analyzed.

3.2. Unity model testing

This section presents the unity application that has been developed for this project. The objective of this application is to present the product without having to create a physical prototype that would cost much more (money- and timewise). Finally, this application will also enable testing of the different softwares and mechanisms in place. All the files mentioned can be found in a separate folder.

3.2.1. Purpose of the application

The purpose is to give a visual idea of how the system will work. The script behind the blinds in unity does not represent how they will perform in a real-life situation. This Unity app has the objective of giving a simplified view of our project. It also sets the basis for future work in this area.

3.2.2. Application development

As mentioned previously, the objective of this application is to give an idea of the looks of E-Clipse blinds. Therefore, the idea was to create an interactive scene where a day and night cycle goes through in a few seconds and the blinds adapt to the sun's rotation. Since the blinds are mostly going to be used within workspaces, the application shows one set of blinds installed behind a desk in an office.

3.2.3. Scene

The objects used in this application are the following:

- The environment containing mountains and a sky
- The building made of 4 walls (one is invisible but still blocks the light and one with a window hole), a ceiling and a floor
- Some furniture like the clock on the wall or the desk and chair
- A simplified version of the E-Clipse blinds
- When gaming mode is played, 3 texts can be displayed on the screen: the light intensity on the floor, the speed of time and a little explanatory text.

The application starts at midnight with no light and time directly starts. The cycle lasts for one minute and starts again. During this cycle, the light rotates giving an illusion of the sun going up and down. During this cycle, the blinds go up and down and rotate to let light pass.

Figure 37 shows a screenshot of the game scene after a few seconds.

Figure 37: Game scene

3.2.4. Scripts

All the scripts for Unity are written in Csharp (.cs) and apart from the basic library for unity, no module or library has been used to program the presented scripts.

The scripts used in this application are the following:

- The GameManager.cs is the main script that manages all the other scripts, it contains all the useful functions for the other scripts to use. For instance, it keeps track of which blades are to move or which text needs to be updated on the screen
- DayNightController.cs rotates the light around. There you can modify the length of the cycle.
- TimeStop.cs is used to control the speed of time and play with the law of physics.
- Clock.cs is a script to make the clock always on time, even when time flies.
- LightCheckScript.cs gives the light intensity on the object it is looking at. Unfortunately, the precision of this "light sensor" has made it difficult to use to control the blinds. This script is not used except for the text relative to light that is hidden by default.

3.2.5. Controls

The speed at which time goes can be controlled by the user by pressing the arrow keys or w/s keys. Time can also be stopped with the space bar.

3.3. Electricity generation

The amount of electricity generated by the standard E-Clipse model, equipped on the southern façade of building in Lyon was estimated using the PVWatts Calculator designed by the NREL.

Figure 38 shows that the blinds would generate around 166 kWh/year. Further testing needs to be performed to guarantee electricity bill savings to the customer, but this amount of energy generated guarantees the self-sufficiency of the product.

RESULTS **166 kWh/Year***

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Value ($)
January	1.08	4	N/A
February	2.38	9	N/A
March	3.84	15	N/A
April	4.65	18	N/A
May	5.07	20	N/A
June	5.94	22	N/A
July	6.21	23	N/A
August	5.41	21	N/A
September	4.30	16	N/A
October	2.31	9	N/A
November	1.32	5	N/A
December	0.98	4	N/A
Annual	**3.62**	**166**	**0**

Figure 38: Yearly electricity generation

3.4. Critical analysis of the tests performed

Some constraints were met during the development of the product. Regarding the electrical circuits, the main limitation was because only virtual tests were performed. This may bring some problems as the testing is not performed in real life situations. This is because the decision was made to realise a virtual prototype and not a real one.

Concerning the choice of the different components, several studies were performed to understand the functioning as well as the advantages and drawbacks of using them. This was beneficial as this permitted to choose the best fit for the E-Clipse product.

Regarding the Unity model test, though this application is far from being a precise representation of E-Clipse blinds, it paves the way to future developments. Unity is a tool that allows a business to create a real-life model of their products without having to spend on disposable materials. The tests that can be performed with today's application are qualitative, but the hope is that with further work, the software that runs the blinds could be implemented with a better LightCheckScript so that it is closer to the reality.

The material selection could unfortunately not be tested due to deciding not to have any physical prototype. The E-Clipse team believes that with more time and means, this would be the next step for the testing of the product.

The large number of subjects the team decided to cover during the technical developments prevented them from doing some in-depth tests, especially with regards to the sanitary crisis that severely hindered the possibility of physical meetings and building a physical prototype. Furthermore, considering the nature of the innovation (implementing an automatic to a product) made it difficult to establish some quantitative testing criteria and even more to check for them without a physical model.

Finally, accurately testing the amount of energy that can be obtained by using photovoltaics is a real challenge due to the many factors that should be considered.

Nonetheless, the E-Clipse believes that their technical developments and tests pave the way for future developments of such a product.

4. Teamwork

4.1. Project management & resources

In this section, a review of the project management aspects of the innovation project and the team organisation were reviewed.

A first draft of the organisation of the team for this project was presented at its beginning, in the Mission Letter. However, as the project was moving forward, several modifications were made, mainly due to the adjustments that had to be done regarding the ongoing sanitary crisis.

Different roles and tasks were assigned to the members of the project:

- Project leader: Jérémy Bonté
- Internal meetings contact: Henri Charpin
- External meetings contact: Lucien Viornery
- Deliverable writing: Jérémy Bonté, Lola Rebière, Edgaras Stauryla, Timothée Redarce
- Deliverable reviewing: Alexandre Tauziède, Riddha Berrachid
- Organization and project follow-up: Jérémy Bonté

First, all the project tasks were done with the whole group meeting in face-to-face and with everyone discussing the topic. ECAM Talk was used for the team members were not available to physically join the meetings to ensure they could contribute. Google Drive and OneDrive were used for document sharing and the writing of the deliverables.

At the beginning of each new phase, the group met to discuss and understand its objectives and plan the tasks that needed to be fulfilled. At the end of each phase, the group met with the supervisors for feedback. Weekly meetings were held on ECAM Talk with the group to ensure all team members were on the same page.

During meetings, decisions were taken by simple majority. In case of an equality of votes, the coordinator or the team leader depending on the task had the final say.

When the project reached its technical development phase, the team discussed which developments were going to be performed depending on personal preferences and skills. A list of tasks was established, with each task being related to one of the three concentrations (mechanics, robotics, design). For each task, a due date was set, and a coordinator was chosen. The coordinators were responsible for their task's follow up and would report directly to the project leader. Adding some intermediate managers to the group's organisation helped in ensuring that no time was lost with communication issues or having too many meetings with too many people. A messenger conversation which included the whole group was also active at every stage of the project, which allowed the team to always keep in touch.

Most of the softwares which were used were available to the team members on their personal computers, including: MS Word, Granta EduPack, Solidworks, Unity, Bilan Produit. It allowed the team to move forward on the project while working remotely from their homes.

Given the sanitary conditions and the presence of the holidays in December, team members were given a lot of autonomy during the technical development phase.

4.2. Feedback and discussion

Performing all the different tasks involved in the development phases of a product was beneficial for the team members. It gave a clear understanding of how the technical side of a project was linked to the business one and the market study. Working on a project from scratch and learning more about the creativity processes and tools involved in the search for ideas proved to be an eye-opener for most of the team members. Having a lot of freedom and autonomy during the project as well as having a more professional relationship with the professors (the supervisors) helped the team members mature and project themselves better in a professional environment.

This project also showed how important collaboration is between all the different services or employees in a company. Moreover, it also helped the team members improve their communication skills as well as their organization within one team. While, at some point, there were some communication issues between the team members, the experience helped them prepare to being confronted to the same situation when working in a company.

The ongoing sanitary crisis due to the Covid19 outbreak during the project forced the team to change their working methods, especially for meetings. Working remotely became mandatory and changed the output of some tasks (which were performed better when done with all the group meeting face-to-face). It was also felt more difficult to work from home, where there were more distractions, rather than at ECAM for some team members. Meetings with the supervisors were also impacted, which hindered the follow-up of the project.

The main point that could be improved for future projects is communication. While having too many meetings or procedures is detrimental to the work produced, having too little blurs the vision of the advancement of the project. During the first phase, where deadlines were short and tasks more explicit, the team performed fine and understood the importance of peer-reviewing the work, which was at first underestimated. During the technical developments, however, the team struggled to maintain a good balance in their internal contacts which lead to miscommunications and delays. On a larger project with much more at stake, this could have been a huge problem.

Working with people coming from different backgrounds and having different skills is something omnipresent in the work area and getting a first experience of this as part of their studies was a real advantage to have before entering the professional world.

In the end, all the team members found the innovation project to be a valuable experience. This is especially true considering their upcoming end of studies internship, at it served as a proper first experience of handling a real project.

5. Conclusion

The project helped the team understand better the dynamics of project management, which had either only been theoretically taught or seen in projects which did not last long enough for them to matter.

The innovation project helped:

- Understand the management of a project from its beginning to its end.
- Learn new soft and technical skills on various subjects.
- Understand the importance of communication and organisation within a team.
- Help students mature professionally.
- Acknowledge external feedback of work delivered and provide corrections.
- Think the project not just from the technical point of view but also from the customer/user's point of view.
- Have a better understanding on how the clients' needs will have an impact on the development of the product.
- Understand the importance of product specifications and testing to ensure they are met.

The E-Clipse team believes that the innovation project was especially useful to understand some aspects of product design often overlooked during their studies: a clever and technically well-designed product may not meet commercial success if it does not have a potential market (users with needs).

6. Appendix

Appendix 1 : Refer to annex 1

Appendix 2 : Code

```
#include <LiquidCrystal.h>

LiquidCrystal lcd( 7, 6, 5, 4, 3, 2); // Input of LCD screen for testing

//Input for the Motor
int enA = 11;
int in1 = 10;
int in2 = 9;

//Create an array for the height with a step of 10 cm
int Height[17]={10,20,30,40,50,60,70,80,90,100,110,120,130,140,150,160,0};

//Create an array for the tilt with a step of 10°
int Tilt[10]={10,20,30,40,50,60,70,80,90,0};

//Input for the Sensor
int LowRight = 0;
int LowLeft = 1;
int MedRight= 2;
int MedLeft= 3;
int HighRight=4;
int HighLeft=5;

void setup() {
  lcd.begin(16,2);

  //Declare the state of the motor pins
  pinMode(enA, OUTPUT);
  pinMode(in1, OUTPUT);
  pinMode(in2, OUTPUT);

  // Turn off motors - Initial state
  digitalWrite(in1, LOW);
  digitalWrite(in2, LOW);

}
```

```
void loop() {
 //getting the value of the sensors
 int LR = analogRead(LowRight);
 int LL = analogRead(LowLeft);
 int MR = analogRead(MedRight);
 int ML = analogRead(MedLeft);
 int HR = analogRead(HighRight);
 int HL = analogRead(HighLeft);

 //Print value on screen for testing lower sensors
 lcd.setCursor(1,0);
 lcd.print(LR);
 lcd.setCursor(1,1);
 lcd.print(LL);

 //Print value on screen for testing medium sensors
 lcd.setCursor(5,0);
 lcd.print(MR);
 lcd.setCursor(5,1);
 lcd.print(ML);

 //Print value on screen for testing higher sensors
 lcd.setCursor(9,0);
 lcd.print(HR);
 lcd.setCursor(9,1);
 lcd.print(HL);
```

```
 //Scenario 1: The lower sensors are exposed, the blinds needs to go all the way down
if (ML==6 && MR==6 && HL==6 && HR==6) //neglect other sensors
{
  if (LL>=400 && LR>=400) // there is too much luminosity, the blinds need to go down
  {
    while (Height>0) //Loop runs until the blinds are completely down
    {
      analogWrite(enA, 255);  // run motor at maximum speed
      digitalWrite(in1, HIGH); // Motor is anticlokwise
      digitalWrite(in2, LOW); //Blinds goes down
      Height[17]=Height[17]-1;
    }

  }
  if (LL<=400 && LR<=400) //there is not enough luminosity, the blinds need to go up
  {
    while (Height<80) //Loop runs until the blinds are up mid lenght
    {
      analogWrite(enA, 255);// run motor at maximum speed
      digitalWrite(in1, LOW); //Motor is clockwise
      digitalWrite(in2, HIGH); // Blinds goes up
      Height[17]=Height[17]+1;
    }
  }
  else
  {
    digitalWrite(in1, LOW); //Only one sensor is above limit
    digitalWrite(in2, LOW);//Nothing happens
    delay (2000);
  }
}
```

```
//Scenario 2: The medium sensors are exposed, the blinds needs to go medium height
if (LL==6 && LR==6 && HL==6 && HR==6) //neglect other sensors
{
  if (ML>=400 && MR>=400)
  {
    while (Height>80) //loop until blinds are down mid length
    {
      analogWrite(enA, 128);  // run motor at 50% speed
      digitalWrite(in1, HIGH); // Motor is anticlokwise
      digitalWrite(in2, LOW); //Blinds goes down
      Height[17]=Height[17]-1;
    }
  }

  if (ML<=400 && MR<=400)
  {
    while (Height<160) //loop until blinds are completely up
    {
      analogWrite(enA, 128);// run motor at 50% speed
      digitalWrite(in1, LOW); //Motor is clockwise
      digitalWrite(in2, HIGH); // Blinds goes up
      Height[17]=Height[17]+1;
    }
  }
  else
  {
    digitalWrite(in1, LOW); //Only one sensor is above limit
    digitalWrite(in2, LOW);//Nothing happens
    delay (2000);
  }
}
```


```
//Scenario 2: The medium sensors are exposed, the blinds needs to go medium height
if (LL==6 && LR==6 && HL==6 && HR==6) //neglect other sensors
{
  if (ML>=400 && MR>=400)
  {
    while (Height>80) //loop until blinds are down mid length
    {
      analogWrite(enA, 128);  // run motor at 50% speed
      digitalWrite(in1, HIGH); // Motor is anticlokwise
      digitalWrite(in2, LOW); //Blinds goes down
      Height[17]=Height[17]-1;
    }
  }

  if (ML<=400 && MR<=400)
  {
    while (Height<160) //loop until blinds are completely up
    {
      analogWrite(enA, 128);// run motor at 50% speed
      digitalWrite(in1, LOW); //Motor is clockwise
      digitalWrite(in2, HIGH); // Blinds goes up
      Height[17]=Height[17]+1;
    }
  }
  else
  {
    digitalWrite(in1, LOW); //Only one sensor is above limit
    digitalWrite(in2, LOW);//Nothing happens
    delay (2000);
  }
}
```

```
//Scenario 3: The highest sensors are exposed, the blinds need to tilt
if (LL==6 && LR==6 && ML==6 && MR==6) //neglect other sensors
{
  if (HL>=400 && HR>=400)
  {
    while (Tilt>0) //loop until the blinds are tilted all the way honrizontally
    {
      analogWrite(enA, 10);  // run motor at maximum speed
      digitalWrite(in1, HIGH); // Motor is anticlokwise
      digitalWrite(in2, LOW); //Blinds tilts
      Tilt[10]=Tilt[10]-1;
    }
  }
  if (HL<=400 && HR<=400)
  {
    while (Tilt<90) //loop until the blinds are tilted all the way vertically
    {
      analogWrite(enA, 10);// run motor at maximum speed
      digitalWrite(in1, LOW); //Motor is clockwise
      digitalWrite(in2, HIGH); // Blinds tilts
      Tilt[10]=Tilt[10]+1;
    }
  }
  else
  {
    digitalWrite(in1, LOW); //Only one sensor is above limit
    digitalWrite(in2, LOW);//Nothing happens
    delay (2000);
  }
}
}
```

Appendix 3 : Report to annex

Appendix 4 : Report to annex

Appendix 5 : Report to annex

APPENDIX 6 : PROTOTYPING DEVELOPMENT

What is prototyping?

Prototyping is the fact to create a design physically to test if it works. In the case of a system, prototyping it is building a simplified version of it to see if it works. This is useful to check basic functions before going forward in the project and avoid having to solve all the problems at the end. Applying this principle to website and application creation gives the design prototype. Creating a prototype of a web app is useful to check if the user experience will be smooth and the design will satisfy all the needs. It is important to validate the design before creating all the backend (software, database, user management, etc.). In the case of the E-Clipse web app, the backend is not relevant compared to the progress we have made in the project. Having a first draft as a prototype enables us further UX/UI testing and may also give feature ideas.

How to prototype?

The tools for prototyping applications are various. Some avoid colors to remain very basic, we talk about wireframing. This is often the first step towards prototyping, to get an idea of where "features" will be placed on the screen. Expensive solutions like the Adobe Suite provide softwares that do both wireframing and prototyping, and there are a few free solutions with less options. Figma is one of them and it is the solution that E-Clipse has chosen. A Figma prototype is divided in three categories: the designs, the assets and the relations or links.

Designs

Designs in a Figma prototype are the equivalent of the pages that will be displayed in the end. They include the color palette, the different font styles used for texts, the forms the user will interact with, cards display, and the layout that governs it all. Designs are related to the visual aspect of the app and they imply a certain atmosphere for the app. The designs can be drawn directly with the tools in Figma or imported from other tools. This can be especially helpful as Figma does not natively support animations. Plugins can be added to get a better design experience.

Assets

Assets are closely bound to designs as they are the smaller parts that appear on many designs. These assets can be buttons, user inputs, header, and footer designs, etc. A button asset for example will hold all the button variations (hovered, focused, active, inactive, etc.) It helps create designs that are adapted to any situation by having many variations of these assets.

References

https://www.gamma-sci.com/types-light-sensors

https://www.seeedstudio.com/blog/2020/01/08/what-is-a-light-sensor-types-uses-arduino-guide/

https://sciencing.com/uses-photocells-5494652.html

https://innovationdiscoveries.space/types-of-lighting-sensors/

https://boutique.semageek.com/fr/895-capteur-de-luminosite-lux-lumiere-tsl2561.html

https://euro-makers.com/fr/resistances/1840-photoresistance-18-50-k-ohm-5mm-arduino-3701172907834.html

https://store.arduino.cc/arduino-uno-rev3

https://www.matooma.com/fr/s-informer/actualites-iot-m2m/m2m-comment-connecter-vos-objets

https://www.rs-online.com/designspark/eleven-internet-of-things-iot-protocols-you-need-to-know-about-fr

https://news.energysage.com/solar-panels-work/

JUNG, W., HONG, T., OH, J., KANG, H. and LEE, M., 2019. Development of a prototype for multi-function smart window by integrating photovoltaic blinds and ventilation system. *Building and Environment,* 149, pp. 366-378.

KANG, H., HONG, T., JUNG, S. and LEE, M., 2019. Techno-economic performance analysis of the smart solar photovoltaic blinds considering the photovoltaic panel type and the solar tracking method. *Energy and Buildings,* 193, pp. 1-14.

KANG, H., HONG, T. and LEE, M., 2019. Technical performance analysis of the smart solar photovoltaic blinds based on the solar tracking methods considering the climate factors. *Energy and Buildings,* 190, pp. 34-48.

REINHART, C.F., 2004. Lightswitch-2002: a model for manual and automated control of electric lighting and blinds. *Solar Energy,* 77(1), pp. 15-28.

T. TAUFIK and R. N. HASANAH, 2018. Light Sensing Smart Blinds, - *2018 Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS)* 2018, pp. 1-4.