Co-funded by the Erasmus+ Programme of the European Union

Industry 4.0 for a Sustainable World (Renewable energy sources – solar)

MESI4.0

1. Participating Institutions

Gymnazium Teplice, Teplice, Czech Republic

SZ Geschwister Scholl, Bremerhaven, Germany

La Salle Buen Consejo, Puerto Real, Spain

Siauliu Didzdvario gymnasium, Siauliai, Lithuania

Content

2. Description of the final project

The final project is about solar renewable energy in the countries that participated in the project – Czech Republic, Germany, Lithuania and Spain. This analysis lead them to understand the unbalanced historical representation of the solar renewable energy in the four countries participating in the project. They completed the analysis with the study of the localization of the main solar renewable energy sources in the four countries at a national and regional level and they understood the latitude and longitude dependence of this information.

In order to go further in understanding the causes of this unbalanced distribution they performed a statistical analysis of the quantification of the energy per country using the data of Eurostat. They planned a research on the differences and similitudes on the quantification of the energy used by country. The data obtained was analyzed, graphs were constructed and interpreted and included in this final document.

They analyzed how the solar renewable energy helps to the *sustainability of the world,* their visual impact, the chemical raw materials used, the impact of the solar panels. Finally, they summed up the advantages and disadvantages of the solar renewable energy sources and conclude that the transition between actual non-renewable energies and sustainable ones would be a slow process and this energy source does not produce any combustion. So, there will be a reduction on the greenhouse effect that would help on the sustainability of the world.

3. Participating students

Gymnazium Teplice, Teplice, the Czech Republic:

SZ Geschwister Scholl, Bremerhaven, Germany

Schulzentrum
Geschwister
Scholl
Bremerhaven

La Salle Buen Consejo, Puerto Real, Spain

Siauliu Didzdvario gymnasium, Siauliai, Lithuania

4. Renewable energy source - solar

4.1 Characteristic and classification

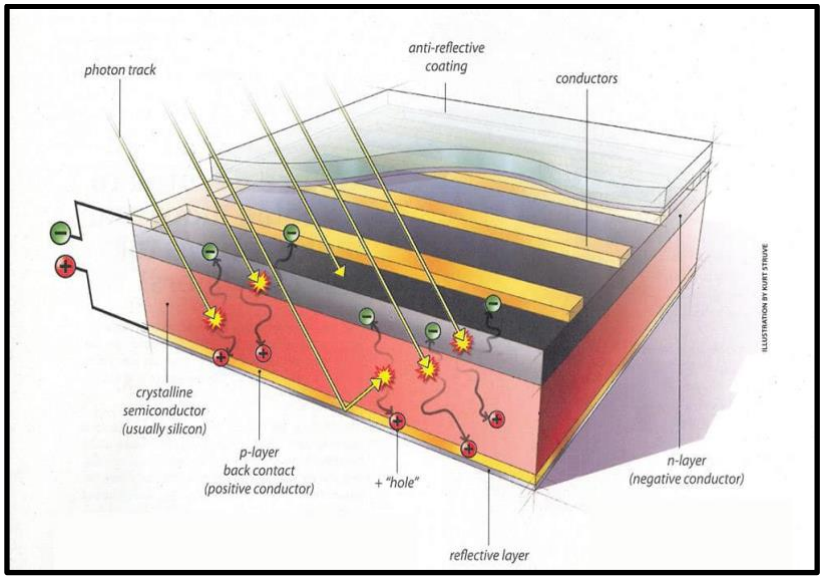
4.1.1 What is the solar energy resource? How does every kind work?

Solar power is energy coming from the sun that is converted into thermal or electrical energy. it is the cleanest and most abundant renewable energy source.

4.1.2 Classification within the solar energy renewable sources

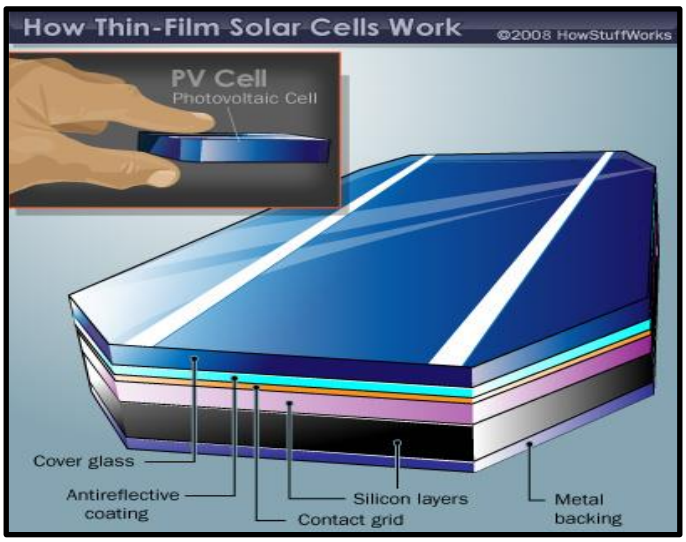
Photovoltaic systems

Solar cell systems, which produce electricity directly from sunlight. Solar energy releases electrons from their atoms and makes them flow through the semiconductor material which produces energy.



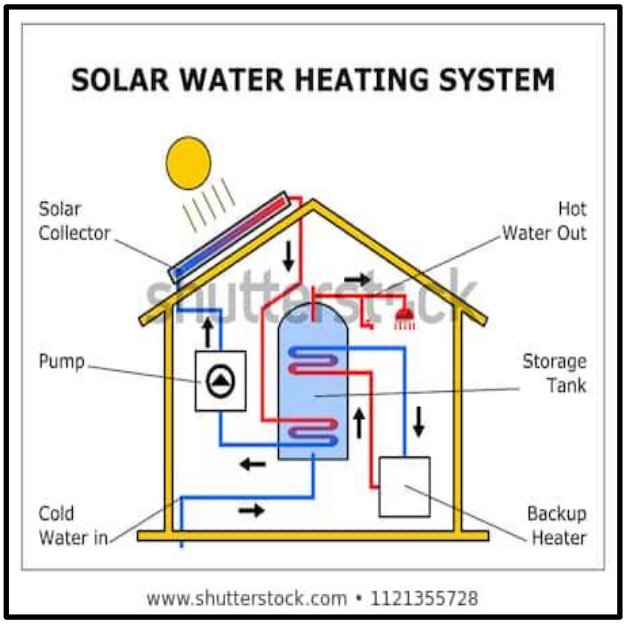
Thin film solar cells

This type of technology can also be run with thin film solar cells, which use layers of semiconductor materials only a few micrometers thick. This has made it possible for solar cells to double as rooftop shingles, roof tiles, building facades, or the glazing for skylights or atria maximizing use of the available space from where sunlight would be captured.



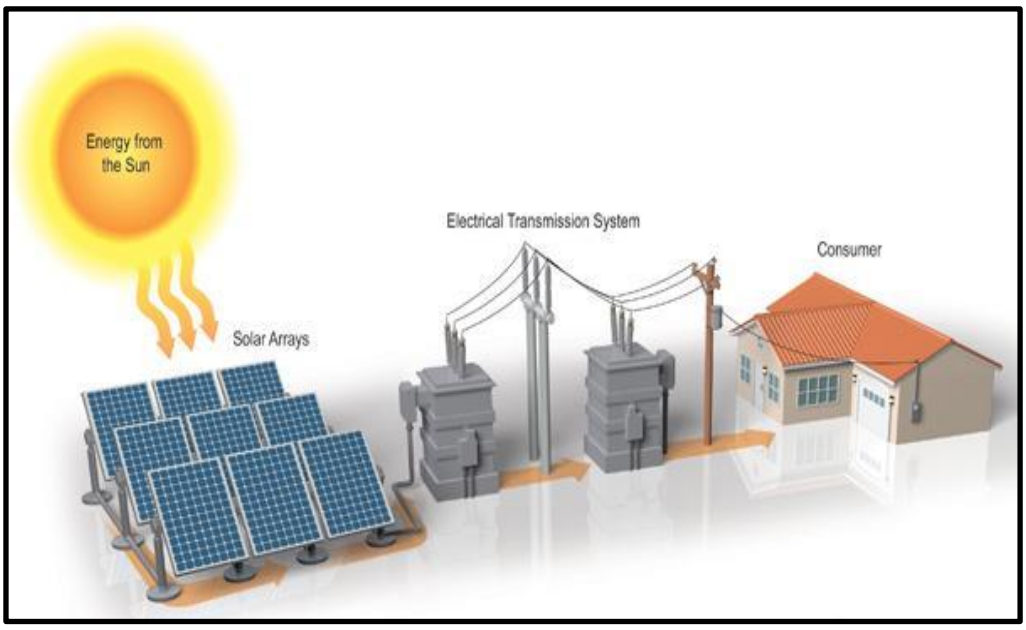
Solar water heating systems

It involves heating up water using the sun's heat. The idea behind this solar water heating systems comes straight from nature: the shallow water of a lake or the water on the shallow end of the beach is usually warmer compared to deeper water.



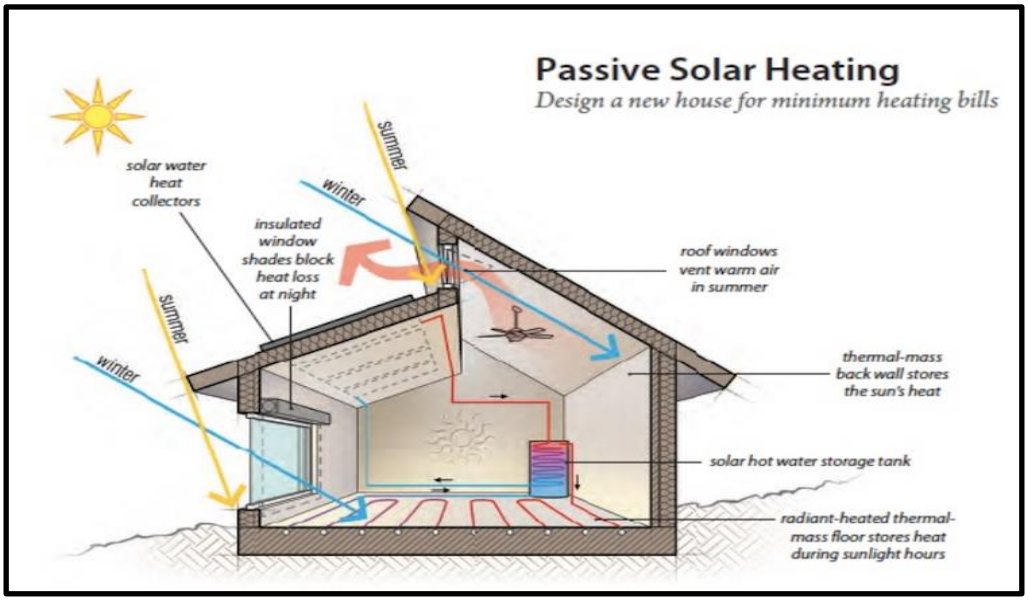
Solar power plants

This kind of energy is usually used in industry. As most of us know, most power plants use non-renewable fossil fuels to boil water. The steam from the boiling water makes a large turbine rotate which in turn activates a generator to produce electricity, so in solar power plants, sun energy is used to boil water instead of nonrenewable fossil fuels.



Passive solar heating

A further way that solar power can be harnessed is through the method of passive solar heating and day lighting.



A photograph of a solar farm.

4.2 History of solar renewable energy

4.2.1. Beginning of the solar renewable energy in the world

In 1860, the world's first solar energy system was invented by a French investor Augustin Mouchot. After his predictions that our coal supply would run out, Moachet trialed on his "sun meter". In 1976, William Grylls Adams, Professor of Natural Philosophy at King's College, demonstrated how you can use selenium cells to harness rays from the sun and generate electricity. Adams's findings were proved instrumental documentation in furthering the field of solar study.

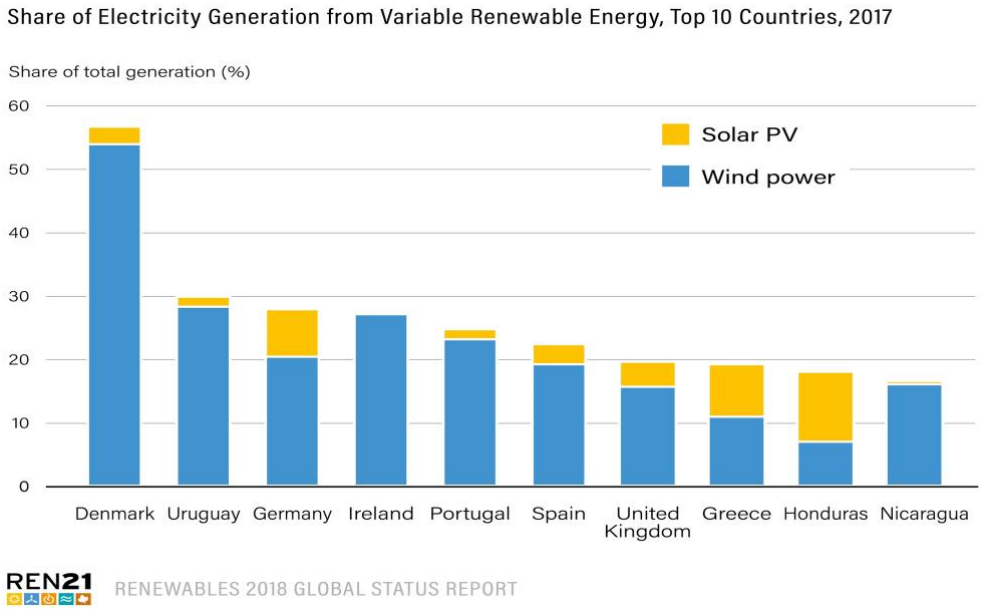
In the XX century, Albert Einstein and the study of the "photoelectric effect" provided advanced scientific knowledge to construct new solar cells. The "photoelectric effect" examines light-cells carrying potent forms of energy that can be harnessed to power buildings across world. The photoelectric effect could be described as the emission of electrons when light is shined upon certain materials.

The first solar US satellite went to space in 1958. The Vanguard 1 was launched to space using energy as its power source. In 1978, the Tohono O'Adham Reservation in Arizona became the first solar-powered village in the world. And in 1996, the first solar project in the Mojave Desert (California) was constructed in finding the most cost-efficient way of installing collective solar power-plants.

4.2.2. Beginning of the solar renewable energy in Spain

Spain is one of the top ten countries by installed capacity of photovoltaic solar energy. Moreover, Spain is the first country in the world that concentrates the highest volume of solar power. We are also one of the countries with more hours of sunshine. In consequence, Spain is a good candidate for the construction and development of photovoltaic solar energy facilities.

Currently, the country plays a leading role in the development of solar energy, and Spain is also positioned itself as the European leader in solar energy for the 2007-2010 period. The country was in second place after Germany in installed capacity, although other countries (such as Italy) have leapfrogged Spanish development. Comparing solar and wind energy in Spain in 2015, solar power produced less than a third of that of wind power.
The next graph compares the share of Electricity generation for the top 10 countries in 2017.



The Spanish government wanted to produce 12 percent of primary energy from renewable energy by 2010. That would mean generating a solar capacity of 400 megawatts.

Despite the desire of the Spanish government, Solar energy does not go through its best in 2019. In order to be transformed into electricity and access the grid, solar energy has to overcome a large number of requirements, which include government permits and authorizations for companies that operate in a specific area. And these are the ones that, with the obstacles that they put, prevent solar energy from becoming a viable option.

The next graph summarizes the decrease in the prices of solar energy in contrast with the number of installations. Furthermore, the graph informs about the inflexion in 2017 of the increase of the number of Solar PV installations.

4.2.3 Beginning of the solar renewable energy in Lithuania

Solar power in Lithuania created 2.4 MWh power in 2010. At the start of 2014 Lithuania had a capacity of 61 MW of solar power.

It has been measured at two locations in Lithuania: In Kaunas at 54.54 N and Silute 55.21 N, 200 and 40 km from the West coast respectively.

We use only the solar collectors in Šiauliai.

4.2.4 Beginning of the solar renewable energy the Czech Republic

The Czech Republic experienced a boom in solar panels a few years ago, but subsequently turned its back on them. They have proven to be expensive, inefficient, and if the problem of recycling is not systematically solved, it is also harmful to the environment. However, solar panels are an increasingly common source of energy. Their number has doubled every two years since the turn of the millennium. If solar power continues to grow, within 14 years it will generate 100% of the energy worldwide.

In 2009 and 2010 there was a big boom with solar energy in the Czech Republic. The boom was caused by a reduction in acquisition costs. In previous years the application of solar power plants was a rarity, and between 2002 and 2008 it was possible to talk about units or dozens of installations.As of now (2019), there are many solar farms in the Czech Republic. In 2010, there was a big boom with solar farms. Most of the electricity generated in the Czech Republic is produced in coal-fired power plants (47,6% in year 2015), nuclear power plants (32,6% in year 2015) and in power plants using renewable energy sources (11,2% in year 2015). Of all renewable sources, solar plants generate the most electricity, although it is only around 2.5% (Water about 2,1% and wind about 0,7%). So it is not important in terms of energy production, but it should be because it is from inexhaustible sources. The most important owner of solar farms in the Czech Republic is a company called ČEZ. ČEZ owns 13 solar farms now and 2 of them belong to the largest 3 in our country.

Finally, in the Czech Republic, many households own solar panels. Most often they are located on the roof. The reason is saving money by producing its own electricity.

Regional solar farms:

Our region focuses mainly on thermal power plants and the chemical industry. There is a coal deposit and this is the most used. Solar power plants occupy roughly 240 ha.

There are several companies in the Ústí nad Labem region for the production and installation of photovoltaic panels to produce energy from solar radiation and these are, for example, R.I.P Děčín S.R.O based in Děčín and Střechy Arven s.r.o. našel in the regional town Ústí nad Labem.So, the energy production from sunlight is not important, unlike thermal power plants here.

4.2.5 Beginning of the solar renewable energy in Germany

Germany was not only one of the first countries to use solar energy to produce electric energy, but it is also within the biggest installers for this renewable energy resource. The costs of photovoltaic (PV) production are currently decreasing, which is the reason for cheap energy and large-scale PV plants. One of the largest PV Plants worldwide is located in eastern Germany and has the name of Waldpolenz Solar Park. This plant is special, since it is the world's largest thin-film photovoltaic power system. Producing 40,000 MWh of electricity per year, the investment of 130 million Euro was definitely worth it!

For over 15 years, solar energy has been constantly growing in our country. In 2011, Germany produced 18 TWh of energy from this source. That would be 3% of the total produced energy. Till the introduction of the last decade, Germany installed many photovoltaic plants worldwide to expand this form of energy. From 2010 to 2012 Germany installed 30% of the world's photovoltaic plants. After all this progress less plants were introduced, since the government set limits. In 2017, Germany collected 40% of the produced energy from photovoltaic.

Germany has the target to substitute fossil energy and reduce it. The aim to be achieved by 2030, is that 80% of the energy should be made with renewable energies. An important part of that energy-mix should be solar energy.

In 2014 the “Erneuerbare-Energien-Gesetz” (renewable energy sources act) was introduced. First published in April of 2000 with multiple modifications it helped to increase the amount of renewable energy sources in the German power grid and opened the way to new jobs and basically a new economy. Clean energy sources.

4.2.6 Data interpretation. Countries comparison

Spain is the one with the most number of solar hours, although they don’t use this resource as much as they could. Moreover, comparing it with the wind energy they use the third part of sun energy.

Czech Republic has made great use of this kind of energy. There has been a ‘revolution’, between 2009 and 2010. Nowadays, there are a lot of solar panels throughout the all country. Most of the electricity is generated in coal-fired power plants. In spite of that, the main way to produce energy are with the chemical industry and thermal power plants.

Lithuania has had an increase in using this renewable energy from 2010 to 2014. They only have two locations of two solar production plants around the country and they only use the solar collectors in Šiauliai.

Germany is developing and using new types of solar technology systems cheaper than they used to use, in order to facilitate the increase of production in this kind of energy in the country. Mainly, the production is located in southern Germany, this is because of the number of hours of solar insolation is obtained in this area. Due to the fact that these systems are rising, employment does so. The objective of having 80% of renewable energy sources is going to be to reach by 2030.

4.2.7 Conclusions

Solar power energy is a relatively new energy source technology in these countries and they have had a big increase in its production since 2010. Indeed, nowadays, it is one of the most important types of energy sources despite the fact that it is not as well used as it should be. Solar production is well-known in all the countries; however, it is unbalanced developed so as to each country have different hours of solar provided depending on the latitude.

4.3 Distribution of solar renewable energy sources in the Czech Republic

4.3.1 Solar farm Ševětín

This farm is the third biggest solar farm in the Czech Republic. It is located near České Budějovice and it takes up 60 ha (about 80 soccer fields). Company ČEZ Ševětín officially launched on 14th December 2010. Ševětín has a power output of almost 30MW.

4.3.2 Photovoltaic power plant Ralsko Ra 1

The largest complex of solar power plants in Ralsko in Česká Lípa District was opened on 29th December 2010 by the ČEZ group. It is located in the territory of the former military area, which according to the experts is also one of the most suitable locations for photovoltaic installations – the total annual average of solar radiation reaches up to 3.8 thousand MJ/m. The total installed power is 38.3 MW (it consists of several smaller sources of 14.269 MW, 12.869 MW, 6.614MW and 4.517 MW, which are a few kilometres apart but are connected to a single sampling point).

4.3.3 Solar farm Vepřek

The second biggest solar farm is situated in Vepřek near Mělník. It takes 82,5 ha. was launched on 7th May 2010 by company DECCI a.s operating under FVE CZECH and it was built as a complex of 26 blocks. It's power output is 35,1MW.

4.4 Distribution of solar renewable energy sources in Germany

Although the largest solar farms in Germany are located in Meuro, Neuhadenburg and Templin, most of the solar energy is generated in Bavaria and Baden-Württemberg, i.e. in southern Germany, which is understandable due to the higher number of hours of sunshine in that area.

Germany's largest solar farms are located in Meuro, Neuhadenburg and Templin with capacities over 100 MW.

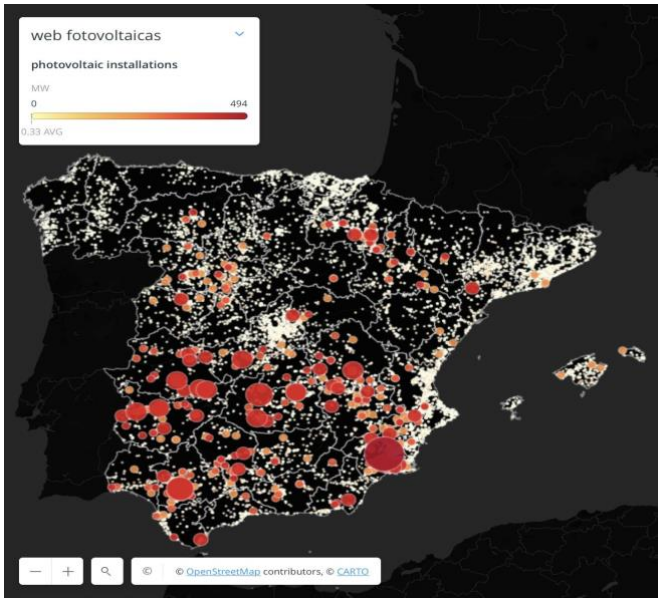
4.5 Distribution of solar renewable energy sources in Spain

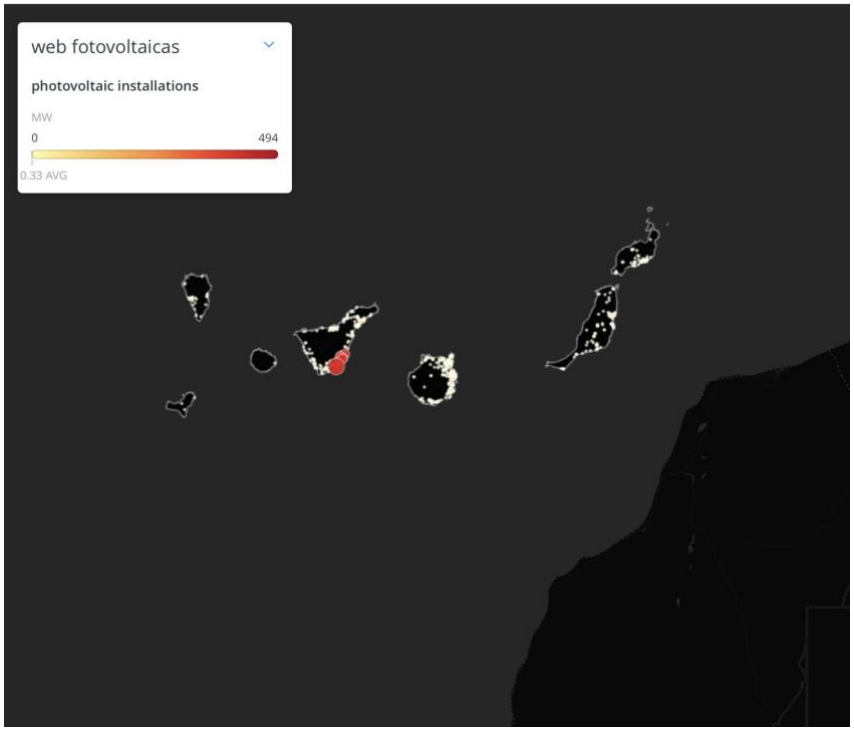
At a National level, Spain is one of the countries in Europe with more hours of sunshine, to which are added the European commitments in the installation of renewable energies as well as the strategic convenience of reducing the great external energy dependence and increasing energy autonomy.

The main farms in Spain and its power are summarised in the next map. Those are ordered considering the total production of solar energy in megaWatts (MW).

The information of the table is completed with a map of Spain which informs about the concrete location in the peninsula of the main solar energy farms.

The biggest solar farm in Europe is placed in Seville (Spain). Don Rodrigo, solar farm, produces 266000 mW/year. It has a surface area of 265 hectares and it supplies energy approximately to 93000 Spanish homes. Don Rodrigo is composed of 500 000 solar panels and uses a total length of 3 000 km of wiring.





For further information follow the link below.

https://www.esios.ree.es/es/mapas-de-interes/omapa-instalaciones-fotovoltaicas

The main companies in charge of Solar Farms are: Alreso Energy Solution and Altech solar.

4.5.1. Andalusian solar renewable energy sources

This first farm solar is Esasolar and it is in Seville. Esasolar is an industry of engineering, manufacturing and supply of photovoltaic structures with a long experience that has installed more than 500 MW in the world.

Gemasolar is a concentrated thermosolar power plant with a molten salt thermal storage system owned by Torresol Energy. It is located in the municipality of Sources of Andalucía, in the province of Seville.

This industry, located in Seville (Spain), is the largest research, development and testing center in Europe dedicated to solar concentration.

Position in the map of the two main solar farms

4.6 Distribution of solar renewable energy sources in Lithuania

Lithuania has two main solar farms located at: Kaunas at 54.54 N and Silute 55.21 N, 200 and 40 km from the West coast respectively.

Solar power in Lithuania created 2.4 MWh of electricity in 2010. At the start of 2014 Lithuania had a capacity of 61 MW of solar power. It had been measured at two locations in Lithuania: In Kaunas at 54.54 N and Silute 55.21 N, 200 and 40 km from West coast respectively.

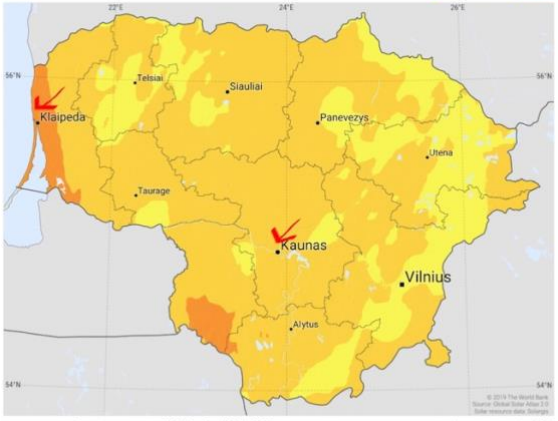
SOLAR RESOURCE MAP

GLOBAL HORIZONTAL IRRADIATION

LITHUANIA

WORLD BANK GROUP

ESMAP SOLARGIS



Long term average of GHI, period 1994-2018

Daily totals: 2.8 3.0 kWh/m²

Yearly totals: 1022 1096

4.7 Quantification of renewable energy source-solar

Solar energy is a renewable energy source and it's very important. This means that we cannot run out of solar energy, as opposed to non-renewable energy sources. We will have access to solar energy for as long as the sun is alive – another 6.5 billion years according to NASA. Solar energy can be used for many different purposes. It can be used to generate electricity in places that lack a grid connection, for distilling water, or even to power satellites in space. According to the review of the literature on renewable energy, the world surface receives 120.000 terawatts of solar irradiation, "That supposes 20.000 times more power than the earth needs". To defend the optimism deposited in this type of energy, the Union of Concerned Scientists support that in only 18 days of solar irradiation on the earth contains the same quantity of energy than all the non-renewable energies of the earth like the carbon petroleum and natural gas.

In this section, we aim to answer two questions:

1. How much energy is produced by solar renewable energy in different countries?
2. How important is for Industry the consumption of electricity produced by solar panels instead of consuming electricity produced by other renewable or non-renewable energy sources?

In order to answer the questions, data from Eurostat corresponding to Solar renewable energy and others is analysed. The data used refers to the Total energy supply. The Total energy supply is one of the most important aggregates of the energy balance. For the total of all energy products this is the total energy delivered/consumed in a country excluding deliveries to international aviation and international marine bunkers. For primary products (those directly harvested from nature) it shows the available supply. For derived products (manufactured products, secondary products) it covers only their international trade, stock changes and deliveries to international aviation and international marine bunkers. Production of derived products is recorded in the transformation output. Consequently, total energy supply for derived products can be negative - which means its original primary form of supply was accounted for in the form of the respective primary energy product.

The analysis consists in the description of polygons for each country and a boxplot to compare the four countries' renewable energy consumption.

The data corresponds:

A1:A13: Spain

B1:B13: Czech Republic

C1:C13: Lithuania

D1:D13: Germany

4.7.1 Czech Republic

In Czech Republic, as it can be seen in the graph, the total energy supply decreased from 2007 to 2009 and increased from 2009 to 2010. However, the supply remained almost constant between 2011 to 2017 with small variations and finally we can say that it remained totally constant for 1 year, from 2017 to 2018.

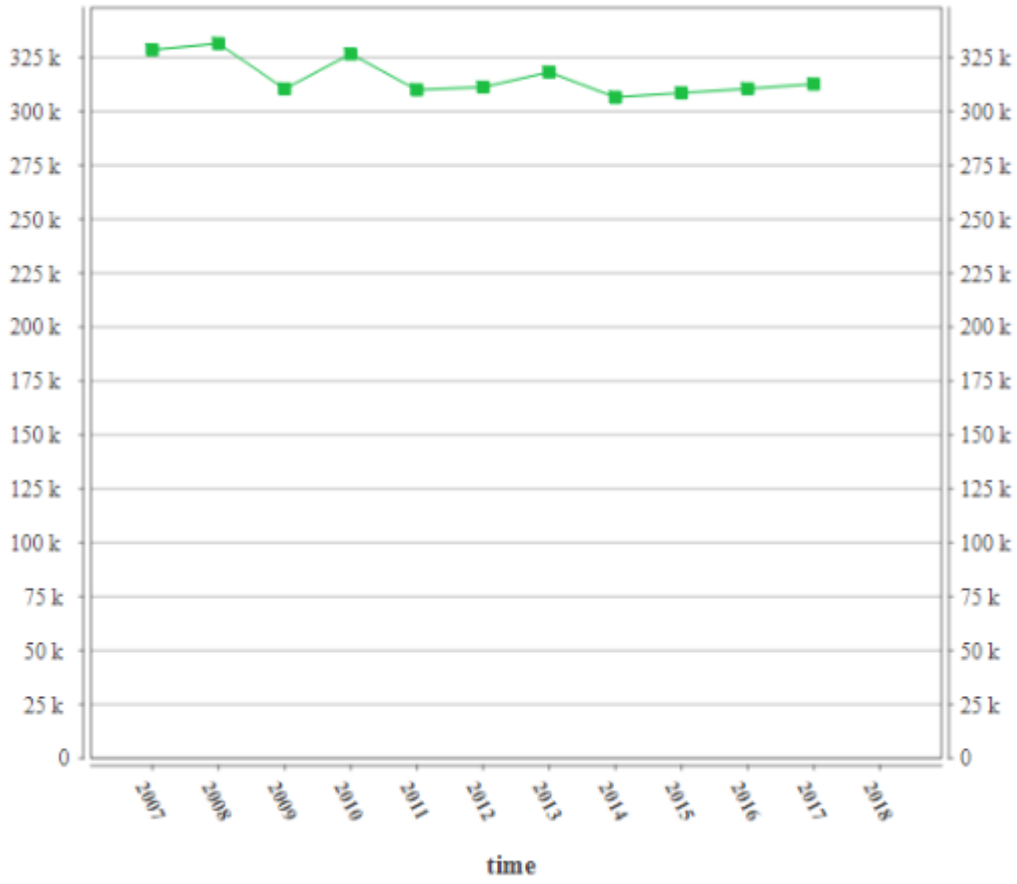
Concluding, in the Czech Republic the total energy supply will continue to have variations of increase and decreases and will sometimes remain constant.

In Czech Republic, as it can be seen in the graph, the total energy supply decreased from 2007 to 2009 and increased from 2009 to 2010. However, the supply remained almost constant between 2011 to 2017 with small variations and finally we can say that it remained totally constant for 1 year, from 2017 to 2018.

Concluding, in the Czech Republic the total energy supply will continue to have variations of increase and decreases and will sometimes remain constant.

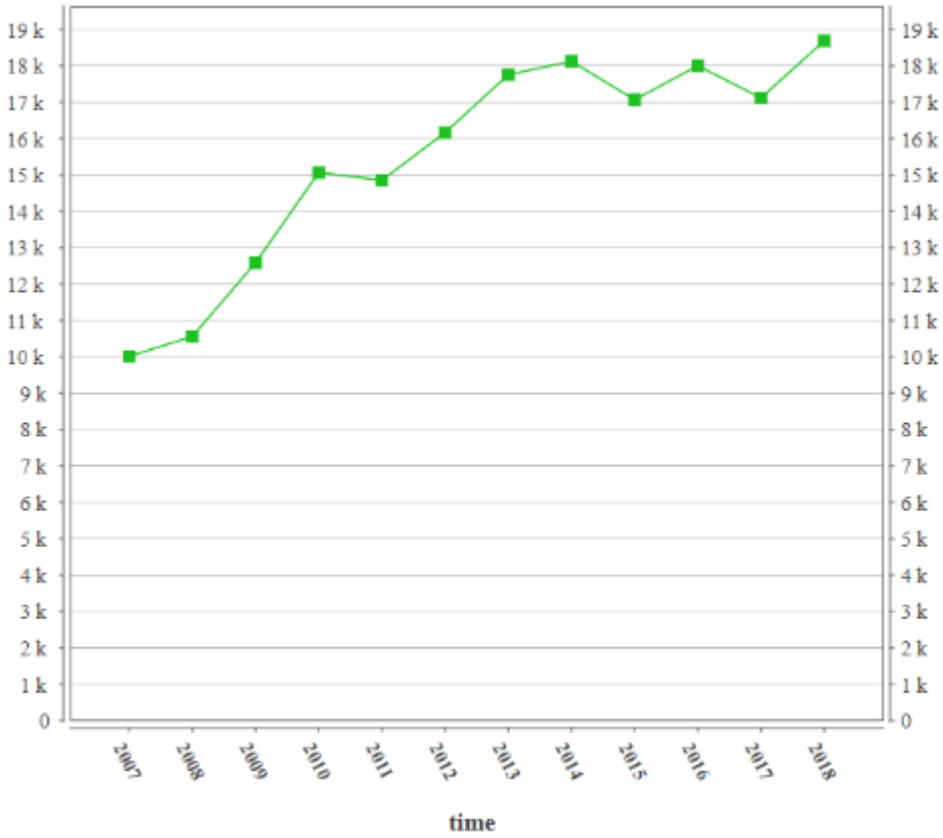
4.7.2 Germany

From 2007 to 2014 the energy supply in Germany (graph included with data from Eurostat) had many decreases and increases, increase from 2097 to 2008 and decrease 25 k of supply increase a lot from 2009 to 2010 but not as 2008, in 2010 is the last important decrease to 2011, since 2011 to 2013 the supply is constant, in 2013 to 2014 is the last decrease. However, and since 2014 to 2017 the supply in Germany had a small increase.



4.7.3 Spain

The next graph describes the total energy supply in kMW in Spain in the last years (Graph obtained from Eurostat).



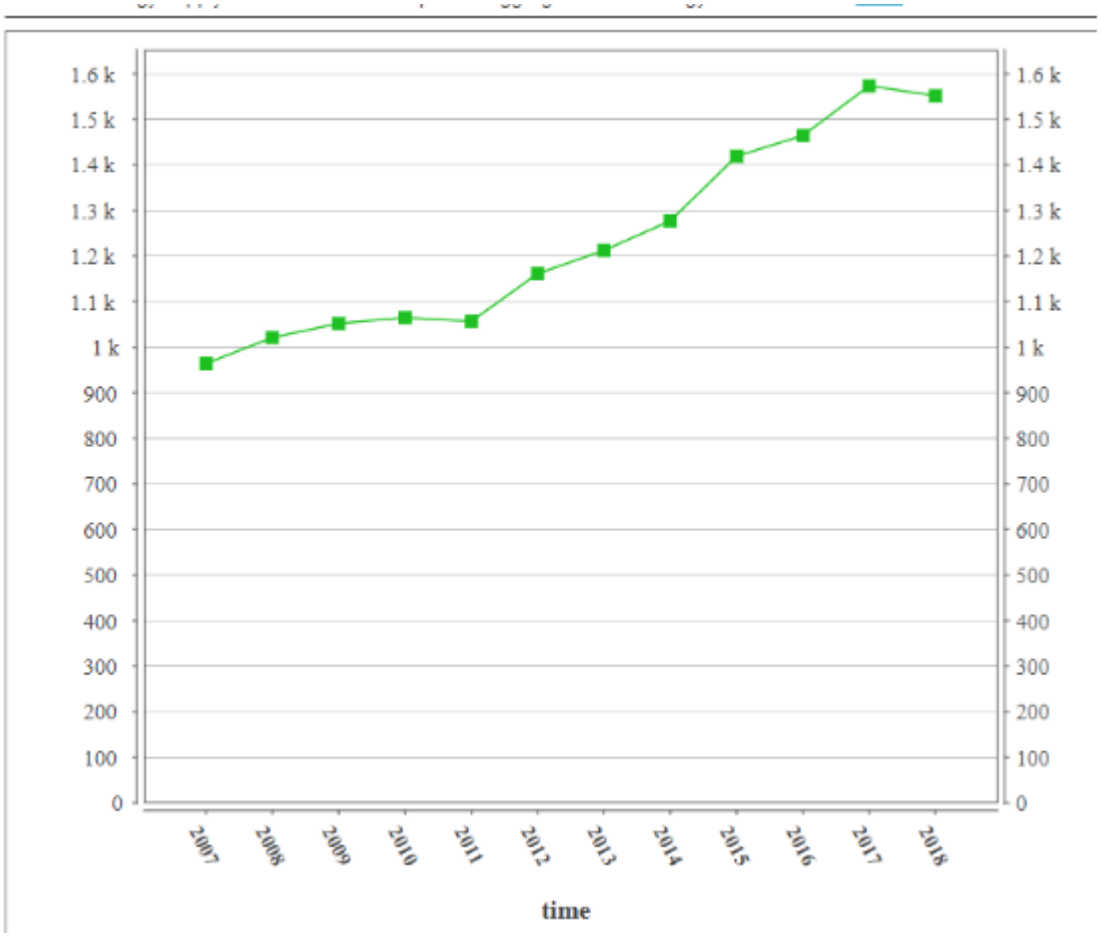
Around 22 % of the final energy we consume is electricity and it comes from different sources. In the EU, including Spain in 2016, approximately 44% of the electricity consumed came from power stations burning fossil fuels and 30% from renewable energy sources, while 26 % came from nuclear power plants. Among the renewable energy sources, the highest share of electricity consumed came from wind turbines, hydropower plants, solar power plants and biofuels.

In Spain, energy renewables and biofuels increase from 2007 to 201o in 5 thousand tons of oil, during 2010 there is a small decrease but from 2011 to 2014, there is another increase of 3 thousand tons of oil, from 2014 to 2017 there are two small decrements and two small increases but from 2017 to 2018 there is an increase of almost thousand tons of oil.

4.7.4 Lithuania

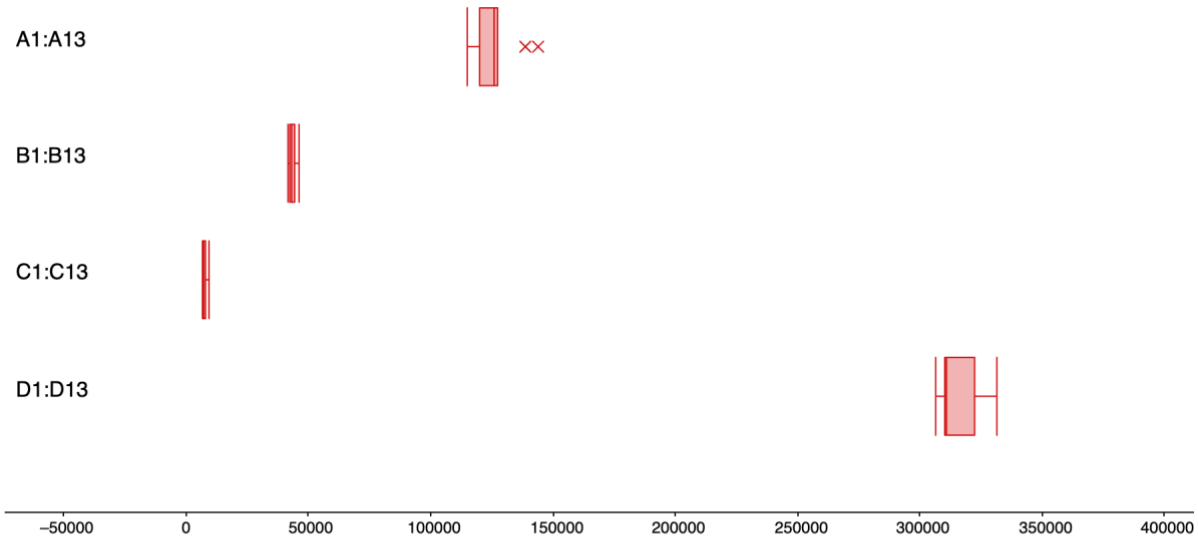
The graph of Eurostat informs that in Lithuania the energy produced increased from 2007 to 2010. This year it decreased little until 2011. From 2011 to 2017, it did not stop increasing and, finally, it decreased a bit in 2018.

Concluding, we can see a very important renewable energy and biofuels rise. Beginning 2007 with 964 thousand tons of oil and in 2018 Lithuania has 1551.47 thousand tons of oil.



4.7.5. Data interpretation. Comparison between countries

The next box plot constructed with the Eurostat data allows to compare the importance of Solar energy in the four countries of the consortium.

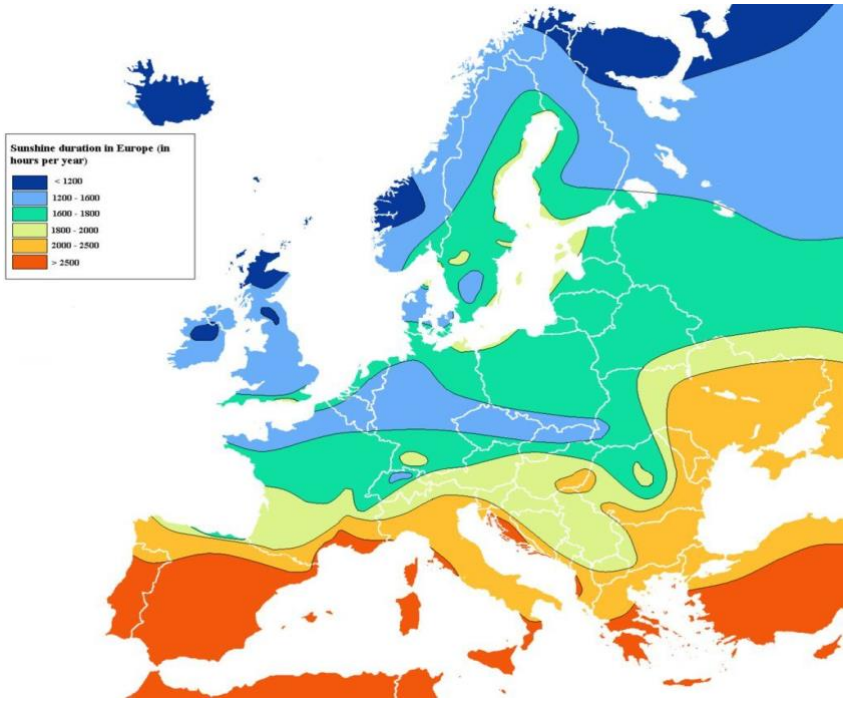


Estadísticas

	n	Media	σ	s	Mín	Q1	Mediana	Q3	Máx
A1:A13	12	126176.0543	7927.1651	8279.654	114924.501	120005.0885	125954.549	127344.4685	143910.055
B1:B13	12	43418.6293	1367.1475	1427.9389	41638.363	42274.5265	43147.412	44353.473	46109.972
C1:C13	12	7476.6839	933.1102	974.6018	6682.1	6804.3845	7041.4165	7906.2245	9312.682
D1:D13	12	315427.5357	8258.0794	8625.2827	306505.154	310200.582	310866.034	322406.645	331454.171

As we can see, the country with the highest average is Germany with 315427.53, followed by Spain, Czech Republic and finally Lithuania which is the country with the lowest average with 7476.68.

Number of hours of sunshine



Spain: more than 2500 hours of sunlight.

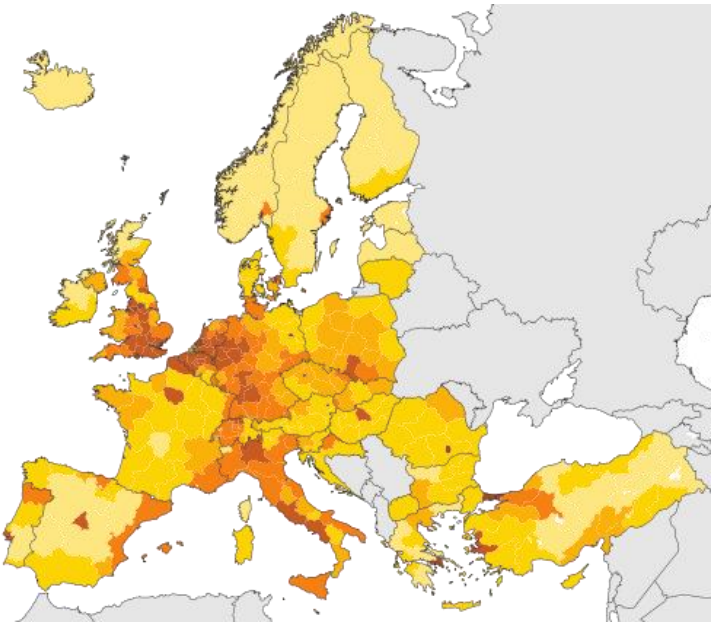
Europe: between 1200 and 1600 hours of sunlight.

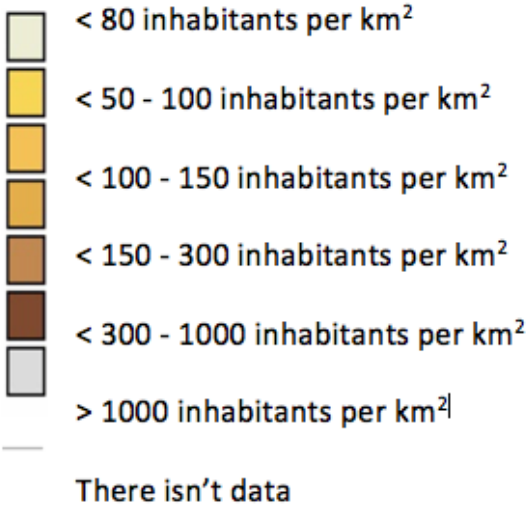
Czech Republic: between 1200 and 1600 hours of sunlight.

Lithuania: between 1600 and 1800 hours of sunlight.

Germany: between 1600 and 1800 hours of sunlight.

Amount of people





4.7.6 Conclusion

Concluding, as we have seen during our work, Lithuania is the country with the least solar energy. But they have different reasons for that, they are a country without a high number of habitants and they do not have the same hours of sunshine as other countries like Spain for example. Germany is the country with the highest average of solar energy produced, although, they are not the country with the most hours of sunshine, but they are the country with the most of habitants so this is an advantage in this aspect. Following Germany, we have Spain. Which is a country that produces a lot of solar energy and the primordial reason for that is the huge quantity of hours of sunshine and they have a lot of habitants too. With almost 47 million of habitants. Finally, Czech Republic does not produce a lot of solar energy. It has approximately 11 million of habitants and they do not have a lot of hours of sunshine in comparison with the other countries.

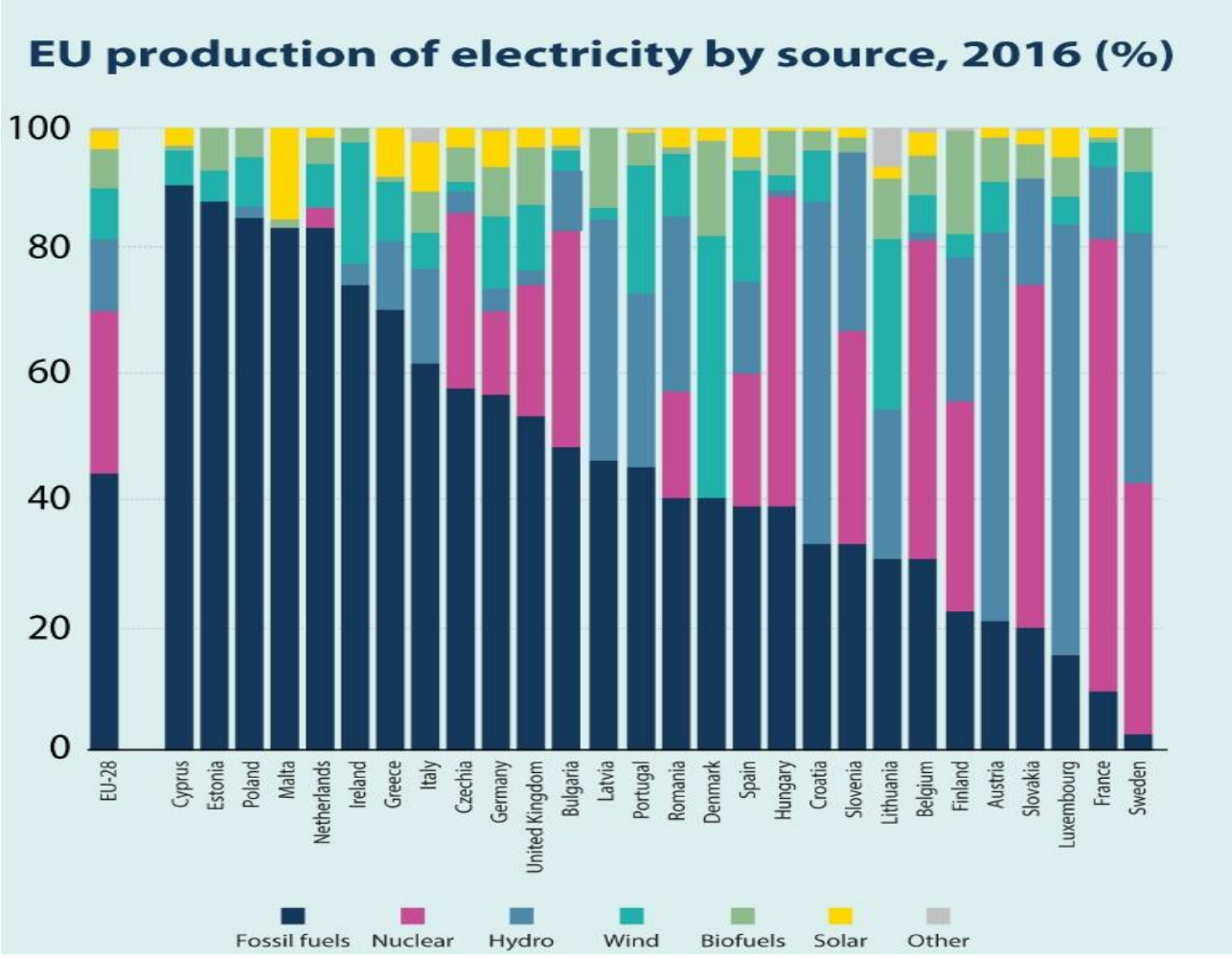
4.7.7 Which is the functional relationship between the solar hours and solar energy production and consumption?

To begin with, the production of solar energy can be divided into two types: thermal and photovoltaic. The analysis of the relationship between the solar hours and the solar energy will be done with the Spanish data.

Starting the day, we can see that there's only thermal solar energy used, because there is still a remainder of energy from the previous day. This remainder is a 2,5% of total general energy produced.

During the morning, you can see an increase in the thermal solar energy production, which goes from the 2,5% to the 8,2%. There is also an increase in the photovoltaic solar energy produced that goes from nothing to the 12,5%. The production of solar energy remains constant till around 8:00 pm. At this moment, it starts to decrease the production to begin a new cycle of production that goes from the 1% to back to the 2,5%.

Summing up, the production of solar energy increases during the solar hours and decreases during night time.



4.8 Interestings

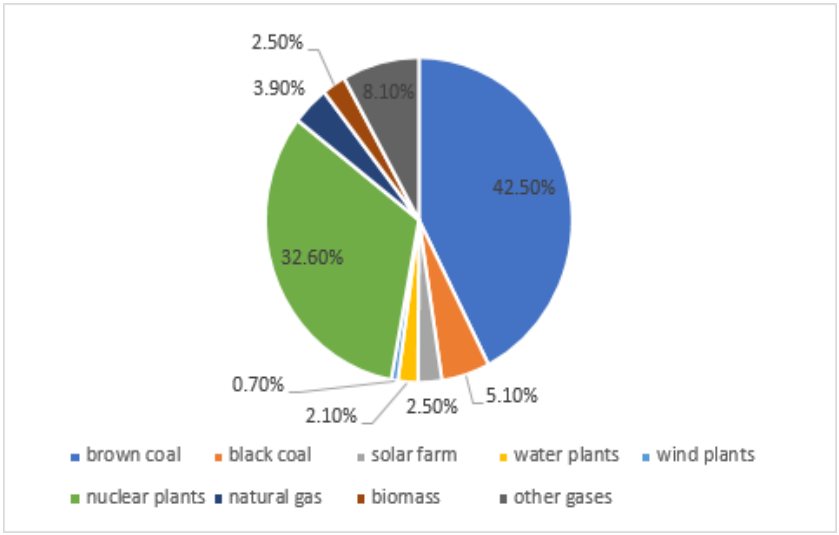
The analysis of the interest of solar renewable energy for a sustainable world aims to answer the questions:

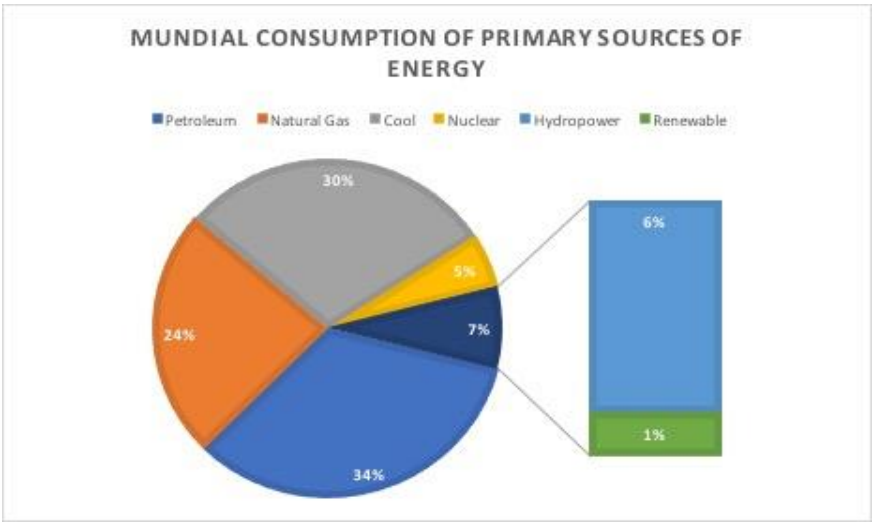
1. How does solar energy help the sustainability of the world?
2. Do solar panels and farms have either a negative visual impact or an ecologic impact?
3. Is the massive construction of the solar panels sustainable in relation with the chemical raw materials used?
4. Self-sufficient homes and cities: What kind of impact could have solar panels?
5. Conclusions

4.8.1. How does solar energy help the sustainability of the world?

The first benefit of solar energy is environmental. Solar energy creates clean, renewable power from the sun and benefits the environment. Alternatives to fossil fuels reduce carbon footprint at home and abroad, reducing greenhouse gases around the globe. Solar is known to have a favorable impact on the environment.

Fortunately, countries such as Spain, Germany, Czech Republic and Lithuania are also able to use more profitable solar energy.





Czech Republic

Most of the electricity generated in 2015, in the Czech Republic is produced in coal-fired power plants (47,6%), nuclear power plants (32,6%) and in power plants using renewable energy sources (11,2%). Of all renewable sources, solar plants produce the most, just about 2,5% (Water about 2,1% and wind about 0,7%).

Lithuania:

Solar energy creates clean, renewable power from the sun and benefits the environment. Alternatives to fossil fuels reduce carbon footprint at home and abroad, reducing greenhouse gases around the globe. Solar is known to have a favorable impact on the environment. By investing in solar energy, you can help reduce our reliance on fossil fuels in favor of one of the most abundant, consistent sources of energy we have available: our sun.

Germany:

Solar energy is a renewable energy. This means no greenhouse gases are emitted during the process of “making” energy. The sunlight is used to produce energy. This is useful because the energy coming from the sun is 10 times more than what humanity needs from fossil fuels. If solar energy is used more commonly, fossil fuels do not have to be used which leads to a cleaner environment.

4.8.2 Do solar panels and farms have either a negative visual impact or an ecologic impact?

As far as we are concerned, renewable solar energy farms have an ecological and visual impact. Due to the fact that installing these panels means eliminating almost everything in the environment, consequently none of us can deny that we are changing it.

First of all, they have a visual impact, because it is not very nice to look ahead in the landscape and suddenly see a solar farm with a huge number of solar cells.

Secondly, they have an ecological impact, because they have to destroy the whole vegetation near them. So, you are changing and damaging nature and the environment.

Finally, solar energy systems offer significant environmental benefits in comparison to the conventional energy sources, thus they greatly contribute to the sustainable development of human activities. At times, however, the wide scale deployment of such systems has to face potential negative environmental implications. These possible problems may be a strong barrier for further advancement of these systems in some consumers.

On the other hand, although they have very good impacts, the potential environmental impacts associated with solar power, land use and habitat lost, the use of water, and the use of hazardous materials in manufacturing, can vary greatly depending on the technology, which includes two broad categories: photovoltaic solar cells or concentrating solar thermal plants.

Solar power will certainly affect the earth under the solar panels, as you are shielding the ground from the sun's rays. In addition, solar panels have a definite lifetime, and create toxic waste that has to be disposed of properly. However, at least solar panels can be widely distributed, becoming the roof material for buildings. Solar power will certainly affect the earth under the solar panels, as you are shielding the ground from the sun's rays. In addition, solar panels have a definite lifetime, and create toxic waste that has to be disposed of properly. However, at least solar panels can be widely distributed, becoming the roof material for buildings.

4.8.3. Is the massive construction of the solar panels sustainable in relation with the chemical raw materials used?

Nowadays, the manufacture of photovoltaic panels involves the use of polluting materials, and the sheet photovoltaic fine contains more toxic materials than traditional silicon-based cells, such as Cadmium telluride.

It is considered that they can have a useful life of up to 40 years; however, after 20 or 25 years of useful life, the panels become polluting garbage that contains components dangerous to the health of people. Moreover, if its materials are not reused when the useful life ends, they will become more rubbish that accumulated in the Earth.

In conclusion, the process of manufacturing photovoltaic cells is also a danger for health known to workers who are at risk of inhaling dust of silicon. In consequence, they can develop different types of diseases, such as cancer. Nevertheless, compared to conventional forms of energy, the cycle of life of photovoltaic systems needs less hazardous materials. For example, cadmium emissions are almost 300 times higher in the case of coal-fired power stations.

4.8.4 Self-sufficient homes and cities: What kind of impact could have solar panels?

The solar panels have different impacts on the Earth:

- Climate: It does not consume any type of combustion, so does not produce CO_2 and does not affect global warming.
- Geology: The cells of the solar panels are made of silicon. Nowadays, there is enough silicon in the Earth in comparison with the amount used to construct the cells. So, from a geological point of view, its use does not affect the Earth.

- Noisy: The solar panels do not make any kind of noise.
- Social medium: Normally the solar panels can be used either in the ground or in the roof.
- Useless life: The minimal life of a solar panel is 15 years.

4.8.5 Conclusions

How does solar energy help the sustainability of the world?

To conclude, the sun produces 10 times more the energy that we consume, so if our share of solar energy was bigger, we could leave non-renewable energy sources (like coal or nuclear energy). That way we could have a more sustainable environment, which means a world with less diseases, allergies, greenhouse gases…

In addition, Industry 4.0 could play a very important role in the improvement of the solar energy industry, using the Internet of Things (IoT) and Big data.

Do solar panels and farms have either a negative visual impact or an ecologic impact?

They usually make an impact because whether we want to or not we are changing the landscape. The question is the negative visual and ecological impact it may produce.

About that, it is obvious that it produces a visual change whether you like it or not, there are different opinions about seeing a landscape occupied in part by solar panels, basically it is a matter of taste.

Talking about the ecological impact, we have several cases, some good and some bad but we all know that the good ones stand out much more and that the bad ones lose importance or do not have so much.

advantages	**disadvantages**
Does not require any type of combustion, so there is no thermal pollution or CO2 emissions that favour the greenhouse effect.	Requires a normally high financial investment
Can generate electricity in remote locations	You won't always have the energy you want
Maintenance is cheap	Requires a normally high financial investment

To sum up, solar energy is a clear advantage although I have put 3 advantages and 3 disadvantages, actually there are many more advantages than disadvantages and therefore it is very profitable, because in a future with certain improvements in such technology could transform solar energy into the engine of the renewable world.

Is the massive construction of the solar panels sustainable in relation with the chemical raw materials used?

To conclude, solar panels use polluting and toxic materials. When the solar panels stop working the remains accumulate and pollute the planet. The process of manufacturing photovoltaic cells is dangerous for human health who inhale dust from silicon. But it is obvious that it would have more benefits than prejudices.

Self-sufficient homes and cities: What kind of impact could have solar panels?

There is no doubt that solar panels would have a very good impact and pros outweigh the cons like anyone could read in section four. First of all, they do not make any type of combustion so there is no CO2, so it does not affect the environment, also it does not make noise. The construction of all the solar panels with their maintenance would create a lot of jobs.

4.8.8 General conclusion

In summary, we could say that the transition between actual non-renewable energies and sustainable ones would be a slow process because, for example, the creation of enough PV panels to supply the demand would take a long time. Moreover, another against is the environment´s transformation but it also means the creation of a lot of employees to make all that change we had mentioned before. As we have said with anteriority it does not produce any combustion so the greenhouse effect should not be affected by the solar farms.

4.9 Experiments

The main means of transport in the Bay of Cadiz where our school is located are cars and catamarans. These means of transport emit large quantities of CO2 polluting the waters of the Bay of Cadiz, in general, and the nature reserve of the Toruños Park. In this context, two experiments were carried out:

A. How did the construction of a solar catamaran make it possible to achieve the electrical voltage necessary to move through the waters of the bay?

B. Were the waters of the Valdelagrana Beach healthy and to what extent did they affect the sustainability of the nature reserve of the Toruños Park?

4.9.1. The voltage of the Solar Catamaran

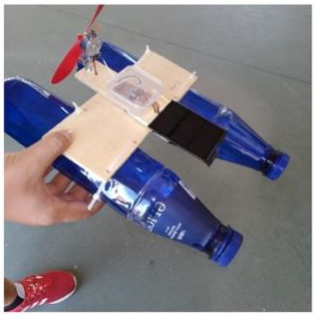
Students constructed the solar catamaran with recycled bottles of water and a photovoltaic solar panel. The position of the photovoltaic solar panel was crucial to increase the speed of the catamaran.

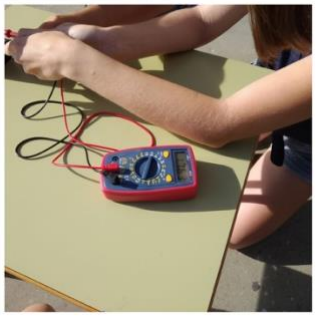
The measurement of the intensive curl should be estimated by taking care of the rotation movement of the Earth with respect to the sun (solar time) jointly with different angles of the solar panels with respect to the surface of the Earth.

The results obtained were:

Angle (º)	Electrical or voltage (mV)	Electrical current (mA)
0º	1900	280
10º	1914	270
20º	1915	270
30º	1916	280
40º	1908	260
50º	1903	260

Concluding that the best angle for the balance between electrical or voltage and current was 30º.





After its construction, they probed and competed to be the winner.

4.9.2. Sustainability of Valdelagrana Beach

The Toruños Park in Valdelagrana Beach has an area of 10 rea of 10 km^2 (about 1400 football pitches). It is located in Cádiz Bay, near the cities of Cádiz (116.979 inhabitants), Puerto Real (41.650 inhabitants) and El Puerto de Santa María (88.364 inhabitants). It is 1,5 km from the shipyard which you can see just looking west. The research question was: is it sustainable to have an industry near a natural park?

Firstly, the table with all the environmental indicators was fulfilled.

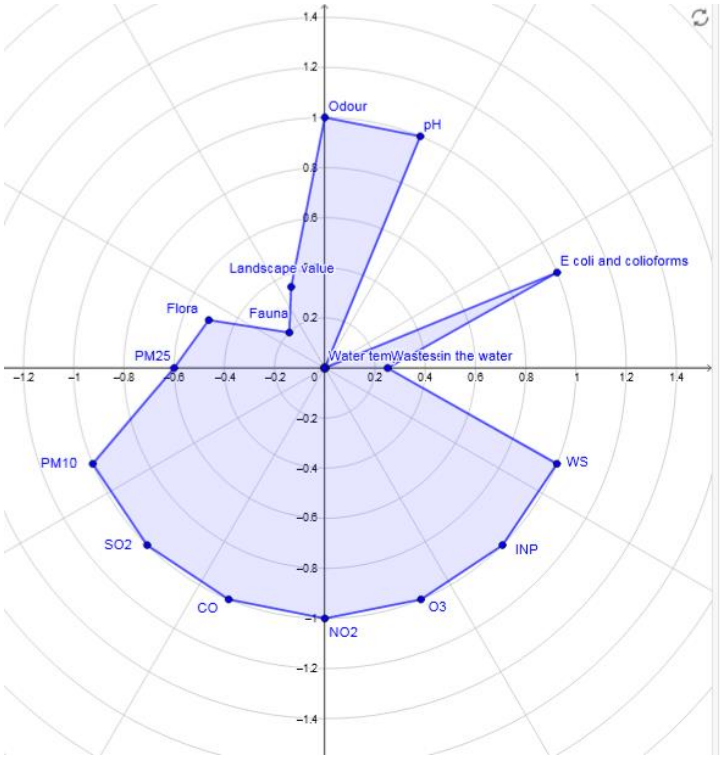
TEAM number and name	Odour. From 0-10 (0 no odour, 10 strong smell of chemicals).	pH	Escherichia coli and coliforms (1 UFC/ml)	Tar, glass, plastic, rubber or wood waste. Floating materials	Tar, glass, plastic, rubber or wood waste. Floating materials	Industrial noise pollution	Ozone (µg/m3)	Nitrogen Dioxide (µg/m3)	Carbon Monoxide (mg/m3)	Sulphur Dioxide (µg/m3)	Particulate Matter PM10 (µg/m3)	Particulate Matter PM25 (µg/m3)	Flora. Number of species found/km2:	Fauna. Number of species found/km2:	Landscape valueaVa
3 Sonne	0	7		2	0	0	80		0				10	4	9
3 Sonne	0	7		2	0	0	80	30	0	2	15	20	10	4	9
10 Słońce	4	7		4	4		95	2	0	2	25	7	10	4	16
5 saulė	0	6		0	0	0	15	2	0	2	25	7	6	1	13
4 Slunce	0	6		7	7	0	110	25	0	5	20	5	7	1	Nice (2-4)
9 Zon	3	6		2	5	0	100	15	0	2	10	20	6	3	3
1 Sun	0	6	0	2	4	0	80	20-30	0	15	20	5	6	1	16

Escherichia coli and coliforms measurements were taken and the results were ready in 48 hours, all the teams had results between 0-250 UFC/ml.

Temperature measurements were written down in pieces of paper “in situ”. Values were between 19-26ºC.

Secondly, the information was analysed using technological affordances (google Calc, Geogebra) and team cooperation.

This allowed to construct the diagram of the sustainability of The Toruños Park.



And finally conclude:

a. Reason why Is or is not sustainable to have the Industrial Park of "Trocadero" and "Río San Pedro" near "Los Toruños" natural reserve?

Some responses were:

- It seems sustainable because the environmental factors of O_3, NO_2,... Are at a sustainable level. However, the graph says it is not sustainable because our levels of flora, fauna, waste in water and sand and the temperature were not measured accurately enough. Especially the temperature was hard to measure with our limited possibilities.
- It is sustainable. Because the measurements we did are not completely right, because for example we didn't see every animal of every plant in the park. Or the water temperature is changing all the time.
- It is sustainable but the industrial park affects some factors like the temperature.

b. Reason why is or is not sustainable to have the Valdelagrana Touristic zone near "Los Toruños" natural reserve?

Some responses were:

- Tourist zone are often noisy and many people are dropping waste, which could polute the water and beach, for a clean reserve it would be better to not have a tourist zone.
- Because the tourists pollute the area and the animals are maybe scared of them.
- Factors like temperature, waste in water and PM25 are affected by tourism, therefore tourism affect the sustainability of the reserve, but the others factors are really sustainable.

c. Based on the environmental factor diagnosis obtained in the Geogebra sustainability chart, which suggestions would you make to the authorities of the Industrial Parks, "Trocadero" and "Río San Pedro" and the Valdelagrana Tourist zone to increase the sustainability of "Los Toruños" natural reserve?

Some responses were:

- We would suggest them to measure the quality of the air and water really often to control the quality of the park.
- The authorities should do more laws about the environment, for better protection of the natural parks.
- Create new environmentally friendly rules in order to increase the sustainability of the park.
- Having sustainable timetables to work in Navantia because that causes so many waste.
- It's important to keep some reserves like Rio San Pedro alone so nature can flourish on its own, without clean places many animals and plants could die and seriously hurt the environment.

5. Students' experience with this project

5.1 Colegio La Salle-Buen Consejo, Puerto Real, España

Lucía García Barrera:

In order to improve Industry 4.0, everyone's collaboration is necessary, because sustainability is increasingly necessary in the world in which we live. For this, we must use renewable energies that we will find in the different areas of the countries. Applying these energies, we will stop so much the CO2 transmission on our planet.

Raúl Páez Vega:

The improvement of the Industry 4.0 needs of more exploitation of renewable energies and to not depend of the other energies. Doing this change, we can set aside the energies that indirectly injury our planet.

Pablo Espinosa López:

The improvement of the Industry 4.0 needs of the use of methods that do not use toxic waste for the environment. Furthermore, the elements used for the construction of solar panels need to be reusable and disposable, and not harmful.

Álvaro Gómez Calvo:

I just have one thing in my opinion that we can improve and it is about that in the maps we can see that renewable solar energy is not implemented everywhere. And, it should.

Sofía Ramos Góngora:

The fourth Industrial Revolution means changing more the physical elements to the digital. A digitalization of the process. So, this increase, creating more machinery that could be a substitutive of the heaviest work of mankind will be the best. Clearly, on the other hand, I am opposed to creating machines that do absolutely everything, going to the extreme. Since this would suppose that the humanity lost great part of the employment, since this would be usurped by the machinery.

6. Software

Google Education (Google drive, calc, google slices, google photos and collage), Edmodo, Geogebra, Voltage analysis software.

7. Bibliography

¿Qué impacto ambiental tiene la energía solar fotovoltaica? in Conectate al sol. Retrieved from https://conectatealsol.com/news/que-impacto-ambiental-tiene-la-energia-solar-fotovoltaica/

¿Qué impacto medioambiental y social tiene la energía solar fotovoltaica? in Quetzal ingeniería. Retrieved from https://www.quetzalingenieria.es/impacto-medioambiental-social-energia-solar/

Compare prices of solar energy in Green Match. Retrieved from https://www.greenmatch.co.uk/blog/2015/01/impact-of-solar-energy-on-the-environment

Demanda de energía eléctrica en tiempo real in Red Eléctrica de España. Retrieved from demanda.ree.es

Energía solar en España in Wikipedia. Retrieved form https://es.m.wikipedia.org/wiki/Energ%C3%ADa_solar_en_Espa-ña

Energía solar in Acciona. Retrieved from https://www.acciona.com/es/energias-renovables/energia-solar/

Environmental impacts of Solar Power in Union of Concerned Scientist. Retrieved from https://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/environmental-impacts-solar-power.html

Farerwayer (2009). Los paneles solares contaminan después de 25 años de uso. Retrieved from https://www.fayerwayer.com/2009/01/los-paneles-solares-contaminan-despues-de-25-anos-de-uso/

Fernández Mungia, S. (2018). España nominada a los Fossil Subsidy awards por su apoyo al carbón in Diario Renovables. Retrieved 26 April of 2019 form https://www.diariorenovables.com/search/label/Otras%20fuentes#archive-page-1

Fylladitakis, E. Environmental impacts of Photovoltaic systems. Helios Lab: Open Educational Resources. Retrieved April 26 of 2019 from http://www.labri.fr/perso/billaud/Helios2/resources/es15/Chapter_15_ES.pdf

Los costes de la energía solar renovables disminuirán a la mitad para 2020 in Panorama. Retrieved from https://www.energias-renovables.com/panorama/los-costes-de-la-energia-solar-fotovoltaica-20180115

Pepe (2011). Centrales solares instaladas en España. Centralsolars. Retrieved 26 April of 2019 from http://centralsolars.blogspot.com/2011/03/centrales-solares-instaladas-en-espana.html

Photovoltaic structures in Esasolar. Retrieved from http://esasolar.com/

Plataforma solar de Almeria (PSA) in Gobierno de España. Ministerio de Ciencia, Innovación y Universidades. Retrieved from http://www.psa.es/es/index.php

Renewable Energy in Spain in Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Renewable_energy_in_Spain·

Renewable Energy in Lithuania in Wikipedia. Retrieved from:

https://en.wikipedia.org/wiki/Solar_power_in_Lithuania

Solar Energy in SEIA (Solar Energy Industries Association). Retrieved from https://www.seia.org/initiatives/about-solar-energy

The different types of solar energy in Greentumble. Retrieved from https://greentumble.com/the-different-types-of-solar-energy/

The health & environmental benefits of solar energy in Energysage. Retrieved from news.energysage.com

The History of Renewable Energy: Where It All Began. Retrieved from https://www.projectsolaruk.com/blog/history-renewable-energy-began/

The two types of solar energy, photovoltaic and thermal in Planete energies. Retrieved from https://www.planete-energies.com/en/medias/close/two-types-solar-energy-photovoltaic-and-thermal

Torresolenergy. Retrieved from http://torresolenergy.com/en/gemasolar/

What is the source of the energy that we consume? in Eurostats. Retrieved from https://ec.europa.eu/eurostat/cache/infographs/energy/bloc-3b.html