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Sustainable & Smart Rehabilitation of Districts

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ACRONYMS AND ABBREVIATIONS

SUSTAINABLE ENERGY SYSTEM

BIWT	Building Integrated Wind Turbine
DH	District Heating
EGS	Enhanced Geothermal System
HAWT	Horizontal Axes Wind Turbine
GPP	Geothermal Power Plants
MED	Multi Stage Distillation
PV	Photovoltaic
USD	United States Dollar
VAT	Vertical Axes Wind Turbine

GREEN CONSTRUCTION

PA	Permeable Pavement
PC	Permeable Concrete
PICP	Permeable interlocking concrete pavers
PG	Plastic grid pavers
CGP	Concrete grid pavers
SUDS	Sustainable urban drainage systems

WASTE MANAGEMENT

CBA:	Cost-Benefit Analysis
GHG:	Greenhouse gasses
EU:	European Union
LCA:	Life Cycle Assessment
LCC:	Life Cycle Costing
LCT:	Life Cycle Thinking
MBT:	Mechanical Biological Treatment
MRFs:	Materials Recovery Facilities
MS:	Members States
MSW:	Municipal Solid Waste
PSW:	Plastic solid waste
S-LCA:	Social LCA
WFD:	Waste Framework Directive
WM:	Waste Management
WMP:	Waste Management Plan

TRANSPORT & ICT INFRASTRUCTURE

3G:	3rd Generation
AC:	Alternating Current
AC:	Alternating Current
ACS Lite:	Adaptive Control Software Lite
AID:	Automatic Incident Detection
AMI:	Advanced Metering Infrastructure
AMR:	Automatic Meter Reading
AP:	Access Point
ATCS:	Adaptive Traffic Control System
AVL	Automatic Vehicle Location
BEB:	Battery Electric Buses
HEV:	Hybrid Electric Vehicle
HFAC:	High Frequency Alternating Current
ICE:	Internal Combustion Engine
ICT:	Information & Communication Technology
ICTs:	Information and Communication Technologies
ISA:	Intelligent Speed Adaptation
ITS:	Intelligent transportation system
LED:	Light-Emitting Diode
LTE:	Long Term Evolution
MDMS:	Meter Data Management Systems
NAN:	Neighborhood Area Network

BESS: Battery Energy Storage System

BEV: Battery Electric Vehicle

BRT: Bus Rapid Transit

CAESS: Compressed-Air Energy Storage System

CCTV: Cámera Cerrada de Televisión (Television Closed Camera)

DC: Direct Current

DC: Direct Current

DC: Data Concentrator

DER: distributed energy resources

DG: Distributed Generation

DSP: Digital Signal Processors

EESS: Electro-chemical energy storage systems

EM: Electric Motor

EMS: Energy Management System

ESS: Energy Storage Systems

ET: Evapotranspiration

EV: Electric Vehicle

FCHB: Fuel Cells Electric Buses

FCV: Fuel Cells Vehicle

FESS: Flywheel energy storage system

FRAME: Framework Architecture Made for Europe

GEV: Gridable Electric Vehicle

GHG: Green - House Gas

GPB: General Protection Box

GPRS: General Packet Radio Service

GPS: Global Positioning System

GRT: Group Rapid Transit

GSM: Global System for Mobile Communications

HAN: Home Area Network

HEB: Hybrid Electric Buses

PCC: Point of Common Coupling

PEV: Plug-In Electric Vehicle

PHESS: Pumped Hydro Energy Storage System

PHEV: Plug-In Hybrid Electric Vehicle

PLC: Power Line Communication

PQ: Power Quality

PRT: Personal Rapid Transit

RES: Renewable Energy Sources

RFC: Regenerative Fuel Cell

RFID: Radio Frequency Identification

RMS: Ramp Metering System

SCADA: Supervisory Control and Data Acquisition

SCATS: Sydney Coordinated Adaptive Traffic System

SCOOT: Split Cycle Offset Optimization Technique

SESS: Super-Capacitor Energy Storage System

SN: Sensor Node

SWAT: Smart Water Application Technologies

UMTS: Universal Mobile Telecommunications System

VMS Variable Message Signs

VPH vehicles per hour

VtG: Vehicle To Grid

VtH: Vehicle To Home

VtV: Vehicle To Vehicle

WAN: Wide Area Network

WI-FI: Wireless Fidelity

WIMax: Worldwide Interoperability for Microwave Access

WMTS: wireless local area network

WPAN: wireless personal area network

WRI: World Resources Institute

WSN: Wireless Sensor Network

INTRODUCTION

Nowadays, the population of our world is expanding. It becomes a trend that people prefer to live in the urban area, resulting in lacking of resources in cities. This phenomenon has lead to many unexpected issues, for instance, the creation of shantytowns and the global warming. Since a couple of years, researchers, governments and companies, are searching for a long-term improvement of the existing cities. These works that contain existing issues are being applied, the goal which is to improve the life quality, health and the sociability of all citizens. These efforts are all put under a common name “Smart City”, the concept of which is trying to seek answer towards all actual and future needs along with the development of society, split in a large number of points, technical, social, and political.

According to the characteristics and factors of the “Smart City”, six main domains of thinking can be pointed out.

The first one, the “Smart Economy”, has the goal not only to solve to all employment and productivity issues, but also to find innovative spirit and entrepreneurship, in order to create a competitiveness in a good way of thinking and in a common way of improvement.

The second one, named as “Smart people”, rests on the social and human capital, asking for high level of qualification, plurality, flexibility, creativity and open-mindedness, in order to create a high social network, with high quality and auto improvement.

Then it comes to the “Smart Governance”, which is about looking for transparency, participation of all, at all level of decision making, focusing on the changes in all public and social services.

According to the “Smart Mobility”, saving time and accessibility for all is one of the priorities. By using modern networks and ways of communication, the aim of this part is to develop national and international accessibilities not only to places, but also to data and knowledge in a sustainable, innovative and safe way for the benefit of all.

The natural resources are running out, and our way of using them has put us in a critical situation. “Smart environment” is seeking for optimization solutions to our demands, our health and the earth at the same time, according to the pollution, the environmental protection or the sustainable resource management.

The last factor put in front by the “Smart City” innovation is the “Smart Living”. Its aim is to optimize our quality of life with individual safety, high housing quality, social cohesion and education facilities.

All the characteristics above are linked together, requiring a high level of applications and efforts to reach a real success in reality. It is difficult to do all of them at the same time.

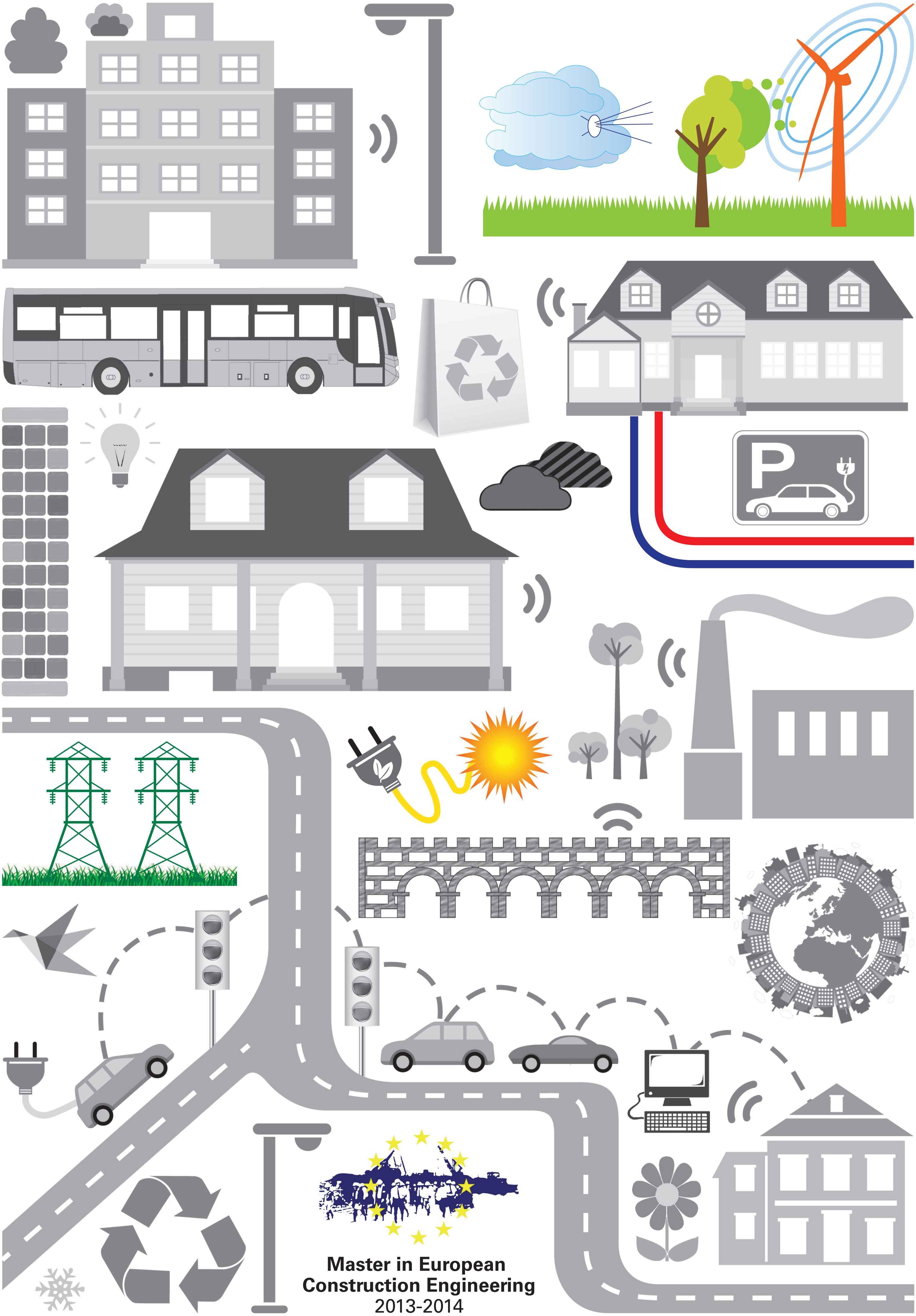
The objective of this paper is to focus on the existing knowledge of the main social and technological points which are under development right now, seeking answers to a part of the “Smart City”.

The first part is the development of the Sustainable Energy System. Regarding to all the technologies about the concept, this document will try to point out the different sources of energy that are developed for the sake of substituting the fossil fuel and all the other sources and creating undisposed waste. In order to have a complete autonomy from these actual sources of energy, all the renewable ones need to be developed and to offer a higher profitability and capacity. If the use of the sun and wind energy potential is already in a good way of development, other sources, as marine energy or bio-fuels are still unused.

The energy is not the only resource needed in the cities. Water and green spaces are fundamental for the health of the city and its inhabitants. The Green Construction part, will develop the main technologies used, in order to recover a green lung inside the city and solve the rain issues at the same time. Making use of all surfaces for its development, the creation of green roofs and green facades will be the first step for this new way of thinking about a city. Those solutions will also limit the impact of the rain in the city, avoiding floods and all its inconvenient. Other technologies will be used, such as Sustainable Urban Drainage System or Permeable Pavement, to avoid all inconvenient from the water and to ensure safety for the inhabitants.

The third point, will be the consequence of the over population in a small area. The Waste Management is becoming more and more complex, because of the urbanization, requiring more resources and improvement to collect the waste and to recycle it in order to be able to reuse and save those resources. Indeed, the nature is becoming more difficult to obtain, people have to start thinking about reuse, to save energy and money and to avoid misuse. The development of this new way of thinking requires new facilities to take care of the waste, new ways of collecting this waste, and also new ways of thinking. All the improvements on those three different levels will be developed in this part of the document.

Speaking of the “Smart Mobility”, Transport & ICT infrastructure has to show the latest technologies that are being developed in order to solve and avoid traffic and public issues. Starting with giving real time information to all users, drivers, pedestrians or cyclist, in order to limit the overlap of people, improving the public transport, in a renewable and sustainable way, or optimizing the public facilities, as public lightning, all those points will require a new kind of network, the “Smart Grid”. The build of this network will allow direct communication and information, in order to optimize the energy consumption from any sources, people or devices and any kind of electric, fuel and even time.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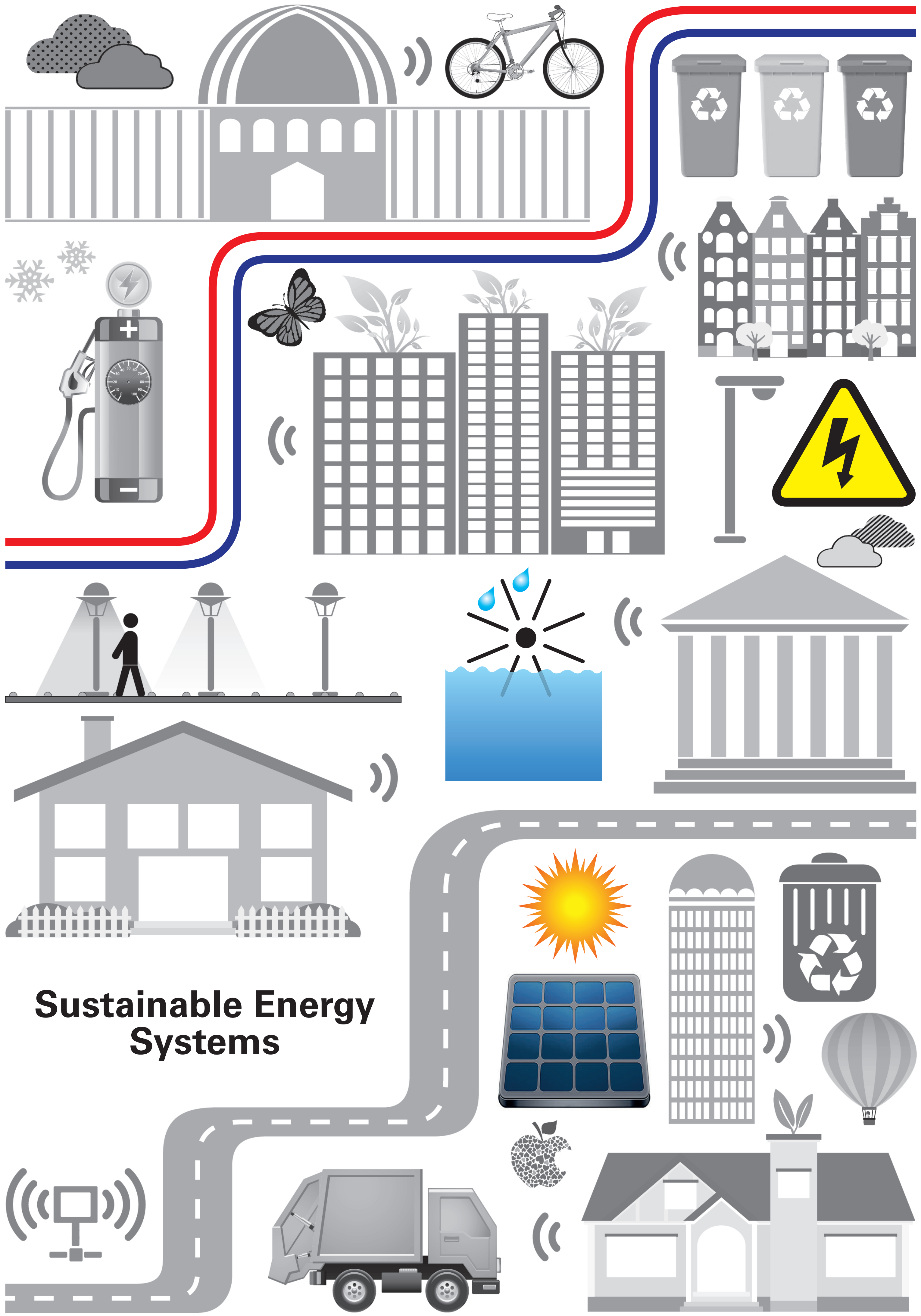

Sustainable Energy
Systems

PHOTOVOLTAIC ENERGY.

The photovoltaic energy is a renewable energy source which uses the photovoltaic effect in order to produce an electric current in a semiconductor material due to the absorption of light radiation, and convert it into electricity.

The sunlight is converted directly into electrical energy using an electronic device called photovoltaic cells made of a semiconductor material, normally silicon, which is the most used raw material. By impinging light (photons) on these cells the electric current is generated (photovoltaic effect) and by grouping photovoltaic cells, we get the photovoltaic panels.

The photovoltaic effect was discovered by Edmond Becquerel in 1839, but it wasn't until 1950 when the first monocrystalline silicon cell was developed with an efficiency of 1% and it has been growing steadily since then. The development of the technology continued growing and improving the performance while decreasing the costs of the production. The application of photovoltaic electricity is connected to the grid started at the beginning of the 21st century.

The photoelectric effect.

Photovoltaic cells use semiconductor materials such as silicon, germanium or gallium arsenide. These kinds of materials are normally insulators, but when they receive energy, like light energy; they start to act as conductors and are able to produce electron currents. So, a semiconductor material is exposed to the sun radiation, which contains photons (lighting energy), bringing the needed energy in order to break the link between the electrons and the atoms of the semiconductor used and creating an electric current.

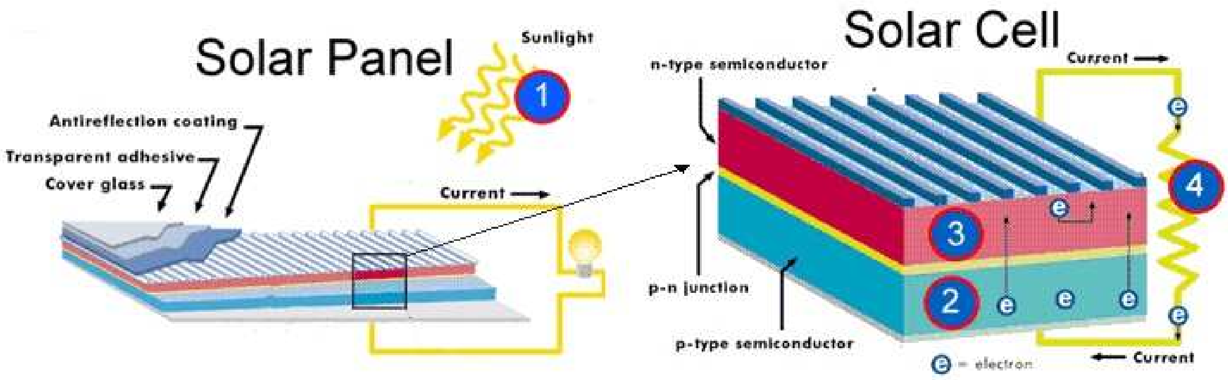


Figure 1: Photovoltaic cell scheme. [www.biggreensmile.com, 201?]

In the case of silicon, it isn't a really photoconductor material, so some phosphorus atoms, with excess of negative charges are added. This is the material "type n" from the figure. Also the material in the bottom, the "type p", is silicon with some addition of boron in order to produce an excess of positive charges. So, in this way, a diode is produced and the electrons from the "type n" are attracted by the positive charges of the material "type p" producing the electric current.

The current generated by a photovoltaic cell is really small, so grouping them is necessary to achieve a higher current. Several cells electrically connected to each other in a support structure set up a photovoltaic module. Modules can also be connected together to make an array.

The produced current is a direct current (dc). To transform it into alternating current (ac), an inverter device is needed.

The photovoltaic systems can be connected with each other in two different ways:

- Connected in series: voltages are added and currents remain.
- Connected in parallel: currents are added and voltages remain.

Influential factors.

Photovoltaic panels (PV) produce energy while receiving solar radiation, even on cloudy days, but their performance decreases proportionally to the decrease in solar radiation. Cold is not a problem for the use of PV. In fact, like most of the electronic components, photovoltaic panels work more efficiently at cold temperatures, always within limits.

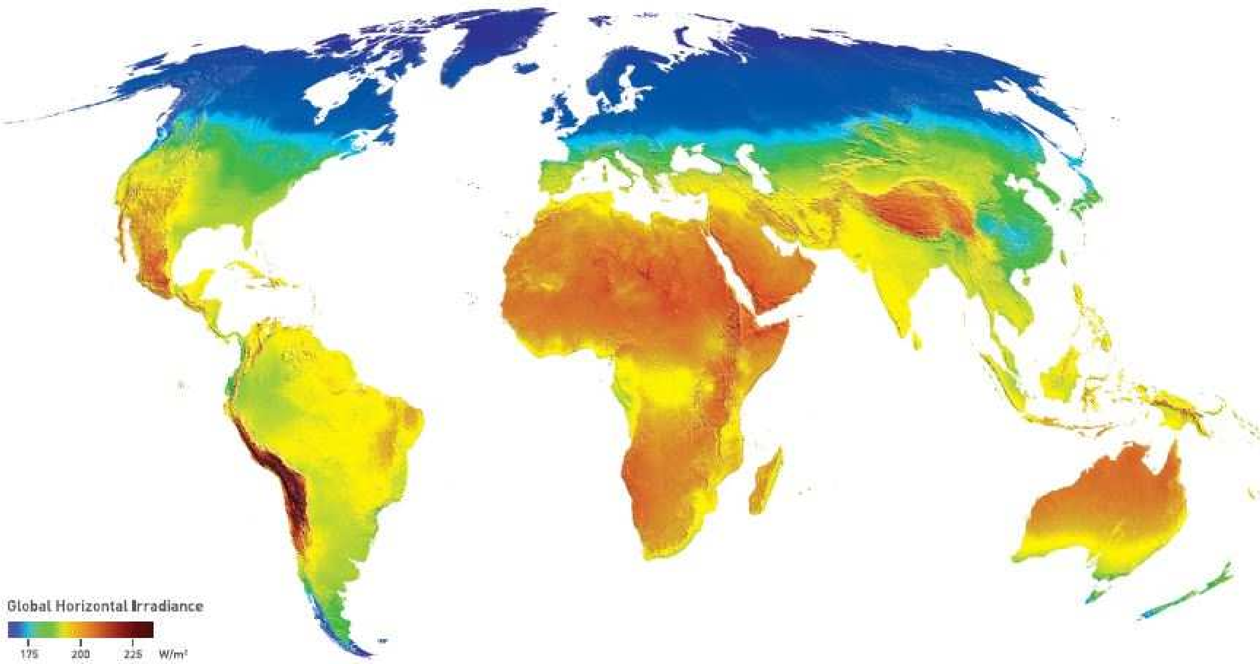


Figure 2: World sun irradiation [www.china-aircon.com, 2011]

Solar panels should be placed in a location where they receive full sunlight. Places where they receive shade (vegetation, snow, other buildings, building elements, other modules...) should be avoided, at least, during the middle of the day, because being in the shadow will affect their performance.

Due to the change of position of the Sun during the year, the ideal slope of the panels varies depending on the latitude in which the panels are placed. In any case, it is recommended to exceed 15º of inclination in order to allow rain water to drain off. The inclination must be increased in areas where snow is frequent.

Furthermore, the solar system will have better performance in the north hemisphere if the solar panels are oriented to the south and if they are in the south hemisphere they should be oriented to the north.

Maintenance.

The operation of solar photovoltaic systems requires minimum actions of small and mostly manual character. In regard to larger installations, the control of the main operating variables can be monitored and automated by a remote control system.

Maintenance is normally minimal, limited almost exclusively to clean the surface of the modules and supervise their correct orientation. In the case of remote facilities, also include the reviewing of the status of the electrolytes of the batteries periodically.

Main applications.

Of-Grid Systems.

These kinds of systems are applied in places where there isn't access to the electrical grid and consequently it's cheaper to install a photovoltaic system than constructing an electrical line from the electricity network to the point of use.

As the PV panels only produce power at times of sun and energy is needed for 24 hours a day, an accumulation system is required. An extra energy should be created during the day in order to use it during the night.

Typical applications of the off grid systems are: satellites and space crafts, consumer goods, television and radio repeaters, mobile phone masts, maritime and terrestrial signalling, water pumping stations, forestall protected areas, isolated buildings and villages, streets and roads lighting…

Hybrid Systems.

These systems are used when the dimensioning of the photovoltaic installations is below the security margin. This can be due to economic considerations or because there is other energy source also available.

Hybrid systems can be combined with another energy source like wind turbines, diesel generators, biomass... They can also be grid-connected, in order to get the needed support.

On-Grid Systems.

In places with electricity flow, the connection to the network of the PV systems is an ideal solution to reduce emissions of carbon dioxide ($CO2$) into the atmosphere. This application normally fits well with the demand curve for electricity because the moment when the panels generate more energy (during the day), is when the electricity demand is higher.

In grid-connected installations, the installation size does not depend on electricity consumption in the house or building, greatly simplifying the design. The main applications of the on-grid systems are:

Auto-generation.

These systems encourage a distributed power generation system in which energy is produced not only in a few points (large power plants), but it also can be generated in multiple locations. Auto-generation can be applied in residential, commercial or industrial buildings. Typically, residential installations have a power of less than 20 kW and in big commercial or industrial buildings installations till 1 MW can be mounted. We can distinguish two:

No integrated systems: They are modular systems, easy to install, that usually takes benefit of the roof surface to put the photovoltaic panels.

Integrated systems: In these systems the traditional structure elements of the building are replaced by new architectural elements including the photovoltaic panels. The most common integrated elements are: façades coatings, curtain walls, parasols, pergolas, glazed flat roofs and skylights, shingles…The main advantage of integrated systems is the saving of space, but they may be less productive because usually they cannot take the maximum benefit of the best orientation.

Photovoltaic power plants.

The electricity production plants are industrial strength applications which need a lot of space and can be installed in rural areas or in large buildings. These installations are becoming more and more used during the last years. The reductions in the production cost are enabling PV plants to become economically competitive, and the support policies and incentives are being helpful too. Solar trackers and concentration devices are usually used in solar power plants to increase its performance.

An average photovoltaic power plant used to have a capacity between 500 kW and 100 MW, but it's becoming bigger and bigger. Actually the biggest PV power plant is in Arizona, with a rated output of 290 MW. This industry is achieving electricity outputs similar to conventional coal stations, and in the future is expected that it can grow to gigawatt scales, reaching the level of the nuclear industry.

Benefits.

- Clean Energy: Does not generate waste.
- Inexhaustible and free energy source.
- The most of the less developed countries have a lot of solar radiation and do not have to import it, and it is also available in all the regions of the world.
- It can be used in different scales: from mill watt in consumer goods till gigawatt in photovoltaic centrals.
- Very low maintenance needed.
- Silent technology during its operation.
- Proven technical lifetime of 30 years, and it is expected to increase in the future.
- PV systems consume do not need to consume energy during their operation.
- Photovoltaic systems do not need to consume water during the energy production; they consume it only for cleaning the installation when the rain and weather conditions are not enough.
- No moving parts to wear out or break down.
- Modular systems can be quickly installed anywhere.

Disadvantages.

- Installations require a large amount of soil.
- Solar radiation is not uniform throughout the world.
- Producing and maintaining solar panels is polluting.
- Large solar installations affect the environment due to its large size.
- Low energy efficiency compared with other renewable energy sources.
- Photovoltaic systems produce direct current energy and it has to be converted to alternating current.

Statistics about PV energy in the World and Denmark.

The total photovoltaic electricity capacity reached in 2012 was 96.5 GW. As it's shown in the next figure, the evolution since 1992 has been growing exponentially. Only in 2012, 28, 4 new GW were installed.

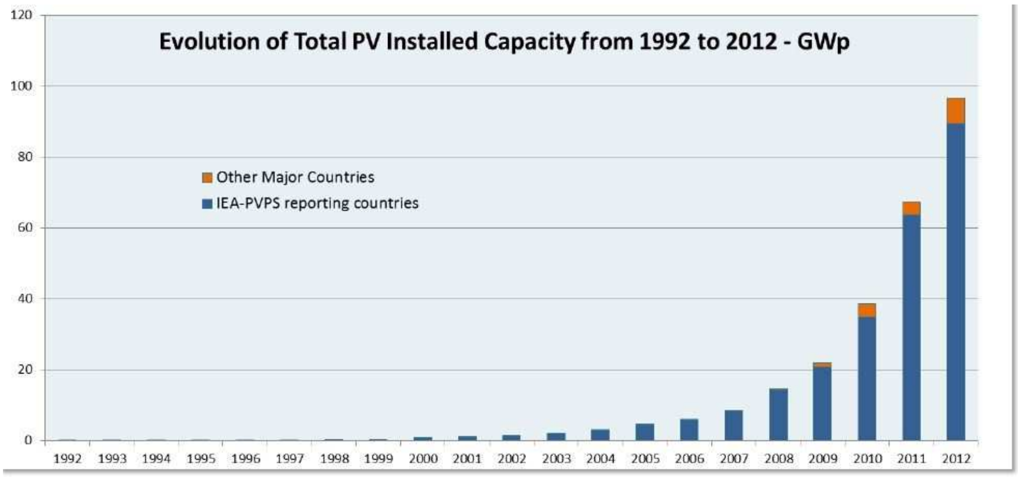


Figure 3: Evolution of Total PV Installed in the world during the last 20 years [International Energy Agency, 2013]

Europe is nowadays the leader continent in photovoltaic capacity as it's shown in the next graph, but Asian and American countries have also experimented an enormous growing in the last years:

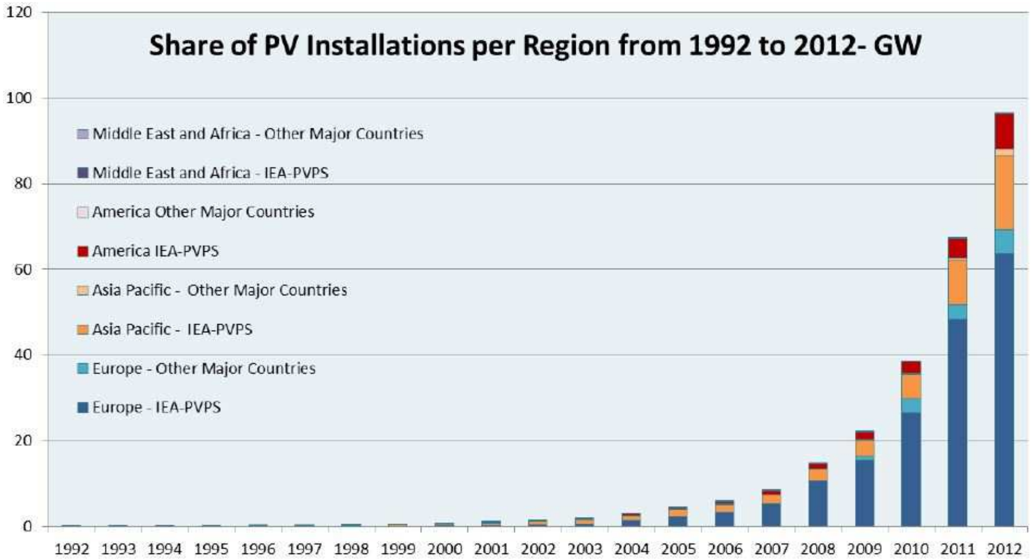


Figure 5: Distribution of PV installations per region [International Energy Agency, 2013]

Nowadays, the top 10 countries in total amount of photovoltaic capacity are the following:

Total installed capacity – MW	
Germany	32.411
Italy	16.250
USA	7.221
Japan	7.000
China	7.000
Spain**	5.100
France	4.003
Belgium	2.567
Australia	2.400
Czech Republic*	2.085

Figure 4: Top 10 countries in total photovoltaic capacity in MW [International Energy Agency, 2013]

And about the contribution of photovoltaic energy to the electricity demand, the next graph shows the main producers. European countries are leader in photovoltaic contribution, and Denmark appears in the tenth position:

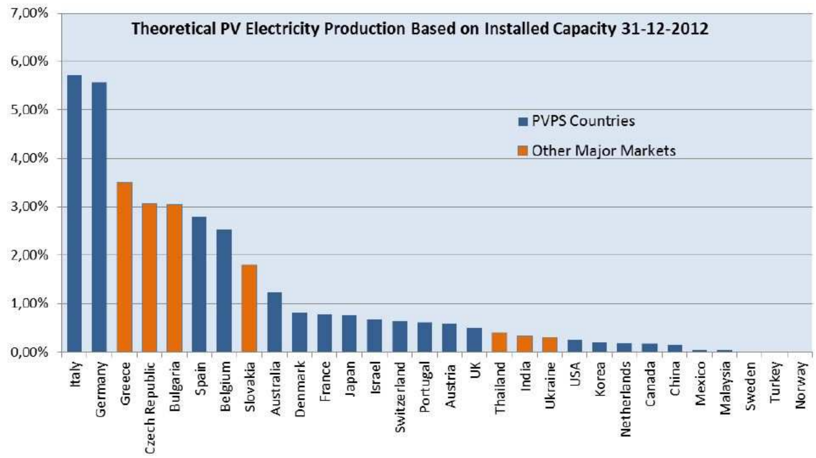


Figure 6 Top 10 countries in photovoltaic contribution to the electricity demand [International Energy Agency, 2013]

And about Denmark, the next graph shows the different data available about its photovoltaic production:

Country	Final Electricity Consumption in 2012	Installed PV capacity 31-12-2012	PV Installations in 2012	Theoretical PV Production with 2012 installed base	PV Contribution to Electricity Consumption
	GWh	MW	MW	GWh	%
Denmark	34.500	327	316	280	0,81%

Figure 7: Statistics about photovoltaic production in Denmark [International Energy Agency, 2013]

Technologies

The performance of a solar cell is one of the most important features to consider. It is measured by its efficiency to transform the received sunlight into electricity. Normally, commercial solar cells have an efficiency of 15%, this means that only the 15% of the light is used to generate energy.

Other important features of the different types of solar cells are the efficiency of the module, which can be a little less than the efficiency of the cells, the area needed per KW produced or the lifetime.

All the actual features of the different kinds of system are shown in the table below:

	Cell effic. (%)	Module effic. (%)	Record commercial and (lab) efficiency, (%)	Area/kW (m2/KW)[a)]	Life-time (yr)
c-Si					
Mono-c-Si	16 - 22	13 - 19	22 (24.7)	7	25 (30)
Multi-c-Si	14 -18	11 - 15	20.3	8	25 (30)
TF					
a-Si	4 – 8		7.1 (10.4)	15	25
a-Si/μc-Si	7 – 9		10 (13.2)	12	25
CdTe	10 - 11		11.2 (16.5)	10	25
CI(G)S	7 - 12		12.1 (20.3)	10	25
Org.Dyes	2 – 4		4 (6-12)	10 (15)	na
CPV	na	20 - 25	>40	na	na

a) A module efficiency of 10% corresponds to about 100 W/m²

Figure 8: Data about existing PV technologies [IEA-ETSAP and IRENA, 2013]

In the next table, the relation between the prices and the efficiency of the different kinds of cells is explained:

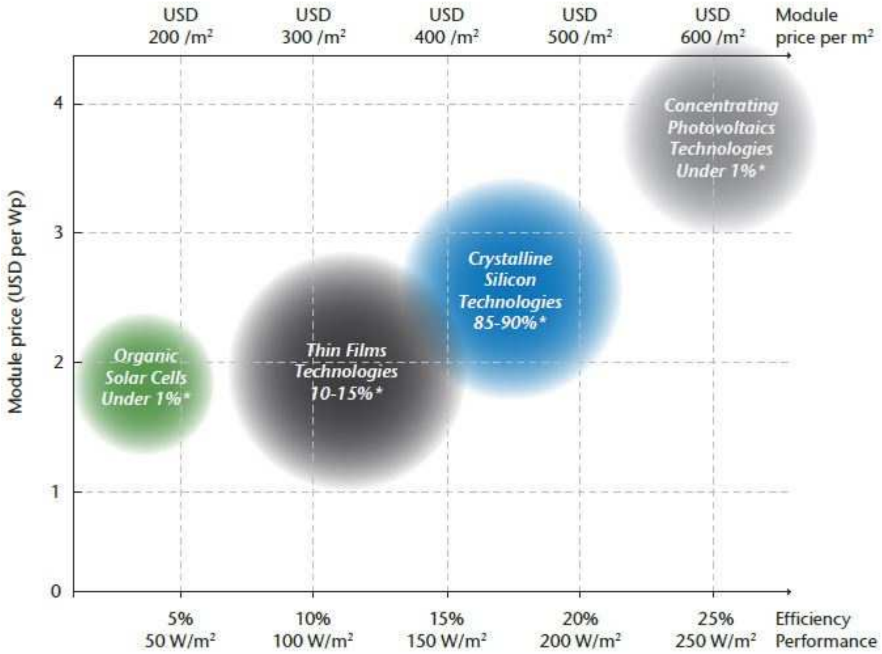


Figure 9: Relationship between prices and efficiencies of different PV technologies [International Energy Agency, 2010]

1sr Generation: Wafer-based Crystalline Silicon Cells:

Silicon is among the most abundant elements on the terrestrial crust, and also the most common material used in order to produce photovoltaic cells representing about 89% of the market today. The most ordinary kind of cells is crystalline silicon cells, which are made with finely cut slices from a single crystal of silicon (monocrystalline) or from a block of silicon crystals (polycrystalline). In commercial modules their efficiency is usually between 13% and 19%, but the record efficiency is around 25%. There are three main kinds of producing solar cells with wafer-based silicon technologies by using silicon in the following different forms:

- Monocrystalline silicon (mono-c-Si).
- Polycrystalline silicon (multi-c-Si).
- EFG ribbon silicon and silicon sheet-defined film growth (EFG ribbon-sheet c-Si).

In order to produce this kind of cells, the next steps are followed:

1- Purification and production of polysilicon.
2- Fusion of polysilicon and formation of ingots and wafers.
3- Transformation of wafers into cells by creating p-n junctions, contacts and the back-coating.
4- Cell and modules assembly with protective materials and frames to increase the strength of the modules.

In the next table the past and future development forecast on wafer-based silicon are explained:

	1980	2007	2010	2015-20	2030+
Module effic., %					
Mono-c-Si	≤8	13-18	13-19	16-23	25-40
Mult-c-Si			11-15	19	21
TF	na	4-11	4-12	8-16	na
c-Si material use, g/Wp			7	3	<3
c-Si wafer thick, mm			180-200	<100	na
Lifetime, yr	na	20-25	25-30	30-35	35-40
En. payback, yr	>10	3	1-2	1-0.5	0.5

Figure 10: Development of PV 1st generation technologies in past, present and future. [IEA-ETSAP and IRENA, 2013]

2nd Generation: Thin-Film Solar Cells (TF).

Thin film modules are beginning to be produced in massively. They are manufactured by depositing extremely thin layers of photosensitive materials onto low-cost large substrates of materials such as glass, stainless steel or plastic. The actual efficiencies of these cells are between 6-12%, and the target for 2020 is to achieve a 12-20% of efficiency. They represent around 11% of the global market.

This kind of cells uses small amounts of active materials so they can achieve a cheapest manufacturing than c-Si. Their energy pay-back time is also shorter despite their lower efficiency. The cells with plastic substrates are usually frameless so they can achieve a flexibility that allows them to be adapted to different surfaces.

The production process is based on the following steps:

1- Placement of a transparent conducting layer on the substrate.
2- Deposition of the active layer.
3- Creation of the contacts in the back.
4- Encapsulation in a glass-polymer box.

Four types of thin film modules (depending on the active material used) are commercially available at the moment:

- Amorphous Silicon (a-Si).
- Multi-junction silicon (a-Si/µ-Si).
- Cadmium Telluride (Cd-Te).
- Copper-Indium-Selenite and Copper-Gallium-Dieseline (Ci [G] S).

In the next table the past and future development forecast on thin-film solar cells are explained:

a-Si	2010	2015-2020	2030-
Max. effic., %	9.5-10	15	Na
Commercial effic., %	4-8	10-11	13
a-Si/µc-Si			
Max. effic., %	12-13	15-17	Na
Commercial effic., %	7-11	12-13	15
Cd-Te			
Max. effic., %	16.5	na	Na
Commercial effic., %	10-11	14	15
CI(G)S			
Max. effic., %	20	na	Na
Commercial effic., %	7-12	15	18

Figure 11: Expected development of PV 2nd generation technologies. [IEA-ETSAP and IRENA, 2013]

3rd Generation: Emerging and novel photovoltaic technologies.

Several investigations are currently on development process, and some of them and beginning to be used. They have the potential to increase the efficiency and reduce the cost of the traditional ones. The most relevant a developed are concentrating PV (CPV), organic solar cells, advanced inorganic thin-films, and some novel and emerging concepts. A few of these technologies are beginning to appear in the market and the feasibility of other options depends on developments in material science and nano-technologies.

- Concentrating PV
- Organic solar cells
- Advanced inorganic thin films
- Novel and emerging solar cell concepts

Concentrating PV.

This is the most developed of the emerging technologies. In concentrating photovoltaic systems, optical concentrators, such as lenses or mirrors, are installed with a solar tracking system in order to focus as much sunlight as possible on high efficiency and small photovoltaic cells.

This technology is finalizing its testing phase and is beginning to be used in commercial applications, especially in large power generation plants. The costs are still really high, so future research to reduce them is needed.

Many materials for the cells and concentrators are being tested. The concentrators used in these systems can increase the sun radiation on the photovoltaic cells in a range from 2 to 1.000 suns.

In concentrating photovoltaic devices, reflection and refraction lenses must be used. In order to achieve high concentration levels, a high accuracy for the optical and tracking systems is needed, so that they can be always pointing directly to the sun. For that purpose, single or double axis trackers are required. Moreover, very high temperatures will be generated with the concentration of the sunlight in the photovoltaic panels, so the installation of heat sinks is necessary.

It is also important to know that concentrating photovoltaic systems only use the direct component of the sunlight, so they will be more effective in areas with very high sun radiation.

Organic solar cells.

They are based on active organic or polymer materials. The cost of this technology is very low because of the materials price and simplicity of the manufacturing processes, which need low energy inputs. It is expected to achieve costs below USD 0.5/ W.

On the other hand, the negative aspect of organic solar cells is their low efficiency (around 4%), and the instability over the time, and further researches on that fields are needed.

Currently, there are two kinds of organic cells: the hybrid dye-sensitized solar cells (DSSC), which are also composed of inorganic elements, and the completely-organic cells (OPV).

Advanced inorganic thin films.

They are advanced and emerging thin film based solar cells. New production systems are used, such as the sphere approach, which uses glass backgrounds covered by a thin multi-crystalline layer with a special interconnection between sphere cells and the multi-crystalline silicon thin films which are produced at high-temperatures (> 600 °C). These technologies are expected to achieve efficiencies of 15% in laboratory tests.

Novel and emerging solar cell technologies.

Several technologies are currently being developed and their feasibility has not been proved at the moment. The main concepts are based on the application of nanotechnology and quantum effects to improve the efficiency of solar cells. In order to get that, some researches want to match the solar spectrum using new active materials or other ones expect to modify the solar spectrum to increase the energy absorption of the actual active materials.

The first results have shown that quantum effects and nano-materials enable a more favourable trade-off between output current and voltage of the solar cell

In the next table a summary of the actual performance and the forecast for future performances and targets is shown:

	2010	2015-2020	2030-
CPV			
Effic.(lab-effic.),%	20-25 (40)	36 (45)	>45
Major R&D areas and targets	lifetime; optical efficiency (85%), sun-tracking, high concentration, up-scaling;		
Inorganic TF (spheral cells, poly-c Si cells)			
Effic.(lab-effic.),%	(10.5)	12-14 (15)	16-18
Major R&D areas and targets	deposition, interconnection, ultra-thin films; up-scaling, light tailoring		
Organic cells (OPV, DSSC)			
Effic.(lab-effic.),%	4 (6-12)	10 (15)	na
Major R&D areas and targets	Lifetime (>15 yr), industrial up-scaling		
Novel active layers			
Effic.(lab-effic.),%	Na	(>25)	40
Major R&D areas and targets	Materials, deposition techniques, understanding quantum effects, up-scaling from lab production		

Figure 12: Expected development of photovoltaic 3rd generation technologies [IEA-ETSAP and IRENA, 2013]

Mobile Solar Panels: Photovoltaic trackers.

A photovoltaic tracker device is used in order to orient the solar panels unto the sun during its trajectory along the day. So, by the use of the trackers, the angle of incidence between the sun and the photovoltaic panel is as nearest to 0º as possible and the performance of the panels is maximized.

Typically, these devices are composed of electrical, mechanical, or hydraulic systems to produce the rotation of the panels. The number of such devices is determined by the number of axes of rotation (azimuth and / or overhead) that is to be set.

Its use is becoming bigger during the last years, and trackers are estimated to be used in at least 85% of the installations bigger than 1 MW in the period between 2009 and 2013.

Trackers are always used in concentrated photovoltaic systems because these systems do not produce energy unless they pointing to the sun.

- Active solar trackers.
- Passive solar trackers.
- One Axis Trackers.
- Two Axis Trackers.
- Trackers with mirrors.
- Bifacial tracking concentrators.

Flexible cells.

Flexible cells are an application of thin film cells. They deposit the active material in thin plastic surfaces and in this way the solar cell can be flexible. By using this technology, a great number of new applications, especially for integrating in building applications such as roofs-tiles and consumer goods applications can be created.

Future Trends.

To increase the weight of photovoltaic in the energy market, the cost of solar technologies should be substantially reduced. The higher percentage of the cells cost is caused by the raw material needed for the production of solar cells because achieving the high purity crystalline silicon required involves an expensive process. The low efficiencies of photovoltaic collectors is also one of the main problems to solve. Using thinner silicon wafers in order to save material and improve the conversion efficiencies, are the fields in which photovoltaic researching will be focused in the next years.

SOLAR THERMAL ENERGY

Solar Thermal Energy is a form of renewable energy in which the sun is used to generate heat. After this process it is possible to harness this energy in a wide range of uses. Actually, this way of absorbing energy has been used for a long time to do different tasks and modern technology make it possible to use it in more and more applications nowadays.

However, it is very important not to confuse the concepts of solar thermal energy with the photovoltaic technology. Solar Thermal has the aim to concentrate the energy from the sun in order to create heat by using different working fluids such as water, oil, salts, nitrogen, helium etc. As a maximum rate this system can get 100 megawatts of power. Differently, photovoltaic or PV energy directly converts the sunlight into electricity which means that panels can only be used during the daylight while the heat can be stored during the day and then converted into electricity at night.

The sun generates every second 4x10^26 watts of energy which is thought to last for another 5 billion years. Therefore, it is worth it to take advantage of this energy as much as possible. Moreover, this kind of energy is the most cost-effective solar technology in the long run competing against fossil fuels. We live in a huge industrializing planet and one important issue is how to make solar thermal technology-energy more economical and efficient.

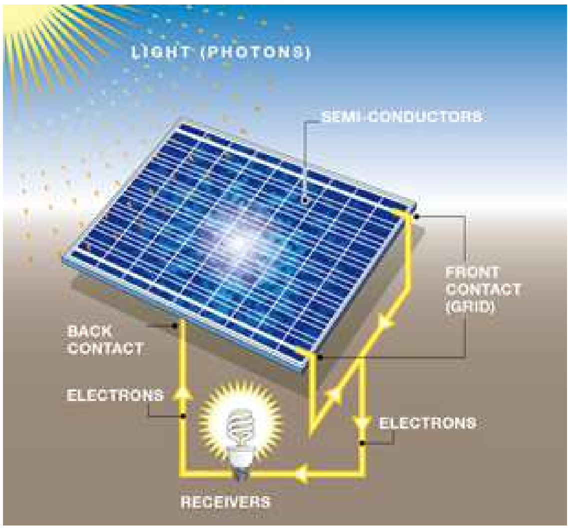


Figure 13: Parabolic dish (Solar Thermal)

In the left figure, we can see that the engine is driven by a parabolic dish which collects and absorbs the sun to convert it into a heat source in order to run the engine and produce power. In the right figure, we can appreciate that by using semi-conductor in a photovoltaic panel we get electrons from the light (photons) of the sun.

Solar thermal collectors

The solar energy system can be classified in three collectors by the Energy Information Administration (EIA): low, medium or high temperature collectors.

Low-temperature systems:

We need a solar collector to absorb the energy. This type of collector does not reach the boiling point of the water; it reaches as much 60º. They can be used to heat sanitary water and swimming pools. Heating is the most obvious application in this case. It can be used either throughout the year or seasonally. Depend on the system we used, passive (we do not need a pump to impulse the water because the system is settle on the roof and the gravity makes the water go down) or active systems (we need a pump to impulse the water to the height we want), other external energy could be necessary in order to run the passive system. Each panel is composed by an absorbent layer which receives the solar radiation that is transformed into heat. Once the radiation is transformed, this is transmitted to a fluid (commonly water) which will transport it along the connections. For Low-temperature collectors are generally used flat plates which we can see on the next picture:

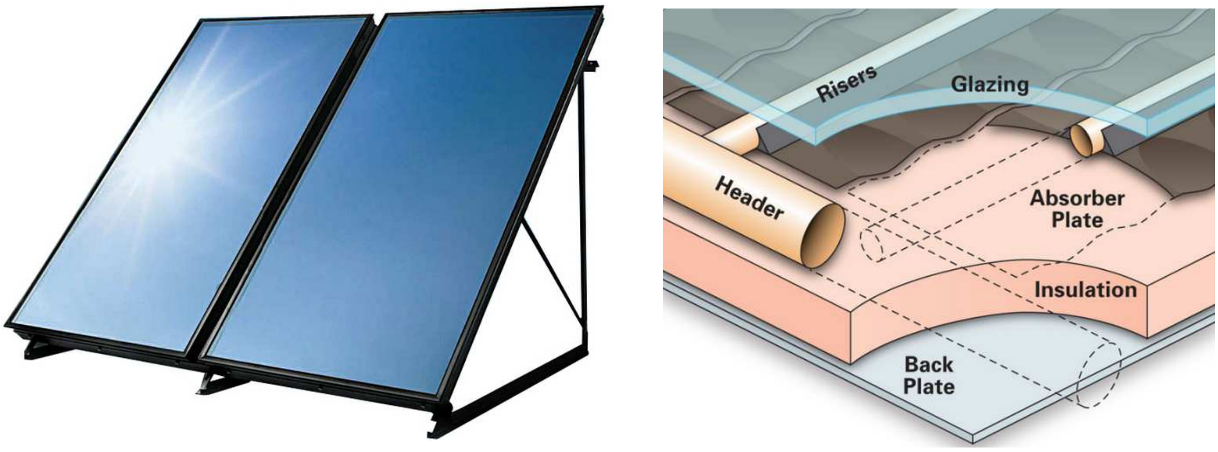


Figure 14: Flat plate (Low-temperature system)

Flat plates consist of an absorber plate (composed by a sheet of copper) bonded to pipes which contain the heat-transfer-fluid. The copper and the pipes are enclosed to an insulated metal frame and topped with a sheet of glass (commonly called ''glazing'') to protect the absorber plate and create an insulating air space. The number of panels needed to heat a pool effectively depends on the surface area of the pool, and the specific location (latitude) of the pool and the slope of the surface on which the panels are located. Actually, the existing pump of the pool should be sufficient to the water to go through the thermal collectors. The components needed to carry out this system are collector subsystem, circulation subsystem, control subsystem and backup heater, which are commonly the natural gas.

Medium-temperature systems

Medium-temperature collectors are also usually flat plates but in this case we used the heat of the plates to generate heating water or air for either residential or commercial use. This type of collector exceed the boiling point of the water, which is <100º. They are usually used for industrial processes such as thermal fluids, desalination of sea water or refrigeration using solar thermal energy. This system can be used to reduce natural gas in a standard water heater by about 70%, which is very beneficial for the environment as we reduce the carbon emissions. Moreover, this method allows us to have more instantly available hot water. In standard system water consist of the next process: from the storage tank the water is passed through the solar collectors where it is heated and then the water returns to the tank. In sunny days we can have in the storage tank the temperature around 60º. To circulate the water we have also two systems: active and passive. The active heater uses a small pump to make the water flow whereas the passive heater utilizes a siphon action. The only drawback of the passive system is that the storage must be set on the top of the house to use the gravity as a medium of force. This domestic hot water could be used for instance for showers, laundry, process applications, space heating and even for space cooling.

High-temperature systems

This system concentrate the solar rays from the sun by using mirrors or lenses focus the light into a specific zone in order to produce high temperatures which may be even above 100º. Some examples are:

- SOLAR TOWERS: In this system the sunlight is focused into a boiler, which is located at the top of the central power, by an array of moveable mirrors that track the trajectory of the sun. The boiler uses a synthetic oil or molten rock salt as these elements have very good conductivity. This tower could produce between 30 to 200MW.

Figure 15: Solar Tower Manzanares (Spain)

- PARABOLIC TROUGH: This method uses wide areas of parabolic trough covert by mirrors with a tube running across their distance at the focal point. By using a heat exchanger, the system has not only an efficiency of solar electricity, but also of the thermal one. These plants use conventional power generators

Figure 16: Solar Parabolic trough (Solar-millenium)

which need other hybrid systems such as condensers and accumulators. With this system we could be able to generate around 80MW as maximum.

- PARABOLIC DISH: This solar thermal energy sets the engine itself at the focus of a parabolic dish shaped mirror. The temperature at the focal point might reach nearly 3000º which can be used to electricity generation, melted steel or even to produce hydrogen fuels. It is possible to generate between 8 and 26 KW as maximum. This is the most common way to concentrate solar energy because the mirrors can reflect the rays from the sunlight in a parallel way. This allows the system to focus all the reflections in a single point. At the same time, we can concentrate the rays of the sun on the line focus or the point focus. The difference compared with the other systems, is that the others do not concentrate the solar rays. Instead of that, the area needs to be heated being directly exposed to the sun without auxiliary components. This mean, that the other systems are less efficient even though they are easier to build and the technical failures are less frequent.

Figure 17: Parabolic dish

We make use of three different systems and processes to get solar thermal energy. In the next picture we can see the 3 types of circuits:

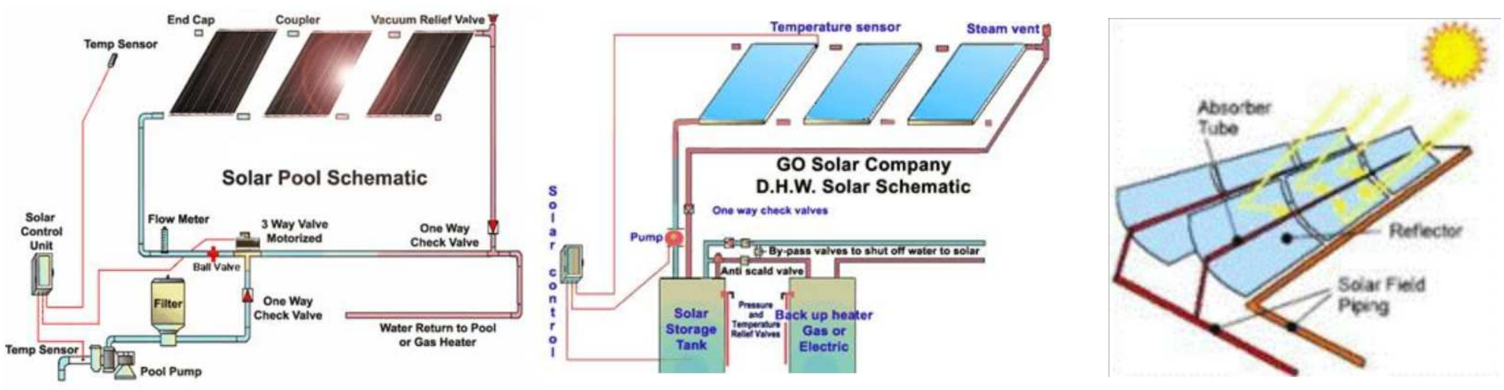


Figure 18: Types of circuits

Solar Thermal Energy Applications

This type of energy has a wide range of applications which we can take advantage of in the field of sustainability and efficiency, above all.

Domestic Water Heating

This method uses the sun's energy using a flat plate solar collector which absorbs the energy, and then it transforms this into heat and finally transfers the heat to water or another sort of liquid which can flow throughout tubes and pipes. This allows us to maintain a reservoir when we need hot water at home. In addition, this system frequently helps to reduce the bills of electric, gas or hot water in approximately 50%. There could be used two different systems to produce hot water: active and passive. We understand as an active system that needs to be pumped whereas the passive one means the use only natural convection such as the gravity. Therefore, if we want to use a passive system the best disposal would be to install the collector on the roof of buildings.

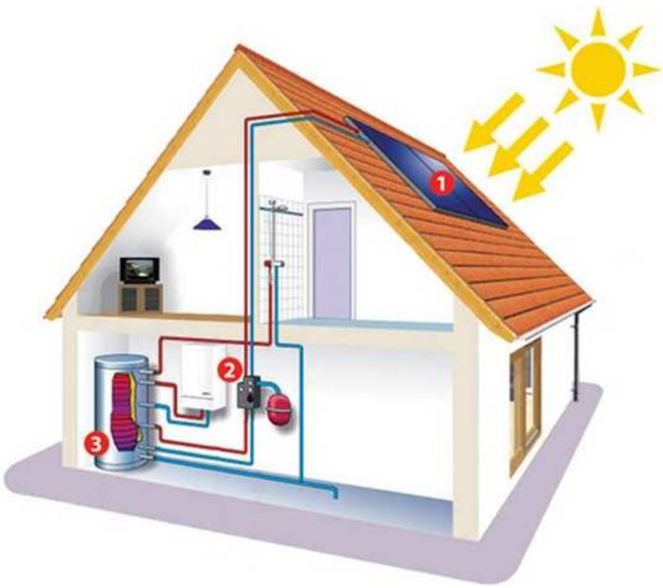


Figure 19: Domestic water heating (Harveys)

Domestic Space Heating

By using a solar heater we can collect sun energy with a thermal mass, which is storage when the building is cold inside. This thermal mass might be a masonry wall, the floor or any storage used to absorb and then store all the energy. A lot of systems are involved in the distribution of the heat and the control of the devices to circulate it throughout every room and to prevent us from losses caused from the collector area. All these systems could be joined with a solar hot water device. This may result in an economical reduction by the non-use of electrical heating systems.

Solar cooking

This is a technology which has suffered a great development in the last years in a lot of countries. It is a design of a box with a glass cover. The box is insulated and it is necessary to use a reflective surface to focus the heat on the pots. This could be paint with different colours but it is more recommended to use the black one in order to increase the absorption. The result is that the radiation increases the temperature in a way that we achieve to boil the contents inside the pots. Thus, the cooking time is lower than the conventional stoves and at the same time we are not using fuels. The only disadvantage is related to the effective hours of sunlight.

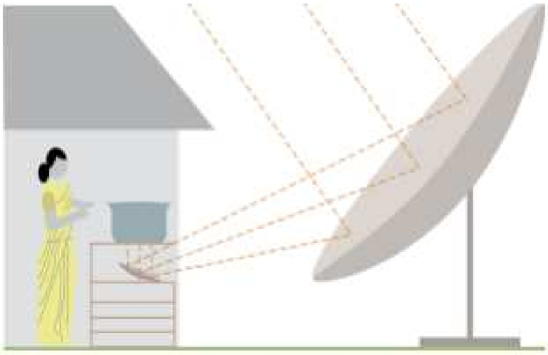


Figure 20: Solar cooking (CSTEP)

Crop Drying

This is usually used for crops and some products like grain, tobacco, coffee, fish or vegetables. We can improve its quality if we dry it properly. Solar thermal energy could be applied to aid drying of these products. The point is to increase the heat of the product that is inside a box and also to use hot air to avoid moisture inside. This flow of air is promoted by using the ''stack effect'' that takes advantage of the situation of the hot air rises. The size of the compartment might vary depending on each product and the scale of the drying system, which we are using at that moment. Moreover, the crop drying technologies help to reduce the environmental degradation which usually is caused by the use of fossil fuels as well as to get beneficial effects on health.

Figure 21: Crop Drying (CSTEP)

Space Cooling

The hottest countries of the world need cooling rather than heating. There are a lot of methods to minimize the heat. This could be solved with the settlement in shade or near water of course as well as the use of vegetation. These buildings must be designed with domed roofs and thermally massive structures, above all in arid climates. In some countries dwellings are built underground in order to maintain the same temperature throughout the years. So, this is a way to avoid the exposition to the sun rather than absorb its energy. This technology can turn the solar power energy into air conditioning. The absorption cooling is fundamentally an air conditioning system which is not lead by electricity but by a heat source that is the sun. This works in a way that solar panels catch the sun's heat to increase the temperature of the water in a storage tank. The resultant hot water is pumped by a generator to a chiller. This machine contains an absorbent liquid which yields the refrigerant that produces the chilled water as a result. The inside air in the building is pushed by the use of a fan. The cool air circulates around the building and the hot one is replaced. If we make use of a passive solar cooling on the other hand, we can cool the building without the use of machines of air conditioning. That is, we use shading and natural ventilation by using suitable materials in the construction. The technique of shading could be considered with the use of deciduous trees on the sunniest side of the house or building and for more resistance we could set these trees also on the east and west side to achieve the maximum results. It is necessary to set materials like wood and thermal, whose thermal mass is low as it is very difficult to heat them and at the same time these materials cool down very quickly. In addition, by using reflective exterior surfaces we can avoid large amount of the sun thermal energy which should be put away by the use of right surfaces like this. It depends also on the colour and the texture of the material. To follow the adequate approach we have to set reflecting roofs which avoid the sunlight instead of absorbing it. These systems are much more recommended in areas such as Africa, Australia, south-western of USA.

Figure 22: Solar space cooling

Day Lighting

This is the easiest way to take advantage of the solar thermal energy. Provide sun light to use it in buildings. A lot of new buildings such as commercial or office blocks are designed in a way which the electric light must be provided during the light time every day to perform the activities there. It would be very beneficial if we could install a design in which we could attract all the possible light. The energy saved would be quite significant and also the natural lighting would be preferable than the electric lighting.

Solar Pool Heating

This system consists of a pool heater which collects energy from solar panels (low temperature system) to warm the water which is pumped into the pool increasing its temperature. This method is quite cheap compared with electric or gas pool heaters as well as more environmentally friendly. The solar pool heating works in a way that cold water from the pool is pumped to a filter reaching the solar panels (usually low-temperature solar collectors) setting it on the roof in the most cases. When the water crosses these panels, it is heated by the energy from the sun and finally, the water returns to the pool. This process is repeated as many times as it is necessary to reach the heat we want for our pool. We can use two types of solar pool heating panels; glazed and unglazed. A glazed panel contains a transparent glass which is applied above the top of the absorber to reduce the heat loss. This system is insulated to increase its ability to operate in freezing conditions. On the other hand, an unglazed panel consists of an absorber made of metal, polymers or even rubber. They are more common in moderate climates.

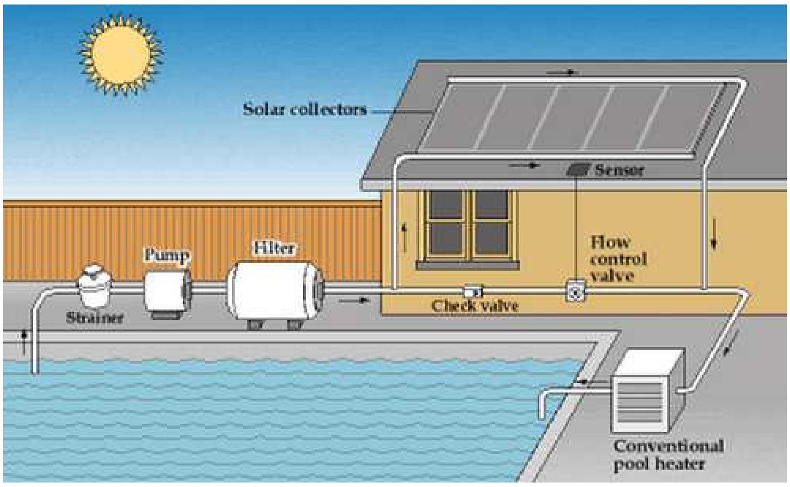


Figure 23: Alternative energy primer

Economic advantages and disadvantages

In terms of economy, solar thermal energy reduces the standard cost in a 70%. If we use this type of energy in houses, we can save energy, reduce our bills and at the same time we could be environmentally friendly. A lot of commercial building owners are starting to use this type of energy in to minimize the quantity of carbon-based greenhouse gases.

Solar power is the second most expensive energy source available. In the next picture we can see that both photovoltaic and solar thermal energy are less cost-effective of alternative energies nowadays. Therefore, it is strongly necessary to improve and advance in these types of energies in the next future as we can take advantage of them considerably if we find the way to enhance the power we receive from the sun. Unfortunately, today the solar thermal energy only represents a tiny fraction of renewable energy.

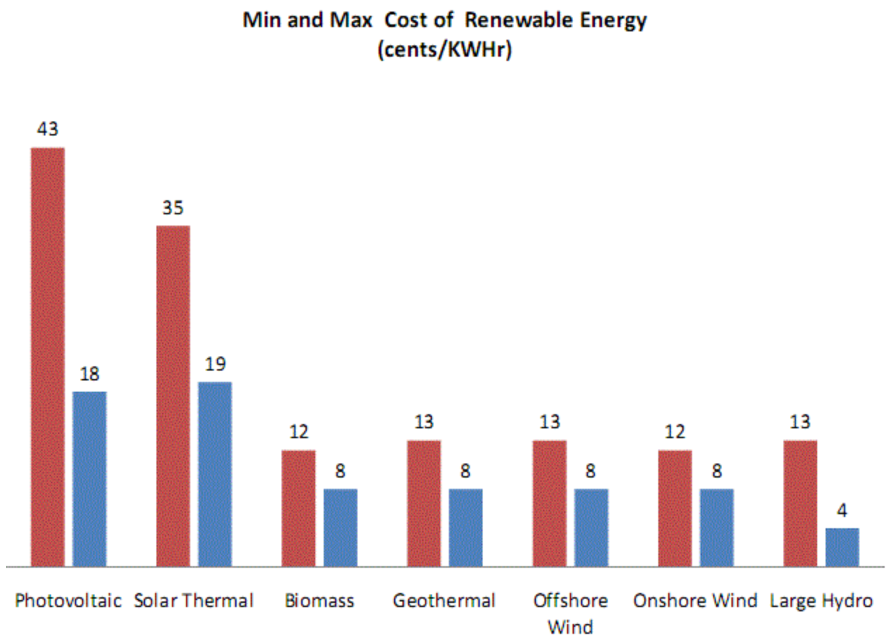


Figure 24: Large.standford (Andrew Danowitz, 2010)

Conclusions

All in all, we could say that this energy is not very empowered nowadays in terms of worldwide. The countries which are using this sort of energy more frequently are China and India which has suffered a great development in the last years in renewable energies. Secondly, we find that USA is improving its use recently, above all in the third group of solar thermal energy, most specifically in high temperature with the use of solar towers, parabolic trough and parabolic dish. Europe is developing some systems to absorb this energy even though it is not enough yet to take advantage of this energy properly. It is thought in general terms that in 2035 we are going to have suitable devices to enhance the power of the sun over the world. Anyway, solar thermal power generation is a unique choice among the renewable technologies nowadays. The system is highly understood and known around the world. The prototypes to catch the sun-light energy and commercial power plants are very developed and they are very affordable in areas with plenty of sunlight even though in the future it will be quite better. Taking into account the materials which are necessary to carry out these systems, we can say that the production of these release very low co2, therefore it is not harmful at all for the environment and the atmosphere. By increasing the use of this energy at the same time, we are reducing the fossil fuels used nowadays and the costs.

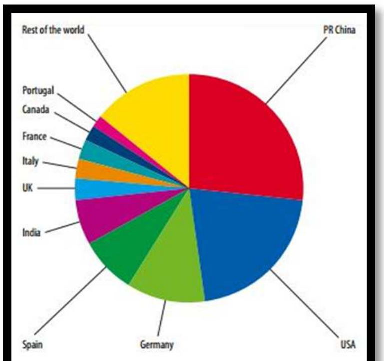
These properties of solar thermal energy make this a great and power source of energy. Most renewable sources are relatively expensive compared to coal and nuclear but more efficient and ecological.

WIND ENERGY

Introduction

Definition

The wind energy is the energy obtained from the power of the wind. This means to transform the kinetic energy of the airflows into another kind of energy useful for the human activities. We have different devices to make this transformation: wind turbines, if we want to obtain electrical power, sails to propel ships, windmills to get mechanical power and wind pumps to drainage or to pump water.



Country	MW	% SHARE
PR China	75,324	26.7
USA	60,007	21.2
Germany	31,308	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France	7,564	2.7
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	242,734	85.9
World Total	**282,587**	**100.0**

Figure 25: Wind Energy capacity in 2012 (GWEC, 2012)

We can find uses of the wind energy since 3000 years, principally to mill grain, to pump water or to propel ships. But in this paper we are going to attend to the devices used for obtaining electric energy, the wind turbines. The first wind turbine to generate electricity was developed by the Danish Poul la Cour in 1891. During the following years and much of the twentieth century, this technology did not awaken great interest. All changed at the beginning of the 1970s, when the price of oil suffered a high increase, so governments started to invest in other alternative technologies. We can see an exponential growing of the wind energy, from this point due to the improvement of the technology and the increasing support from the governments. (Burton, et al., 2001)

Figure 25 shows the top 10 countries in wind energy capacity. This represents the quantity of power capacity using wind energy, but if we regard the percentage that represents the wind over the rest of energies per country, we can see that in Denmark 21% of the energy comes from wind, or in Spain that it is 16%, which represents an great important part of the energy and it is still growing (Global Wind Energy Council, 2012).

Principles of working

It could be said that wind energy is an indirect form of solar energy. From the sun arrives energy that heat the earth surface in an irregular way, so that the air is heated more in one zone than other. Hot air rise, because its density is lower, dragging air from the neighbouring region. When air raise, it get cold, increasing its density, so it falls to repeat the cycle again. These convective currents are what we call wind.

Air circulation is influenced by several forces: pressure gradient because of solar radiation is higher in the Equator than in the Poles, gravity force, Coriolis Effect for the earth rotation and friction force mainly in the lower atmosphere (Grogg, 2005).

Due to the friction force, wind suffers a variation of the velocity with the height. The variation is function of the soil type and follows a statistic exponential law, Hellmann's law (Kaltschmitt, 2007):

Location	α
Unstable air above open water surface	0.06
Neutral air above open water surface	0.10
Unstable air above flat open coast	0.11
Neutral air above flat open coast	0.16
Stable air above open water surface	0.27
Unstable air above human inhabited areas	0.27
Neutral air above human inhabited areas	0.34
Stable air above flat open coast	0.40
Stable air above human inhabited areas	0.60

$$V_h = V_0 \left(\frac{h}{h_0}\right)^{\alpha}$$

Here we have some examples of different values of the Hellman's coefficient (Kaltschmitt, 2007). We see that the lowest values of it, is over water and coastal areas, so the influence is lower. The highest values are for urban areas, so here the influence is bigger. This is an important factor to design ours turbines.

The power that we can take from the wind is proportional to the cube of its speed. But it is not possible to take all the power that comes from the wind because that means, in order to take all the energy, that the exit wind has to be stopped, but it is not possible. The engineer Carl Betz concluded that the maximum power that could draw was 16/27 (≈0, 59) of the maximum wind power. This coefficient is Betz coefficient and is the optimum theoretical, but the normal turbines takes much less than this proportion from the wind. The best turbines nowadays can achieve the 70-80 % of the Betz coefficient (Grogg, 2005).

Benefits and disadvantages

Attending to the authors Fthenakis & Kim (2009), Jha (2011) and BoroumandJazi, et al. (2013), then the main advantages and disadvantages of wind energy are collected.

The benefits of the wind energy are mainly the related to being a renewable energy; it is an energy that never ends. It has low polluting power, after the solar energy, it is the least contaminant. It is not necessary any combustion process during the generation and transport, which is beneficial to the environment. The electricity that a wind turbine produces reaches a capacity similar to 1.000 Kg of oil energy, avoiding burning this quantity of fuel and the CO2 emission that it entails. Wind energy has less aggressive impact on the ground and the water; it doesn't greatly alter the soil composition because it doesn't produce discharges of pollutants or large earthworks as other energy sources.

As an emergent sector inside the energy field, other benefit of the wind energy is that jobs are being created to cover the necessities of the sector. Governments are investing more and more in these resources, so the technology is being greatly improved. Now turbines are more efficient, being wind energy the cheapest among the renewables. We can find another benefit in the improvement of the construction process; nowadays the times of construction of wind parks are very low.

The disadvantages of wind energy are mainly two: the intermittence of the wind and the impossibility to store the electricity, and the different impacts. The wind has high variation during the time, it depends on the hour, day, season… and the electricity produced by the turbines has to be consumed at the time that is produced, so is difficult to coordinate the irregular production with the demand of electricity. Impacts produced by wind turbines may be of different types. One of the most important is the noisy annoyance. Other impact could be over the wildlife, bird for instance, that can crash with the blades of the turbine. The visual impact is another negative effect because as the turbines need big open areas, many times are in the nature and can damage the landscape. Other disadvantage of this need of big spaces is that big areas, sometimes, have to be expropriated. The neighbour areas also experiment a decrease in its value.

Wind Turbines

After this quick overview about what is the wind energy and some of its main features, now we are going to focus on the devices to obtain this energy in order to know the different types and its characteristics, to create a guide for later use in the sustainable rehabilitation of urban areas.

Classification

One first classification that can be done is attending to the power rating. There are some official classifications, but each one changes depending on the organization that have done it, so after regarding the ITDG (UK), NREL (USA) and EWEA (Europe) organizations, the classification depending on the power rating is:

Wind turbines	Power Rating
Large power	>500kW
Medium power	100-500 kW
Small power	10-100 kW
Micro-turbines	<10kW

But this is not the only classification; different classifications could be done, attending to other different aspects of the turbines technology:

- According to the working axis: we have two different configurations, the Horizontal Axis Wind Turbines (HAWT) or the Vertical Axis Wind Turbines (VAWT)
- Depending on the number of blades, to classify the HAWT
- Depending on the position of the rotor, they can be windward or leeward machines
- According to the anchoring of the propeller hub, if the blades can be oriented or not.

Hereafter, during the study of the turbines, we will differentiate the turbines according to the position of working axis.

How to select the wind turbine?

There are a lot of factors to decide when we want to install a wind turbine. We have to choose the emplacement, the typology of turbine, number of blades, height… all influence by the power we want to obtain, the environmental impact and the economic aspects. Here are shown some examples about how to decide different features.

The first step to select the proper wind turbine is to characterize the wind. We have to know all the characteristics of the wind before. We should know all the wind parameters, the wind speed distribution, the local air flow and how are them related with the topography (Herbert, et al., 2007).

With all the features of the wind well defined, it is necessary to decide the other features of the turbine. For the scope of this work, it is not possible go too deeply on this study about how to select the wind turbine. As it was said before, there are a great amount of factors involved, so it is impossible to explain each one in detail. Some explanations about how to define some aspects are shown. For instance, as it was shown before, the wind speed changes with the height, so as higher is the turbine, the more energy produce. The figure 26 shows how the power and size of turbines changes with the height (Bullis, 2009).

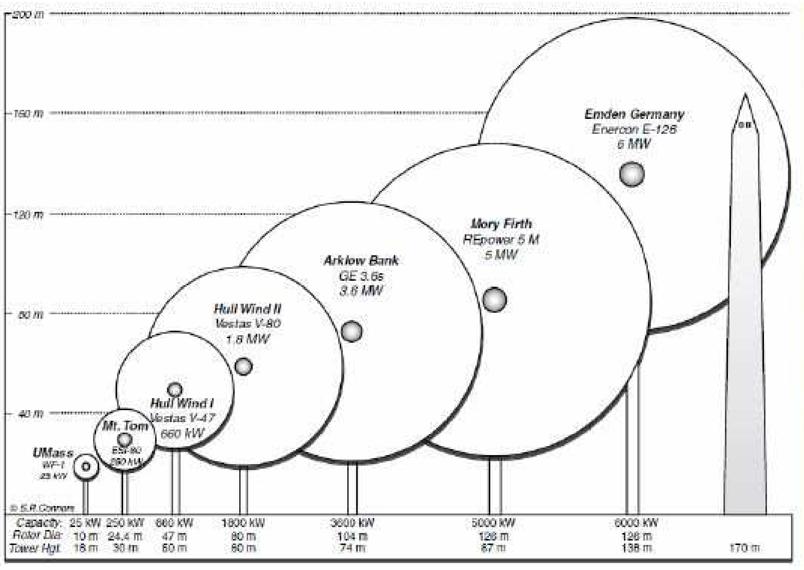


Figure 26: Wind turbines variation with height (Bullis, 2009)

Other thing to choose is the kind of turbine to use. In Hau (2006), it is shown the optimal point of work per each typology of wind turbine, function of the tip-speed ratio, which could help us to choose the proper turbine (Figure 27):

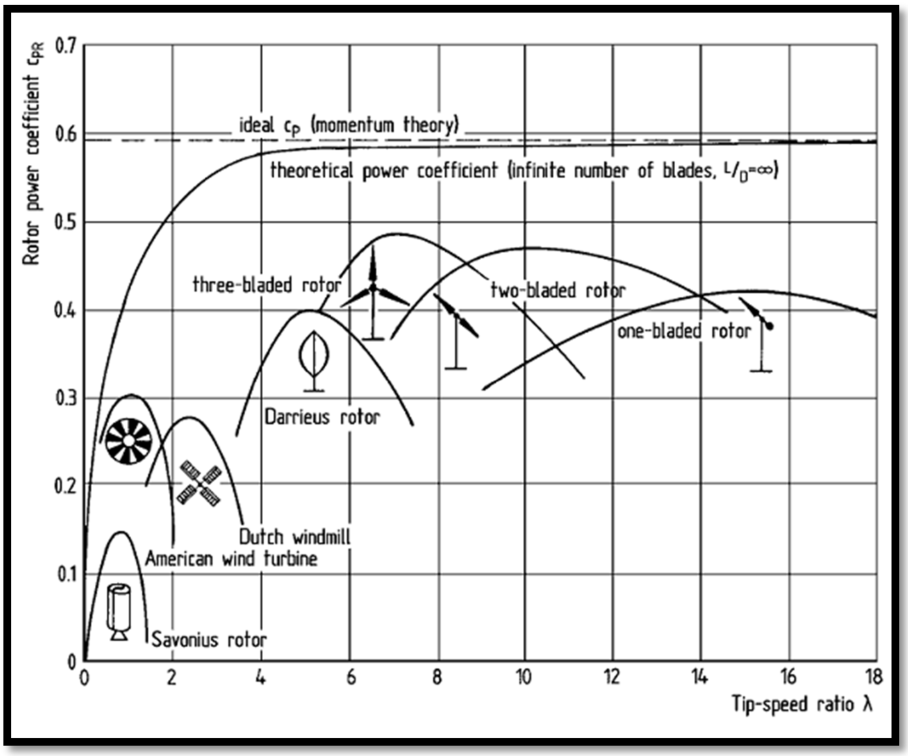


Figure 27: Rotor power coefficient Vs. Tip-speed ratio (Hau, 2006)

Once we know the main aspects of wind energy, the classification and how to choose a wind turbine, we are going to go on with the explanation of the main wind turbines technologies to apply them in the renovation of a town.

Horizontal axis

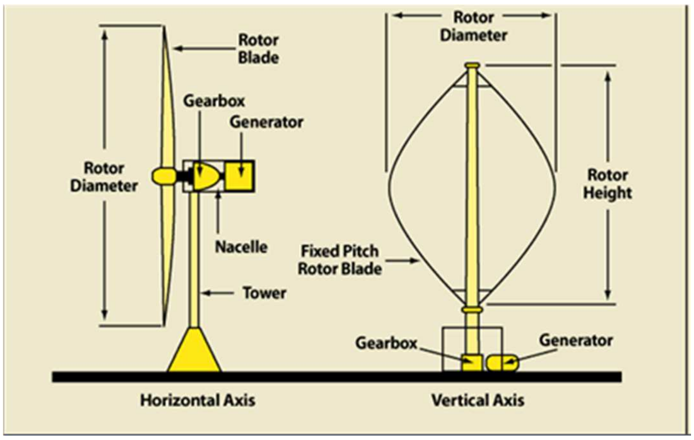


Figure 28: HAWT &VAWT (Dharmasiri, 2013)

The horizontal axis wind turbines are known as HAWT. These turbines are those in which rotor blades are connected to a horizontal shaft, parallel to the ground. In the figure 28 we see a schematic representation of the disposition of the different elements of a wind turbine depending on if it has horizontal axis or vertical (described in the next point). This configuration, HAWT, is the most used in the modern wind turbines for its aerodynamic lift. (Ozger, 2006).

There are two main configurations of HAWT, one with the rotor upwind, to face the wind and the other with the rotor downwind with the wind passing before through the nacelle and tower.

In the figure 29 we have the main elements that compound the wind turbine. They are almost the same that are used on a VAWT, so they are going to be described here, in a HAWT. We can distinguish three principal blocks of components, the rotation elements, the generation elements and the structural components.

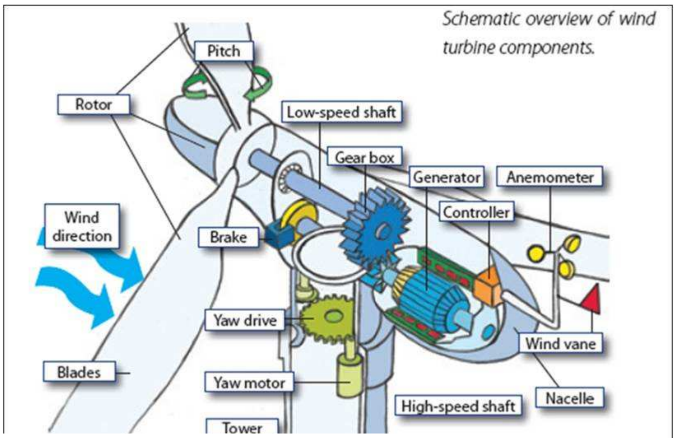


Figure 29: Wind turbine components (Jha, 2011)

Rotations elements are compound of the blades, with or without pitch, that are connected at the hub, which transmit the rotation to the low-speed shaft and enter the rotation into the generation elements. The generation elements are inside the nacelle. The low-speed rotation becomes high-speed rotation in the gear box. Then high-speed shaft moves the generator transforming the movement into electricity. The structural components are in charge of bear the nacelle, which has a rotation movement over the tower through the yaw drive and yaw motor. The tower serves to raise the nacelle and support efforts, and the foundation transmits the efforts to the ground (Jha, 2011).

Comparing HAWT with VAWT, we find more differences apart from the disposition of the rotation shaft. With the same quantity of wind, HAWTs produce more electricity, takes more energy from the wind (more efficient) and are the most common typology to produce electricity in a big scale. They are also heavier. The wind that HAWTs need has to be from a specific direction, it can be changeable or turbulent. Works with winds between 6 m/s and 25 m/s (20-90 km/h) and are self-starting. It can be installed in extreme weather zones. HAWTs are dangerous for the birds and the installation and transport are difficult (Islam, et al., 2013).

Vertical axis

The vertical axis wind turbines are known as VAWTs. In these kinds of turbines the rotation axis is in vertical position, perpendicular to the ground. In the previous point, we have seen in the figure 28 the two types of turbine. In this case the generator and gearbox are on the floor, reducing the weight of the turbine. We can find application of these turbines in Persia in their windmills. Now the VAWTs are suffering an increase of their use, due to its possibility to be used in small areas, to produce energy for small areas. The technology is improving and the prizes are going down and are easy to maintain (Islam, et al., 2013).

There are three different types of VAWT: Savonius rotor, Darrieus turbine and Giromill. In D'ambrosio & Medaglia (2010) there is a description of each technology:

Savonius rotor

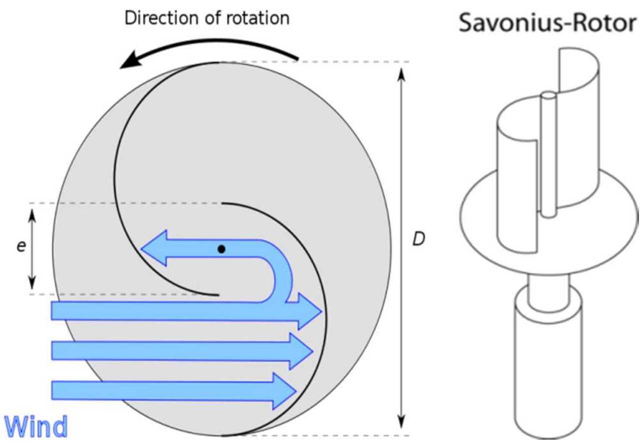


Figure 30: Savonius rotor (Wikipedia)

- It was developed in 1922 by the Finnish engineer S.J. Savonius. It is a simple rotor, with an S-surface around a central axis.

Its efficiency is the lowest among the wind turbines because of its configuration. It rotes with a speed lower than the wind. It has not use to generate great among of electricity.

Its application is reduced, but its benefits, as reliability, low noise, simplicity and economic, make it useful for small generations in a family house for instance.

But other applications apart from the electricity generation are more important for this device, as using it on advertisement or to small pumping of water

We can find a variant of the Savonius, using a helical shape in order to improve the torque and use it with low speed winds

Darrieus turbine

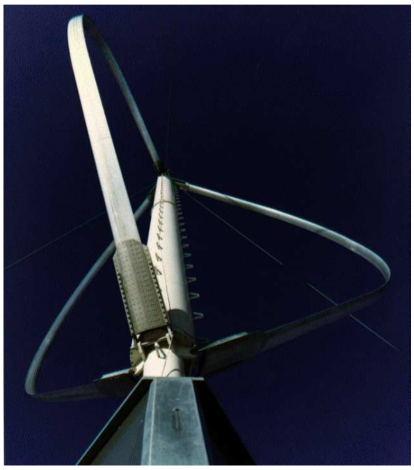


Figure 31: Rotor Darrieus (D'ambrosio & Medaglia, 2010)

It was developed by French engineer Georges Jean Marie Darrieus in 1932. This kind of VAWT is one of the most used and has settled the basic for the development of similar turbines.

This device consists, normally, in a system compound of two or three curve blades around a vertical axis of rotation. It has some problems due to its configuration, the angle of attach changes, so some efficiency is lost, and the mass are in the perimeter, generating a big centrifuge force.

Several big turbines have been developed, reaching a high of 100 meters and a power of 4.000 kW.

Giromill

Figure 32: Giromill (D'ambrosio & Medaglia, 2010)

It was developed also by the French engineer Georges Jean Marie Darrieus in 1927, before the previous one. Also is called H-rotor.

In this turbine, the blades are straight and are supported by a horizontal structure, instead of the curve-shape blades directly attached to the shaft. It is compound of 2 or 3 air foils or blades. It works in the same way of the Darrieus with the wind hitting the blades, rotting the system.

Comparing it with the Darrieus, it is simpler to build, so it is cheaper, but it is heavier than the Darrieus and less efficient. During the start it is needed a motor. It has application with turbulent wind when the HAWTs have not got application.

We can find some prototypes of this generator, with 45 m of height and 38 m of diameter. The powers developed have arrived until 300kW.

After having seen the three main typologies of VAWTs, we are going to sum up some of the principal features of this kind of turbines. Comparing with the HAWT, the VAWTs can produce more than 50% of the electricity during a year for the same swept area. It has application for small areas and residential productions. They can produce energy with winds that comes from 360º in a turbulent way. The range of wind speed is between 2 m/s and 65 m/s (7, 2-234 km/h), but it has difficulties with the start, sometimes needs energy. They resist better the extreme conditions. They are lighter, so are easier to transport and cheaper to build (Islam, et al., 2013).

Wind farms

To obtain electricity, the most common is to find the turbines connected in groups, what is commonly known as wind farms. Sometimes turbines can be found in isolation. These groups of turbines can be On-shore or Off-shore.

- On-Shore

On-Shore wind farms are the most frequent way of finding groups of wind turbines. The most important thing when we build a wind farm is to select the perfect emplacement. Previously we need to make a deep study of the wind of the zone. Usually the turbines are emplaced on large areas in hilly regions using the acceleration that obtains the wind due to the topography. The exact position of each turbine is well studied, being often the spacing between turbines from 3 to 10 times their diameter because of the turbulence generated per each turbine affect to the surrounding turbines. All this happen with the wind farms of HAWT, but with the VAWTs it is possible to have smaller occupations of the ground due to they work when the wind is turbulent, so they could be placed closer (Luleva,2013).

The biggest wind farm is in Alta (EE UU) with a capacity of 1.320 MW. In USA we find 10 of the 13 biggest On-Shore wind farms in the world.

- Off-Shore

Off-Shore wind farms are the wind farms that are emplaced in bodies of water, and it involves not only marine areas, also include lakes or fjords for instance. In this areas the wind is better to obtain electricity, is more constant, less turbulent, and more uniform and the speed is higher for the same height comparing to this same height in On-Shore wind farms (Garvine & Kempton, 2008).

On this technologies, Europe is the leader, and most of the research inside the wind energy field are been developing on this way, because for the moment its application is low, but the possibilities are huge. The biggest Off-Shore wind farm is London Array (UK) with a capacity of 630 MW (Ames, 2013).

Application for renovation

As a final point of our study about wind energy, it is going to be analysed the technologies that could be applied for a sustainable renovation of a district, village or city. We have done an overview of the technology and we have seen the main technologies. The big size turbines and wind farms described previously are designed for the generation of large amounts of electricity; to supply the electricity needed the entire village for instance. But the scope of this paper is the renovation of a village or district, so the proposed actions to do it are of small entity. The objective is to install generators for small applications, such as family self-generation or for street lighting, for instance. We are going to show the main small wind turbines used currently and also the typologies of wind turbines to integrate it in a building.

- ***Small wind turbines***

These turbines are those that have a lower power of 5kW. Their applications are diverse, as lighting, domestic equipment, telecommunications, marine platforms, for example. They have a residential scale, with diameter between 2 and 7 meters, even reaching weights of 16 kilograms.

Most of small turbines has horizontal axis, but vertical axis are experiencing a high growth. These usually are installed on the roof and are connected directly to the grid through some devises that provide electricity with constant frequency.

Here we show the most sold wind turbines in the word, but in the next link you can find a big list of different commercialized wind turbines: www.allsmallwindturbines.com. The specifications of each turbine, with all their information, have been taken from their web pages:

1. Bergey: this company commercializes different size of turbines. They have 1kW or 7.5 kW if it is off grid turbine, or 6kW or 10 kW if it is grid tied turbine. With rotors from 2.5 meters to 7 meter of the biggest one.(http://bergey.com/)
2. Xzeres: Recommended for residential uses, agriculture or small business. They have two turbines ones with a power of 9 kW and 7, 2 meters of diameter and the other with 2 kW and 3, 7 meters (www.xzeres.com/).
3. UGE: This Company provides services of sustainable renewable solution for small application. It is the only between the five that use vertical axis wind turbines with a helical Darrieus design (www.urbangreenenergy.com).

4. Gaia-Wind: They have more than 20 years of experience in the sector. They turbine is called Gaia-Wind 133 turbine, with a rate power of 11kW and a diameter of 13m (http://www.gaia-wind.com/).
5. Evance: They have a turbine with a power of 5kW and a diameter of 5, 5 meters. They also give solution of more power, using several of their turbines (http://www.evancewind.com/).

Above we show one figure of each turbine, taken from their respective web pages:

Figure 33: Berger

Figure 34: Xzeres

Figure 35: UGE

Figure 36: Gaia-Wind

Figure 37: Evance

- ***Building integrated wind turbines***

Apart from these small wind turbines, there are other turbines that could be integrated inside the building, the Building Integrated Wind Turbines (BIWT). It could be over the roof or even integrated into the façade. Most of these wind turbines are small turbines, but also there are examples of BIWT with large wind turbines; it is the case of the Bahrain World Trade Centre, which was the first building in the world in incorporate wind turbines in its façade in 2008 (Dutton, 2005)

Figure 38: Bahrain World trade Centre (Wilson, 2009)

We can find in the market a lot different devices that can be integrated on a building. Most of the small wind turbines described previously could be place over the roof and there is other that has been developed specifically for its use as integrated turbine. One good way to proceed in the construction of new buildings is taking into account that the turbine is going to be integrated into the building, because you can reinforce the structure from the beginning and be able to install bigger turbines to obtain more energy. Main benefits are the low noise impact and improvement of aesthetic. Here we show some examples of the most used wind turbines in its integration into the buildings (Wilson 2009), the information is completed with information from the web pages of each brand of turbine:

❖ AeroVironment AVX1000:

Figure 39: AVX1000

AeroVironment is the leader company in wind turbines for using on the roofs. The turbine is designed to make the most of the wind changed by the façade. AVX1000 is their second generation turbine. It has a power rating of 1kW.

These turbines are installed in line at the edge of building roof. They are more efficient that other designs with vertical axis turbines, because use better the accelerate winds from the façade.

❖ Aerotecture International helical rotor wind turbines:

Figure 40: Aerotecture

This turbine was designed by Bill Becker. It can be installed in different position horizontal, vertical or diagonal. Its design is extremely light, made of plastic, with a diameter of the rotor of 1, 5 meters and a length of 3 meter. The form of the rotors is a helical Darrius shape. There are two different models, 610V (1-2kW) and 712V (2,5kW).

❖ SWIFT Wind Turbine:

Figure 41: SWIFT

This turbine has been developed by the company CASCADE Renewable Energy. The turbine is made of carbon fibber and the tower is made of aluminium (0, 6 meters over the roof). The rotor has a diameter of 2, 1 meters and five blades, with two lateral fins to orient the turbine. The power rating is 1, 5 kW for the wind velocity of 14 km/h. The cost is approximately 10.000-12.000 €.

❖ Vertical axis:

Figure 42: VAWT

As we have said before, VAWT can be place over the roof or with special fasteners. In the pictures we can see a Savonius helical turbine at the right; this can have a lot of different dimensions and power rating. At the left we see a helical Darrieus turbine; this has a high of 5 meters and a 3 meters diameter, with a power of 6 kW. To use these turbines, they have to be very silent.

GEOTHERMAL ENERGY

Geothermal Energy is the energy of the earth. Humankind has developed technologies to extract and exploit this energy since the Roman era.

The geothermal energy uses the heat from the earth. The temperature increases with the depth by thirty Celsius degrees per kilometer. This increase is the geothermal gradient.

The water confined in the upper crust earth is heated by the internal convection process of the Earth. This phenomenon can be seen at cracked crust points like geysers. This heated and confined water is the geothermal reserve.

The direct application of this reserve is the use of hot water. This is the oldest application of the geothermal energy. It can also have a recreational use like spas and swimming pools, or be used in the industrial process.

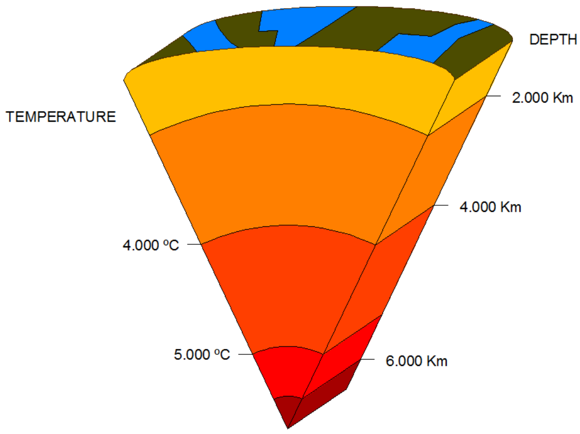


Figure 43: Distribution of Temperature and depth

There are two types of geothermal energies, although the classification is not fixed: sallow geothermal and deep geothermal. It depends on the depth of the extraction point. Deep geothermal energy normally has the extraction point around 5 km of depth. On the other hand, shallow geothermal energy has the extraction point around 400 meters of depth.

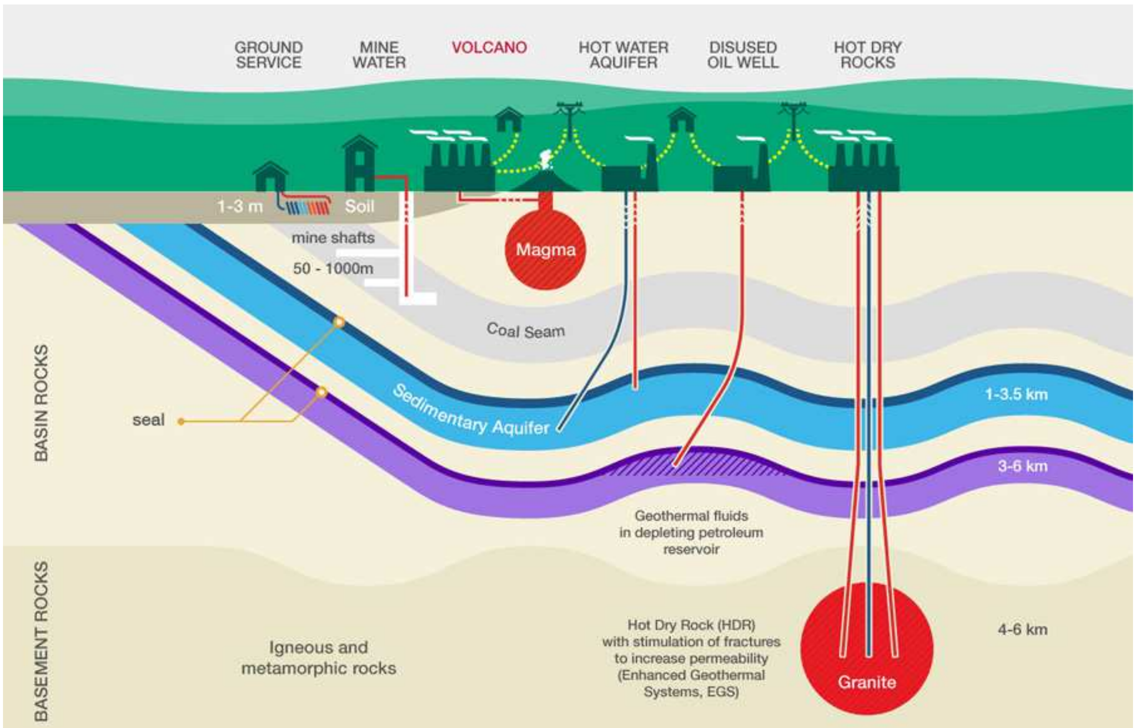


Figure 44: Types of geothermal energy, Dr Ed Stephens (2013).

Deep geothermal energy is applied to obtain electricity in Geothermal Power Plants (GPP), Enhanced Geothermal Systems (EGS), industrial process, district heating.

Shallow geothermal energy is applied to heat-cool pumps and also in the industrial process.

In localized areas of the world, the geothermal reserve can be extracted directly as fluid in order to produce electricity in the power stations. The fluid can be water, steam or a combination. Sometimes power stations not only produce electricity, they also can combine heat and power, in order to use heat as district heating.

According to Fridleifsson (2001), another way to collect directly this reserve is using underground heat exchangers as heat pump. This technology recovers the heat of the ground.

Geothermal energy is a natural resource with many advantages: renewability, abundance and stability. It helps in the objective to fight against climate changing. The technology developed to use this energy is safe and the maintenance is cheap.

The environmental impact is produced by the gas emissions. The steam contains some green-house gases like: CO2, H2S, NH3, CH4, N2 and H2. Emissions are localized and always less compared with fossil fuels. This view has been supported in the work of Barbier (2002). Landfill occupation and the contamination of the water are other environmental impacts.

Geothermal power stations

The most important use of the geothermal energy is the production of electricity. Geothermal energy is used to produce commercial electricity since 1913.

Geothermal power stations need temperatures higher than 150 ºC. They are localized in natural geothermal reserves.

The general principle of operation involves extracting a hot fluid which is used to generate electric power and once this process is finished, the fluid is injected back into the earth, as we can appreciate in the figure 45.

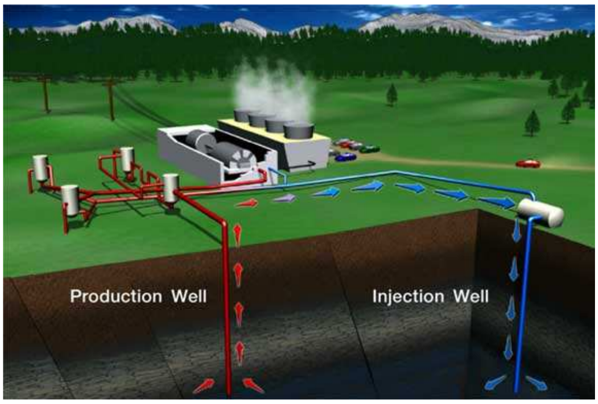


Figure 45: Geothermal power plant, Geothermal Education Office (2000).

According to the European Council of Geothermal Energy publications, there are three ways to convert the energy contained in water and steam into electrical energy:

- Dry Steam Power stations
- Flash Steam Power Station
- Binary cycle Power Stations

Dry steam

Dry steam power plants use the geothermal reserve of hot steam. The steam is extracted with pipes in a borehole.

The steam is used to move the turbines and then, to produce electricity. The steam once used can be released to the atmosphere or collected in a condenser and injected again to the earth.

An example of a Dry Steam Power plant is the plant of Larderello. It was the first power station of this kind and still working.

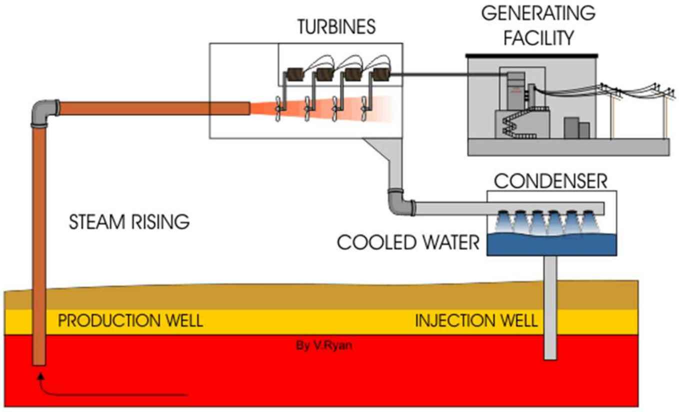


Figure 46: Dry Steam Power Plant, V. Ryan (2005 – 2009).

Flash Steam

Flash Steam power plants are the most common type. They produce most of the amount of the geothermal electricity. Flash Steam plants have water dominated process above 180º C.

Flash Steam power plants extract the hot pressured water with pipes from the earth. During this process it reduces the pressure and is separated into water and steam. The steam is used to move the turbines and to produce electricity. Then the steam is cooled in a condenser. The entire water overflow is injected to the earth again.

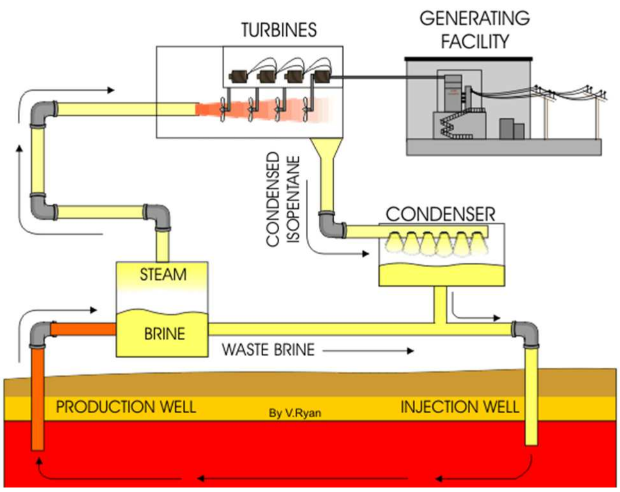


Figure 47: Flash Steam Power Plant, V. Ryan (2005 – 2009)

Binary cycle Power Plants

Binary Power plants are different from the other types. The process has a secondary fluid to produce the energy. They work with geothermal water reserves between 100 and 180 ºC.

The hot water is extracted with pipes. The hot water boils a secondary fluid and then, is injected into the earth again. This secondary fluid moves the turbines and produces energy and is boiled again in a closed cycle.

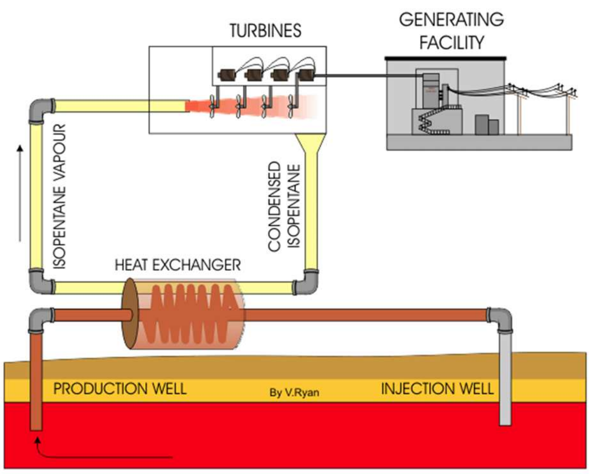


Figure 48: Binary Cycle Plants, TeraWatt Geothermal (2012)

This type of power plant is more efficient than the other ones because there is no waste of heat during the process.

Enhanced Geothermal Systems. EGS

There are places in the earth without natural geothermal reserves. These areas can extract the heat from the hot rocks inside the earth. This process is called Hot Dry Rock.

EGS´s technologies are based in heating a fluid using the hot rocks of the deepness and use it to produce electricity. These power plants produce less energy compared to the geothermal power stations.

An example of an EGS Power plant is the plant of Soultz-sous-Forêts, France. It was built in 2008.

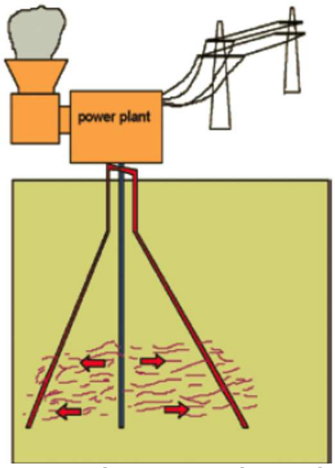


Figure 49: Enhanced Geothermal Systems, European Geothermal Energy Council (2007)

Heat-cool pumps

Shallow geothermal energy obtains heat and cool from the ground. The temperature at 50 meter of depth is stable. This method consists of a cycle of a fluid heated with the warm rocks inside the earth and piped up to the building. Once the fluid has heated the building is returned to the ground to be heated again. Most of the systems have an accumulation tank and heat pump. The cycle can be the inverse, which means that it can also be used to cool the building depending on the season.

According to Geo Trainet users guide, there are different Shallow Geothermal methods depending on the distribution and depth of the pumps: horizontal loops, vertical loops, energy piles, ground water wells, water from mines and tunnels. Currently there are also inclined loops.

This system can be small suitable to individual houses or large more convenient for big buildings located near to a geothermal aquifer or thermo active foundations.

The figures below show the two systems: horizontal loops and vertical loops.

According to Geo Trainet Guideline the factors to considerate in the design process of the system are the temperature of the surface and the subsurface, thermal conductivity and diffusivity of the different soil and rock layers, ground water level, flow and composition, aquifer properties and rock strength.

There are other factors to consider during the design process such as the family size, habits of a daily life, electrical equipment and devices and the isolation of the building.

Shallow geothermal energy has lot of future potential because is a clean energy, close to zero emissions (depending on the power system of the heat pump), easy to use and cheap to maintain, and can be use everywhere.

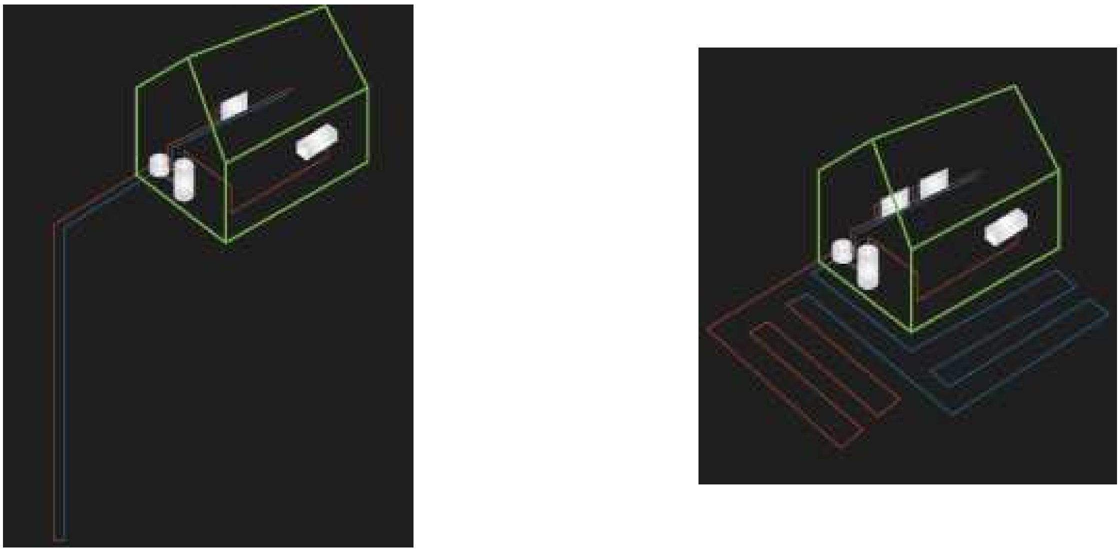


Figure 50: Vertical & Horizontal Loop, Energia Geotermica (201?)

District heating

District Heating DH is the net of distribution of heat from a production station to the consumer. The net substitutes the heat system of each house. This is a more efficient way to warm houses. It produces fewer emissions.

Iceland is the country leader in DH using geothermal resources. It is logic because most of the country enjoys natural geothermal resources.
DH is an increasing implanted system in many countries. According to Lund, et al. (2011) from 2005 to 2010 DH has increased 24% in installed capacity and 14% in annual energy use.
The production stations can be combined with electrical productions. These power plants are called Combined Heat Power CHP.

The figure below shows the distribution of Geothermal District Heating around Europe.

Figure 51: Main European Geothermal District Heating Sites, European Geothermal Energy Council (2007)

Industrial process

The application of the geothermal energy in the industrial process is difficult because normally it requires a lot of power. On the other hand the applications are very diverse all over the world.

According Lund, et al. (2011), there are applications such as concrete curing, bottling of water and carbonated drinks, milk pasteurization, leather industry, chemical extraction, CO2 extraction, pulp and paper processing, iodine and salt extraction, and borate and boric acid production which can use geothermal energy in their production process.

The industry is the most interested in reducing the energy consumption so the use of this energy is increasing every year.

Geothermal Desalination. Kimolos project

Desalination process needs a lot of power. The combination of the resources from the earth and the sea means sustainability. That combination can be applied in some areas of the world with water necessities and geothermal resources. The technology developed uses temperatures between 60 and 100 Celsius degrees. The process to transform sea water into fresh water is called Multi Stage Distillation (MED).

Kimolos project was the first desalination plant. It was a pilot project in the Kimolos Island, Greece. It is still working and producing fresh water with a competitive cost.

Bathing /swimming

Bathing is the oldest use of Geothermal Energy since the Roman era. They built public baths. Currently it is common because at least 67 countries have spas, as Lund, et al. (2011), say. It is very difficult to quantify the amount of energy because most of the spas use natural geothermal resources as hot flow water.

Current status and future trends

According to Lund, et al. (2011), currently Geothermal Energy is used in at least 78 countries over the world. The technology to obtain electricity and heating-cooling is developed continuously. There are a lot of researches about this subject not only in the European Union.

The future of this energy is granted. This clean and no limited resource is an accurate alternative to the fossil fuels according to the Kyoto´s objectives of the Climate Change.

The future trends using this energy, according to the European Council of Geothermal Energy, are different applications like snow melting, agriculture and aquaculture.

Geothermal snow melting and de-icing

There are a lot of areas in the world with security problems in the roads during the winter caused by the ice and snow. Specially, bridges are more affected by the cold than the normal roads. Also sidewalks, highways, and waiting areas for pedestrians can be covered by snow. Moreover airports can be closed because of the accumulation of ice and snow.

Geothermal energy can be applied to solve the snow problem in the roads. The system has in the pavement heat exchanger devices. The capacity of the system depends on the environmental conditions.

There are two different systems: There are high temperature systems that can melt snow. On the other hand, there are low temperature systems suitable for prevention of ice formation.

The principle is the same as in the heating-cooling pumps.

In the bridges the system can be designed at the same time that the foundations.

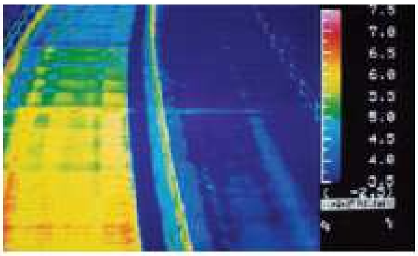


Figure 53: Infrared picture of the Swiss SERSO, European Geothermal Energy Council (2007)

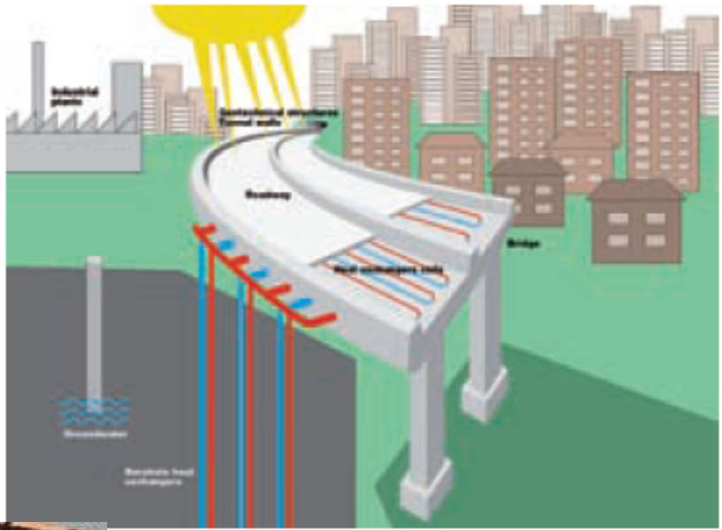


Figure 52: Different geothermal sources are suitable, European Geothermal Energy Council (2007)

Figure 54: Geothermal snow melting and de-icing is based on hydraulic systems, European Geothermal Energy Council (2007)

Geothermal Agriculture and aquaculture. Drying agriculture products.

Geothermal energy can be used to heat green houses and heat the water tanks of aquaculture. It is a cheap solution compared to the fossil fuels and other resources.

These applications are currently being developed and its use is increasing because geothermal energy is one of the objectives of the European Union and the agricultural policy (CAP). It is a good solution for isolated and agricultural areas.

Geothermal energy is a stable energy. It can be applied to maintain the temperature of the water stable, so fishes can grow up out of season. It also can be applied to the production of spirulina and other seaweeds.

Geothermal Energy can be applied also to dry agriculture products. It makes the products competitive. There are some examples around Europe for different products: grains, vegetables, fruits, wood, fish…

WATER ENERGY

The water energy is the energy that is obtained from the transformation of the energy of the water into electricity. It can be split into two big groups, the freshwater and the seawater.

Freshwater

The electricity that comes from the fresh water is known as hydroelectricity. Hydroelectricity is the generation of electricity from the hydropower. The electricity is generated taking advantage of the drop of water; the potential energy of the water mass is transformed into electricity energy using hydraulic turbines.

Inside the renewable energies, it is the most used. It represents 16% of the total energy generated in the world and it is increasing. The area that generates more hydroelectricity is Asia-Pacific, with 32%. Its costs are more or less low, making it competitive inside the renewable energies field.

In the freshwater, there are three are main typologies to obtain electricity: Conventional, run-of river and pumped-storage.

Conventional

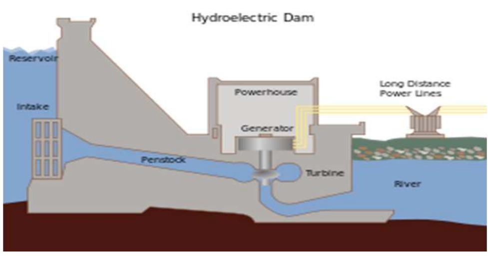


Figure 55: Conventional dam (TVA, 201?)

If a building contains a dam at the base to store water and get a water height difference that is called head. The energy that we take from the water, potential energy, is a proportion of the head.

We take the water from the upper reservoir and passing it through the turbine-generator set at the bottom of the dump.

Run-of-the-river

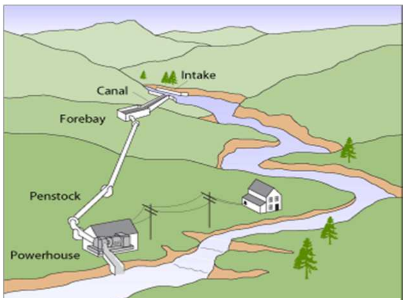


Figure 56: Run-of-the-river (DOE's Office of Energy Efficiency and Renewable Energy)

This type of hydroelectricity generation consists in a small deviation of the water from a river, with or without a small dump. We have an intake that takes water, diverting it to a channel that conduct water to a fore bay, where is connected the pressure pipe. At the bottom it is the powerhouse, where electricity is generated. To finish, the water is returned to the river

For this system is necessary a river with a big constant caudal because it have not any kind of storage.

Pumped-storage

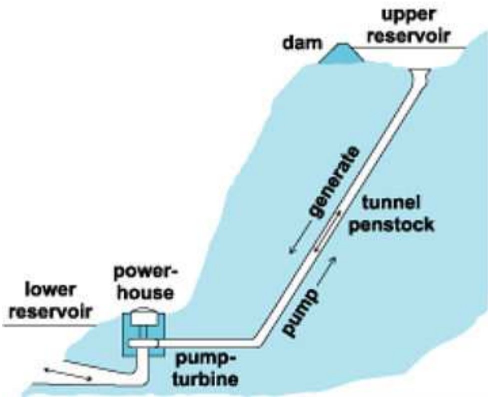


Figure 57: Pumped-storage system (UKERC, 201?)

The pumped-storage consist in a system formed by two reservoirs in a different level, connected both by a pipe, with a reverse turbine at the bottom part of the pipe. This turbine can act as a pump to puss the water or as a turbine to generate electricity.

The principle of working is simple and efficient. During the day it generates electricity, when the demand and the prize are higher. During the night, the electricity is cheaper, and the demand is less than the necessity, so instead of missing this electricity, we use it to pump the water to the upper part again and thereby have it available to use it next morning and the process starts again.

Sea water

Marine energy is the energy of the sea. It is also called oceanic energy. It is a renewable and abundant resource because three out of four parts of the world are covered by sea. This is a clear energy because it does not produce green-house gas emissions.

The energy came from the movement of the waves and tides, salinity gradient and the difference of temperature of the ocean. Humankind has used this energy since the middle ages using tidal mills. Currently, electricity is produced with Marine Energy and increases every year.

Waves Power

It is the recovery of the energy of the surface waves. The technology developed absorbs the power of the waves to produce electricity by different ways. The first Wave Farm was the Aguçadoura in the coast line of Portugal in 2009. It is used to produce electricity offshore. This project is still researching new prototypes and developing new devices.

Figure 58: Aguaçadoura Wave Farm, Pelamis Wave Power, (201?)

Tide Power

This is the energy of the movement of the water because of the moon. It is a no limited resource. The technology uses the same principles than the classical hydraulic energy. Most of the power stations hold the water helping with barriers when the sea is up and take the energy from the return movement of the water.

The biggest Tide Power Station is the Rance Estuary, France. It was built in 1967 and is still working.

Figure 59: Tidal power plant on the estuary of the Rance River, Bretagne, France, Tidal Energy (201?)

Salinity Gradient

This energy comes from the difference of salinity of the sea water and the normal one. This difference is used as a steady base load of electricity. Salient Gradient Power Plants have to be close to the consumer.

Ocean Thermal Energy Conversion

The technology developed obtains the energy of the difference of temperature between the deep cold sea water and the surface warm water. Ocean Thermal Energy Conversion Power Plants have a cycle process piping the deep and surface water.

Currently status and future trends

Oceanic energy is being used more and more. Moreover the ways to obtain electricity are being researched continuously. There are new prototypes and new ways to transform the power of the sea into electricity.

BIO-ENERGY

Biomass

Biomass is the use of organic matter as an energy source. By its broad definition, biomass covers a wide range of organic materials characterized by their heterogeneity, both in origin and in nature.

Various types of biomass can be distinguished, depending on the origin of the substances used as plant biomass, related plants in general (trunks, branches, stems, fruits, vegetable residues, waste, etc...) And animal biomass, obtained from animal products (fats, remains, excrements, etc...).

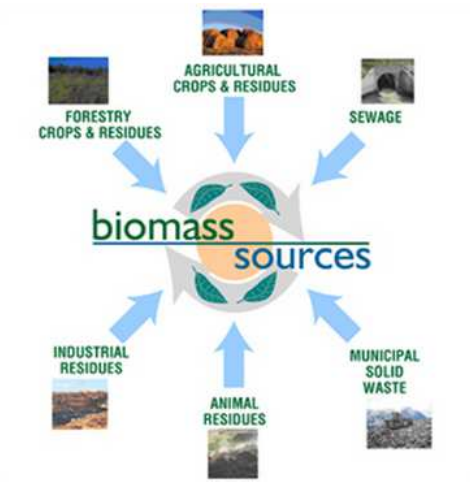


Figure 60: Biomass sources

Another way to classify the types of biomass is made from the material used as an energy source:

Natural

It is embracing the forests, trees, shrubs, crop plants, etc. For example, in a series of forestry residues or by-products are produced with high energy which are not suitable for the manufacture of furniture and paper, such as leaves and twigs, and that can be used as an energy source.

The wood waste can be harnessed to produce energy. Similarly, can be used as fuel residues processing industries of wood, such as sawmills, timber and furniture factories and other more materials. The “energy crops” are another form of biomass consisting of crops or plantations that are made exclusively for energy purposes, i.e., to harness their energy content.

Among these crops have, for example, trees such as poplar or other specific plants. Sometimes, they are usually not included in the biomass energy that is restricted to that obtained secondarily from waste, residues, etc.

Residual

This corresponds to residues of straw, sawdust, manure, slaughterhouse waste, municipal waste, etc.

The energy used of residual biomass, for example, involves obtaining energy from wood waste and agricultural residues (straw, shells, bones...), urban waste, livestock waste, such as manure or manure, sewage sludge, etc. Agricultural waste energy can also be harnessed and energy plants are using residual straw fields not used for animal fodder.

Livestock waste, on the other hand, is also a source of energy. Slurry and manure from dairy farms and pigs can energetically recover for example by exploiting the gas (or biogas) produced from them, to produce heat and electricity. And in the same way you can leverage the power of urban waste, they also produce a fuel gas or biogas by fermenting organic waste, which can be captured and can be used for energy producing electricity and heat that can be termed as plants biogas energy recovery from landfill.

Dry and wet biomass

As the proportion of water in the substances forming the biomass can also be classified into:

Dry biomass: wood, firewood, forest residues, remnants of the timber industry and furniture, etc...

Wet biomass: residues from the manufacture of oils, sludge, slurry, etc...

The next picture shows an example of biomass process with the use of wood pallet:

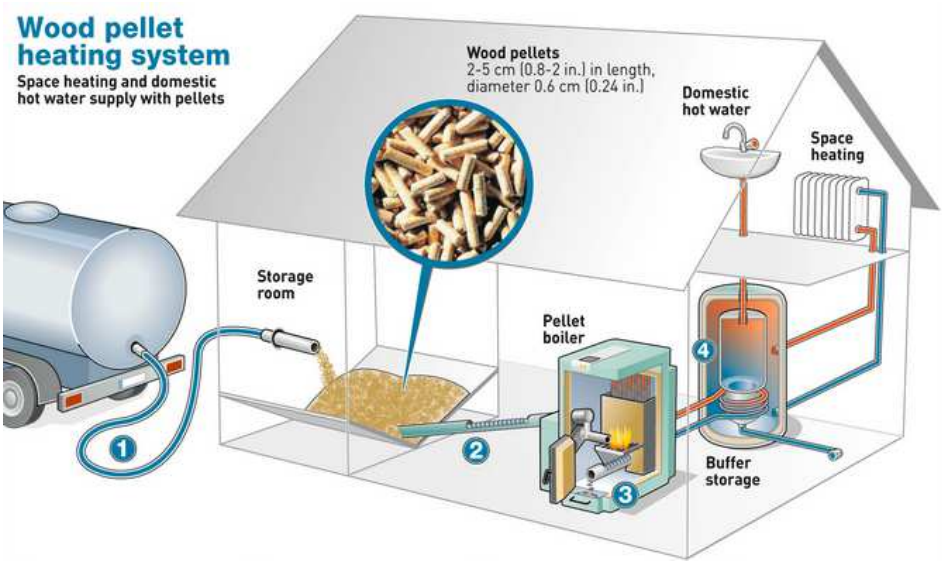


Figure 61: Wood pellet heating system

Biofuels.

Biofuels are a mixture of hydrocarbons derived from biomass which are used as fuels. For the production of biofuels, agricultural species such as corn and manioc which are rich in carbohydrates, or oleaginous plants such as soybean, sunflower and palm can be used. Also can be used forest species such as eucalyptus and pines.

Figure 62: Bioenergy [www.energydigital.com, 201?]

By using these materials, the CO_2 sent to the earth's atmosphere is reduced because these materials are absorbing the CO_2 during its development. During its combustion, a similar amount of CO_2 is produced comparing to conventional fuels.

Some experts claim that the net balance of carbon dioxide emissions from the use of biofuels is null because the plant through photosynthesis, capture the same amount of CO_2 during their growth than the produced in their combustion. However, many of the operations required for the production of biofuels need to use fossil fuels, such as the use of agricultural machinery, fertilization or transport of products and raw materials, and, consequently, the net balance of carbon dioxide emissions is positive.

The most used and developed biofuels are bioethanol and biodiesel.

- **Bioethanol**, also called biomass ethanol, is produced, as well as other alcoholic products from the fermentation of sugars from various plants such as sugar cane, beet or cereals.

- **Biodiesel** is produced from vegetable oils which can be reused or not. In the last case are normally used oils from colza, canola, soya or jatropha, which are grown for this purpose.

- **Biogas** can be produced using as raw material: animal excrements, sugarcane, waste from slaughterhouses, distilleries and yeast factories, coffee pulp and husk and vegetal dry matter. This technique allows solving the energy demand problem in rural areas, reducing deforestation due to logging for firewood, it also can recycle waste from farming and is a "clean" and renewable energy resource.

- Other alternatives, such as **bio propanol** or **bio butane**, are less popular but the researches in these areas may improve their performance.

The use of vegetal biomass into fuel production could benefit the global energy situation with a significant impact on the environment and society, as detailed below:

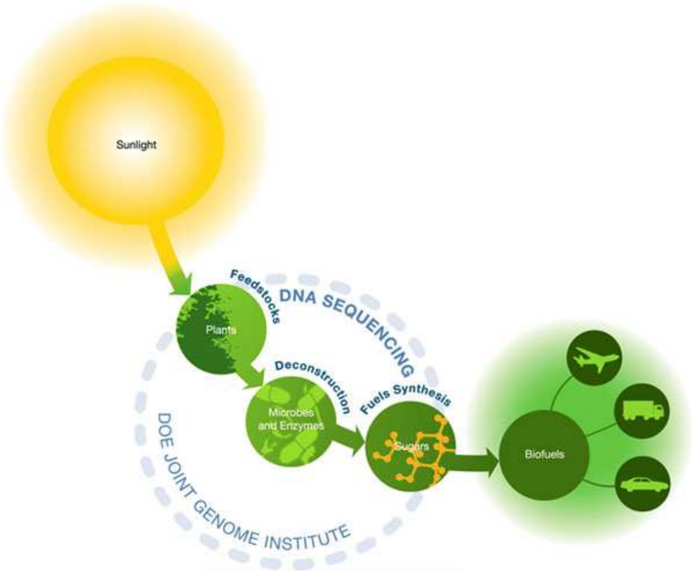
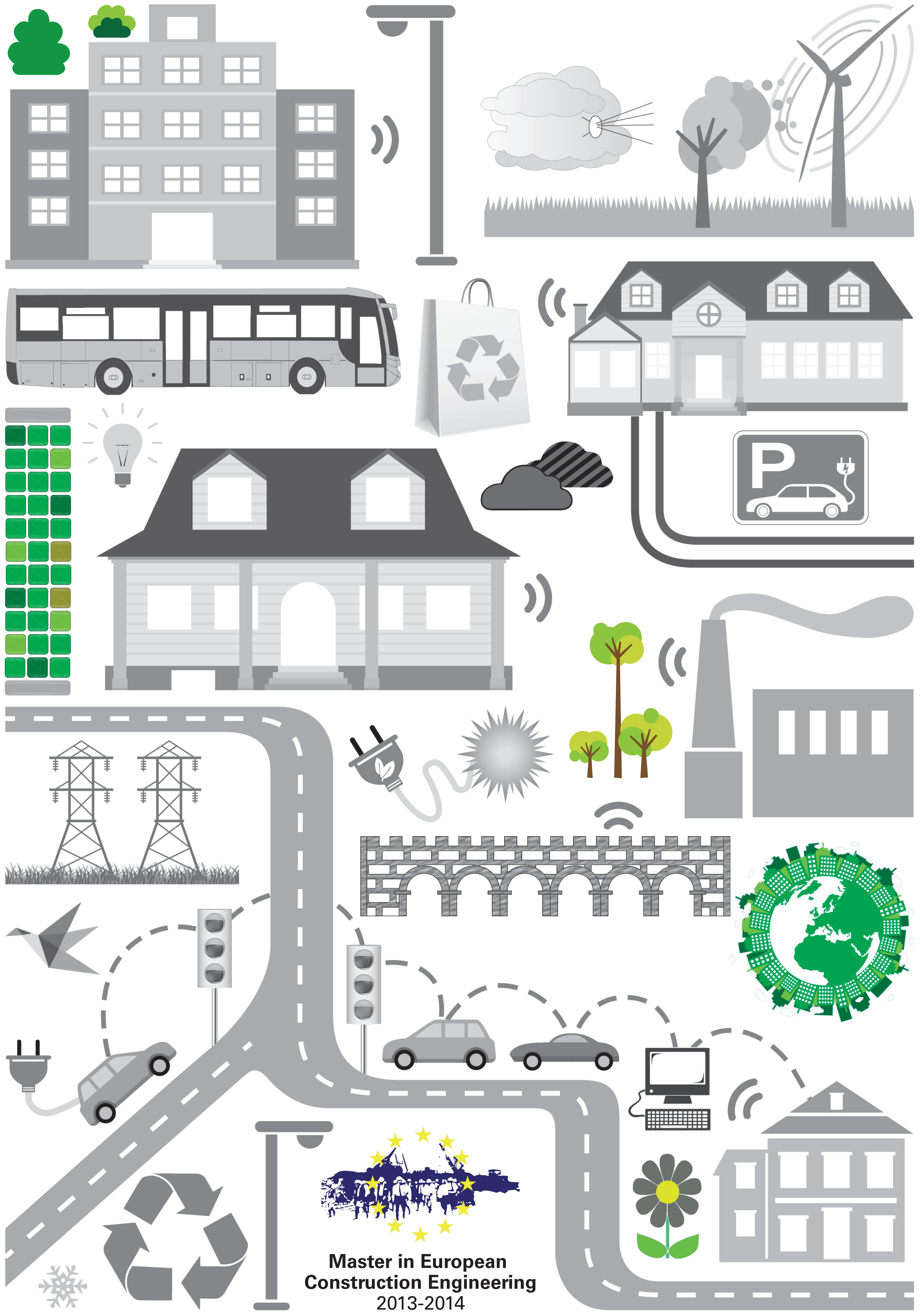


Figure 63: Biofuels scheme [debatos.com, 201?]

- The use of biofuels as a source of renewable energy can help reduce the consumption of fossil fuels.
- They are a viable and sensible alternative to depletion of fossil fuels such as gas and oil, which is observed as increase in prices.
- Are produced from agricultural crops, which are renewable energy sources.
- They can be obtained from own crops in a region, allowing local production of biofuel.
- Allow to have fuel regardless of import policies and fluctuations in oil prices.
- Produce less harmful emissions to living things, water and air.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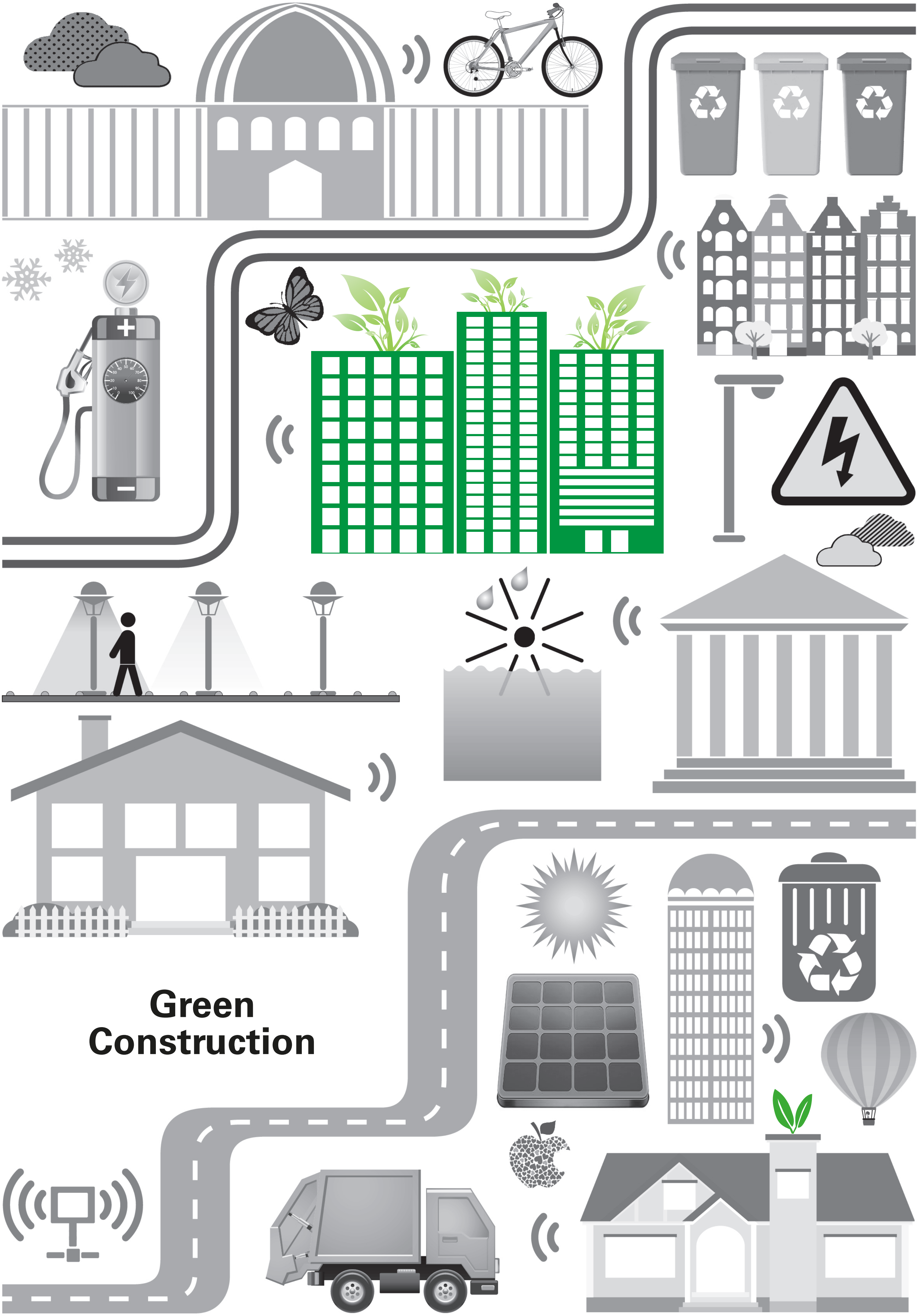
2013-2014


Green
Construction

GREEN ROOF

Generally speaking, the green roof can be defined as creating spatial vegetation on an artificial structure, which could be extended to any roofs of protecting the residents underneath, no matter indoor or outdoor. This planting space can be located on a platform layer, or on a middle floor of a tall building (usually defined as 'sky garden').

In general, green roofs are divided into two types, the intensive and the extensive, which differ from the thickness of the layer for growing plants (intensive green roofs are more than 200mm while the extensive green roofs range from 20 to 200 mm). To make a more specific classification, it can be divided into three different types, according to their thickness of layers and functions: extensive green roofs, intensive green roofs, and solar garden roof (Johnston and Newton, 1993). In the following parts, the intensive, the extensive and the solar garden roof are explained in detail.

Nowadays, the green roofs are becoming more and more popular strategy to solve environmental issues. The reason why that is the green roofs have a lot of benefits. First of all, they can prevent the water on the surface from running off; create a habitat for the wild life and improve the energy efficiency of the building. (English Nature, 2003; Dunnett and Kingsbury, 2008) Additional, for the owner of the building and the community, the construction of a green roofs can enhance the life of the roof two to three times; make the indoor environment cooler in summer and warmer in winter. This way the consumption of air-conditioner will decrease; reduce the "heat island" effect of the city; reduce smog and improve air quality; provide green space for public usage. In addition, for the environment, the green roof can decrease the carbon monoxide impact and prevent combined sewer overflow; removal of nitrogen pollution in the rain and eliminate the acid rain effect.

Speaking of the detail advantages and disadvantages of the main two types of green roofs, the intensive and the extensive green roof, the major points are summarized in the table below.

	Extensive Green Roof	**Intensive Green Roof**
Description	• 50mm-150mm thick soil • Little/no irrigation • Low maintenance (0.8 to 2.25 $/m²/year)	• 200mm-2000mm thick soil • High irrigation • Normal maintenance (6.5 to 44 $/m²/year)
Advantages	• Lightweight (80 to 150 kg/m²) • Low maintenance • Applicable for reconstruction • Lower price (400 to 1000 $/m²) • Applicable for wide range areas • Applicable for 0-30º slope roof • Let the vegetation to grow	• Different usages of roof (i.e. leisure, planting food, as open space) benefit to owner • More diversity of plants and habitats • Better properties of insulation • Able to simulate a ground safari • Visually accessibility
Disadvantages	• Limited choice of plants • Generally no usage of leisure and so on • Not attractive in dry and cold seasons	• Relatively higher price (1000 to 5000 $/m²) • More weight load (300 to 1000 kg/m²) • Require irrigation and drainage systems, thus more demand for water, energy materials etc.

	• Generally not suitable for the reconstruction of green roof	

Figure 64: Advantages and disadvantages of green roofs (Source: adapted from Peck Callaghan & Kuhn (1999), p14)

Basic components

Green roofs are possibly designed as deck of a roof, the elements of which include steel, concrete, plastic, substrate, as well as to consider the structural. A great many specific layers are needed, which differ from the underneath illustration and may demand for special conditions. These systems have the basic functions, including protecting the surface of roof from root penetration, drainage of rainwater, and supporting the growth of the vegetation layer.

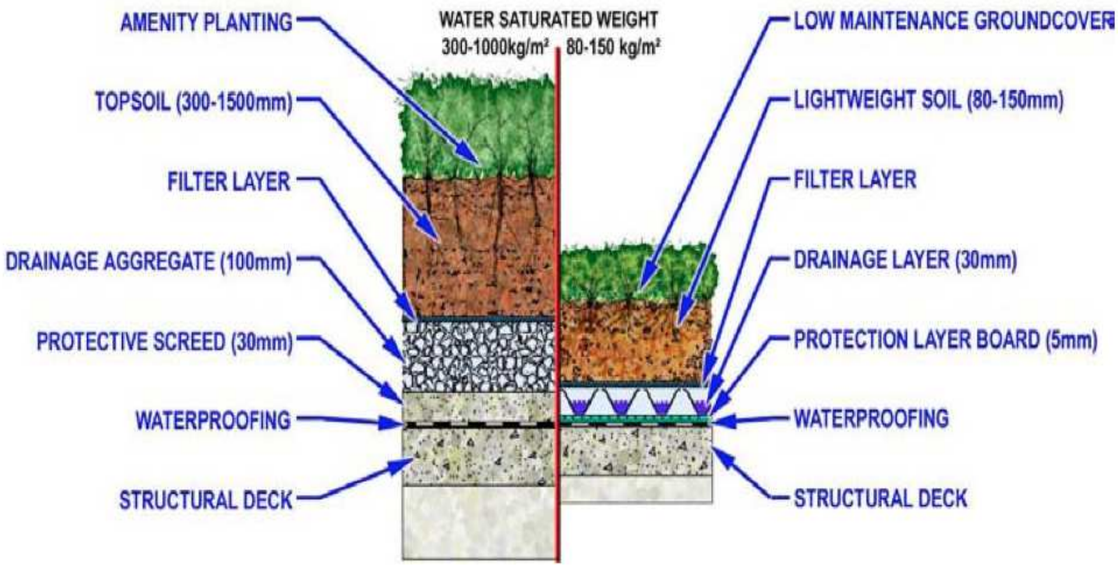


Figure 65: Composition of different layers of green roof system (Source and copyright © Urbis Ltd., 2006, Adapted from images from Greenlink Küsters Ltd.)

- ***Waterproofing:***

The waterproofing is the crucial part of the green roof. To make the waterproofing effectively working during a long period, it should meet the demand of standards. On the contrary, if it fails, the green roof may consist a separate root barrier. There're many systems of waterproofing, involving in Asphalt Roofing Felt/Bitumen, which have a limited useful lifetime of 15-20 years demoting from the change of temperature and ultraviolet radiation. In order to enlarge its lifetime, separate root barriers are used to protect it, the membranes along with the protection barriers are fluid applied membranes, single-ply roof membranes, and concrete admixture water-proofing.

- ***Protection Layer***

This layer exists between the drainage layer and waterproofing, which is made of non-woven geo-textile to protect the waterproofing from being damaged mechanically. It is highly recommended to build a strong protection layer with 400 to 800 gr/m2, in order to make the green roof bearing greater loadings.

- ***Drainage Layer***

The functions of the drainage layer are as follows: to remove excess water or underflow in a shorted period to keep the green roof system cool and function well, to protect the waterproof membrane, to help the ventilation of the medium layer, to provide an interior airflow, and to decrease the vacuum around the edges of an green roof underneath the medium layer. To sum up, the main purpose of this layer is to let the rainwater flow away from the roof after a rain, which is very important for the roof system.

The main types of drainage materials are granular materials, porous mats, lightweight plastic and polystyrene drainage modules. According to the European roof drainage standard (EN 12056-3), the design of drainage layer will differ from the location of building because of the different amount of rainfall. For example, a storm ranging from 0.01l/s.m2 to 0.022l/s.m2 may happen once a year in U.K, the design of drainage layer should meet the highest demand for heavy rain.

- ***Soil / Medium / Substrate***

It is crucial to use the suitable soil type and suitable depth of medium/substrate/soil for the vegetation on the green roof, because it will not only influence the plants that grow on, but also effect other functions of the roof system like water drainage and the maintenance of the volume. In general, the type of soil used in the extensive green roof is thin layer of lightweight mediums, which needs low fertility soil to develop better. According to a German research, the best growing medium for the extensive green roof is a combination of 40% substrate and about 60% pore space. What's more, the properties of medium/substrate/soil about fire resistant and characteristics of lightweight are important factors for making a good green roof system, resulting in lower cost and better capability to remain dry for long time.

- ***Lightweight fills / thermal insulating layers***

On the intensive green roofs lightweight fills are common used to make the difference between levels. On the extensive green roofs, they are used as a thermal insulating layer. Most lightweight fills are soft and physically not durable to last a long time if exposed to the outside space. Lightweight fills are usually made of some expanded material, which has a lot of air in it. Lightweight fills are made of various materials: extruded polystyrene sheets (most common used), polystyrene cement, autoclaved aerated concrete, foamed concrete, and cements (perlite, vermiculite, and LECA), which are usually good thermal.

Extensive green roofs

The extensive green roofs are composed with a thinner layer of substrate (from 20 to 200 mm). Therefore, it can be widely applied because the need for structure support on building is very small. Moreover, it needs less devotion to maintenance and irrigation, so that people prefer to use the extensive green roofs than the intensive ones, especially in the large area where need to be greened (Johnston and Newton, 1993).

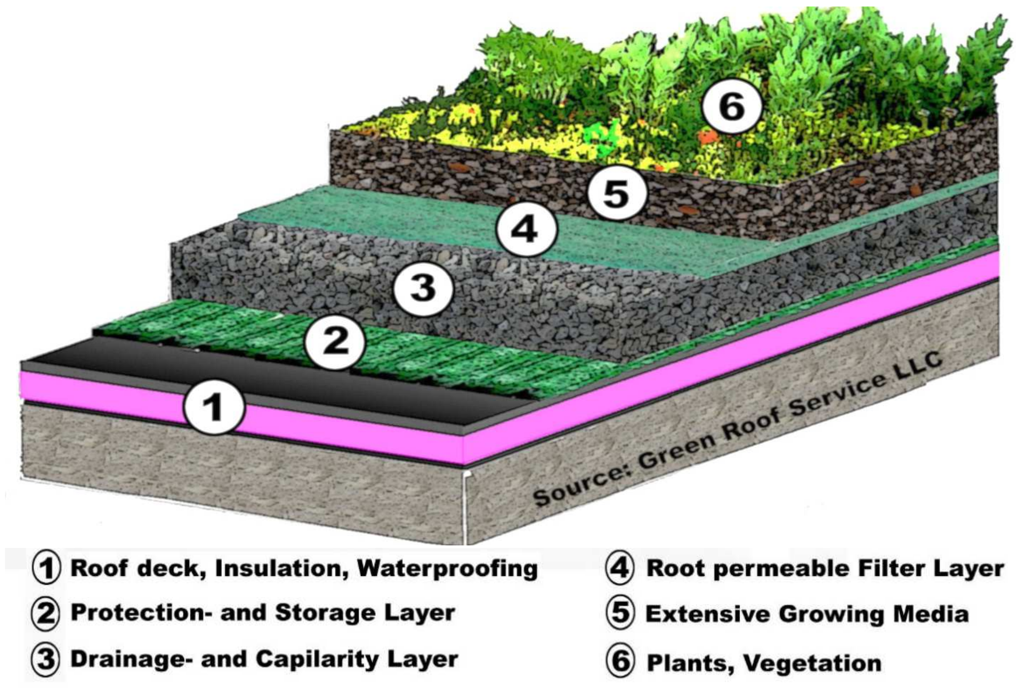


Figure 66: Layers of extensive green roof system (Source: adapted from Roof Systems Consultants)

However, the extensive green roofs need a severe environment for the growth of the plant due to the thinner substrate layer, which limits the supply of water and easily changing of temperature during day and night. In consequence, the plants that can be used on the extensive green roofs are limited to a small range (Dunnett and Kingsbury, 2008). The sedums are the most used plant for the extensive green roofs, not only because they are easily adapted to the severe environments which are dry and hot, but also because they are green all over the year so that the green roof can be covered the whole year, and the sedums are very easy to grow which makes them widely applied on many occasions (Gedge and Kadas, 2005).

Usually, a typical extensive green roof system is composed with a series of elements beginning with a suitable reinforced roof, on top of which is a waterproofing membrane. Following that layer is a drainage mat, which has ripples on its bottom side that has a space of air where water is able to flow away to the edges of roof. Then the next is the moisture retention blanket that is followed by the growing medium and plants. The composition of a typical extensive green roof system is shown in the following picture.

The graph above (figure 66) shows that the extensive green roof system is composed of 6 layers. Each layer has its unique function and characteristic, which will be described in the next coming part. In the graph below (figure 67), we can see more detail of technic data about the extensive green roof, including the plants usually used, soil type, min and max slope, water demand etc.

	System with granular drainage		System with drainage plants
Plants	Sedum herbs perennials	Sedum herbs	Sedum herbs
Extensive soil mix	4”	2”	3”
Separation fabric	1/8”	1/8”	1/8”
Granular drainage	2”	2”	-
Protection mat	1/4”	1/4”	1/4”
Nominal thickness	6”	4”	4”
Dry weight	28 ibs/ft^2	19 ibs/ft^2	14 ibs/ft^2
Saturated weight	41 ibs/ft^2	26 ibs/ft^2	23 ibs/ft^2
Min slope	0:12	0:12	1/4:12
Max slope	1:12	1:12	1:12
Water retention	60%	50%	50%

Figure 67: Technical data about the extensive green roof (Online Source: adapted from Green Roof Technology)

Intensive green roofs

Compared with the extensive green roof, the intensive green roofs grow plants on the thicker layer of substrate or medium (over 200mm). The intensive green roofs are usually applied on commercial to make a large green area consisting of various kinds of plants, including grasses, flowers, shrubs, or trees. It is quite common that walkways and benches, tables, greenhouses, and even fountains are designed along with the green area, in order to create a space attracting people to join the manmade nature environment. The following graph shows how does a typical intensive green roof is composed of.

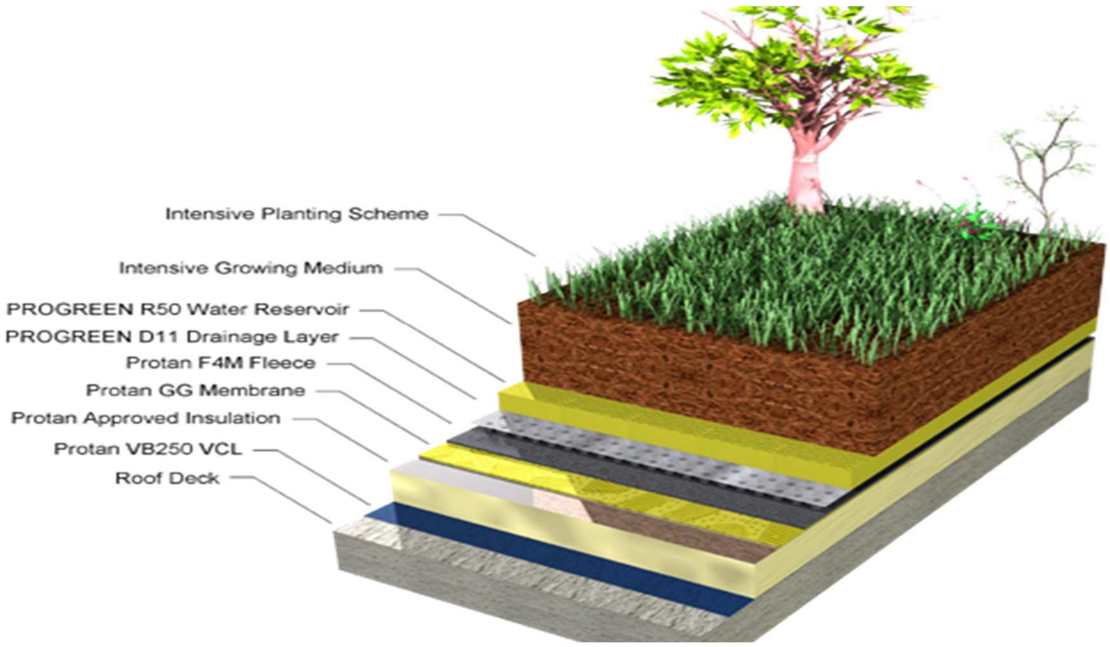


Figure 68: Layers of intensive green roof system (Online Source: adapted from PROGREEN - Intensive Roof System)

The intensive green roofs need more energy to maintain, the reason why is that they have to support more load of plants, which demand fertilizer and water, especially in dry weather it needs to be quite often watered. Moreover, the depth of intensive green roofs system soil vary from 200mm to 1000mm for shrubs and trees respectively, comprising construction of drainage system, irrigation system, root penetration and more than 1 foot substrate, which altogether weigh 80-150 pounds/ft2. In the graph below, we can see the detail of technic data about the intensive green roof, including the plants usually used, soil type, min and max slope, water demand etc.

	System with drainage plants	**System with drainage plants**	
Typical plants	Grass shrubs trees	Perennials grasses shrubs	Grass shrubs trees
Intensive soil mix	9”	8”	12”
Separation fabric	1/8”	1/8”	1/8”
Granular drainage	6”	-	-
Drainage plate	-	1-1/2”	2-1/2”
Protection mat	1/4”	1/4”	1/4”
Nominal thickness	15”	10”	15”
Dry weight	69 ibs/ft^2	34 ibs/ft^2	52 ibs/ft^2
Saturated weight	105 ibs/ft^2	57 ibs/ft^2	85 ibs/ft^2
Minimum slope	0:12	1/4:12	1/4:12
Maximum slope	1:12	1:12	1:12

Water retention/Year	80%	70%	80%
Irrigation system	subsurface	surface	surface

Figure 69: Technical data about the intensive green roof (Online Source: adapted from Green Roof Technology)

Solar garden roof

The solar garden roof, as it means by words, is a combination of green roof and solar panels as a system functioning altogether, which is now under experiment in New York and will be the future trend of green roof construction industry.

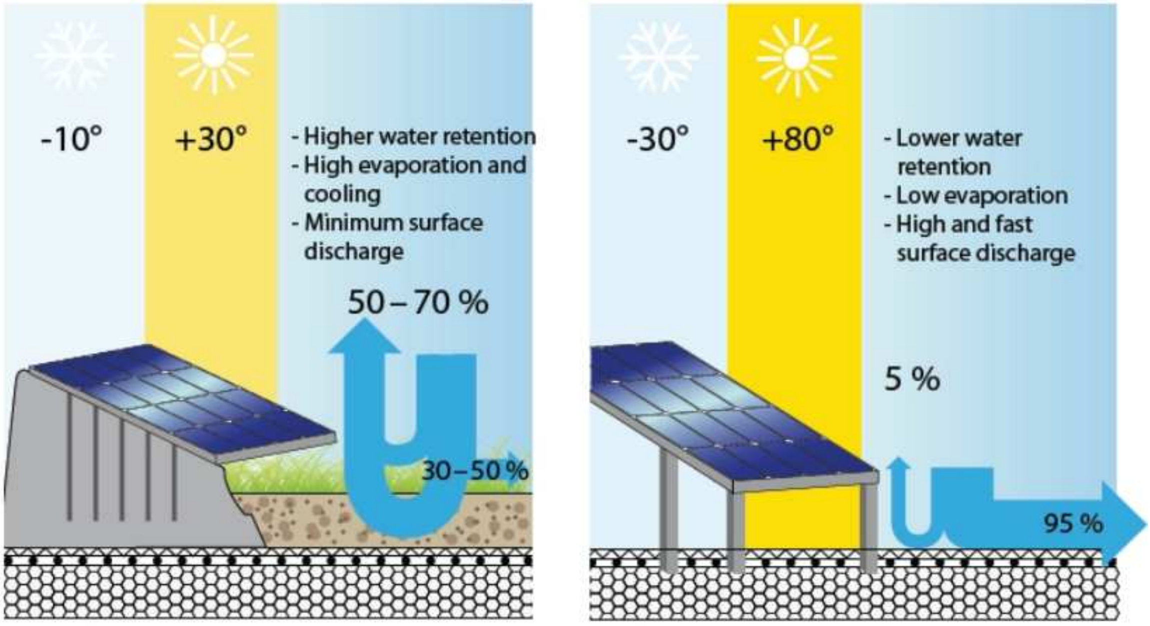


Figure 70: Solar power with/without green roof (Online Source: adapted from Optigreen)

In the figure above, we can see that with a combination of solar power and green roof, this so-called “Solar Green Roof” is secured by superimposed load, which gets higher water retention, high evaporation and cooling, minimum surface discharge. On the contrary, the solar power plant that is anchored in the roof substructure without roof greening, has lower water retention, lower evaporation, higher and faster surface discharge. The experiment about green roof garden that is being conducted in New York, the Department of Parks and Recreation Building on Randall’s Island. Since decades ago, they started the study on the top tech on green roof. In 2012, they started to install the so-called ‘Sun-Root™ Modules’, which was the first solar garden roof system in USA, combined with engines and plants. The installation took 6 months and the whole tests were very successfully made.

To apply this tech is of great importance, and there exists mature tech to do the installing, which can be found on the webpage of the Department of Parks and Recreation Building on Randall’s Island. The technic data of the green roof associated with solar panels are shown as follows, which indicates that the solar green roof system can bear more load, cost less energy, and the maintenance is lower. What’s more, the construction of layer must be taken into account because of the protection of wind drift. (Source from Optigrün AG webpage)

Weight	1.0 – 1.4 KN/m²
Depth	From 80 mm
Roof pitch	0 – 3° (0 – 5 %)
Vegetable form	Sedum
Water retention	50 - 60 %
Discharge coefficient	0 %: C = 0.17** 2 – 8 %: C ≤ 0.45
Water storage	About 25 l/m²

Figure 71: Technical data of solar green roof system (Online Source: adapted from Optigreen)

Cost of green roofs

According to the previous study, it is estimated that the cost of construction a green roof begins at 10$/ ft² for simpler extensive roofing, and 25$/ ft² for intensive roofs. The maintenance costs of each year for these two types of green roofs can range from 0.75–1.50$/ ft².

The figure 72 shows costs of extensive green roofs in North America, Germany and Hong Kong, ranging from 400$/m2 to 1000$/m2. In the table above, we can see that constructing a new extensive green roof will cost less money than a reconstruction project, which is 60% to 70% the price. While the figure 73 shows the costs of green roof, extensive green roofs 500$/m2 and intensive ones 200$/m2 respectively.

The cost of green roof is much higher than the common building roof, however, the owner of building can get the investigate back in a few years through the benefits of green roof, for example, decreasing energy cost, storming rain water so that the use of water can be reduced, and enhancing the life time of roof so that the maintenance fee could be less. (Hedley, A. J., et al., 2006)

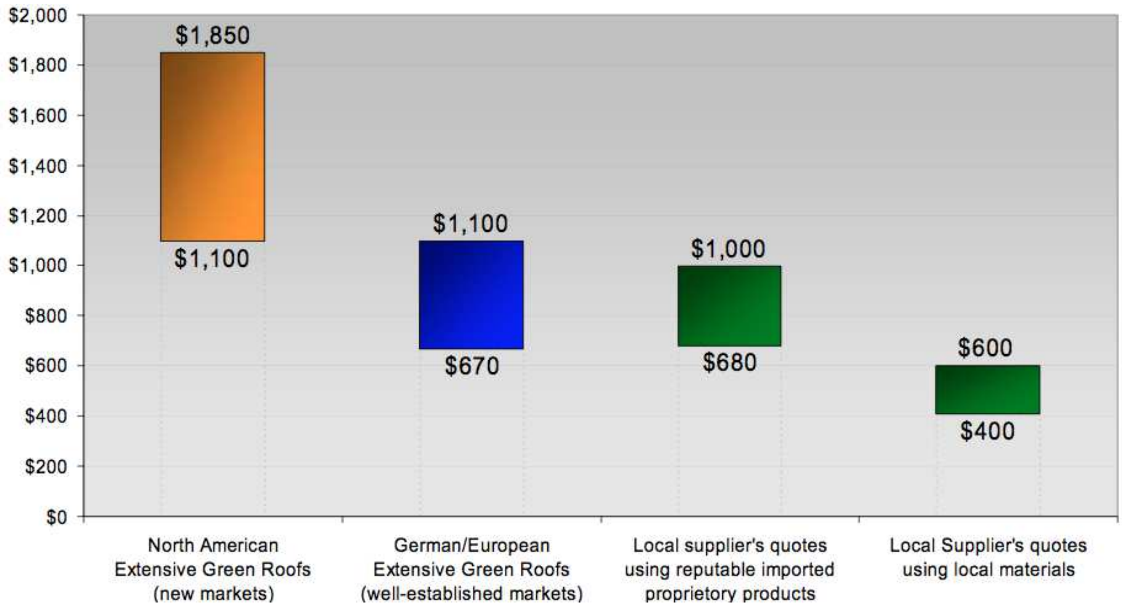


Figure 72: Cost of green roof in different areas (Online Source: adapted from Civic Exchange, 2006)

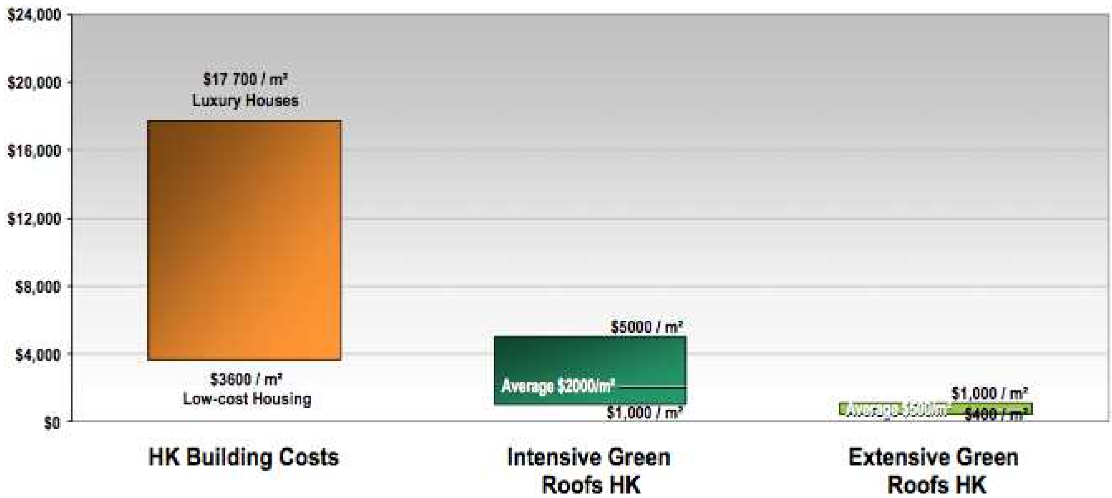


Figure 73: Cost of green roof in Hong Kong (Online Source: adapted from Civic Exhange, 2006)

What's more, some studies have been conducted to assess the benefits of green roof throughout the whole life cycle. For instance, an experiment was done in University of Michigan to compare how the costs of conventional roof differ from the green roof construction, the area of which is 1,950 m2. As the result of the research, the water from rain has been stormed and environment quality has been improved by absorbing dust and bad gases like nitrogen oxides and carbon dioxide. In this case, the cost of green roof could be $464,000, while the conventional one only cost $335,000. However, according to the calculating and emulating, the green roof can save probably $200,000 during its life cycle time. (http://www.epa.gov/hiri/mitigation/greenroofs.htm)

Application and future trend

Usually, the extensive green roof will be applied in single family residential, which requires highly knowledge of building owner to choose this kind of tech. In practice, it seems that there's a limit of application of extensive green roof for the existing building, because some study shows that the main reasons why are as follows: Firstly, the promotion between government and social communities about public range and private range is lack. Secondly, the whole life cycle of a building is lack of the consideration about this part, including the design and construction process; Thirdly, the cost of this green roof is higher than normal roof, the building owner will not be pleased to pay extra for the future benefits that the green roof will bring, like energy efficiency leading to lower cost of electricity (Ngan G., 2004).

According to the classification of buildings, the application of green roofs will be different. The intensive green roofs are usually applied on commercial buildings owning to their larger scale and wide range of plants, while the intensive green roofs are usually applied on residential buildings. In the table below (figure 74), you can see the general application of different types of green roofs.

Type of Building	**Description**	**Rooftop Space (H/M/L)**	**Need for Urban Greenery (H/M/L)**	**Recommendations**
Commercial buildings	Multiple level sky-rises (mostly offices) buildings. Rooftops are often exposed and windy, and cluttered with utilities and obstacles.	Medium	High	Intensive Green Roofs should be promoted for new buildings. For existing buildings, extensive green roofs can be promoted.
Residential buildings	Buildings range from 1 layer house to multiple levels buildings.	Medium - Low	Medium-Low	Using probable budget to make the environment greener, when extensive green roofs are often promoted.
Industrial buildings	Industrial building are often wider than other buildings. Building owners are willing to pay for green roofs because of the various benefits.	High	Medium	For new buildings, intensive green roofs can be promoted, while extensive green roofs will be promoted for existing buildings.
Other Low-rise structures	Covered Pedestrian Walkways and Footbridges, Covered roads and noise enclosures, vent buildings, stadiums, and service.	High-Medium	High	Due to the lack of rooftops and large areas, extensive green roofs can be promoted.

Figure 74: Application of green roofs according to different types of buildings (Source and copyright © John YAU (Chun Wang), 2002)

As mentioned in the paper above, the green roofs have a great many benefits for both building and environment. However, there're some difficulties in applying this technology in reality. For one thing, it is crucial that the green roof should be considered as a whole system and is together with other tech like solar panels. In UK, nowadays they started to use recycled materials to support the vegetation in the green roof layer. The material could be for example recycled paper, recycled aggregates that coming from the waste and landfill, sewage sludge and clayey and so on. This could be the future trend for the green roof development (Hills et al., 1999)

Natural minerals	
Sand	Fine texture can result in lack of pore space and problems of saturation of the substrate if drainage is poor. Conversely, coarse sands can be so free-draining as to require constant irrigation.
Lava (scoria) & pumice	Lightweight and valuable if locally available.
Gravel	Relatively heavy.
Perlite	Particles tend to collapse over time (Hitchmough 1994).
Vermiculite	Very lightweight, but has no water- or nutrient-holding capacity and may disintegrate over time (Hitchmough 1994).
Artificial minerals	
Light expanded clay aggregate (LECA) Expanded shale	Lightweight, produce large amounts of pore space because of their size, and absorb water because of their porous nature.
Rockwool	Very lightweight but energy-intensive production and no nutrient-holding capacity.
Recycled or waste materials	
Crushed clay brick or tiles, brick rubble	Stable and uniform, some nutrient and moisture retention. Brick rubble may contain mortar and cement, which will raise the pH of the substrate.
Crushed concrete	Limited moisture retention and nutrient availability, alkaline. However, cheap and available in quantity as a demolition material.
Subsoil	Heavy, low fertility, readily available as by-product of construction.

Figure 75: Future materials for green roof construction (Source: Adapted from Dunnett & Kingsbury (2004), p73)

PERMEABLE PAVEMENTS

The development of new materials and the new necessity of being more economical, environmental and social sustainable have motivated the investigation of new performances regarding pavements. Permeable pavements have been developed to replace impervious ones and achieve, at the same time, goals like the prevention of floods and the maintenance of aquifers´ quality as it is explained in the following parts.

The most important quality of the permeable pavements is that they allow water to come through their pores in the case of concrete or asphalt pavements or, on the other hand, between the interlocking gaps of concrete pavers, concrete grids and plastic grids as well.

Permeable materials are suitable to different places like: pedestrian roads, car parks, roads in residential areas and garden areas to protect the grass. The important clues to reach the advantages of permeable pavements are:

- Select the most suitable permeable material by taking into account the final use.
- The correct preparation of the sub-bases depending on the level of required infiltration, the location, the expected durability and the climate.
- The appropriate maintenance tasks in order to keep the permeable properties of materials as far as it can be possible. (The university of Rhode Island, 2005)

Regarding the different layers which compose a permeable pavement it can be distinguished: (Thorpe, D. & Zhuge, Y., 2009)

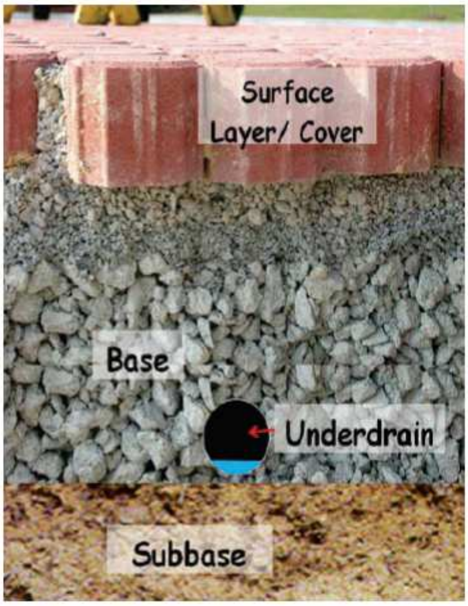


Figure 76: General vertical section (The University of Rhode Island, 2005)

- Surface layer: the top sheet of the pavement in which different materials can be used.
- Gravel base: this is the bearing layer which supports the loads. It is needed in all types of permeable pavements having the exception of the permeable concrete ones.
- Sub-base: this is the next layer below the gravel one.
- Underdrains: collectors placed in the sub-base which lead the water to other areas. They are very common when the predominant soil material is clay.
-

The classification criteria follows the next division:

- Permeable asphalt (PA)
- Permeable concrete (PC)
- Permeable interlocking concrete pavers (PICP)
- Plastic grid pavers (PG)
- Concrete grid pavers (CGP)

Figure 80: Permeable concrete (The university of Rhode Island, 2005)

Figure 79: Permeable asphalt (The University of Rhode Island, 2005)

Figure 78: Permeable interlocking concrete pavers (The University of Rhode Island, 2005)

Figure 77: Concrete grids (The University of Rhode Island, 2005)

Some advantages and disadvantages can be mentioned in order to have a clearer idea of these pavements:

Advantages.

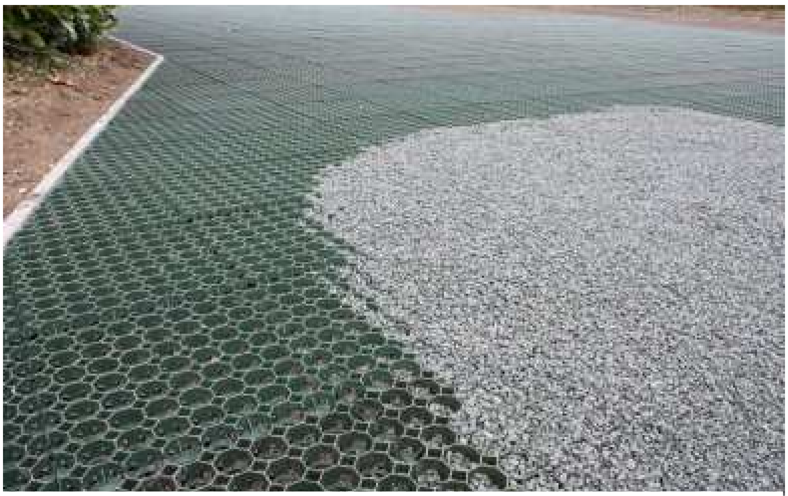


Figure 81: Plastic grids (www.terram.com)

These pavements offer the capability of filtering water and retaining the water pollution. Several studies (Scholz, M., 20013; Legret, M. et al, 1996) show that more or less 65% of suspended material and around 80% of lead material are kept in the surface of the pavement or in the intermediate layers. In addition is also very important to provide geotextiles at the bottom of the layers to improve its environmental behaviour. The election of the most suitable geotextile is sometimes the concern in order to achieve the best filtration result. (Scholz, M., 20013) On the other hand, another investigation (Rodriguez, J., 2008) shows details that if the level of water pollution is so high a large quantity of these contaminated particles is transferred to the subsoil. As a consequence of this, industrial areas and also any high pollutant place are not a suitable location for this type of pavements.

The use of porous pavements helps other drainage pipe systems for example to filter the water from the surface into the subsoil, this fact can reduce around 10% the total quantity of conventional water catchments. As a consequence, several quantity of money can be saved and also because of the reduction of the time spent on the installation of the collectors and avoiding taking into account different water regulations.

The increase of water in the subsoil decreases the demand of irrigation water, fact that makes save money as well.

The fact of allowing the water to reach the subsoil through the porous of the pavement reduces the risk of flooding. This aspect has quite importance in cities during heavy rainy periods of time, it provides a proportional help to other systems in order to avoid that problem.

On the other hand permeable pavements have also a thermal characteristic. The possibility of the water to humidify the subsoil causes the decrease of the temperature in comparison to normal pavements. When the sun heats these surfaces, steam comes from the soil to the atmosphere, maintaining a steady humidity and temperature of the area and avoiding the heating island. (Asaeda, T & Ca, VT., 2000)

The variety of types of permeable pavements can have an aesthetic positive effect. From the architectural point of view the combination of types and colours can increase the value of properties and neighbourhoods.

To summarize, permeable pavements offer three important aspects of SUD systems: they allow the water to reach subsoil´s layers increasing the quantity of water in aquifers, at the same time the quality of the water is better as a result of the filter effect of pervious pavements and finally, they can provide interesting aesthetical aspects.

Disadvantages.

Before developing some general information about most distinguished drawbacks of permeable pavements it would be better to mention that the general lack of experience in this area can be the reason of some of the negative points and, on the other hand, can be considered as another disadvantage as well. There are no reliable documents which could guarantee the final objective and the expected behaviour and performance for a long time. (Watson, L., 2010)

The permanent exposition to the attack of the atmosphere agents, sun, changes of temperature (…) causes the solidification of the binder, therefore the aggregates included in the mixes lose cohesion. This fact produces and is also the cause of an uninterrupted degradation process. (Yalçinkaya, Ç.)

Rainwater can damage porous pavements in a different way. Sometimes it can access inside the structure of the pavement and keep it wet for a long time, as a result of this the binder loses adhesion properties causing at the same time the deterioration of the structure. (Yalçinkaya, Ç.)

Permeable pavements are not designed to replace water pipes collectors or other water management systems. They have to be designed taking into account the performance improvement of other impervious areas or to manage the rainwater in order to get better social, environmental, local (…) conditions. If the amount of water to manage cannot be transferred to the subsoil by these structures another drainage system has to be provided and do not expect this "extra water management performance" from these pavements.

Materials like dust, dirt and any kind of sediment deposited on the surface of the pavement can decrease the level of its porosity. This fact is less important in high speed roads because of the cleaning effect of the tyres but in slow speed lines are often needed special water devices to maintain the pervious properties of the pavement.

The most important concern is on slow speed roads which are used by heavy trucks or other transports. (Yalçinkaya, Ç.)

Apart from the damage of high density of traffic there is another problem which can cause an additional damage on the matrix of the pavement, it is the salt used to de-ice the snow during the winter. As far as it is investigated the salt can decrease the adhesion properties of the binder and desegregates the different aggregates. On the other hand there are studies which give details regarding the effect of the ice over permeable pavements, they show the negative effect of it in this type of surfaces because of the low conductivity which makes ice appear earlier in porous surfaces than in normal ones. (Yalçinkaya, Ç.)

Depending on different aspects like density of traffic, type of binder, quality of aggregates and climate it can be said that the first activities of maintenance can be required after 5 or 8 years and ,in the most favourable cases, after 15 years. These operations are more expensive in this type of pavements than in the conventional ones but, at this point is also needed to say the important benefits of these soils in order to avoid accidents and providing social positive aspects as well, fact that cannot be forgotten. (Yalçinkaya, Ç.)

Classification

Pervious concrete

The main components of this material are: Portland cement, aggregates, admixtures and water in order to create around 15% - 20% of porous. To mix all components and to apply them are used the same devices like are utilized to make conventional concrete. (The University of Rhode Island, 2005)

This type of pavement can be used in different places like: car parks, residential areas, play areas, pedestrian roads, bike parks…

The application of this porous material is more laborious than the pervious asphalt and rougher than the normal one. It can be really effective when aesthetic aspects are demanded. (The University of Rhode Island, 2005)

Regarding the resistance, the maximum capacity to support strength loads is around 20, 5 Mpa and regarding flexural forces is 3.5 Mpa approximately. (Tennis et al., 2004) The range of this value depends on the quality and type of soil below. Pervious concrete offers better stability when it is wet.

The period of use is around 15 years, always depending on how and where it has been installed, its design and maintenance as well.

From the bottom to the top various layers can be distinguished and they are usually: geotextile to separate the crushed rock layer and the soil below, over this one are located around 35 cm thickness of crushed stone with sand as aggregate and finally the top porous concrete layer with around 10 cm thickness. (The University of Rhode Island, 2005)

Some operations of maintenance in this type of pavements are needed. To follow a correct performance the surface needs to be swept in order to remove and clean any sediment which has been deposited on the surface and also annual inspections are needed to keep under control the level of deterioration and disaggregation of the materials.

In winter climates salt can be used to de-ice but not near aquifers to avoid contaminate them. If the level of drainage decreases some 1 cm hole can be drilled every few meters in order to maintain the drainage property. (The University of Rhode Island, 2005)

Regarding the final price of this model of pavement there are some parameters that can have strong influence over it. A layer of stone instead of using a compacted one is usually a bit more expensive than the second. Deep earth movements are not usually required to this type of pavements and usually the thinner is the total section the better is the drainage performance. (The University of Rhode Island, 2005) The size of the project and the location where it will be developed can be decisive in the budget. After taking into account these variables the average price is around 10 -15 Euros/m^2)

Permeable asphalt

Porous asphalt pavement is a mix-asphalt with less quantity of sand in order to provide permeability properties. This fact creates large number of interconnected voids which run the water to the subsoil.

This type of pavement can have different applications like pedestrian roads, car parks and any residential street. It is a type of asphalt recommended to areas which have low density of traffic, some studies prove that they are suitable to be used in highways but their durability is affected severely.

Regarding the performance of this particular pavement it has the same water behaviour than other permeable road materials, they improve the management of rainwater decreasing the source of water which is usually driven by impermeable surfaces. On the other hand porous materials have a filter quality reducing the quantity of water pollution. The type of subsoil is the most important factor which allows more or less quantities of water filtration. These asphalts provide less capacity of strength in comparison to concrete pavements.

Different layers provide these permeable features to this type of pavement, from the bottom to the top they are:

- The subgrade, which determines the quantity of water that can be transferred from the surface
- Geotextiles: this layer avoids the movement of soil materials from the layer above into the subgrade.

- Underdrain: it is optional and it usually consists in a plastic perforated pipe which collects and runs the water to sewers.

- Sub-base reservoir: it is a crushed stone layer and its thickness depends on the final use of the road or pavement.

- Base reservoir: layer made of smaller crashed stones than the layer below.

- Chocker course: it is a 4 – 5 cm thickness layer which provides stability to the pervious asphalt.

- Pervious asphalt: the top layer with 5- 7 cm thickness. This layer needs to have 20 % of air voids in order to allow water filtration to the layers below.

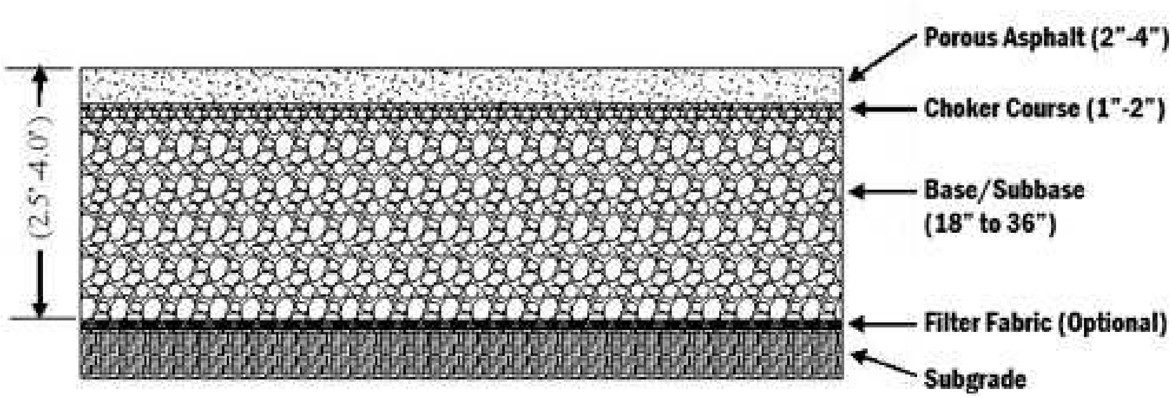


Figure 82: Permeable asphalt section (cfpub.epa.gov)

The relevant concern in terms of maintenance is the clogging of the porous; this fact is usually caused by sediments deposited on the surface during the time. As a consequence after proving the decrease of the permeability, some holes can be drilled in order to recover the initial properties. Sweep the surface can be another solution as well. From the point of view of structural maintenance cycles of ice and deice cause cracks on the surface and it can be an important cause of collapsing. (The University of Rhode Island, 2005) (National Pollutant Discharge Elimination System, 2009)

The final cost is based on different parameters like: location of raw material, initial conditions of the soil, specific requirements or also the size of the project. The average price per square meter is around 5 – 10 Euro. (The University of Rhode Island, 2005)

Permeable interlocking concrete pavers

Concrete interlocking pavers are made of concrete bricks. The filtration of the rainwater to the layers below happens because of the gaps in the joints between pavers. The thickness of the layers under the pavers determines the quantity of water filtration. This type of pavement is usually located in car parks, residential and pedestrian areas, squares, roofs…

The most important benefits are the same as other types of permeable pavements studied above. The high level of water filtration makes this system very suitable to manage water from impervious areas and runs it to the subsoil. Secondly different layers have a filter effect retaining most of the water pollution, increasing the quality of the water and, finally, this type of pavement has also an important environmental aspect regarding water of aquifers.

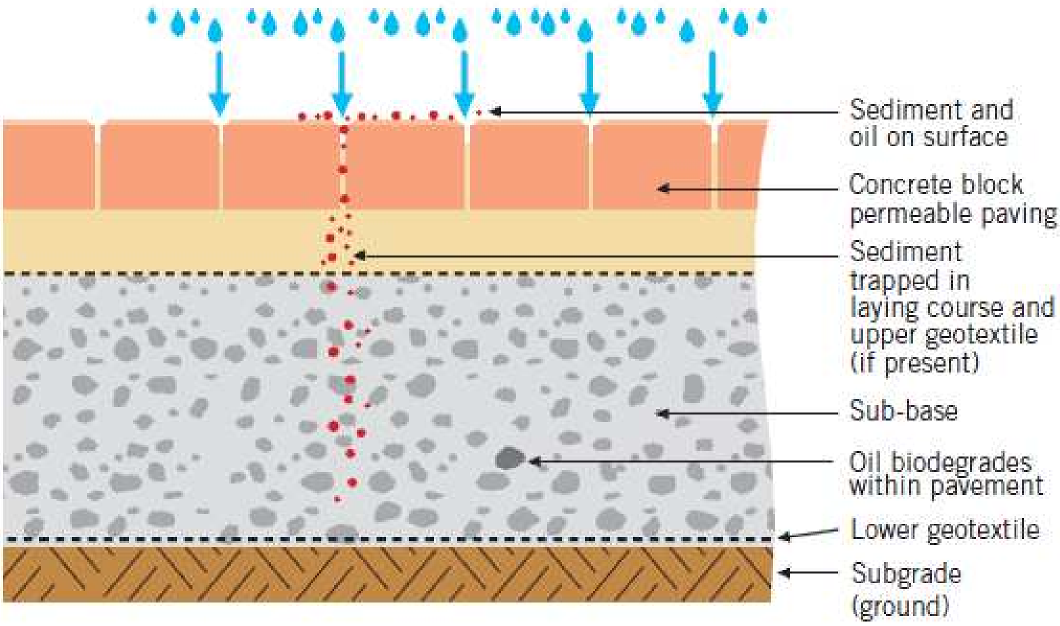


Figure 83: Permeable interlocking concrete pavers section (http://www.marshalls.co.uk, 2008)

There are three types of interlocking pavers depending on the quantity of water is absorbed by the sub-base.

- System A: when the soil has really good permeable properties and additional drainage systems are not needed.

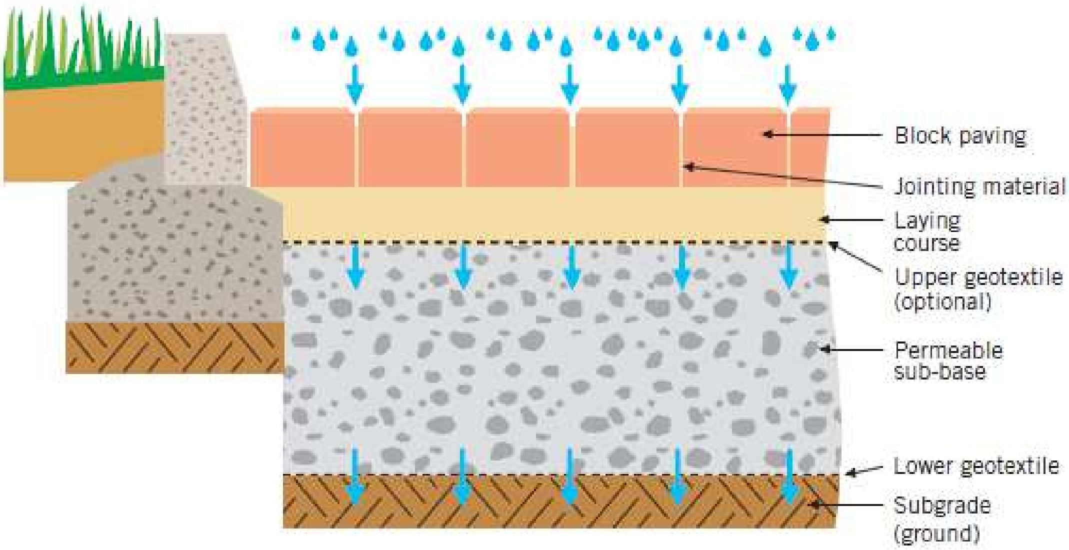


Figure 84: System A (http://www.marshalls.co.uk, 2008)

- System B: when the subsoil can absorb part of the water and the rest has to be drained by pipes.

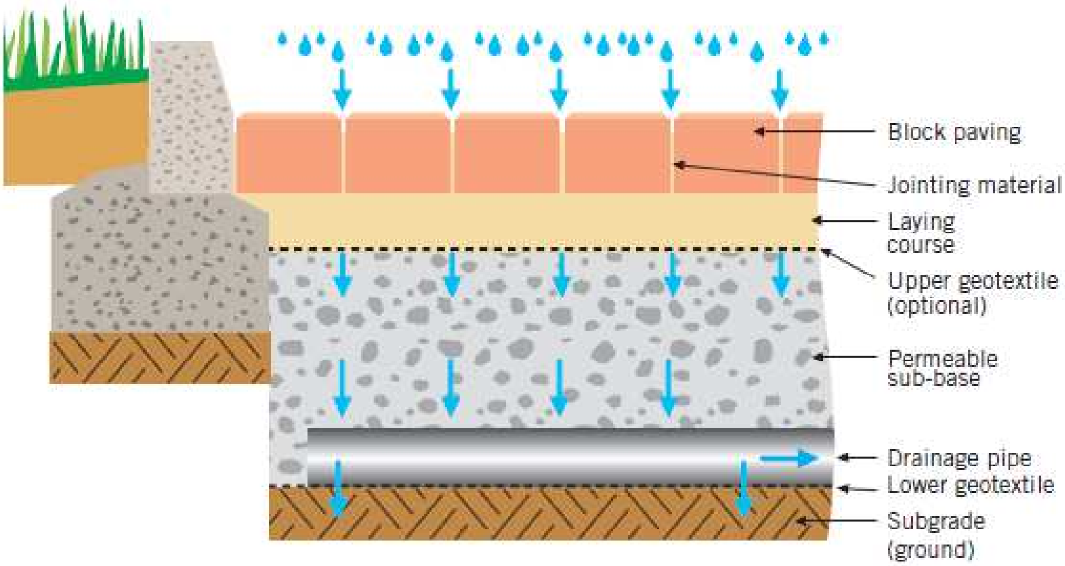


Figure 85: System B (http://www.marshalls.co.uk, 2008)

- System C: when the subsoil is not able to absorb the water and it has to be drained by additional installations. This type is very suitable to contaminated areas.

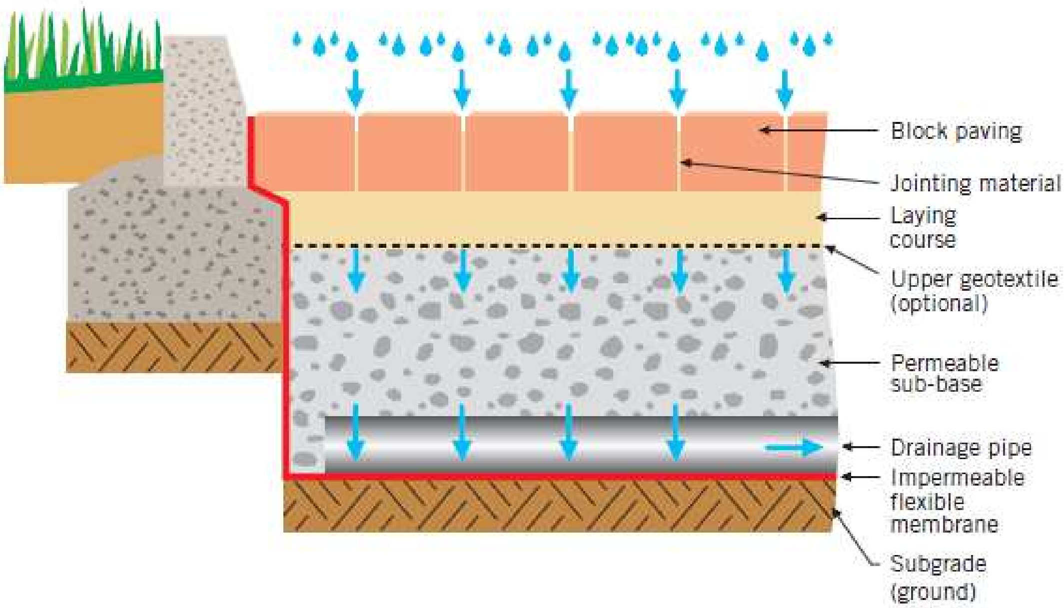


Figure 86: System C (http://www.marshalls.co.uk, 2008)

Lower maintenance is needed in this type of pavement. Cleaning the surface can be enough to maintain the drainage level of the system. Remove possible sediments from the surface is also a required activity of maintenance. Damaged bricks and possible depressions are other types of failures of these pavements, repairing them do not usually require high investments.

Initial costs of this type of pavements are lower than concrete and asphalt permeable pavements. Fixing a price in this case can be difficult also because of the different types of concrete bricks on the market. Location, type of soil and size of the project are parameters that have influence over the final price.

Plastic grids.

Permeable pavements based on plastic grids consist on top interlocking cellular layers which allow large quantities of water to runoff into the subsoil. All gaps in this plastic structure con be fulfilled with grass or different types and sizes of gravel depending on the site and the load this pavement needs to support. (Geogrid, 2008)

Figure 87: Plastic grids (drivewaysandmore.wordpress.com)

The important performance in terms of water management of this material allows it to be used in many different environments with also contrasting objectives. It is used in car parks, pedestrian areas, golf paths and in any place where is required the installation of this type of permeable pavement with this aesthetic and this high level to transfer water to the subsoil. It can be used also in slopes to retain the earth and manage rain water as well. (The University of Rhode Island, 2005) (True grid, 2008)

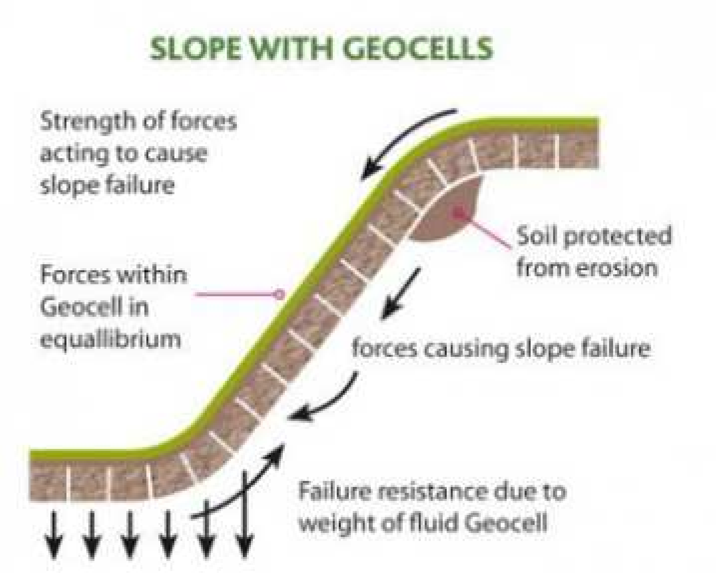


Figure 88: Plastic grids in slopes (www.terram.com)

This type of material demonstrates an important water management performance. It can transfer more water to the subsoil than the previous types of permeable pavements but, what is important to get this performance is that all layers below need to have strong permeability to allow water to be absorbed, this fact is the most important detail. Regarding the resistance of plastic grids they can offer similar strength than concrete pavements. Several models, brands and material compositions have been developed around plastic geo-cell pavements. Therefore, to achieve its best performance the suitability between the type of plastic grid and the load it has to support, use and location need to be studied deeply in order to avoid failures in the project.

Most types of plastic grid pavements are installed over a gravel sub-base. The depth of this layer depends on the final use of it. All the gaps are filled with a mix of soil and sand with grass or gravel.

No many operations of maintenance are required apart from keeping the grass irrigated and replacing damaged plastic grids when it is needed.

The final price of this pavement depends on various parameters like happens in other types of materials, The location and size of the project, the distance between the location of the raw material and the workplace and also the performance required can have influence in the final budget and price. The average price could be usually around 7 – 12 Euro/m^2, but it is only a reference. (The University of Rhode Island, 2005)

Concrete grids.

Concrete grids pavements have been developed to offer the possibility of providing grass and at the same time to combine it to the use of cars. This top layer is an alternative of concrete and asphalt permeable pavements. It cannot be used in the same situations but when it is possible it offers better performance in terms of heating island phenomena and rainwater management. These pavements are usually used in car parks, pedestrian and open areas, trucks parks…

Like it has been explained before in other types of pavements this one has advantages regarding filtering the water. Some studies demonstrate that some pollution, in lower level than concrete, asphalt and interlocking brick pavements, is retained in the different layers. As a consequence of allowing the water to get the subsoil reserves of water are kept, fact which has a positive environmental effect in the closer areas. (National Concrete Masonry Association, 2001)

As it is showed in the left picture, quality of water after being filtrated by this pavement can be worse depending in the type of used pavement (Dierkes, C. Et al, 2007)

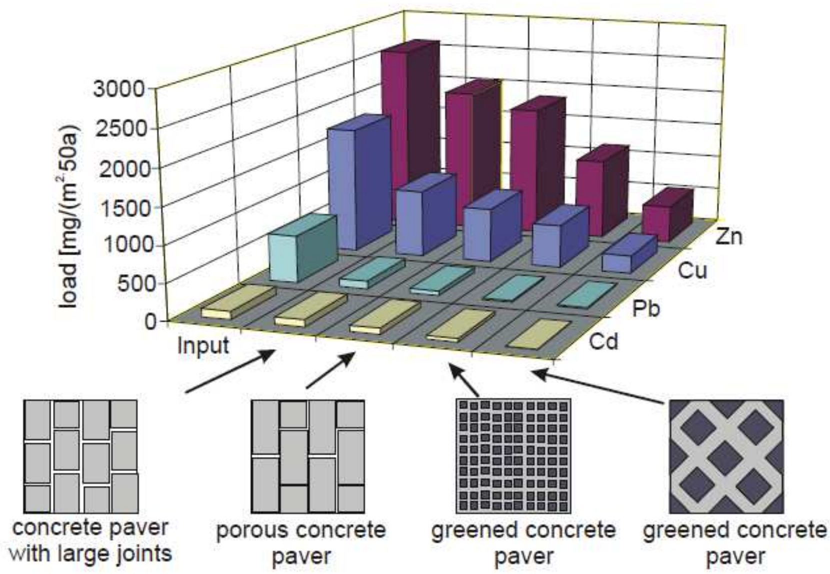


Figure 89: Water quality depending on types of pavements (Dierkes, C., 2007)

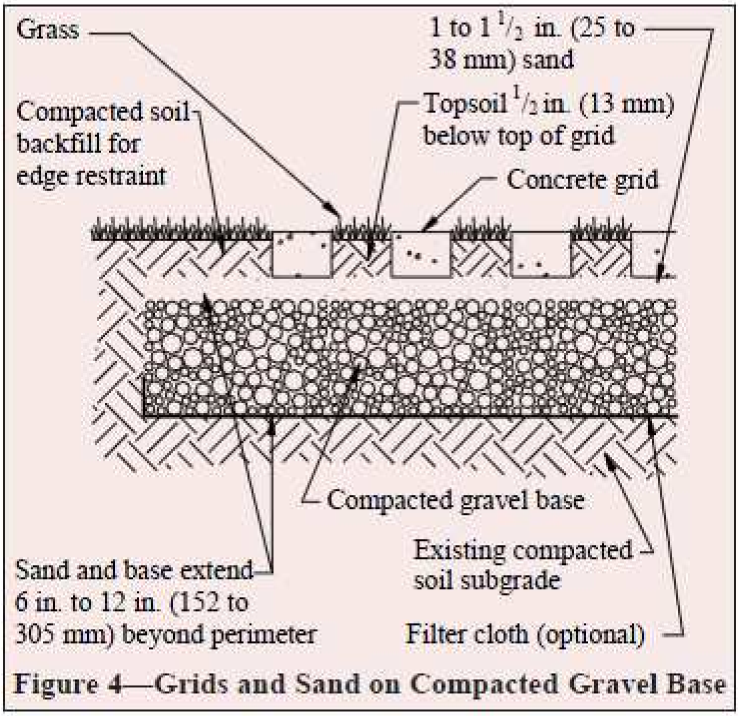


Figure 90: Concrete grid section (National Concrete Masonry Association, 2001)

Regarding the installation of these types of pavements various layers are distinguished from the bottom to the top: there is a sub-base of soil, above this layer there is a gravel one, a layer of sand is the next and finally the top layer which consists in grid pavers with grass of gravel in the gaps. The use of one or another fill material depends on the final use of the pavement. (National Concrete Masonry Association, 2001)

Replacement of damaged concrete grids and keeping grass alive are the most important operating tasks of maintenance.

Final cost of this pavement depends on different parameters like happens in all the other types. Location of the project and the difficulty to develop can be very determinant to fix the price per square meters. In conclusion the reference price could be around 10 Euro/m^2.

Future trends

Large number of investigations have been developed in order to have a deeper knowledge in this area of permeable pavements. Nowadays some problems like durability and suitability to any type high speed road need to be studied and solved to achieve more confident data, also there are parameters like the type of climate that have strong influence on the final and correct behaviour of this permeable structures, this fact makes that sometimes the type of road or pavement in one area is not suitable for another place because of specific aspects are required.

It is a good water management solution based on environmental, social and economic aspects but before executing the project a depth study of the project is needed, this technical solution can only be part of the project and other approaches have to be taken in order to solve the particular problems and achieve the specific objectives.

SUSTAINABLE URBAN DRAINAGE SYSTEMS (SUDS)

Due to the urban development, vegetation is being removed and replaced by impermeable surfaces such as roads, roofs and car parks. Because of this, the water rainfall, that was previously able to be filtered by the soil, is mostly converted to runoff making its volume increase considerably. This runoff goes down to lower topographic levels and, as a lot of vegetation has been replaced by impermeable surfaces, its velocity is very high so it can cause erosion and flooding problems. The runoff increment can overload rivers, thus creating flooding problems in the riverside.

As the velocity of the runoff is very high due to the impermeable surfaces, the water has less time to infiltrate into the soil and so the aquifers cannot be recharged like they used to be. The lack of trees, which can collaborate to stop the runoff, helps to increase the water velocity over the soil as well.

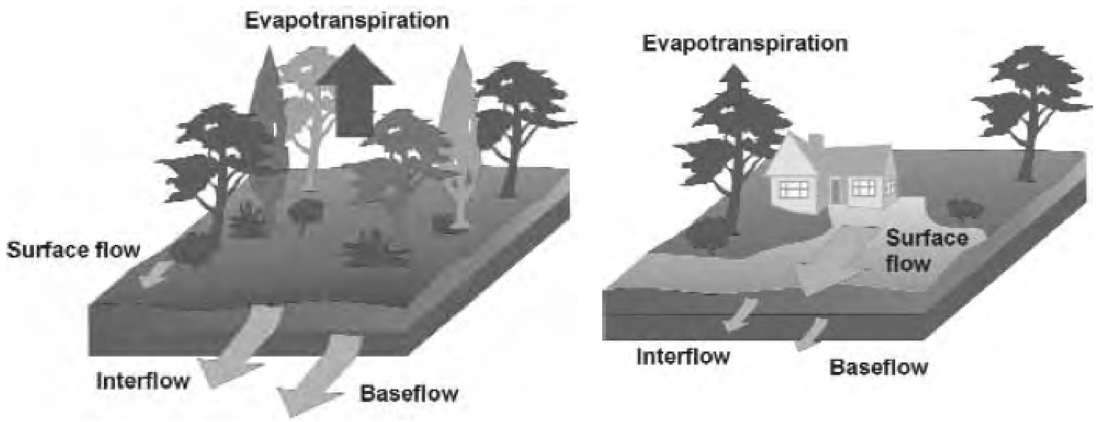


Figure 91: Hydrological processes pre and post development (CIRIA, 2007)

The traditional solution to this flooding problem was to construct a network of pipes that increased the water flow efficiency. These networks were able to collect the rainwater and send it to a sewerage system. However, this solution had short-term problems. While the city grows, more impermeable surfaces appear and thus the runoff increases, so the pipes can no longer lead all the water, being necessary to enlarge the drainage system with the consequently costs.

In addition, this way of drainage has pollution problems. The impermeable surfaces due to urban development have pollutants coming from oils, fertilisers, metals and others. The water is transported through the pipes with these pollutants and it is discharge then into receiving water causing pollution.

Currently, the best solution to these problems is the Sustainable Urban Drainage System (SUDS). SUDS are able to manage the rainwater in a similar way to the natural process. They try to simulate the natural drainage before the development. SUDS catch the runoff as soon as possible and then they release it slowly.

These are the main purposes of the SUDS: (Graham, et al., 2012)

- Reduce the runoff downstream and its power to cause erosion and flooding problems
- Reduce water pollution
- Help to recharge the aquifers, so rivers will have water during dry periods
- Habitat and amenity enhancement
- Increase evapotranspiration, so the climate will be regulated in urban areas

To achieve these objectives a natural drainage has to be simulated through a management train. This concept of management train has different series of drainage techniques in order to reduce runoff quantity and improve runoff quality. These techniques have the following hierarchy: (Woods-Ballard, et al., 2007)

- Pollution prevention
- Source control
- Site control
- Regional control
- Conveyance features

The first step is the prevention before the pollution takes place, which is more effective than fix it afterwards. Secondly, the source control, where the peak runoff rate is reduced so there will be less pollutants in the water, being easier to manage them. Thirdly, the site control, where the runoff will be stored and controlled. Then, the regional control, where the removal of pollutants from contaminated runoff will take place. And finally, conveyance features that are in charge of moving the water between the different stages.

The techniques with a higher hierarchy are always considered before, thus the pollution prevention and source control are preferred to site and regional control.

To manage the runoff quantity there are several processes used by SUDS: (Woods-Ballard, et al., 2007)

- Infiltration: through this process the water goes into the soil. It is the most desirable one to simulate the natural drainage process.
- Detention: it consists on the slowdown of the runoff. At the end, the duration of the runoff will be longer and the quantity will remain the same.
- Conveyance: it is the transport of the runoff from one place to another. This process is used to connect different SUDS technics.
- Water harvesting: to catch the runoff and use it on site.

To manage the runoff quality the SUDS use several treatment processes such as sedimentation, adsorption, filtration, volatilisation, photolysis, uptake by plants, precipitation, nitrification and biodegradation.

Filter strips

Filter strips are a source control technic. They are vegetated areas that are located between disturbed impervious lands and a surface water collection, a receiving stream or a treatment system. Their aim is to collect the runoff coming from a field, and then filter the sediments, pollutants or suspended solids that the water contains before transporting it to its final destination.

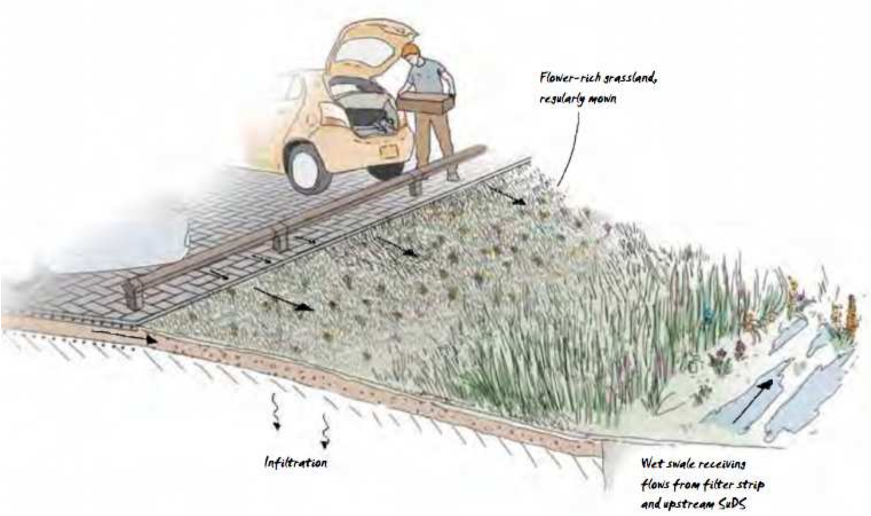


Figure 92: Filter strip receiving runoff from an impermeable car park (Day, 2012)

These strips have a gentle slope and the water pass through them with a low velocity so the sediments and pollutants in the water can be filtered by the vegetation. The vegetation required in filter strips is a mixture between grasses from dry and wet areas. Wildflowers can be added to these grass mixtures in order to increase the amenity value.

Filter strips are a pre-treatment in which the water that enters into them, leave them as clean as possible from sediments and pollutants. They are used before other SUDS techniques and so, those techniques downstream will last more.

Filter strips can remove sediments and organic materials under low velocities. Soluble pollutants that infiltrate into the soil are taken by the roots of the vegetation and thus, releasing water from them.

There are some conditions about the siting of these filter strips. They don't work properly in cold climates where the soil can be frozen, minimizing the infiltration of the water and so the treatment effectiveness. This treatment effectiveness is also affected when the filter strips are located in impermeable clay soils. Filter strips aren't suitable for places either with pedestrian traffic or storm water hotspots where gas pollutants can infiltrate into the soil and can contaminate the ground water. Besides, they cannot be used in steep slopes, because the sheet flow would go very fast and infiltration wouldn't take place.

During storms a lot of runoff goes through the filter strips and with a high velocity so the filters aren't able to work properly. Then, this technique is useful only during small rainfall events. Under-drains can be added to filter drains in order to improve infiltration and to help to dry the soil after storms.

Apart from the siting consideration there are also some design considerations to take into account in order to achieve a good performance of the filter strips. It's important to design the filter strips in a way to be incorporated into the landscape. They can be used to create vegetated areas where people can enjoy wild views. Natural and native vegetation shouldn't be removed from the place where the filter strips are going to be located, it is better to improve this native vegetation.

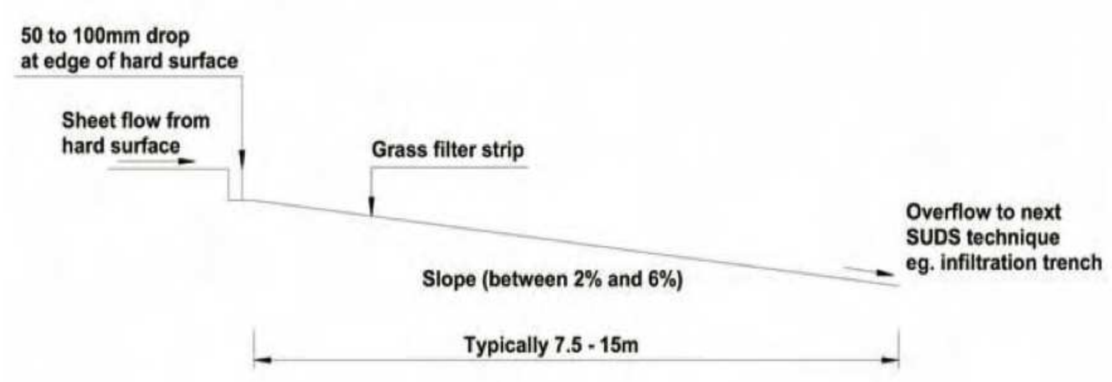


Figure 93: Section view of a filter strip (CIRIA, 2007)

To avoid water from staying stagnant and to increase the treatment, the slope of the filter strips should be between 2% and 6%. As it has been said, steep slopes can make water to flow too fast causing erosion problems and lack of infiltration. They must have an accurate grading slope to ensure a properly sheet flow. The longitudinal slope shouldn't have undulations that can cause ponding.

The highest and lowest part of the slope should have the lowest range of slope to reduce the velocity of the water flow and thereby to reduce the erosion. Upstream the filter strip there should be a minimum drop of 50 mm from the filter strip to the disturbed surface in order to prevent sediment formations. Whereas, downstream should be other SUDS techniques to keep on treating the water.

The length of the filter strips should be extended to the whole area that is going to be drained. The recommended width is 1 meter for each 6 meters length in order to achieve a good quality performance. The maximum length is suggested to be 50 m. (Woods-Ballard, et al., 2007)

Soil stabilization practices to prevent erosion during the construction of the filter strips have to be done. Furthermore, the soil below the filter strip cannot be compacted as this can reduce the infiltration capacity.

Filter strips have to be protected from water flows until vegetation is established and well rooted. To achieve this some actions have to be performed: (Woods-Ballard, et al., 2007)

- Divert the runoff out of the filter strip
- Cover the surface of the filter strips with plastic
- If after four weeks more than 30% of the drainage surface is free of vegetation, it should be replanted to achieve 90% of coverage.

To achieve a good performance, regular maintenance is required:

- Remove litter and debris
- Mowing
- Repair damaged areas

The cost of building and maintaining a filter strip depends on various factors. The maintenance cost is very low, the greatest cost is the land-take.

Detention basins

Detention basins are depressions filled with vegetation where the water runoff can be stored. They provide flow control through the attenuation of the runoff. Detention basins reduce the flood risk downstream. As the water is retained in the basin, gradual infiltration can take place into the soil and so some pollutants can be removed. Thus, they can be used as both site and regional control techniques.

These detention basins are usually dry and they can be used, for instance, as picnic areas, football pitches and children's play areas. Because of this, they should be designed taking into account the visual enhancement, social space and habitat creation. These features can be enhanced if upstream there are some source control technics so the water runoff coming to the detention basins will be less polluted and less frequent. This can also allow a more reduced maintenance and a better integration into the landscape. Furthermore, if the water quality is good there will be high biodiversity.

Design considerations of detention basins: (Anglian Water Services Limited, 2011)

- Silt should be intercepted before coming into the detention basin
- Water runoff should come into the basing in a controlled way, this can be achieved with a source control technic upstream or with a fore bay
- The length-width ratio should be between 2:1 and 5:1 in order to encourage the runoff filtration
- The slope should be about 1 in 100 to the outlet direction so the water can flow by gravity
- Not all the basin have the same depth, there are deeper areas that can be flooded while higher areas are dry
- The maximum side slope should be 1 in 3
- They should have an overflow so water can go through if the outlet is blocked or there are a lot of runoff
- Maximum depths of 600 mm for safety reasons
- The design should be integrated with the landscape

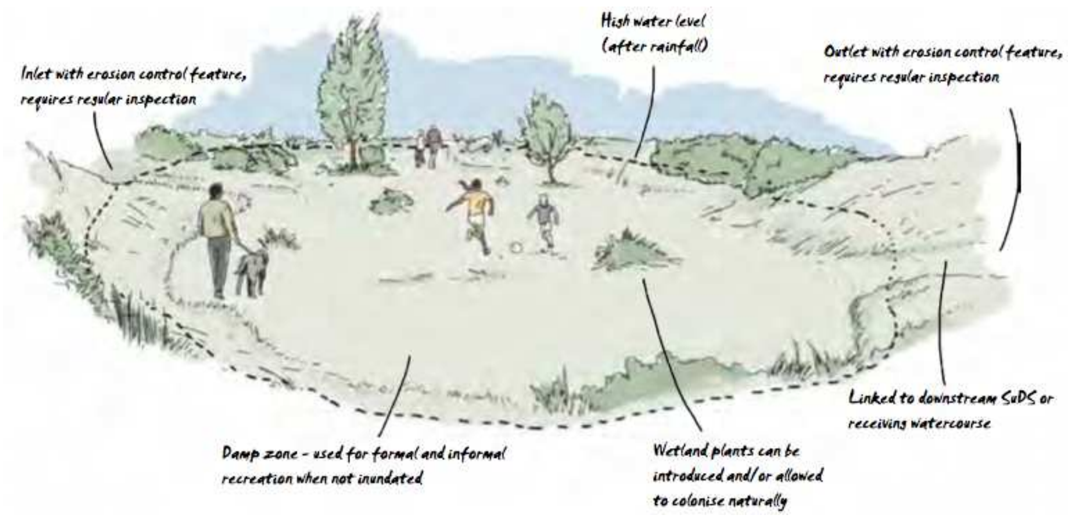


Figure 94: Multifunctional use of detention basins (Day, 2012)

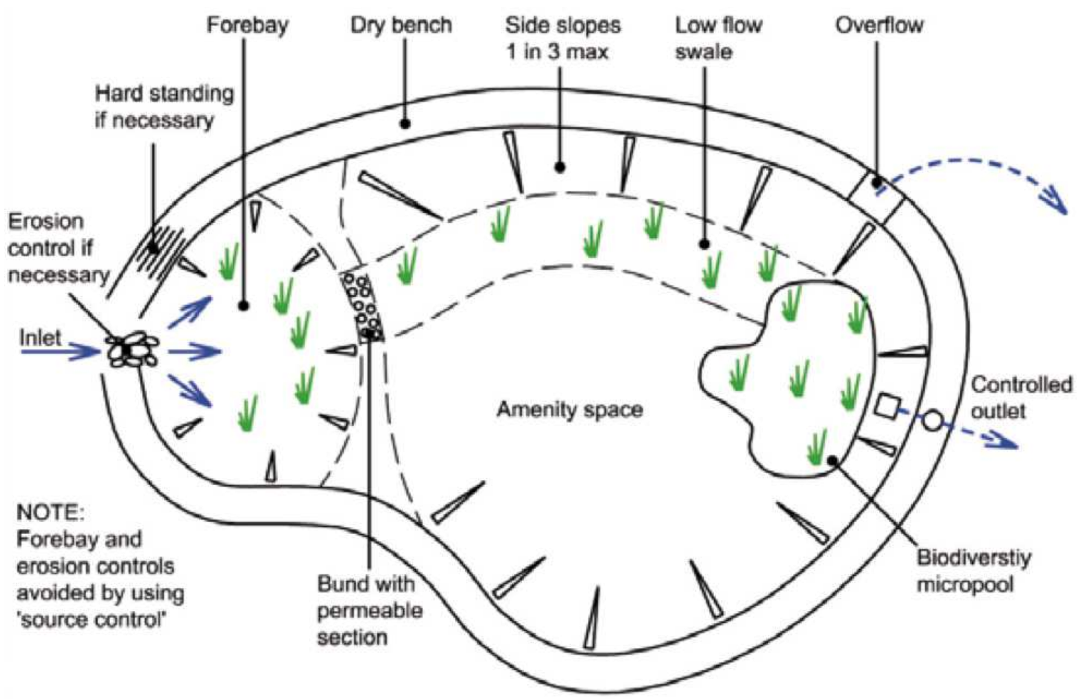


Figure 95: Detention basin plan view (Unknown, 2011)

During the construction of the detention basin, its side slopes and bottom have to be prepared so structural stability is ensured. This has to be also ensured when the runoff came into the basin. They should be constructed during periods with low runoff rates such as summer and spring.

Once the detention basin is built, some maintenance activities have to be performed. Regular mowing is required into and around the basin to maintain access routes and amenity areas. Also backfilling have to be controlled in inlets and outlets to prevent erosion and settlement.

Infiltration basins

They are similar to detention basins except that they store water and infiltrate it, they only can be used as a site control technic. It is necessary to have source control technics upstream to prevent clogging and to ensure that only clean water infiltrates into the soil. They are not suitable for places with polluted soils such as industrial sites.

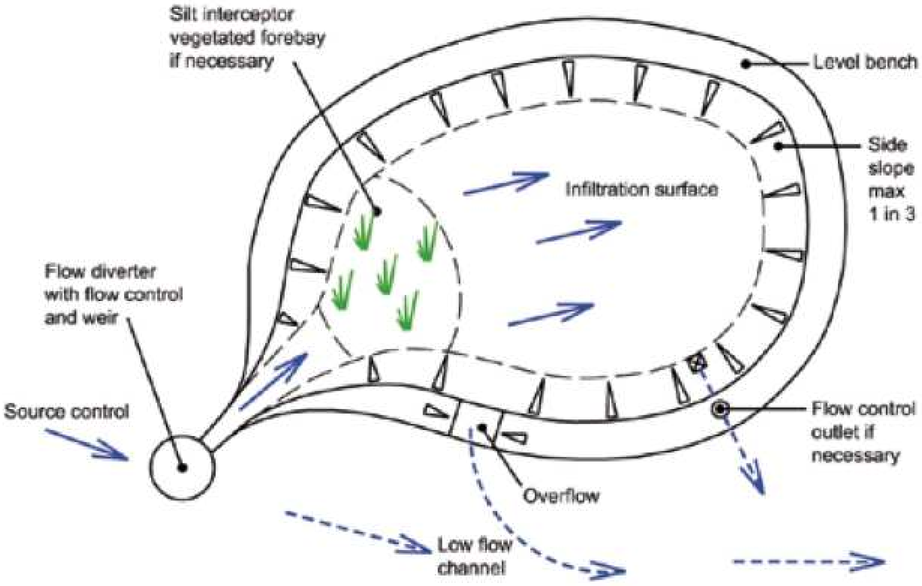


Figure 96: Infiltration basin plan view (Unknown, 2011)

As shown in the figure above, infiltration and detention basins have almost the same design. Geotechnical tests should be performed to check the infiltration potential of the soil and upstream source control technics should be used to remove silt and pollution.

Trenches

Trenches are excavations filled with granular material in which storm water runoff is stored for either filtration or infiltration. There are two types of trenches: infiltration trenches and filter trenches.

Infiltration trenches can receive water flow, and they can filter it into the surrounding soil. They can be used as a source control technic and also as a conveyance technic. The purposes of the infiltration trenches are to increase the groundwater recharge, to reduce the water runoff and to filter soluble pollutants that are in the water. Infiltration trenches are not able to remove coarse sediments. Thus, they should be placed after an appropriate pre-treatment like, for instance, an oil-grit separator. (Storm water Technology Fact, 1999)

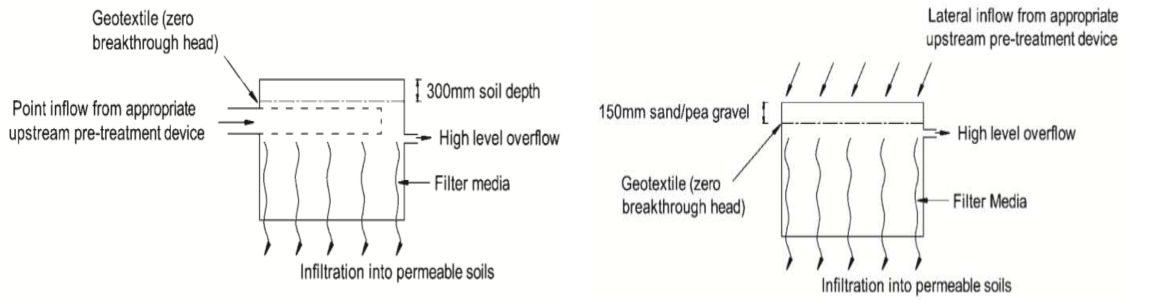


Figure 97: Infiltration trenches (CIRIA, 2007)

On the other hand, filter trenches are used to collect runoff, and to filter and transport it to downstream SUDS techniques. They are used as a conveyance technic. They are located over impermeable soils or where groundwater is vulnerable to be polluted. They consist on a quiet zone where sediments can be removed from the water, and adsorption, filtration and biodegradation processes can take place. The water volume reduction is low so they should be placed after another SUDS technique able to reduce the runoff.

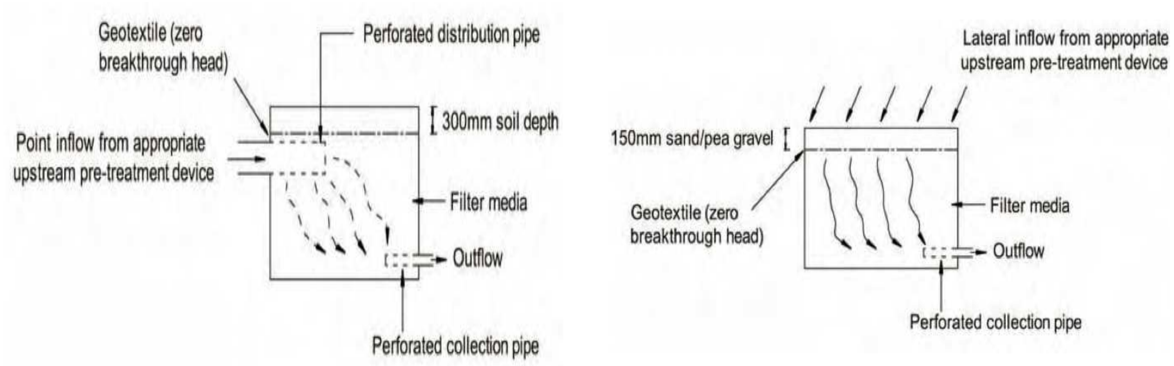


Figure 98: Filter trenches (CIRIA, 2007)

If the available space to place the SUDS technique isn't very large, trenches can be used instead of other techniques because they can have minimal land-take requirements.

The design of trenches is not thought for continuous flow, but for intermittent flow. This is the reason why they cannot be located in sites with a continuous flow from, for instance, groundwater. Besides, they should be placed in relatively flat areas as runoff has to be distributed in sheet flow before entering the trench in order to achieve properly infiltration and pollutant removal. The longitudinal slope of the trenches should not exceed 2%. (Woods-Ballard, et al., 2007)

The bottom of the infiltration trench must be at a minimum of 1 meter above the seasonally high groundwater table. While with filter trenches its base must be above the seasonally high groundwater level. The depth of these trenches is usually between 1 and 3.5 meters. (Storm water Technology Fact, 1999)

The main considerations to take into account during the construction of the trenches are:

- The surrounding area must be stabilized with vegetation before the trench construction.
- During the construction of the trench, it should be used light equipment in order to prevent the compaction of the surrounding area.

Regular maintenance and inspection is necessary for an effective performance of trenches. They have a high clogging potential, so they should be inspected after a storm and the debris have to be removed.

Ponds

Ponds are depressions in the ground where the water is contained. SUDS ponds can be created by excavating or by using an already existing depression. They are used to store and treat runoff although they have a greater focus on storing excess water. They can be used for both site control and regional control.

Most of the water treatment is already done by the upstream SUDS techniques so ponds are in charge of remove the remaining pollution. To achieve this, the water should flow slowly through the pond, which helps to remove pollutants through sedimentation and also allows the vegetation to reduce nutrient concentrations.

Ponds should be sited on flat sloping sites and on a stable ground. The soil below the pond should be impermeable so it can maintain the water level within the pond. If this is not possible, a continuous upstream flow has to be guaranteed.

These are some of the design requirements: (Anglian Water Services Limited, 2011)

- There should be a dry bench with a minimum width of 1 m
- There should be a wet bench with a minimum width of 1 m if the pond is big
- Maximum slope to and within the pond is 1 in 3
- Maximum depth of 500 – 600 mm
- They should be placed at the end of the management train so controlled flows and almost clean water enter the pond
- There should be inlets and outlets to help the water coming in and out the pond
- The outlet should be located at the permanent water level, so the water will always be able to flow through it.

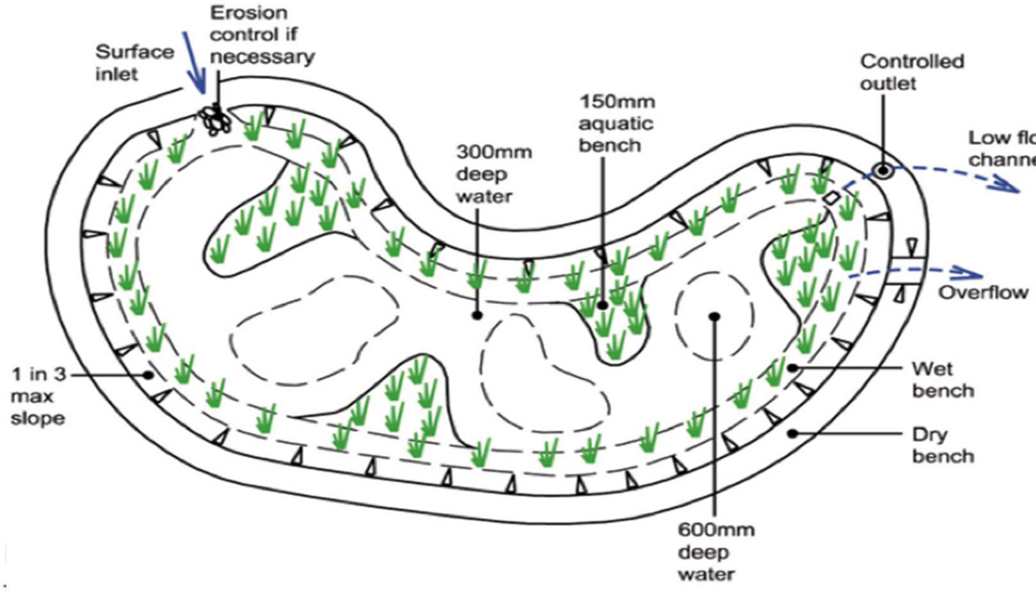


Figure 99: Pond plan view (Unknown, 2011)

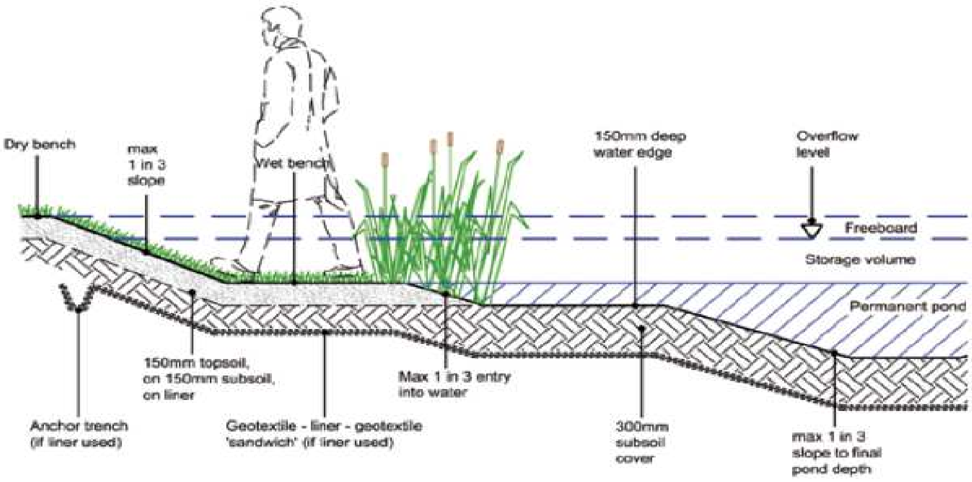


Figure 100: Pond profile (Unknown, 2011)

During the construction of the pond, runoff from bare soils has to be minimised. The sides and bottom of the pond have to be structurally stable during the construction and also when the runoff came into the pond.

Regular maintenance to cut vegetation around the pond is required and also to remove debris and sediments from site and from inlets and outlets. Whenever an inlet or outlet is broken, it should be replaced. In addition, occasional tasks have to be carried out to remove silt accumulation from the bottom of the ponds when required.

Wetlands

Wetlands are depressions that are covered almost entirely with aquatic vegetation. SUDS wetlands can be used in the management train as both site and regional control. They can store water for an extended time so sediments can precipitate and contaminants can be removed by either adhesion to vegetation or aerobic decomposition. Therefore, they can be used for both storm water treatment and storage.

Wetlands need a high land take to be placed, thus they cannot be placed in high-density development areas. They also need permanently wet conditions so they should have continuous groundwater seepage even during dry weather. Besides, the soil below the wetland must be impermeable so it is able to maintain wet conditions. If the soil is not impermeable, an impermeable liner has to be used.

The profiles and slopes in wetlands are generally like in ponds.

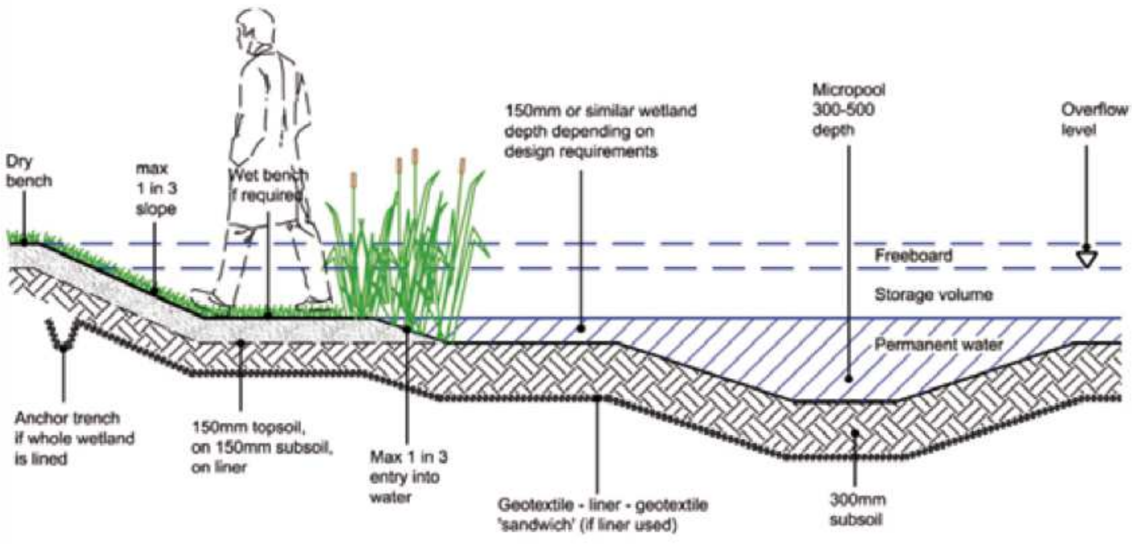


Figure 101: Wetland profile (Unknown, 2011)

It is very important to ensure that the impermeable liner, in case the wetland needs it, is not damaged during construction.

In many ways wetlands behave like ponds and both of them can be built together. The maintenance of wetlands is similar to ponds.

FAÇADE SYSTEMS

The energy consumed by buildings, to a large degree, due to their demand of temperature regulation: is cooling and heating. In order to decrease this great demand it is necessary to make an optimal design of construction technologies, a suitable choice of used materials and a deep study of the building orientation.

A correct design of all the features related with the façades and the orientation of the buildings is essential, since these are the most important factors in which the efficiency of a building can be improved.

It is known that the largest energy losses in a building take place in façades. A wrong choice of the materials, such as coating or insulation, or an incorrect use of construction technology can vary the behaviour of a building in terms of energy savings. Also, a suitable design of the orientation can increase the energy savings significantly taking advantage of the natural resources.

Vertical green façades

Vertical green facade is an eco-technology that has been involved in a constant evolution. Actually, green façades have reached such a complexity that is necessary to make a complete study of them to have a complete understanding.

There are different types of Green Wall: green façades and living walls. Green façades are composed of climbing plants and vines whose roots are in soil or containers. The plants can grow upwards or in down cascade, therefore a structure is needed to keep the position of plants. On the other hand, living walls are a new technology that consists of a monolithic or modular soil, which is in the vertical plane. It requires the same maintenance as a garden (irrigation, drainage, nutrients, etc.)

Figure 102: Living Wall (Klimt, P., 2013)

Figure 103: Green Façade (Unknown, 2010)

Benefits

In urban areas, green walls have a great potential not only in the public sector but also in the private one. Green walls contribute to improve the climatic change in big cities since, plants absorb toxic substances such us carbon dioxides and particles of heavy metals.

Depending on the objective when a green façade is designed, the benefits of this system can be split into private benefits and public benefits. It is not the same if the aim of a green façade is to improve the air quality, for the public benefit, or if the aim is to improve the thermal behaviour of the façade.

Public Benefits:

- Reduction of Urban Heat Island Effect, which consists in general warming of the urban areas due to the substitution of natural areas by pavements or buildings that take the sunlight and become it in heat. Through the implementation of vegetation in buildings façades, buildings and surroundings temperature decreases by shades, reduction of reflected heat and evapotranspiration.

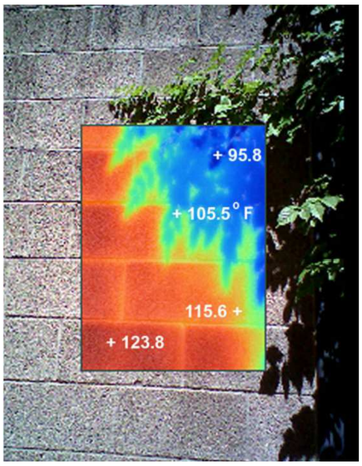


Figure 104: Temperature of concrete wall and vegetation

- Improvement of the Exterior Air Quality which is led to be worse even more due to the increasing number of air conditioners, vehicles and industrial emissions. Vegetation captures airborne pollutants in leafs and it gives filtered air back to the atmosphere. As well as they filter the noxious particles in the air.
- Aesthetic Enhancement that can improve human health and mental well-being. Green wall creates visual interest, hides the unattractive features as well as it increases the value of the property.

Private Benefits:

- Improvement of Energy Efficiency. Green wall contributes to enhance the thermal insulation capacity since it regulates the external temperature. This can affect both the heating and the cooling. In the thick layer of vegetation the air is kept fact that limits the movement of heat through, it as well as act as a buffer against the wind during the coolest months. In addition, by the processes of evapotranspiration and by shading, the temperature of the ambient softens. Besides, interior installations can reduce the demand of cooling and heating.
- Protection of the Building Structure. Green walls protect the finishes of the building from the UV radiation, the temperature variations and the climate elements as well as it avoid the damage of windows and doors by reducing the pressure of the wind on them.
- Improved Indoor Air Quality. In interior applications, plants of green walls can filter the air that, in traditional buildings, is eliminated by ventilation systems. The pollutant particles such as pollen and dust, as well as noxious gases and VOC's are filtered by the leafs.

Figure 105: Indoor Living Wall in University of Guelph-Humber College, Toronto (Sharp, R., 2012)

- Noise decrease. The sound levels can be reduced depending on the growing media, the structural components and the coverage.
- Sustainable Certificates. The use of green walls can contribute to get credits in order to achieve sustainable certificates such as LEED® or BREAM®.
- Increasing of the value. When a building is retrofitted with green façades the design improves as well as the thermal performance, ergo the value of the building increase.
- Apart from these benefits others can be included. Green walls provide privacy, security, shade... Also it is possible the urban agriculture, biodiversity is a plus. This is why, when a green wall is built, a habitat is created.

Technologies evaluation

Costs

The capital and maintenance costs of a green wall depend on different variables. All projects are different, they will have different costs depending on variables such as project size, system type, complexity of the design, use of standard or custom components, building location, access, variety of plants used, maintenance in long and short term,…

The costs of building a living wall are about three times of a green facade as well as the maintenance and replacement costs are high.

Maintenance / Design

In the phases of design, installation and maintenance it is necessary to take special consideration in order to build the green façade appropriately. So special attention in the calculation aspect regarding the structural loads (plants, snow, wind...) and the link between the green wall structures with the base façade. Also, a correct choice of the plants is essential. It is necessary to take into account the location of the plants, (its exposition to the wind and light) as well as the climatic area in which it is going to be installed. Furthermore, the time necessary to grow and cover all the surfaces, some systems spend 3 years to complete the design. In addition, the irrigation and nutrient needs are an important aspect in the phase of maintenance.

Trombe wall

Trombe wall system is a passive solar system that is built in walls facing up to the winter sun. It is built having an external glass layer and an internal high mass layer. There is an air cavity between the two layers. This system works as the greenhouse principle. The heat of the UV spectrum passes without obstacle and this heat is kept in the air cavity, after that, this heat is transmitted to the thicker wall which absorbs the heat to re-radiates in the far infrared spectrum which cannot pass the glass, consequently, the heat goes inside the building. It is necessary to take into account some factors in order to achieve a proper performance of Trombe Wall:

- The internal layer has to be made of high thermal mass, for instance concrete or water. The surface has to be matt and dark and the sunlight has to be as direct as possible.
- The external glass layer has to be as clear as possible in order to let penetrate the UV spectrum wave as short as possible. Because in this way, the heat re-emitted by the internal wall will find more difficulties to pass back through the glass.

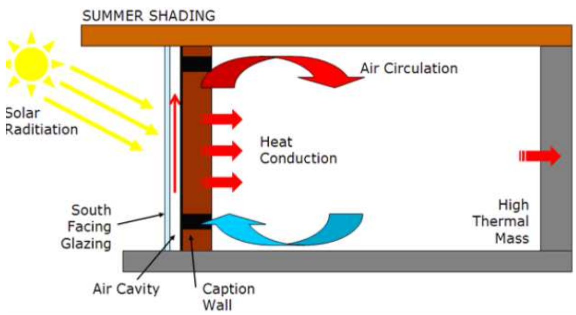


Figure 106: Trombe Wall System.
(Solyria, 2013)

Benefits

- The trombe wall is a passive system that does not require almost maintenance.
- The heat provided is more comfortable than the heat provided by forced air.

- The materials which are used, concrete and glass, as well as the construction of it are inexpensive
- The energy demand is decreased by 30%, so, the costs of heating are reduced (Hordeski, M.F., 2004).

Drawbacks

During cloudy days, the system does not work properly. There is a heat loss through the Trombe wall that can be avoided by the installation of insulation between the wall and the collector space.

Technologies evaluation

Costs

The costs of the construction are not high due to the materials used are concrete and glass that are inexpensive. If in the system, devices such as thermostats, fans, electric blower and so on are included, the total cost can be raised. But the future energy savings are higher than the initial investment.

Design/Maintenance

According to the International Association of Certified Home Inspectors, to improve the performance of trombe walls it is possible to include some variations in the design that allow to reach the best efficiency as possible:

- An opening at the top allows the ventilation of the warm air outside during the hottest days.
- The installation of windows in Trombe walls can decrease its efficiency, but with the implementation of thermostats and electric blowers, the flow of air and heat can be improved.
- With the aim of reducing heat losses during the night-time, movable shades or insulation can be added.
- Water tanks or pipes can be installed inside the wall in order to create a hot-water system.
- The addiction of eutectic salts inside the wall can increase significantly the capacity of storing energy.

In this way a trombe wall system can be improved by a correct use of the ventilation, so, depending on the time of the day and the season, the system can be used in different ways:

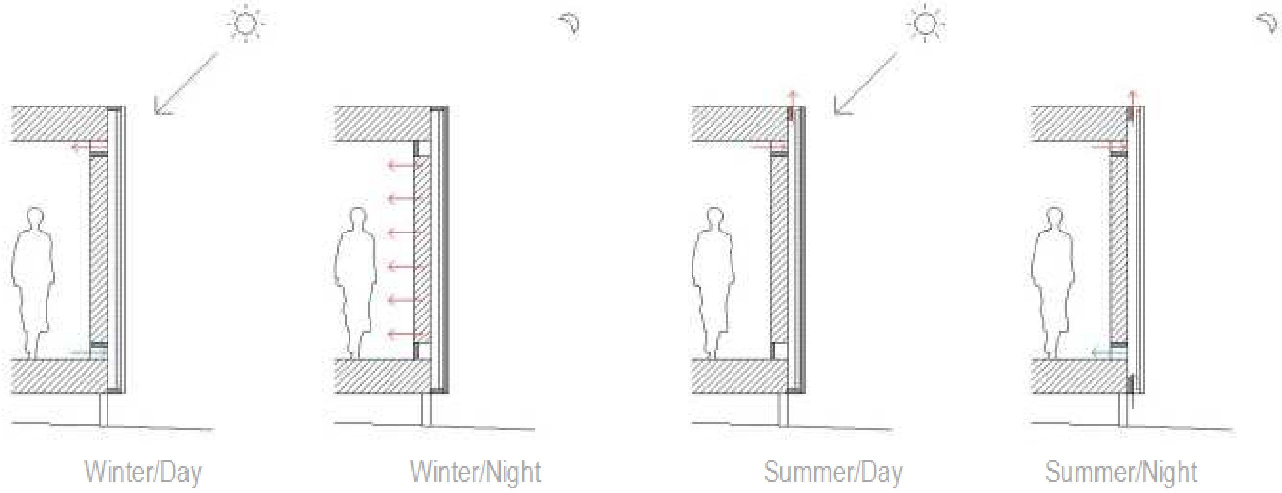


Figure 107: Trombe Wall in Different Climate Times (Tasite, 2012)

Some systems of Trombe Walls have been designed taking into account the above premises, some them are:

- Classic Trombe Wall
- Zigzag Trombe wall
- Water Trombe Wall
- Solar Transwall
- Solar Hybrid wall
- Trombe Wall with Phase-Change-Material
- Composite Trombe Wall
- Fluidized Trombe Wall
- Photovoltaic (PV) Trombe Wall

The above systems were studied in two different cities (Carpentras and Trappes in France) by Zalewski, L., (2001) and the results related with the collect of energy per m2 were:

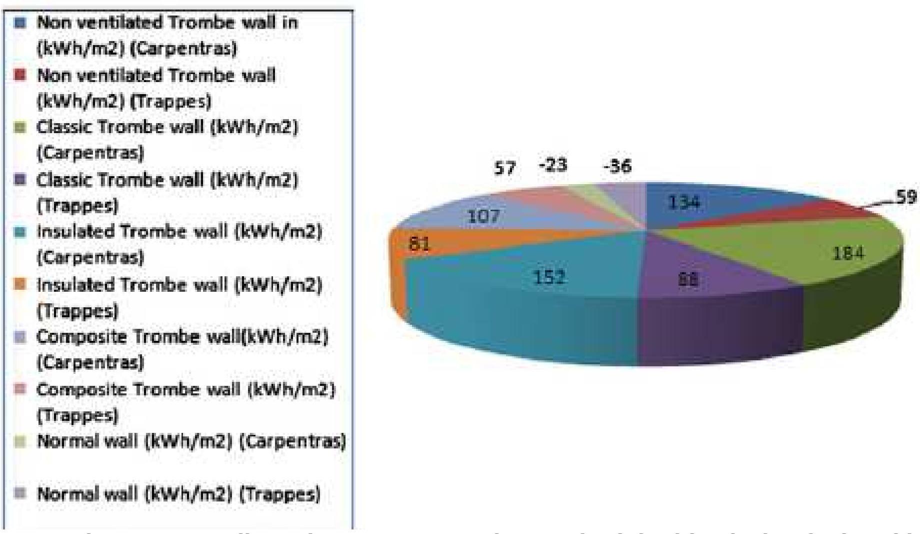


Figure 108: Collected Energy per m2 in standard double glazing (Zalewski, L.; 2002).

Also, the energy collected per m2 in low emittance double glazing was studied by Zalewski, L. (2002) and these were the results:

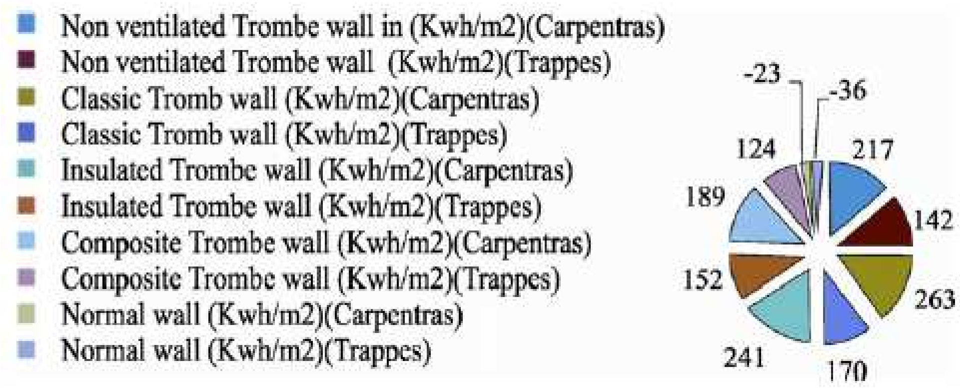


Figure 109: Collected Energy m2 in low-emittance double glazing, (Zalewski, L.; 2002).

Homeostatic façade system

The homeostatic façade system is a technology that consists of a double-skin glass façade in whose interior there is a metallic lattice. This louvers systems change its dimension depending on the temperature in the interior of the building. The mechanism works as muscles do, it regulates itself automatically to avoid the heat loss or gain in order to save energy. This system was developed by Decker Yeadon in 2010.

Figure 110: Homeostatic Façade System. (Yeadon, D., 2010)

The façade can react along segments to little variations. The structure of the lattice of the façade is made of an elastomer (a rubber-like polymer) wrapped over a flexible polymer core. A silver coating distributes an electrical charge, causing it to deform. When sunlight warms up the building, the surfaces of the lattice expand to produce shade inside the building. When temperatures drop, they shrink to allow more light in. In nature, this kind of self-regulation is identified as homeostasis.

Benefits

The main advantages over traditional systems are its low power consumption as well as it has an excellent precision. The contemporary architecture which has become increasingly transparent has been benefit due to this high degree of precision. This system provides, to the building, auto-thermoregulation as well as it reduces the energy consumption, hence, decreases the CO2 emission.

Drawbacks

Nowadays the Homeostatic Façade is a prototype and, because of it is not developed, the costs are high.

Thermal insulation technologies

In the follow table it can be found some of the best insulation materials. They are splited into two groups, traditional insulations and innovative insulations. In the table, the materials can be compared in order to make the best choice to the solutions.

Types

Table 1. List of thermal insulation materials

TRADITIONAL			
Name	Picture	Description	M2*K/(W*cm)
Expanded Polystyrene (EPS)		It is a synthetic polymer. It can be found rigid. It is non-biodegrade.	0.256
Extruded Polystyrene (XPS)		It consist of closed cells and it is produced by the melt of EPS and the addition of gas.	0.276
INNOVATIVE			
Hemp Insulation		It is made of hemp which is a natural material.	0.333

Aerogel		It is a synthetic porous ultra-light material derived from a gel that has an excellent insulation performance.	0.692
Vacuum Insulation Panels (VIP),		It is an insulation that consists of a core with open porous core of fumed silica and an external surface made of laminated layer of metalized polymer. (Nowobilski et al., 1988)	2.079
Gas Filled Panels (GFP)		With the same principles as VIP but instead of using vacuum it is used noble gases as Kr, Ar, and Xe.	3.465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Construction Engineering
2013-2014


Waste
Management

Waste and waste management

Waste management involves all the activities needed to manage waste from its generation to its disposal. Thus, collection, transport, processing and disposal activities from waste have an influence on the way that waste is managed.

The legislation related to the environment, the main European directive about waste, Directive 2008/98/EC on waste (Waste Framework Directive), defines in his article 3.1 **Waste** as “any substance or object which the holder discards or intends or is required to discard” and, at the same time, exposes the importance of managing the waste “without endangering human health and harming the environment. In particular this means without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours and without adversely affecting the countryside or places of special interest”. (European Commission (EC), 2012)

The waste produced in the cities is called Municipal Waste and involves all the waste generated and collected from households and other wastes with a similar composition including fractions of waste separately collected (household / residual waste and waste from small compagnies and public institutions).This waste is collected by the municipality and disposed through the waste management system.

The Waste Framework Directive also differentiates between waste generation and waste treatment. In this way, waste generation includes all the waste generated by economic activities and households and waste treatment involves the waste processed in treatment facilities.

Possible operations for the treatment of municipal waste are (Eurostat Press Office, 2013):

- **Incineration** (with and without energy recovery) is the use of thermal treatments of waste in an incineration plant.
- **Landfilling** as the deposit of waste into or onto land including specially engineered landfill and temporary storage of over one year.
- **Recycling** (excluding composting or fermentation) is the recovery of waste to process and turn it into new products, materials or substances used for the same or other purpose, except the use as fuel.
- **Composting** as the biological treatment (anaerobic or aerobic) of biodegradable matter resulting in a recoverable product.

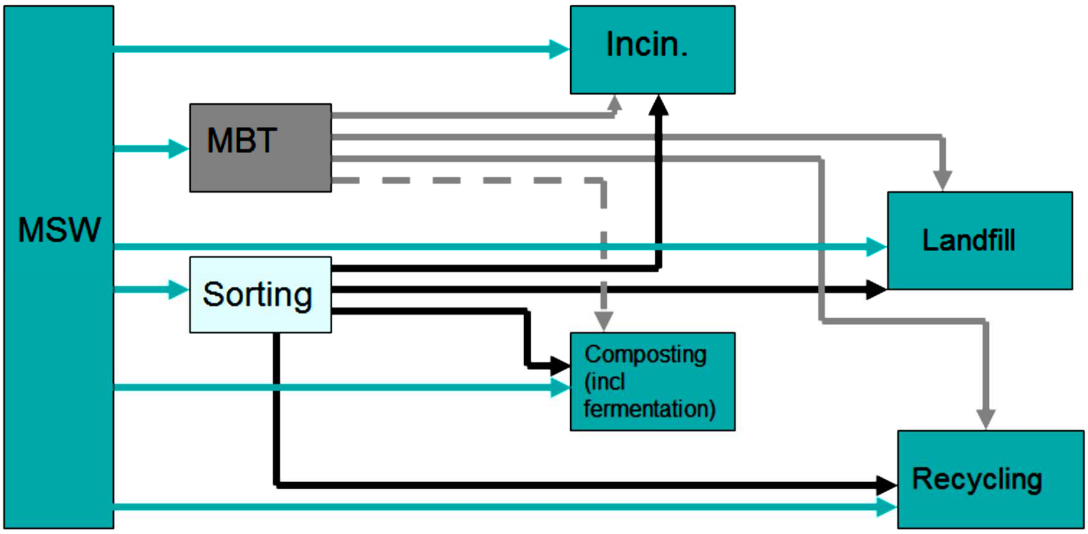


Figure 111: Different options for the treatment of municipal waste (European Commission, Eurostat, 2012)

The different treatments used in some of European Countries during 2011 are shown in the following graphic.

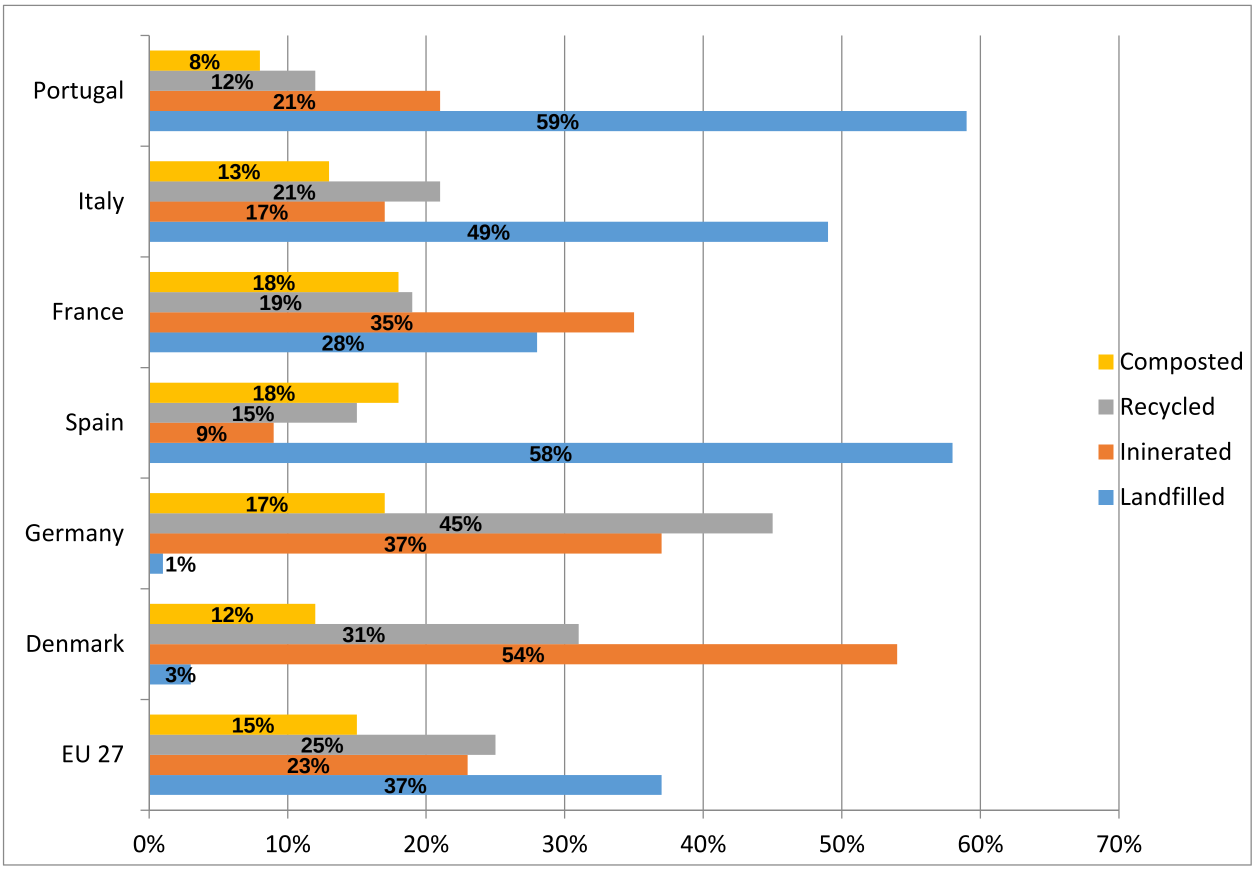


Figure 112: Waste treatment in percentage. 2011 data. Source: Eurostat (Eurostat Press Office, 2012.)

Waste environmental issues

Currently, because of the growth of population and the changes in the ways of life; “consumption patterns”, the management and disposal of waste is now one of the most important problems and challenges throughout the world. The quantity of waste generated has increased in recent years. At this time, the major factors which affect waste generation are the increase of population and their concentration in urban areas, the low price of raw materials, the increased packaging products and the “use and pull” culture, the planned obsolescence in the products, the steady expansion of markets and their production and, of course, the lack of education in waste problems.

Common problems associated with a poor waste management are environmentally unfriendly. Bad odours, dirt, overflowing bins and containers, waste occupying the sidewalks, emergence of insects, rats and other urban pests, are problems that require resolution in different cities. Care should be taken to preserve the environment, improve the quality of life and reduce greenhouse gases.

Taking into account the environmental problems that waste can generate, greenhouse gases emissions is one of the most important because the Kyoto’s Protocol requirements. Greenhouse gases direct emissions come from landfills, incineration activities as well as from collection and recycling operations. In addition, the incineration and recycling can cause indirect emissions from the products produced.

In Europe a high amount of waste is incinerated or dumped in landfill places. This matter supposes a continuous contamination of the air, water and soil with the discharge of CO2 and CH4 Methane to the atmosphere, as well as with a poured of chemical products like pesticides in the earth and groundwater.

A good solution to reduce environmental damage, which presents at the same time, a great benefit in the reduction of generation of greenhouse gases, is the improvement of municipals waste management in terms of recycling and energy recovery from incinerations. These activities contribute to the objectives imposed by Kyoto Protocol.

Data from European Environment Agency shows that:

- The quantity of municipal waste collected in Europe is expected to increase by 25 % from 2005 to 2020. Taking into account the impacts that the increasing values of waste volume can cause to the environment, enhance the recovery of waste as well as divert waste away from landfills, are fundamental tasks.
- Greenhouse gas emissions are expected to decrease by 2020 with the improvements in recycling and incineration with energy recovery activities.
- The reduction of greenhouse gases emissions would be achieved by taking control of the reduction of waste volumes. This reduction will be a benefit to the environment as well as to the society.

If we take into account the above considerations, we will know that a good waste management has an important role within the environmental protection.

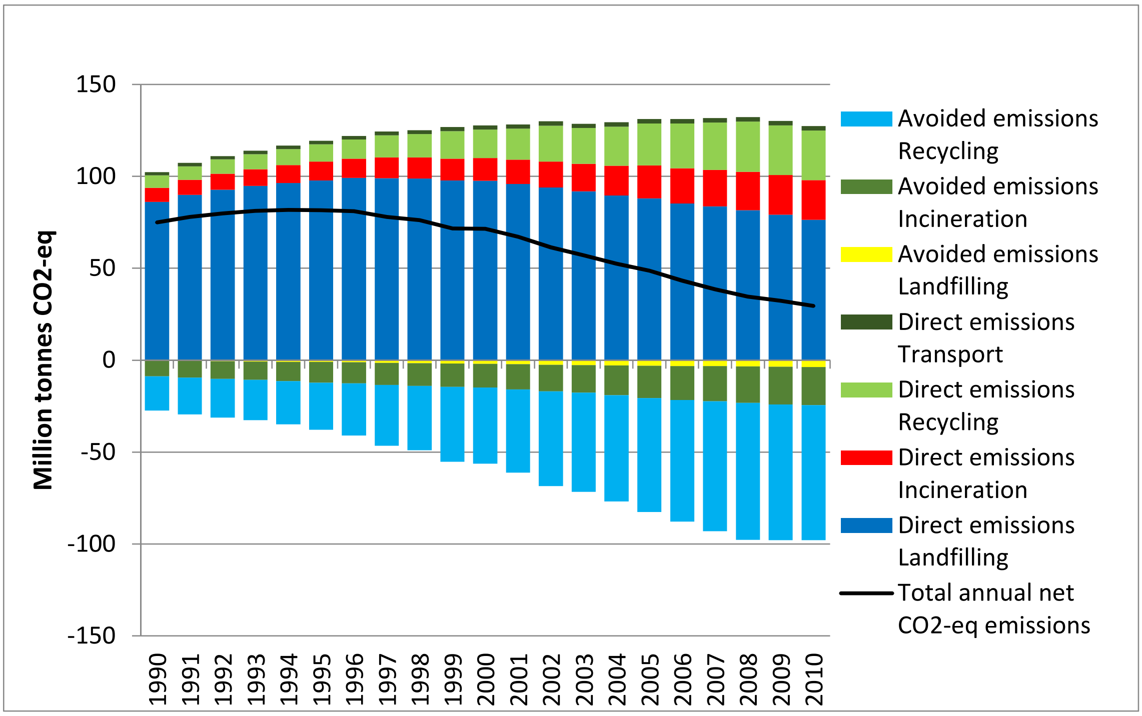


Figure 113: Graphic about reduction of CO2 emissions from 1990 to 2010 (Eurostat European Commission, 2013)

This Graphic above shows a minimization of direct emissions since 2000 in EU-27 (without Cyprus and with Norway and Switzerland) due to the implementation of a better waste management. The emissions avoided, represented as negative in the graphic, are possible with the use of energy recovery in landfills and recycling systems (both activities exposed by European Commission in the waste hierarchy).

The representation of the avoided emissions (negative values) in conjunction with direct emissions let see the importance of a good waste management system in terms of reduction emissions. The black line represents greenhouse gas emissions from MSW management in European Countries.

As we can see the benefits from the energy recovery are less than the benefits from material recovery because since 2000 to nowadays the major reduction of GHG emissions in municipalities is achieved using recycling activities. In the graphic, recycling suppose almost the 75% of the total avoided emissions.

Also, the graphic shows that using this activities in accordance with the waste hierarchy, emissions have 67 Mt CO2 in 2001 to 29 Mt CO2 in 2010 (56 % reduction).So, if Europe continues working in this way, bigger reductions of emissions could be reached, improving the environment and human health.

Statistic data about waste management

The agency Eurostat is the statistical office of the European Union whose purpose is to provide the European Union with high-quality statistical information. For that, it gathers and analyses figures from the national statistical offices across Europe and provides comparable and harmonised data for the European Union. All the data recollected in this chapter comes from Eurostat. (Eurostat European Commission, 2013)

Data about Waste generated in Europe

In the EU27, 503 kg of municipal waste was generated per person in 2011, while 486 kg of municipal waste was treated per person. (Eurostat Press Office, 2013)

This municipal waste can be treated in diverse ways using landfills, composting, recycling or incineration. The following graphics show the different percentages of waste treatments in 2001 and 2011. The graphic represents that the European Commission objectives are being achieved because the amount of waste in landfills has been reduced as well as recycling and composting activities has increased following the European waste hierarchy (explained in the next chapter).

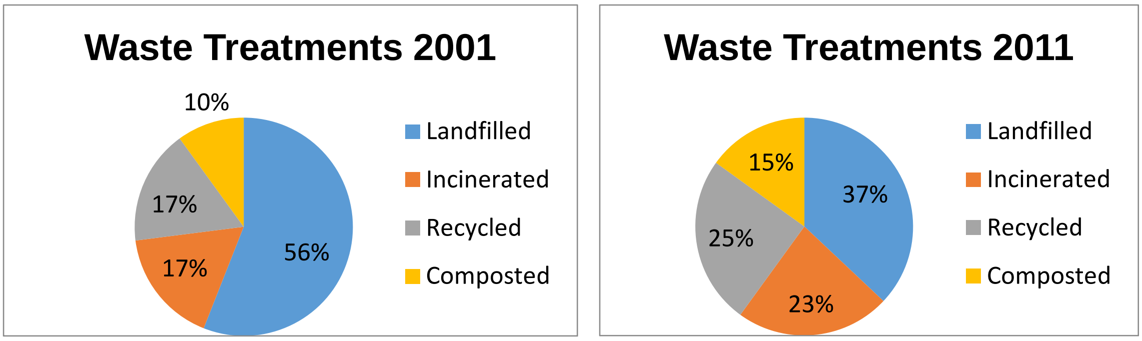


Figure 114: Waste Treatments in 2001 and 2011, EU 27. Data from Eurostat (Eurostat European Commission, 2013)

Data from Eurostat Press Office (2013, p. 1) explain that Denmark, with 718 kg per person, had the highest amount of waste generated in 2011, followed by Luxembourg, Cyprus and Ireland with values between 600 and 700 kg per person, and Germany, the Netherlands, Malta, Austria, Italy, Spain, France, the United Kingdom and Finland with values between 500 and 600 kg. Greece, Portugal, Belgium, Sweden, Lithuania and Slovenia had values between 400 and 500 kg, while values of below 400 kg per person were recorded in Hungary, Bulgaria, Romania, Latvia, Slovakia, the Czech Republic, Poland and Estonia.

European Union establishes that in 2020 the quantity of municipal waste per person must be decreased by 10% compared to the levels recorded in 2010.

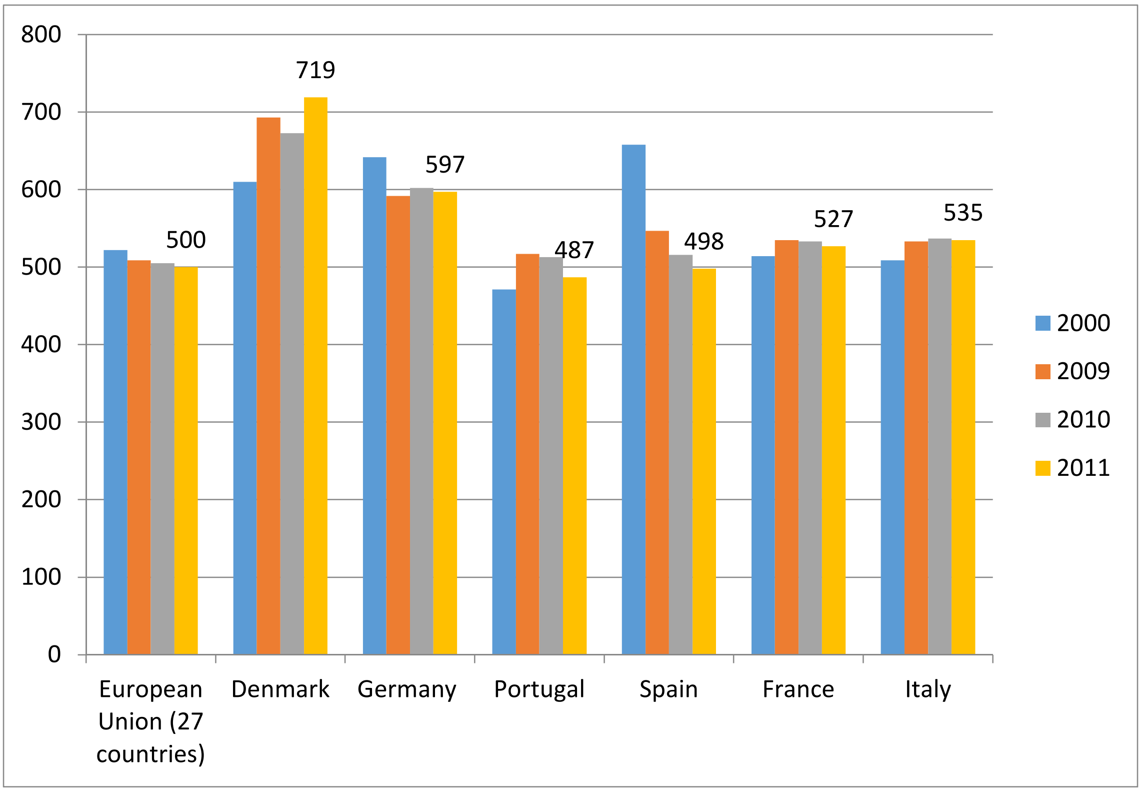


Figure 115: Waste Generated in kilograms per capita. Source Eurostat (2011 data labelling) (Eurostat European Commission, 2013)

Data about Landfills

In 2011, the Member States with the highest share of municipal waste landfilled were Romania (99% of waste treated), Bulgaria (94%), Malta (92%) and Latvia (88%). (Eurostat Press Office, 2013)

The increased rates in Waste recycling has allowed a reduction in the amount of municipal waste landfilled. Most of the European Countries reduced landfilling rates during 2001-2010.

Also, the introduction of taxes on the waste send to landfills is a factor which has contributed to this reduction. In this way, twenty European countries have established new taxes and the majority of the countries with a cost exceeding 30 € per tonne of waste. In addition, other countries have increased their taxes between 50 € and 70 € per tonne.
It is known that the key factor to achieve a reduction of waste landfilled is not only the application of taxes but this initiative is being properly used as a complement of other policies or instruments.

As we can see in the following graphic, the deposit of waste in landfills has been decreased almost 50 million of tonnes in Europe since 2000 to 2011.

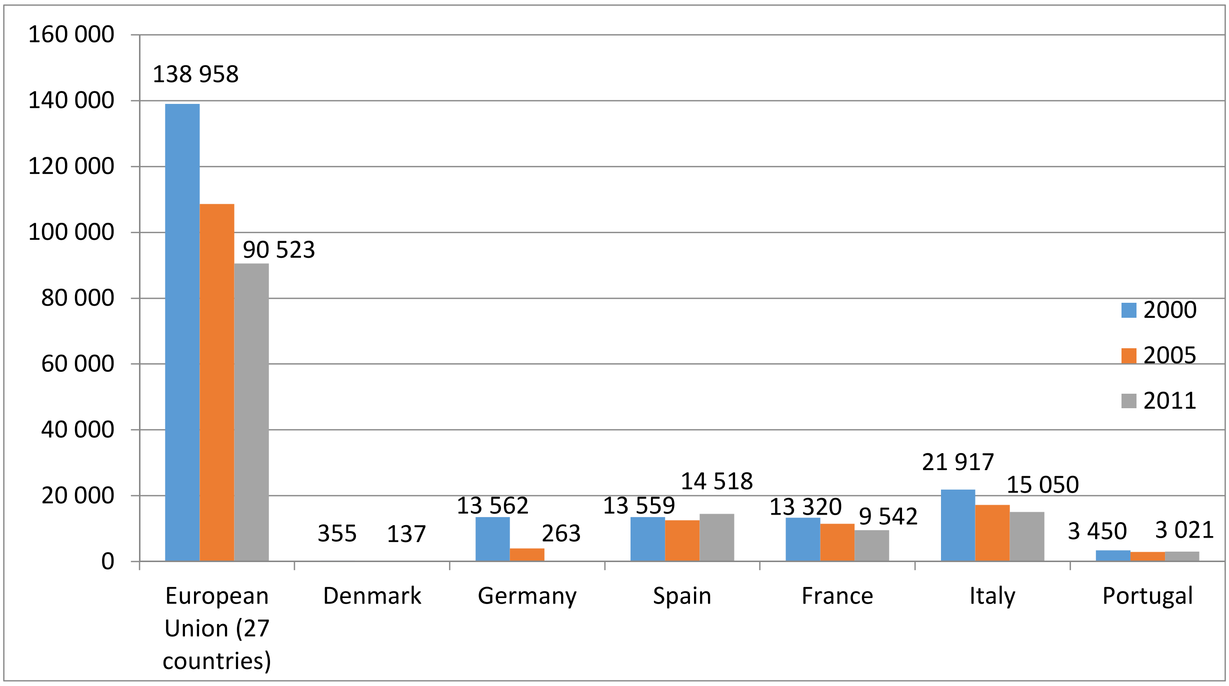


Figure 116: Deposit of waste in Landfills in Thousands of tones. Source: Eurostat. (Data 200-2011 labelling) (Eurostat European Commission, 2013)

Data about Incineration

The highest shares of incinerated municipal waste were observed in Denmark (54% of waste treated), Sweden (51%), Belgium (42%), Luxembourg and the Netherlands (both 38%), Germany (37%), France and Austria (both 35%). (Eurostat Press Office, 2013)

As we can see in the next graphic, the use of incineration activities with energy recovery in Europe has increased since 2000 to today.

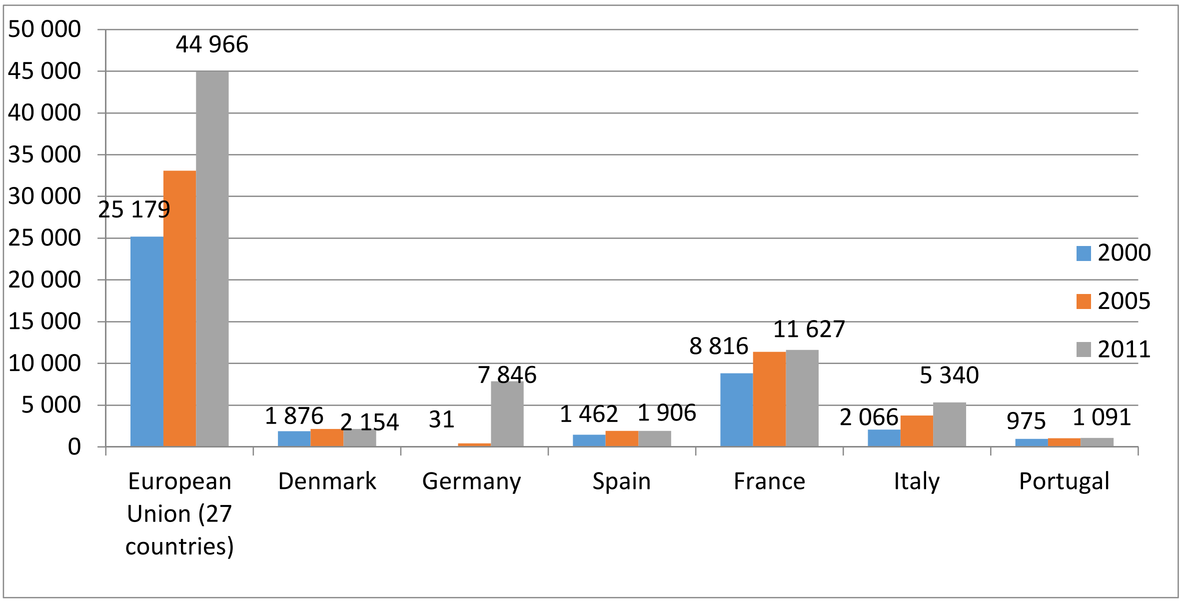


Figure 117: Incineration with energy recovery in Thousands of tones (2000 and 2011 data labelling) (Eurostat European Commission, 2013)

Data about recycling

Recycling was most common in Germany (45% of waste treated), Ireland (37%), Belgium (36%), Slovenia (34%), Sweden (33%), the Netherlands (32%) and Denmark (31%). The Member States with the highest composting rates for municipal waste were Austria (34%), the Netherlands (28%), Belgium and Luxembourg (both 20%), Spain and France (both 18%).

Recycling and composting of municipal waste together accounted for more than 50% of waste treated in Germany (63%), Austria (62%), the Netherlands (61%) and Belgium (57%). (Eurostat Press Office, 2013)

The following graphic shows that the European Commission requirements about material recycling have taken effects in most of the European countries. Many countries have increased their rates about recycling during last year's period. This growth in material recycling can be achieved due to European countries have improved waste management activities like separately collection of waste and recycling different materials such as paper and cardboard, metals, glass, plastic and so on.

However, European Countries have to accelerate the variation in recycling rates because the values shown in the graphic are still far to achieve the 50% recycling target imposed by European Union by 2020.

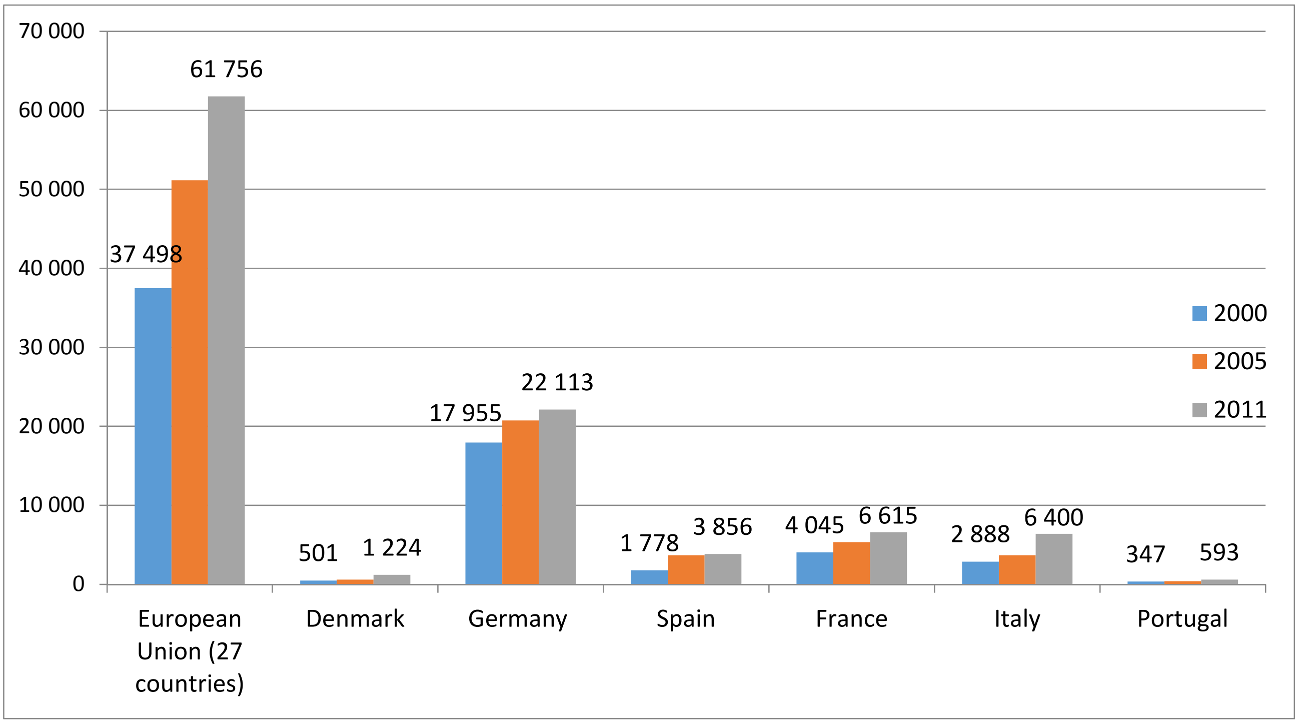


Figure 118: Material Recycling in Thousands of tones (2011 data labelling) (Eurostat European Commission, 2013)

European regulations about waste

Waste legislation and minimum requirements for managing different types of waste has been introduced by the European Union during last twenty years.

Nowadays, the main regulation about Waste is Directive 2008/98/EC which tends to reduce the impacts that waste generation and management can cause for the environment

and human health. Also, the Directive establishes the main concepts about waste management and introduces the waste management hierarchy about the right order to manage waste explained in the following chapter.
The objectives of this Directive to achieve a better waste management across Europe go together with Landfills Directive´s and Packaging´s Directives. Through these regulations, new targets have been exposed to reach in the different European Countries during next years: (European Commission Environment, Waste 2013)

- **Waste Framework Directive presents two new recycling and recovery targets to be achieved before 2020 in the European Countries.** These targets are: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste. The Directive requires that Member States adopt waste management plans and waste prevention programs.
- **Landfill Directives, Council Directive 99/31/EC of 26 April 1999 on the landfill of waste, set some targets about biodegradable municipal waste.** European Union explains that the amount of biodegradable municipal waste (BMW), sent to landfills, has to be reduced progressively until 2016. (**75%** in 2006 (2010), **50%** in 2009 (2013), **35%** in 2016 (2020).
- **Packaging Waste Directive's recycling targets.** Member states has to recover unless the 60 % of all packaging.

To sum up, “by 2020 landfilling should be virtually eliminated, reuse and recycling should be at their maximum feasible level, energy recovery should be limited to not recyclable waste and waste generation should have been decreased”.(European Commission Environment, 2013)

Waste classification

Waste can be classified in some ways however the following catalogue presents the most frequent classification:

- Biodegradable waste: food and kitchen waste, green waste, paper (can also be recycled).
- Recyclable material: paper, glass, bottles, cans, metals, certain plastics, fabrics, clothes, batteries etc.
- Inert waste: construction and demolition waste, dirt, rocks, debris.
- Electrical and electronic waste (WEEE) - electrical appliances, TVs, computers, screens, etc.
- Composite wastes: waste clothing, Tetra Packs, waste plastics such as toys.
- Hazardous waste including most paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and containers
- Toxic waste including pesticide, herbicides, fungicides
- Medical waste.

WASTE HIERARCHY

The European Framework Directive on waste, **2008/98/EC** establishes the main concepts and definitions related to waste management and waste hierarchy. It also sets the principles of waste management; it means mainly take care of human health and environmental issues; including also new recycling and recovery targets to be reached by 2020. The requirement to adopt waste management plans and prevention programs are included, too (Directive 2008/98/EC on waste).

The waste hierarchy is a key point highly used in the waste policies of the EU since the middle of 1970s and proposed an order in terms of priority. It means a ranking of the desirability of various waste possibilities according to their environmental impact (Hultman, J. & Corvellec, H., 2012) with a main purpose of reduce environmental effects from waste to an improving efficiency. The hierarchy sets five different measures of managing waste:

Figure 119: Waste hierarchy diagram (hullcc-consult, 2013)

Regarding the WH, the main important option is to decrease the amount of waste. Followed by reusing, afterwards recycling it is clearly favoured to incineration. And the last option is the landfill disposal as the least favourable result (Rasmussen, C., et. al., 2005).

The previous **waste hierarchy** from **2006/12/EC Directive** that enclosed only prevention, recovery and disposal, has been extended to five stages; *Preparing for re-use* is presented like an innovative idea. The equal value of preparing for re-use, recycling and other recovery has changed, ranking preparing for re-use before recycling, and so recycling is graded before other kinds of recovery.

Although, the waste hierarchy has become a regulatory standard for different waste policies and activities by administrations, educationalists and pro-environment groups over the years; the appliance of WH has become obligatory for all members of the EU, therefore they will take actions to promote new possibilities in order to supply the best general environmental consequence in waste management (Guidelines on the interpretation of Directive 2008/98/EC, 2012).

Consequently, **interpretations** of the hierarchy vary from one waste management plan to another. Whereas there is a growing international recognition of the necessity to pay much more attention on preventive and education policies than waste reduction or recovery activities. Currently, most parts of the activities are for the moment focused on recycling plans, that are essential to be taken into account, but being less effective than prevention or reduction strategies in order to finally get sustainable goals.

Life cycle thinking (LCT)

LCT related to the Waste Hierarchy

The previously stated new European waste directive 2008/98/EC has added the idea of **Life Cycle Thinking** (LCT) into waste management policies as an important tool (EU's approach to waste management, 2010).

This recent notion of LCT has a main aim of identifying potential improvements of services or processes regarding to low environmental impacts and the reduction of the quantity of resources of every life cycle phase. LCT considers the whole life cycle, since the extraction of natural raw materials and the resource treatment, manufacturing, distribution, usage and at last the disposal handling. This approach gives a wider view of all environmental features and ensures that any action has an overall benefit compared to other options.

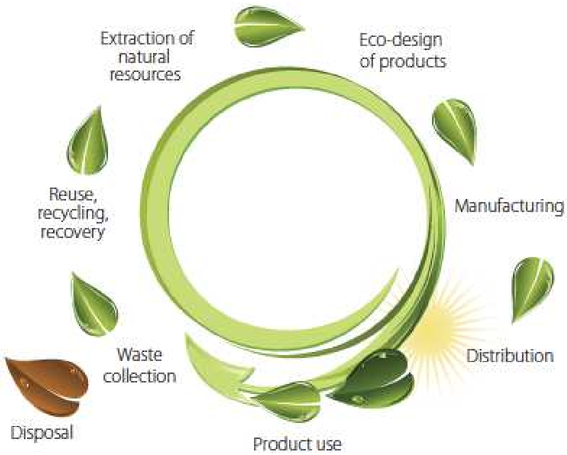


Figure 120: LCT concept (*The EU's approach to waste management*, 2010)

The **waste hierarchy** was designed considering directly life cycle ideas, therefore, using it as a reference that is going to treat the waste with high importance in terms of efficiency of the resources and thus, in an environmental-friendly way (Guidelines on the interpretation of Directive 2008/98/EC, 2012).

Members States are permitted by the European waste directive, when selecting several waste management options, to deviate from the waste hierarchy only by justifying it by LCT on the general impacts, reducing environmental pressures and increasing supply efficiency (Nelen, D., et. al., 2013). Taking decisions regarding to the waste hierarchy do not require to be done by LCT in terms of the impacts produced in the production and management of the wastes referred.

Relation between LCT and LCA

As it has been stated the key aim of LCT is the valuation of the general environmental influence of a specific product/service. LCT purposes to guarantee that certain environmental features are taken into account when some options are evaluated.

Below the concept of LCT, there are other methods for instance *Life Cycle Assessment* (LCA) has stated, *Life Cycle Costing* (LCC), *Cost-Benefit Analysis* (CBA), and *Social LCA* (S-LCA), which add a scientific support for decision and policy making. These aspects can be considered in terms of environmental, social, and cost referred issues. (Guidelines on the interpretation of Directive 2008/98/EC, 2012).

For the case of environmental characteristics, LCT requires the usage of LCA evaluations in order to consider and quantify in different values of the performance.

To sum up this connection, LCT incorporates a basic approach of LCA, without taking into account a specific detailed assessment of each process, taking reference sources to identify trends and conclusions that seem to be representative. For an assessment on life cycle impacts of products other tools may be used such as *Carbon Footprinting* and *Material Flow Analysis*.

Life Cycle methodologies applied into WM decisions

Applying any LCT or LCA into **waste management decisions**, evaluations normally emphasis on a comparison of various waste management options, more than consider the whole life-cycle of the goods that have turned into waste. Hence, LCT/LCA applied into diverse WM facilities that may vary from product LCT/LCA, taking into consideration the whole product life-cycle, having waste management an unimportant function. Nevertheless, if there exists at least one assessed WM option which includes the returning of things to the life-cycle, so that the system-boundary of the assessment may change and should include potential environmental influences.

In that way, LCT and LCA may be chosen as a valuable reference to enhance making decisions in WM, because of the quantitative results and information available to be taken from these assessments. Thus, people in charge of waste policies can understand the advantages and disadvantages summarized in a quantitative perspective that can be required to face in the plan.

Although LCA is not able to replace a whole decision process, it can possibly help public authorities and companies involved in the waste management to choose more environmental selections. Therefore, it may be used as a tool for defined situations at city level at least for determined situation of the WMP.

Conclusions on LCT

To summarize the impact of LCT in waste management there are several important **conclusions** to be taken into account. One of the most important ones is the fact that LCT does not permit establishing an overall priority order, because of the requirement to consider a lot of factors in a waste plan, and so may vary a lot (Nelen, D., et. al., 2013).

It is important to be conscious of the fact that conclusions are not possible to be generalized, and it should be a starting point for specific situations to confront social influences, the stated environmental considerations and economic constrains.

Most evaluations on this field show that the priority is mostly dependent on different features of specific locations regarding to inputs, outputs, methods and facility systems, therefore establishing specific local and largely global environmental priorities ideas are surely going to be a valuable choice.

Waste management plans

There are several ways to design a WMP and its main goal is to achieve an overview of all quantity of waste generated. Moreover it includes the handling options for this waste and the variation of its future projection mostly of the quantities of landfilled, incinerated and recycled amounts.

The influence of past tendencies and the classification of favoured treatment methods of every country have an important repercussion on the strategies to be developed. So that, each country and municipality can do diverse activities to encourage the conceptions of waste minimization, re-use and recycling (Bakas, I., Sieck, M., & Møller, F., 2011).

These plans are developed taking into account general ideas regarding the existing EU legislation which states the encouraging of recycling and discouraging of landfilling. Another general durable goal of the EU is to turn into a recycling-society and look for evading waste by using it like a new supply. [1]. However, the application of EU regulation is not compulsory, and seems to be clearly a guideline on drafting a WMP as following explained.

Referring to a sustainable and management use, some established ideas are prefixed in order to help municipalities to design a WMP (The Sixth Environment Action Programme of the European Community 2002-2012).

- Reduction in waste quantity produced by some waste prevention initiatives and a modification headed for a new sustainable making and consumption designs.
- Reduction waste amount that finishes as disposal and the quantity of harmful waste generated.
- Promoting re-use initiatives.
- Regarding to future waste:
    - Reduce the hazardous levels.
    - High preference of recovering and recycling.
    - Minimize the final disposal and make it securely.
    - Waste expected for dumping is recommended to be treated near to the place of production, this can be extended without reducing the efficiency of waste handling.

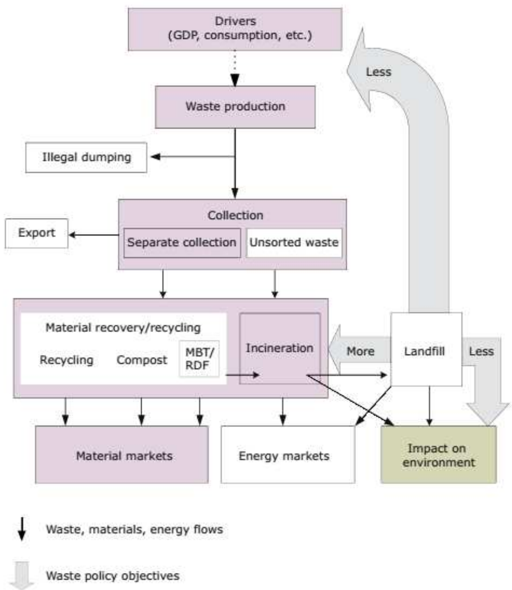


Figure 121: Simplified ideal WMP. (EU. 2009)

There are variances in different aspects that can influence the kind of treatments which have to be chosen too. They may be the present transport facilities, number of inhabitants, existence or not of land, energy necessities and ecological legislations and others (Bakas, I., Sieck, M., & Møller, F., 2011).

The municipal solid **waste management tendency** in Europe may help to establish the starting point in order to have general ideas of the current situation. As a general rule in the MSW management tendency, **landfill** has become the most extended method in most of the EU for a long time, tendency is going down. In 1995 the usual landfilled waste percentage was 68% whereas in 2007 this has been reduced until 40%, and it is supposed to be reduced by 28% in 2020 (Bakas, I., Sieck, M., & Møller, F., 2011). MSW **recycling** is expected to get the 49% and **incineration** with **energy recovery** 23% in 2020.

This expected organization of the different waste treatments, represents a previous evaluation that has been done by considering the preceding developments in waste management.

There are some **overall concerns when designing a WMP**. A waste management plan is required for the EU legislation following some directives, and each Member State should implement a national plan. Apart from that, any municipality should take into account a planning to promote the development of an appropriate organization. An important fact is the consideration of an **integrated waste management plan** taking into account all the requirements for each of the treatments required to have an optimal performance of it as a whole.

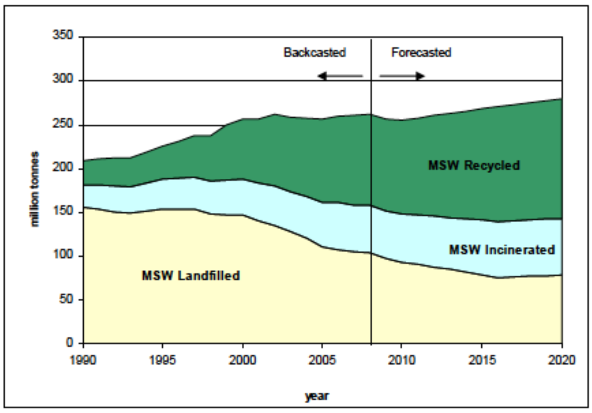


Figure 122: Development in waste and treatment of MSW in EU-27 (1990- 2020). (Bakas, I., Sieck, M., & Møller, F., 2011)

Some **considerations** are vital for the successful of the plan such as the establishment of the scope of the WMP, its geographical coverage (national, regional or local), the kind of waste distribution that will be incorporated (total waste, municipal waste, hazardous waste, packaging waste), sectors that are incorporated, time frame for finalization and members that will take part in its designing (Preparing a Waste Management Plan, 2012).

Apart from that, some elements and phases should be considered in the plan:

1. **Background:** a general problematic of waste may be taken into account, EU and national legislation, national waste policy according to the waste hierarchy, a description of the expected objectives in different areas and inputs from discussion activities.
2. **Status part:** Quantity of waste (waste streams, sources and management options), waste collection and handling, waste delivery, organization and financing and evaluation of previous intentions.

Planning part: Expectations for planning, prediction in terms of waste generation, total and per waste stream, determination of objectives, and action plan with methods (collection systems, waste management facilities, responsibilities, economy and financing).

3. **Implementation**
4. **Plan revision**

The final decisions that are chosen will have a big influence on the community and they will affect also in terms of economic costs, depending on the treatments elected and collecting scheme too.

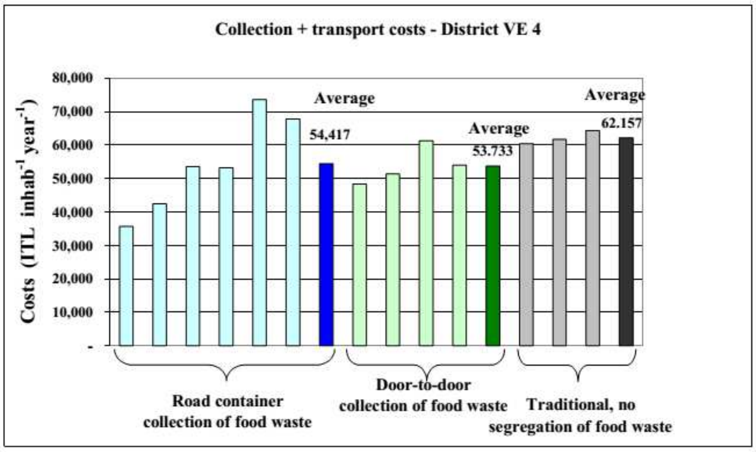


Figure 123: Collection cost of different schemes in an Italian neighborhood. (Favoino, E., 2001)

Current status and future trends.

Regarding future trends in the waste hierarchy, appear diverse ideas that are important to think about in order to avoid considering the established hierarchy as an immovable waste ranking.

The waste hierarchy can be summarized as the idea that landfill disposal is the least option to manage, and in some cases that priority order may be questioned because of its implementation into a specific WMP. The current waste hierarchy was mainly developed by EU organizations, taking into account high population density areas. Therefore the particular case of its appliance into a region with a **low population density** could generate an excessive economic burden on a specific area thinking only about environmental benefits that may obtain (Barrett, A. & Lawlor, J., 1997).

It is completely sure that the environmental factor is essential, but when considering a diverse plan it has been an increasing need to take into consideration economic issues, important to value the feasibility of any waste management plan.

Other practices have appeared in order to find more ambitious waste hierarchies than the ones established by the European Union, due to the fact that some policies and incentives cause that waste changes only from being landfilled to be incinerated.

An example is the **Zero Waste Hierarchy** that represents a concept of designing products and processes by following sustainable natural cycles. It also takes consciousness of social and economic profits considering all kind of waste as new resources for different following usages. **It states from best use (highest) to worse use (lowest):**

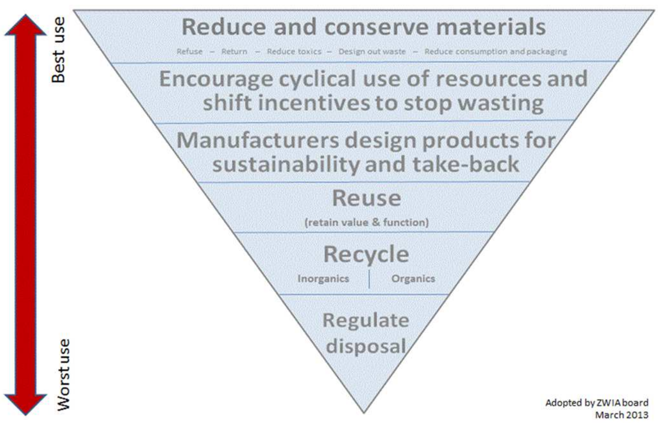


Figure 124: Zero Waste Hierarchy. (Zero Waste Europe)

1. **Reduce and conserve materials:** Return, reduce toxics use, plan out wasting and reduce consumption and therefore manufactured packaging.
2. **Encourage cyclical use of resources and shift incentives to stop wasting.**
3. **Manufacturers design products for sustainability and take back**: design to be durable, repairable, reusable, disassembled, fully recyclable
4. **Reuse (retain value and function:** repurpose products for alternative uses, repair to retain value and usefulness, disassemble for repairing and maintaining products.
5. **Recycle discards safely**
    a. **Inorganics can** develop local markets and uses for all recovered materials, recycle or compost products and packaging for highest value and efficiency.
    b. **Organics,** Edible food to people first; animal feed second; compost or digest the rest, back to land as compost or digest for fuel, promote on-site composting by homes and businesses and maintain source separation for highest and best use of organics.
    c. **Regulate disposal, dispersal, or destruction of resources: prohibit toxic** or cannot be securely reused, recycled or composted; r**ecover energy and landfill is the considered latest stage (Zero Waste Europe).**

Apart from the previous one, there have appeared other new ideas with the main aim of change the value of the waste from non-value disposal to a new resource in order to be used in a following step. A good example on this terms is the so called *“Cradle to Cradle”.* One of its main ideas is treat waste as new food, new resource.

In terms of collecting and transport in the WMP some technologies are being developed different from the existing ways, with vacuum and pneumatic collection systems by pipes network.

WASTE PREVENTION AND REUSE

The development of so-called consumer society has led to massive production of all types of waste, the main factors which are handled when buying a product are the price and intention to satisfy a need or a desire. The first factor comes practically imposed, we will have to adjust it to our economic capacity. But the second one is mainly a factor with a great deal of subjectivity and closely related to our personal values.

The first step to respect something is to know it and value it. For us the rubbish disappears once we take the rubbish to containers. We do not consider what will happen to waste then and we don't think about how the waste gets disposed with which we contribute to pollute the environment.

The reasons may be different: the lack of municipal services available, inability to move to the right places to leave certain waste, but the main reason could be simply laziness. Generally, we can speak of a common lack of environmental awareness in our society.

It is essential to develop training programs in these areas, if we really want to change the situation. It is necessary to carry out researches, but above all education related to this topic.

Waste prevention and reuse awareness have to be spread out to the people.

Waste prevention

Environmental education

The first approximation to the current point of view was established in the Intergovernmental Conference of Environmental Education organized by UNESCO (1977). It was settled the definition of Environmental Education as "a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action." We can use this enviromental education as tool to the prevention of waste. There are two kinds of environmental education: formal and non-formal.

Formal education

Formal education is the education given inside the school year. Geography is a subject especially well placed to deal with the topics of environmental education in the school field. Formal education tries to show children not only information but also encouraging to personal involvement.

Non-formal education

This kind of education refers to the learning that takes place outside of formal education way that means also the education in everyday life (family, friends, work places…). To spread that kind of education some actions can be carried out (Diez, 2006):

- According to kind of people:
  - Communities (neighbourhood, owners, companies, construction companies…)

    - Shops
    - Restaurants
    - Hotels
- According to the purpose:
    - Specific (only one waste or one problem)
    - General
- Media:
    - Speeches
    - Scholar competitions
    - Commercials (radio, posters, leaflets, informative letters)
    - Meetings

Although these actions could be implemented in most circumstances, there is one problematic fact, which is touristic places. It is difficult to develop educational objectives because the majority of population are temporary in that place, so they do not aware of environment. Many packages are generated by the foreigner visitors who use sporadic things.

Reuse strategies

Reusing things is a way to eliminate solid waste at the beginnig of the problem, here appears some useful guidelines (Environmental Protection Agency, U.S., 2012).

Reusing products

Some products are built to be used more than once, so we have to take advantage of this fact, and use them until their real end-life. If our aim is to reduce waste we have to reuse it.

- A durable cup can be washed and used time and again. People can bring their own cups with them.
- Durable cutlery can be used also for parties, picnics and at work.
- Use rechargeable cartridge for printers and fax machines. Apart from reducing waste also reduce money.
- Cloth serviettes, sponges, or kitchen cloth can be washed over and over again.
- Search for refillable bottles for drinks or detergents by the consumer or the manufacturer.
- Use rechargeable batteries to reduce toxic metals or search for batteries with lower toxic metals.
- Use only the single-use items that are necessary (ketchup packet and serviettes).

Maintain durable products

Although long-lasting products cost more at the beginning, they will save money in the long run.

- Search for household appliances and electronic devices with good warranties or those, which are simply repairable. Check on the internet comment of other users about the reliability of the devices.
- Follow strictly the suggestions of owner’s guide in order to ensure the better maintenance.

- Durable tyres for vehicles. Check tyre pressure regularly.
- Mend clothes or patch shoes or handbags instead of disposal them.
- Choose durable furniture, baggage, toys and so on.
- Use low energy fluorescent lights instead of incandescent ones.

Reuse packages

Some items have more than one use, so disposal bags, cans or other stuff; it has to be taken into account if it is practical and hygienic to reuse them.

- Reuse paper and plastic bags.
- Reuse scrap paper and envelopes. Use both sides of a piece of paper for writing notes before recycling it.
- Use curtains, towels and clothing for patching, tea towel and so on.
- Reuse newspapers, boxes and other packages to shipping sends.
- Reuse empty glass and plastic jars and other containers to use them as flowerpot or storage leftovers.

Borrow, rent or share items used infrequently

Some items with sporadic use end in the garbage, a good strategy is to rent or borrow with other people that could use it again.

- Rent or borrow party decorations and supplies such as tables, chairs…
- Rent or borrow tools.
- Before throwing out old devices such as mobile phones, cameras and so on, ask to relatives.
- Share newspapers and magazines to reduce the amount of paper.

Sell or donate goods instead of throwing them out

Before disposal items try to sell or donate them.

- Sell items to second-hand shops or donate them to the charity. This kind of organizations accept all kind of good quality items.
- Give clothes that you do not use to other members of the family or charity associations.
- Think in buying clothes or electronic devices in second-hand shops.
- Encourage the food shops from the area to donate damage goods or food to charity associations.

Incentives and penalties

Waste taxes

This kind of taxes are imposed for the collection, transport, storage or disposal of waste. The money obtained is used for providing economical support to municipality in order to repair and maintain properly all the waste management tools. But also to persuade people to through out rubbish without taking care about any classification system.

Promotion of energy recovery

People have to know the advantages of energy recovery, they have to comprehend the palpable benefits. People could be influenced to admit in their areas the construction of a recovery plant by improving the areas in the surroundings of the plant, such as refurbishing schools, build a retirement homes and so on.

Conclusions

Cutting down on the amount of waste is a task of every citizen but it is not an easy task because people eco-awareness is determined by beliefs, habits, poverty and so on, and this is a difficult thing to change in short-term.

Changing those habits could be the most difficult part of waste management, but if people is involved, the cost to the public authorities could be much less than the construction of recycling plants. This economic benefit is especially significant in small towns where the implication of every user could be higher.

Public authorities should change the mind-set of small neighbourhoods and after that going, gradually broadening the people involved.

MATERIAL RECYCLING

The material recycling includes two different applications. One way is to reuse the waste in different products than the original one. The other way is to prepare the waste with special manipulating techniques to regain the materials and take them for the same usage again. Nowadays there exist many different types of waste and in the last three decades people developed many techniques to gain something useful out of it. But still, in a lot of countries, people don't care about recycling and just burn or dispose the waste, or even worse: they throw it in the ocean. Those habits lead to high pollution of the environment and a loss of energy and materials that have to be gained otherwise. New technologies and equipment for waste recycling plants are mostly very expensive and take a lot of time and effort to realize. So it is necessary to find the best solutions in dealing with the big amounts of waste we produce and pollute the environment as less as possible.

The different types of waste are defined in the following chapter. Furthermore the traditional ways of collecting and handling the waste are explained in addition with new ways and possibilities.

Residual waste

Residual waste is the biggest part of waste we produce nowadays. Depending on the local waste separation, it can contain nearly everything we throw away, which is a big problem for the recycling afterwards. In a recycling system in which plastic, paper, organic and residual waste get separated, residual waste is mostly gets incinerated, because it contains less useful materials. It is also the most expensive waste for consumers, when it comes to paying the taxes, because disposal departments cannot use the most of it. At least, that is the argument for taking high taxes on it. But in reality, the residual waste contains a lot of useful materials, because people do not recycle in the right way by throwing plastic, glass and metal in the residual waste bin, too (BMU 2013).

Existing Treatments

The most common way in dealing with residual waste is to burn it. Depending on the incineration plant, it is possible to use the heat energy and filter out the toxic gases, but this is only possible with expensive technologies. So at a lot of places in the world, the waste just gets burned to get rid of it and nobody cares about the environment and the loss of the energy and materials.

An easy and very common procedure to get at least the iron out of the waste is by using a strong magnet after the incineration to sort it out. The iron stays in shape during the incineration process, if the temperature doesn't reach 1500°C, while other metals get lost because of lower melting points. Another thing is the sorting out by hand before incinerate the waste. This way it is possible to get glass and big plastic parts out of the waste. Therefore it is necessary to have a conveyor belt and employees standing at it to do the sorting. This is a very easy way to gain some more materials but again it is more expensive and therefore not common everywhere in the world. So this is mostly everything which is done in the old or low technical incineration plants (BMU, 2013).

New ideas and solutions

A new way for collecting the residual waste in big residential buildings is an electronic garbage bin called “garbage gate”. This bin is weighing the residual waste and after one year, every one of the building pays exactly for the amount of garbage that was produced. Therefore the inhabitants of the building have a small electric chip with the user data registered, which they hold against a scanner on the bin to open it. The aim of this system is to give people the possibility to reduce their yearly payments by making them more aware of their waste consumption (Schüßler, 2012; Wesoma, 2013; WVL, 2013).

Figure 125: Traditional waste bins (Reclaim, unknown) “Garbage Gate” with scanner (WVL, 2013)

Another innovation for collecting different types of waste from public waste bins and residential buildings are the “underground waste containers”. They are helping the city and inhabitants of buildings to save space and collect a big amount of trash in one bin. From the outside it looks like a normal sized bin, but it is connected to a big container under the earth, that is around 5 m³ big and correlates to 5000 litres of waste. That way it also saves collecting time for the city, because they do not have to get emptied as often as the standard public waste bins in the cities (BSR, 2011; Sotcon, 2013).

Figure 126: Underground waste containers (BSR, 2011; Sotcon, 2013)

Regarding new technologies for recycling and incineration plants, there are many ways for getting a lot of useful material out of the residual waste.

The waste normally gets crushed in the beginning of the process into small pieces, so it is easier for the sensors and machines to sort out the useable materials. This way it is possible to get out glass and special types of plastic with sensors. The aluminium and other metals can be filtered out with conductors and magnets that move over the conveyor belt which transports the waste. With these sorted out materials and the rest of the waste, which still contains paper and plastic, it is possible to gain different products or energies, such as:

- Directly creating heat energy by incinerating it and heating up water pipes for long distance heating systems (Stadtwerke Düsseldorf, 2010).
- Combustible materials for heat energy plants which is nearly as good as coal (GEA, 2012).
- Diesel or heating oil from the plastic that get sorted out (Dieselwest, 2012; Renaud, 2012).
- Foam glass from the colour mixed glass (not recyclable in mixed colours) or crushed glass fillings for construction work (Geocell, 2011).
- New metal from melting the sorted out metal in a smelting plant (DW-TV, 2011).
- The burned waste / ash, if not environmentally harmful, can be used for street construction (Stadtwerke Düsseldorf, 2010).
- The toxic gases can be bound with chemicals to a solid material and be used as fillings in mining (Schreiber, 2010).

Paper/Cardboard

Introduction

Composition of the Paper/Cardboard

Paper and cardboard are made mainly from virgin cellulose fiber structure obtained principally from wood but also from other plants (e.g. flax, bamboo, hemp, etc) or recovered from used paper and cardboard and chemical products. Crosslinking and pressing of the fibers deposited in a chaotic way define the resistance of the material.

Also, Cardboard is composed of cellulose fibers but these fibers constitute a thicker and stiff structure with the mixture of two or more layers composed of paper glued getting more resistance and letting it for use in heavier applications.

The main chemical products (additives) aggregated to this composition to obtain some features like opacity and brightness are: limestone, clay and starch. There are other chemical products that can be added once the product is done or during the making process, in less percentage, like resins, chlorine, dyes, coating agents, retention, cleaning agents, etc. All of these substances change the properties and quality of the final product.

During the paper production process, a fiber mass is generated first called pulp or paste using mechanical or chemical process.

Paper and Cardboard recovered are the materials once used, separately collected and processed by a waste contractor. These materials are recycled later in a paper and board mill. They are a very important source of obtaining cellulose fibers to manufacture new paper because paper and cardboard are easily recyclable residues that only require a minimal operation to adapt them to the final recycling product.

Types of Paper and Cardboard Waste

Paper and Cardboard Waste	
Homes	Cardboard and paper packaging for food, beauty and cleaning products, etc. Newsprint and advertising that is received at the post. These latest advertising products have seen a significant growth in recent years. Graphic papers for notes, printed, etc.
Commercial Activities	Significant quantities of graphic paper for offices Cardboard boxes for the transportation and storage of consumables. Advertising paper distributed for companies and businesses in streets and free newspaper distributed on public roads which has appeared and proliferated in the latter period. Paper cartons and food and cleaning, etc.
Municipal facilities and services	Significant quantities of graphic paper for administrative offices. Graphic paper products in the form of text books, notebooks, paper, etc. in significant quantities in educational activities.

All fields are generated sanitary preparations for bathing, cooking, cleaning, etc.. made from cellulose.

The paper recovered from industry and commercial sector has a homogeneous quality, which let to classify the paper easily. Generally, these materials are recovered directly from waste managers in specific containers. Also, the paper recovered from offices is quite homogeneous and clean. However, it is possible that the paper is mixed with other impurities like ink, staples, paper clips, etc.

Collection of waste paper

In domestic and commercial areas or small business, the paper and cardboard is generated and intended for municipal systems enabled for collection. Different systems to collect waste paper are door to door collection, clean points of collection or through the use of containers indentified because of its blue colour (most of the countries). Each municipality has to ensure the collection with a certain frequency, usually 1-3 times a week.

The paper and cardboard packaging collected in the houses is almost the 40 % of the entirely material that is carried to the collecting place.

The main way to collect waste paper and cardboard is the use of containers installed in the streets like plastic igloo or metal containers which have to be collected using trucks with crane.

Figure 127: Paper Containers (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013)

Traditional Technology for paper recycling

Paper is a material that can be recycled generally from all of their forms and types, to manufacture new paper. However recycling task can be complicated or impossible to implement if the material is in touch with other waste materials. Because of this, paper waste must be separated properly from other types of waste that can make impossible the recycled paper manufacturing in terms of health and hygiene, because of the presence of pathogens or contaminants, and due to the difficulties to eliminate the contaminants from the paper; recycling equipment is not prepared for this.

Paper Waste can be recycled a limited number of times because each time that paper is recycled, fibers are broken and becoming weaker, decreasing the quality of the paper. Due to this, it is necessary to mix the product with virgin fibers in a high rate to create a high quality recycled paper or instead of this develop a lower quality paper.

All the paper waste collected is classified by type and baled to send it to the paper mill. After that, basically the recycling process starts when waste paper is mixed with water in the pulp and stirred. Then, it is separated from staples, plastics and paper fibers are incorporated different substances in order to remove the ink remaining on the surface of the bath. The fiber suspension is drying on a flat surface and is recovered later. Then, the pulp passed through rollers that flatten and compact it. Finally, the recycled paper sheet is obtained. This process is showed in the following figure, Figure 128.

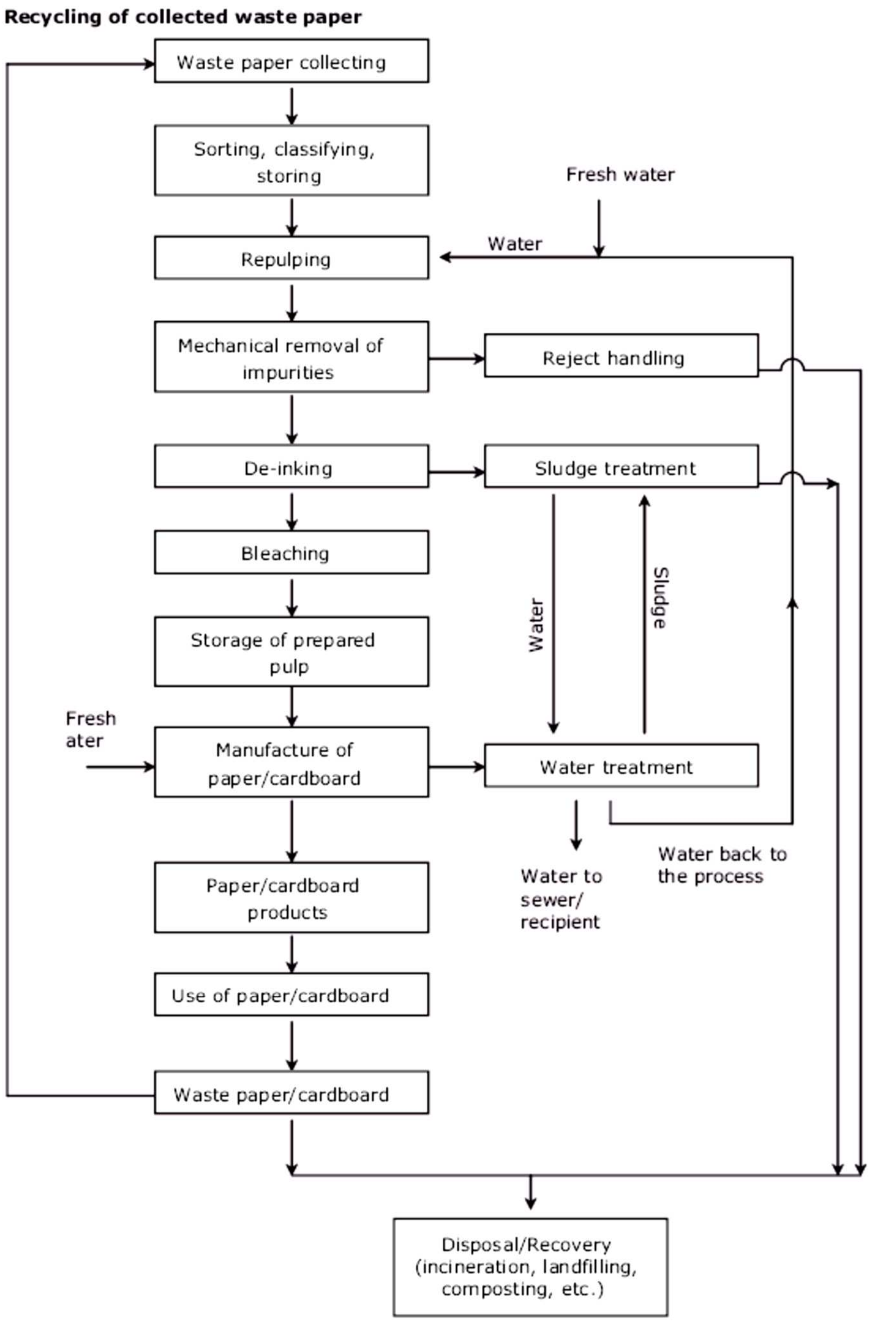


Figure 128: Recycling paper process (European Environment Agency, 2006)

First of all, the material is deposited in the paper containers by the consumers and this waste is picked up later by a company which selects and categorizes the paper and cardboard. Then, it is transported to a paper company where it becomes old paper on recycled paper.

The manufacturing process used for getting recycled paper is (European Environment Agency, 2006):

- **Sorting, Classifying and Storing:** Sorting and classifying Paper Waste collected is done mainly dividing it into different grades in terms of quality. Other types of waste mixed with the paper waste are removed before preparing and baling it.
- **Repulping:** The paper waste is mixed mechanically with water using steel rotor blades. The paper is progressively disintegrated and spreader in water to create slurry. Then, chemical products are added as additives. Contaminant substances are removed from this pulp to avoid the deposit of these substances inside the pulp.
- **Removal of impurities:** The pulp is filtered through sieves of various sizes for separating impurities like plastics, wire, earth, etc.
- **De-inking:** de-inking operations are done when paper waste is printed and presents ink and when is necessary achieved some brightness and cleanliness for the future use of the recycled paper. A requisite for achieving a suitable de-inking process is that the ink particles have to be released from the fibers and kept in dispersion. For this purpose, de-inking chemicals are added mostly of them during the pulping sequence. Thus, the ink can be removed with the use of several processes:

Flotation De-inking: Flotation is one of the most used processes to carry out de-inking activities and consist on the use of projected air into the pulp creating air bubbles. Air bubbles elevate the ink to the paper and create a froth that can be removed. This system is effective with ink particles from 5 to 10 µm.

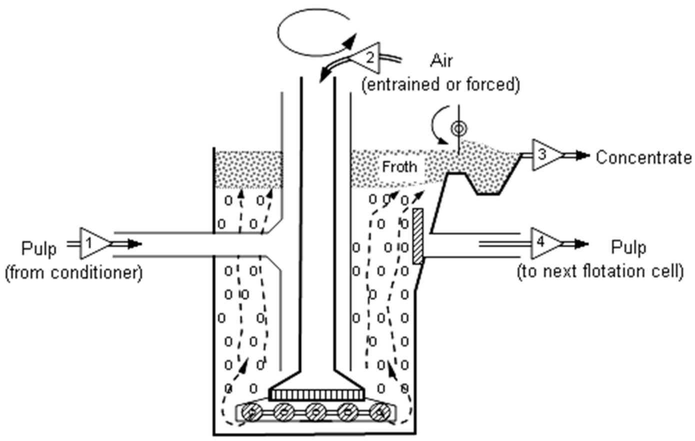


Figure 129: Flotation Process (Thermbal at Wikimedia Commons, 2006)

The pulp (1) comes into the cell and goes to the low part. The air (2) flows vertical from the top and creates bubbles. The material concentrate like froth is collected from the top of the cell (3), while the pulp (4) flows to another cell.

Wash De-inking: This method is used instead of Flotation De-inking when the ink particles are smaller. Wash De-inking apart from remove the ink also this system is used to eliminate fine impurities and fillers.

This method is like a washing phase where substances like dispersants are added to remove inks. So, when the pulp slurry is dewatered, the particles are washed and removed.

Modern plants for the recycled paper manufacturing include often both techniques (Flotation and Washing De-inking) because they are used complementarily.

- **Bleaching:** The bleaching of the paper pulp is carrying out by the use of chemical products which are added to the pulp to increase the brightness. The bleaching activity is done in a bleaching tower.
- **Manufacture:** The paper slurry is in continuous movement and is distributed through presses and driers and then it is rolled in large paper rolls.

Once these operations are finished, the recycled paper is created and it is ready for their future use.

New Technology for paper recycling

Because the methodology for manufacturing recycled paper is quite simple, important improvements haven´t been developed; only different modifications in terms of frequency of collection or recycling scheme but not referring to the recycling process. However, recycled paper can be used for more applications than the generation of new paper.

A new research about the use of recycled paper is:

- Research about Waste Paper for Ceramic Materials

  Scientists have been studying the use of waste cellulose, as well as sludge from the treatment of wastewater attached to the clay that is used in construction. This mixture under pressure and using an extruding machine let to obtain bricks test in the laboratory.

  The addition of the waste gives to the end product a low thermal conductivity, so it acts as a good insulator. Also, this technique can help save energy and raw materials.

This is only an example about the possible usages of recycled paper. Continuing working in this way, new technologies, systems or materials can be achieved with the mixture of waste paper. The reutilization of these materials in other fields contributes the environment as well as sustainability.

Glass

The glass recycling exists since the 1970's in Europe and there are different opportunities to collect and recycle it. The main advantage of glass is that it includes no toxic substances and it is possible to easily gain new glass out of the old one. Important for the recycling process is how the glass gets separated. With mixed coloured glass it is not possible to recreate new glass with the colours green, white or brown, the most common ones on the market. In this case, there are different applications what to do with the used glass.

Existing Treatments

The most used collecting strategy is with public glass containers, distributed all over the cities. The best and reasonable way to recycle the glass is by using three different types of containers for brown, green and white glass. With this separation it is possible to recreate new glass in glass recycling plants, without losing any material. The glass recycling is the perfect example how recycling should be done, by using all of the waste material again for new products.

Figure 130: Separated glass containers + container for small electric devices (Münstersche Zeitung, 2012)

Another cheap and easy option is to put just one type of public glass container into the cities in which every glass type can get thrown in. Regarding this option, the recycling process is only possible with a plant that is equipped with sorting sensors. Otherwise it is possible to crush the glass into small pieces and use it for fillings in different applications of the construction industry. The advantage of the crushed glass is that it is non-toxic and not environmentally harmful for any use in the soil (Schüßler, 2012).

New ideas and solutions

Another way of using the collected old glass, no matter which colour, is to create foam glass or foam glass granulate out of it. Therefore the glass gets heated up and mixed with some chemicals and carbon in a mould. Additional, gas gets pumped into the liquid to create the foam structure when it cools down. In the end, the new created product is a very good insulating material for buildings, pipes and other applications. In addition to that, it is possible to recycle the foam glass in the same process again (Geocell, 2011).

Plastic recycling

Plastic has several specific **properties** such as low weight, durable material and low cost in contrast with other materials; that is why its production has been enlarged over the last decades. Due to its benefits it is used into an extensive variety of products and applications.

Most part of plastic products that are created yearly are manufactured to take part of disposable goods for different kind of packaging or other short-term products. It means that are discarded within a year or less of its manufacture, therefore having a non-sustainable performance. This confirms that packaging is the most important **source of waste plastics**, but other come from waste electronic/electrical equipment and end-of-life vehicles that are becoming significant fonts of PSW.

Figure 131: Plastics waste (blackburnnews; 201?)

Plastic recycling represents the method of using recovered plastic waste to generate new goods. This process permits to have the chance to reduce CO_2 emissions, reduce oil usage and the amount of final plastic waste disposal. It has been settled since the 1970s, but the technologies have been developed and the quantities recycled vary a lot geographically. The ideal recycling or also called *closed-loop recycle* is possible with thermoplastics; nevertheless most of the plastic waste uses a large variety of diverse polymers and components (metals, pigments and glues) that make the process more difficult.

Referring to the **collection of plastic waste**, it can be separated into two main schemes. The first is the *bring-schemes*, that usually have less collection amounts due to the absence of dedicates public policies to enhance it without refunds that economically incentives its involvement. The other main scheme and most extended scheme is the kerbside collection in streets for PSW and other recyclables. It can vary from one place to another and the most used are the mix recyclables (paper, glass, metals/aluminium and plastic containers) that are separated at least in two kinds, innovative *door-by-door* collecting, whereas the collection frequency vary a lot from one place to another. These schemes are successful at taking packaging from households, nevertheless a lot of this packaging plastic waste are generated from food-beverage, thus is necessary to take into account *on-the-go* and *office-recycling* collection systems (Hopewell, J., Dvorak, R. & Kosior, E., 2009).

Existing treatments

There are a lot of complex methods because of the wide range of recycling technologies:

Primary recycling: Re-extrusion

It refers to the reprocess of plastic waste scraps into the extrusion cycle in order to obtain products with equivalent properties. It is also called re-extrusion and *closed-loop recycling*. This process requires that the scrap is semi-clean, able to be separated from contaminants and stable after the second extrusion. Therefore, these strict requirements make this solution a difficult one in term of being extending used and only PET bottles are regularly been primary recycled.

Currently, some of the plastic wastes recycled in this way are from industrial fonts, whereas the main source comes from households, which need a large segregation collection because of the diversity of packaging. This fact produces large operating costs and making this option less feasible.

Secondary recycling: Mechanical recycling

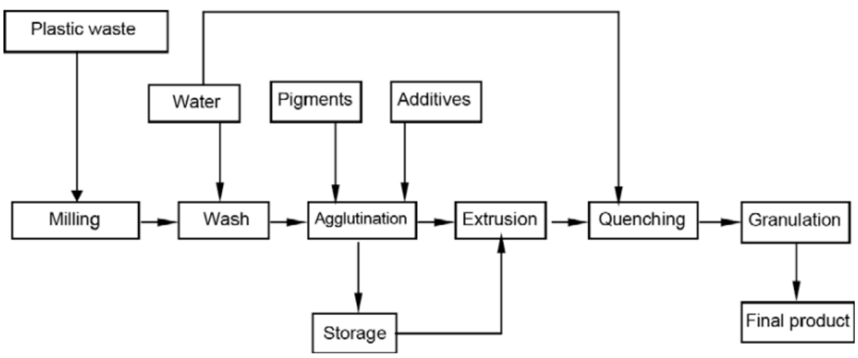
This secondary plastic recycling regards to the re-use in plastic product by a mechanical reprocessing into products with lower properties with non-suitable plastics into the prior application. It can be only performed with single-polymer plastic and it is harder to be done as more contaminated is the plastic waste.

Because of that, the main issue to use this process is the degradation and heterogeneity of PSW. The main one can happen because the heat may produce mechanical traumas, breaking the theoretical reversibility of chemical processes in terms of formation of the plastic by modifying its internal structure.

Some industrial plastic wastes are hardly appropriated, because of their clear separation of polymers, large quantities and little amount of contaminants. Therefore, it is possible to find some daily-life products come out of this secondary recycling such as bags, pipes, window/door profiles, shutters and blinds (Hopewell, J., Dvorak, R. & Kosior, E., 2009).

This recycling involves several preparation steps, taking into consideration the importance of size reduction, explained in the following **general scheme** (Aznar, M.P., et. al., 2006):

1. Cutting or shredding large plastics into small flat pieces.
2. Impurities separation.
3. Floating separation in a floating tank by density criteria.
4. Single-polymer milling.
5. Water pre-washing and drying: another washing process is required to be followed by further processes and a chemical one in order to remove glues.
6. Agglutination: collection to be stored and following sold (previously the addition of pigments or additives is done) or used in other processes.
7. Extrusion to strands and pelletized as single-polymer plastic.
8. Quenching by water-cooling the final recyclers that are able to be convert into new plastics.



Apart from the general system, there are **specific schemes** in terms of different polymers.

PET mechanical recycling is a widely case, they are mostly bottles and they are collected and sorted, compressed and packed by municipalities for transportation to recycling plants. After that, contaminations are removed and the remaining bottles are then shredded, cleaned. The remains bottles turned into flakes and pellets for recycling. Afterwards there are several processes that can be summarized as follows:

- Extrusion molding: pipes, sheets, film and wire covering.
- Injection molding: heated molten resin is injected into a mold.
- Blow molding: inflated with air.

Figure 132. General scheme of mechanical recycling. (Aznar, M.P., *et. al.*, 2006)

- Vacuum molding: a heat-softened sheet is inserted in a mold, and the space between the sheet and mold airtight to form products.
- Inflation molding: extrusion molding in which a melted resin is inflated into a roll to generate a film.

PVC has an intern composition that permits its optimal recycling by a first check and a by-size collection. They are classified into rigid (inner layers´ pipes, plastic furniture and profiles production) and flexible PVC (floor covering, fences, flexible tubes, bags, etc.). (Al-Salem, S.M., Lettieri, P. & Baeyens, J, 2009).

Tertiary recycling: Chemical recycling

This third process, also called *feedstock recycling*, refers to the modification of the structure of the polymer by transforming PSW into basic molecules and chemicals. The final production may be reprocessed for polymerization into new plastics, for production of chemical feedstock or as liquid or gas fuel.

This technology has the advantage to generate high quality plastic and little waste and with the possibility to be used effectively with heterogeneity and contaminated waste (Mastellone, M.L., 1999).

The feedstock recycling includes several technologies, some of them are thermolysis technologies such as pyrolysis (refers to the thermal cracking of polymers that permits to obtain combustible gases with high calorific capacity and chemical products) gasification (obtained CO_2 gasses as a combustible, by compacting reduction, de-gasification and high-temperature pyrolysis, without the requirement of separated polymers) and hydrogenation (applying heat and hydrogen to plastics, breaking the polymers structures and obtaining synthetic liquid fuels). Although all the previous technologies have been developed currently by some chemical companies, it seems difficult to be economic feasible because of the large investment and energy consumption required, apart from the need to ensure enough waste material input (Al-Salem, S.M., Lettieri, P. & Baeyens, J, 2009).

A last important fact is the difference between this chemical recycling and the energy recovery, due to the fact that the border of taking energy in the process is very narrow.

Quaternary recycling: Recovery of energy

The quaternary plastic recycling implies the recovery of energy by burning waste, with the characteristic of very high calorific value of the PSW burned, some from crude oil derivatives, so that they become a suitable energy source. Some considerations are important, such as the existence of flame-retardant in PSW that makes more difficult the technical aspects of energy recovery. Environmental facts due to the contaminants emissions by incinerating them is another issue. Further information concerning the energy recovery is explained in the following specific topic.

Although, there are some advantages and disadvantages by using different recycling methods, some **conclusion ideas** may be stated. Mechanical recycling requires specific conditions, requirements of the type of polymer to be recycled and high energy consumption. Whereas chemical treatment could be considered the best option, due to the possibilities to recover chemicals as feedstock and the option to generate energy in heat and steam ways with specific disadvantages.

New ideas and solutions

In terms of different challenges to improve plastic recycling there have been chosen some possibilities.

Regarding innovations in **technical advances**, only occurs the improvement of the existing plants and specifically in sorting/separation, due to the absence of general inventions of new treatments. One advance is the development of trustworthy **detectors**, optical sorting technologies, together with advanced recognition software that has a high precision of automatic categorization. (Al-Salem, S.M., Lettieri, P. & Baeyens, J, 2009)

Another field has shown some innovations in the existence of different **applications** by using plastic recycled following closed-loop processes, such as carpeting, clothing, furniture, and car parts among others. Another specific example is the use of PSW as aggregate in cement and concrete preparation (Saikia, N. & de Brito, J., 2012)

The **design of plastic products** is being hardly developed by creating product taking into consideration its final composition in order to decrease the waste fractions and typologies. This fact has important relevance in the packaging, due to it represents the most extended used of plastics, so that thinking in an intelligent design, and the selection of basis materials, would improve the performance and make the recycling process easier.

They are being used **alternative materials**, like biodegradable plastics in order to achieve disposable packages and may be used into some organic energy recovery processes (Hopewell, J., Dvorak, R. & Kosior, E., 2009).

Some **policies** are nowadays promoting intelligent design by encouraging industry to add plastic recycled resins on products and promoting goods for disassembly. Another advance is the appearance of 3D printers that may completely change the manufacturing industry of things by using plastic materials that can come from plastic recycling sources.

Organic waste recycling

Organic waste is the waste, which can be decomposed in a short amount of time. This kind of waste is very dangerous, because of the creation of a leachate that represents a serious risk if it gets to the ground water level, but we can take advantage of this waste, using for soil improvement, for animal raising and for providing a source of energy.

The main types of organic waste are:

- **Domestic or household:** it is consisted of food leftovers and garden waste. Domestic kitchen waste normally goes with other things as plastic, it will be a good point that users do not mix the organic waste with other garbage.
- **Commercial:** it is the waste generated at school, hotels and restaurants.
- **Human:** it is the sewage, these waste should never be applied to harvest which are going to be used by humans or animals. With anaerobic digestion, we can produce biogas and liquid fertiliser.
- **Animal:** it is used also for power source, through combustion or through digestion to produce methane or fertiliser, being applied directly to the land.
- **Agricultural:** this waste comes from harvests. This waste could be used as a fuel.

Methods of processing organic waste:

- **Composting:** it is the decomposition of organic materials in big containers or in a pile. This technique happens thanks to a natural process where microorganism and small invertebrates are involved. This process can change organic waste into compost. The main benefits are preventing soil from the creation of leachate in dumping sites and waste can be used as fertiliser. There are some variations inside composting:
    - Backyard composting: composting at household level.
    - Neighbourhood composting: composting at a neighbourhood communities.
    - Co-composting: This method mixes organic food waste with human excreta.
    - Large-scale or centralised composting: this compost is produced in a treatment plant together with biogas (look at anaerobic decomposition point in this chapter).
- **Briquetting:** it is the densification of agricultural waste. Briquettes facilitates easy transportation. The process consists on drying, shredding and mixing with binder (paper, wood or sawdust) the waste, then compressing by a press. If we want precision in our briquette shape we have to use a hydraulic press but if we want a high values of strength and density we have to use a mechanical press (Krizan, et al., 2011).

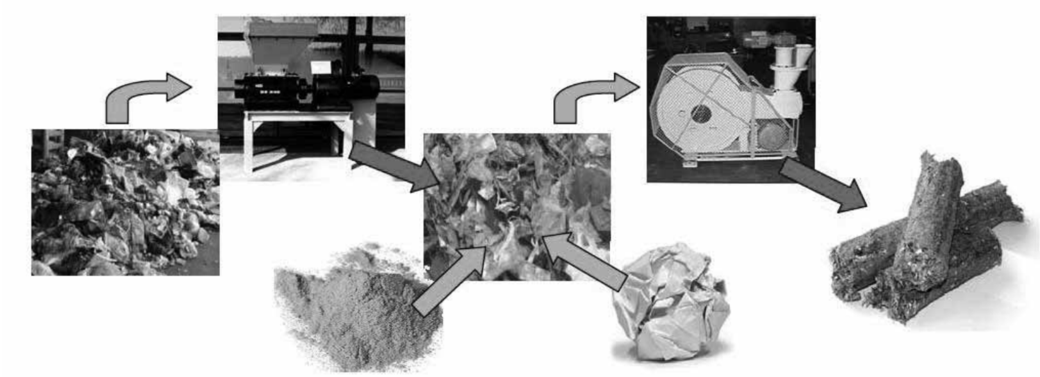


Figure 133: Schematic illustration of municipal waste treatment before gasification (Krizan, et al., 2011)

- **Anaerobic decomposition:** this method uses the natural breakdown of organic material. This process occurs in closed containers, in biogas plants where fertilizer (sludge and substrate) and biogas are created.

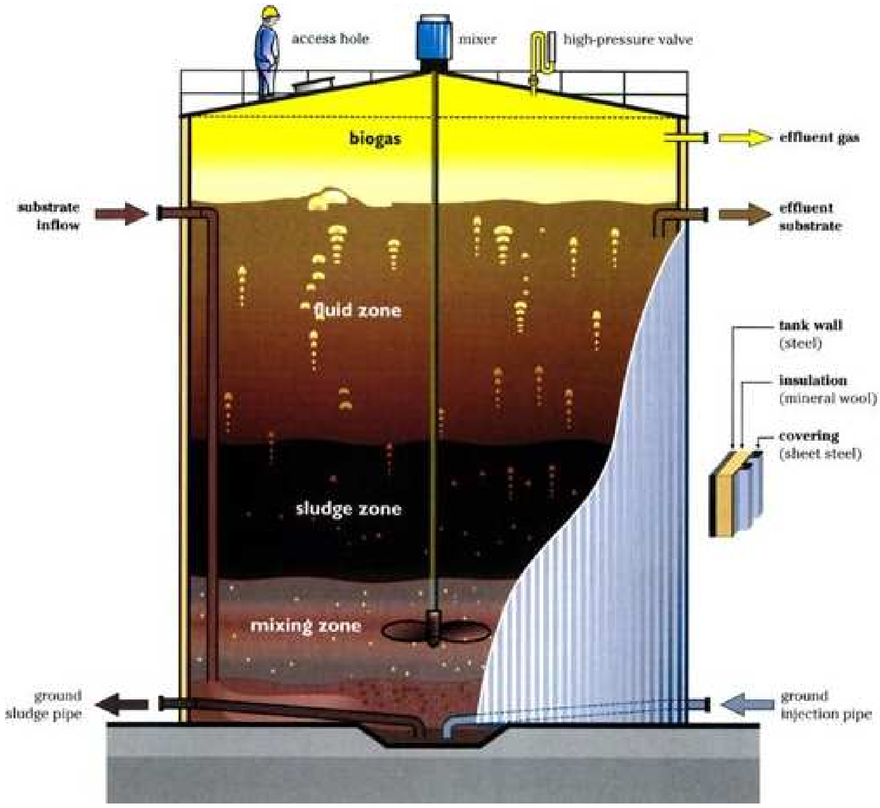


Figure 134: Anaerobic digester from Haase (http://www.daviddarling.info/)

- **Composting toilets:** this method uses human excreta. There are two main types of composting toilets:

o Carousel composting toilet: this toilet has many chambers, so when one chamber is full, the bin rotates.

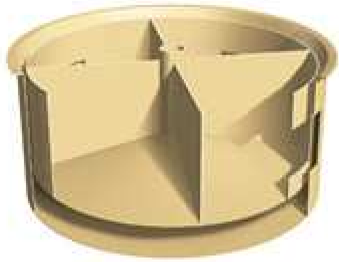


Figure 135: Ecotech carousel composting toilet (http://ecotechproducts.net/)

o Solar composting toilet: this kind of toilet permits thanks to the solar heat the drying of the compost pile, so any leachate is created.

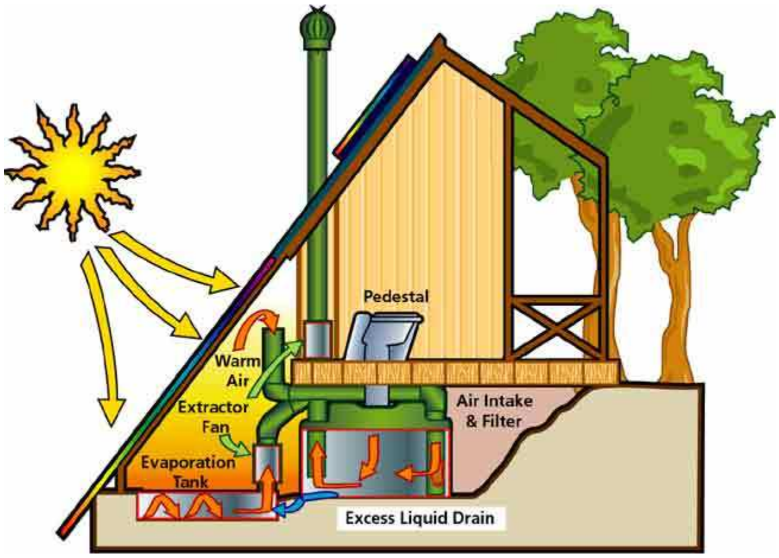


Figure 136: Rota-loo composting toilet (http://www.rotaloo.com/)

Here appears a table, which explain better the connexions between waste-method-resource:

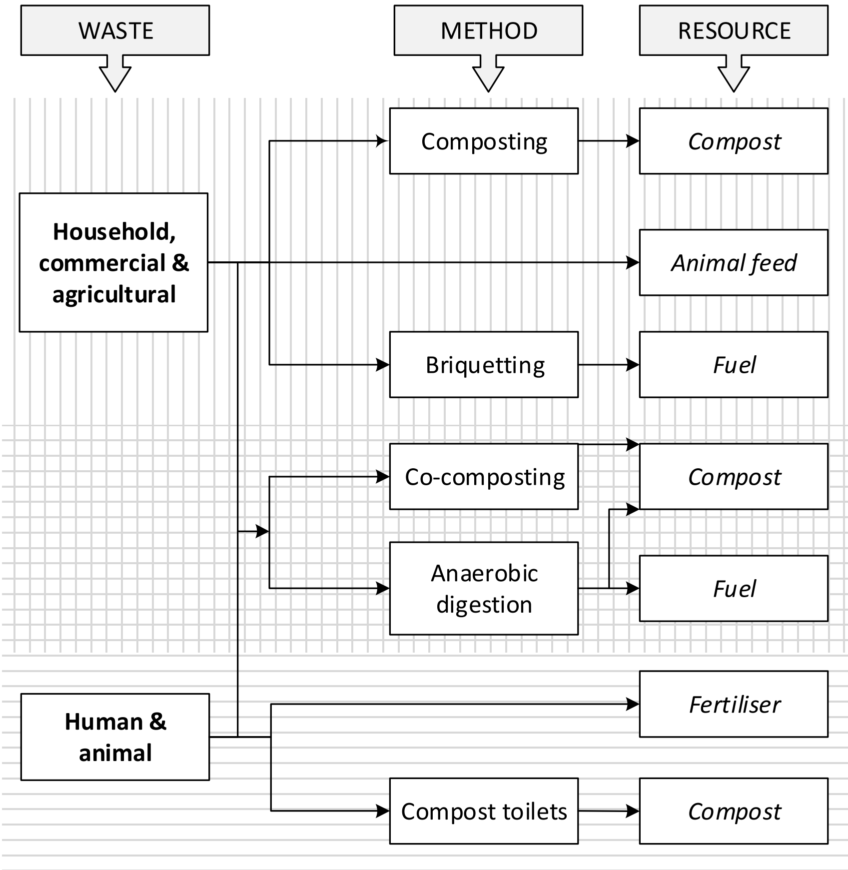


Figure 137: Connexions between Waste, Method and Resource.

ENERGY RECOVERY

The current energy situation motivates the search for alternative energy sources characterized as renewable, sustainable and environmental friendly. Within this context, municipal waste meets these attributes, because it is generated in sufficient quantities and with the necessary energy content for conversion while protecting the environment.

At the same time, another important concern about the waste is the amount which is daily generated. In a world with limited space, a waste treatment system well planned is needed in order to manage the waste properly and reduce as maximum its volume before landfill.

There are basically two types of processes for treating the waste: biological and thermal. Between the biological treatments are the anaerobic digestion and the composting. Both techniques provide valuable products in the end. Moreover, there are the thermal treatments in different variants.

Nowadays exist diverse types of thermal treatment technologies, each of them has been developed until different levels. The only one widely developed and tested in all aspects is incineration. However, this treatment has a low social acceptance level due to concerns about pollutants in gaseous emissions from incinerator stacks. So the other thermal treatments, such as gasification, pyrolysis and plasma arc gasification are becoming more popular these days looking for a more efficient energy recovery.

Regarding the technologies and plants for generating energy out of waste, there are many several options. A lot of different plants are already existing or planned to gain all kinds of energies and fuels out of the waste. All of them follow the aim to create as much useful materials and energies as possible out of the waste, while reducing the pollution of the environment. In the following chapter there is a selection of plants and their techniques more in detail explained.

Biological treatments

Biological treatment processes are widely used in organic waste, mainly non-hazard ones. Different microbial actions take place in anaerobic (biomethanization) or aerobic (compost) conditions.

Anaerobic digestion

Also known as biomethanization, the anaerobic digestion is a biological process that, in the absence of oxygen and through several stages in which a heterogeneous population of microorganisms is involved, transforms the fraction of degradable organic matter from waste into biogas. This gas is mainly composed of methane and carbon dioxide, a smaller proportion of water vapour, carbon monoxide, nitrogen, hydrogen, hydrogen sulphide and others are also present.

The biogas is a secondary energy source because its high heat capacity of 5000-5500 Kcal/m^3 (Nasir, et al., 2012). Therefore, it can be used in cogeneration engines, boilers and turbines generating electricity, heat or biofuel.

The anaerobic digestion is carried out in multiple stages (hydrolysis, acidogenesis, acetogenesis and methanogenesis) as it is shown in the following scheme:

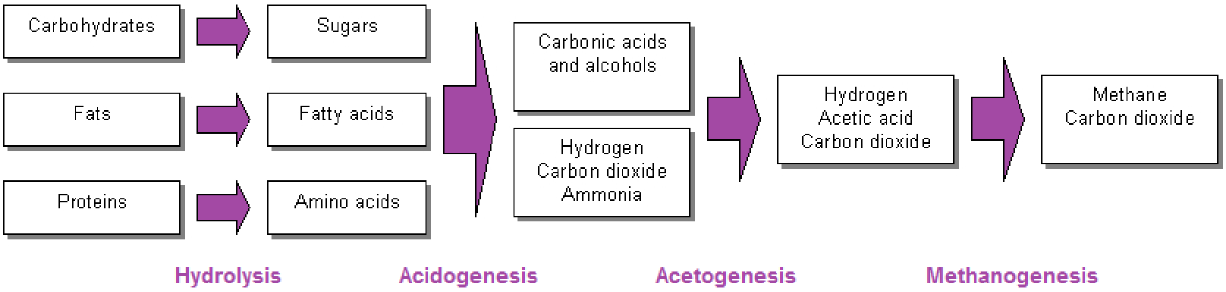


Figure 138: Phases of the anaerobic digestion (Stream Bioenergy, 2010)

The type of digested substrate greatly influences the performance and composition of the produced biogas. Looking for a maximum production, it is preferable to use substrates rich in fats, proteins and carbohydrates because their degradation entails the formation of significant amounts of volatile fatty acids, precursors of methane.

Consequently, it is advisable to treat organic matter from separate collection in order to avoid many of the problems caused by the accumulation of improper materials and to prevent siltings in some parts of the circuit digestion. It is also necessary to optimize the mixture of materials digested to increase the amount of methane got in the process.

Biomethane technologies are classified into two large groups according to the solid content in the process: wet anaerobic digestion technologies (a solution is prepared adding water before the digestion) and dry anaerobic digestion technologies (residue movement inside the digester is ensured by mechanical action or by recirculating the biogas itself). In the first case, the dry content of the residue is below 20%, usually between 3% and 15% and, in the second, the content is between 20% and 40%. (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013). Both technologies offer referrals for treatment of organic matter, regardless of whether it is collected separately or not.

The mainly steps in a biomethanization municipal facility are:

1. Selection, more or less complex depending on the waste origin and the collecting system of the residues.
2. Conditioning of the material to be digested (reducing its granulometry, adjusting the total solid content, mixing with recirculated effluent,…).
3. Anaerobic digestion.
4. Dehydration, separation of liquid/solid phases.
5. Treatment of the liquid fraction of the digester and other wastewater generated.
6. Aerobic stabilization of the solid fraction of the digester.
7. Collecting and use of biogas produced. It can be used for cogeneration of heat and electricity. After treated, it can also be injected into the gas distribution network or used in vehicles.

If the organic materials to be treated are not coming from a separate in origin collection, or if the quality of selected material is not suitable due to a high portion of unsolicited matter, biomethane facilities have serious problems and their performances do not justify the costs or installation.

Composting

Composting is an aerobic biological process that, under right conditions of ventilation, controlled humidity and temperature, transforms degradable organic waste into a stable and sanitized material called compost, which can be used as organic manure.

The composting process mimics the transformation of organic matter in nature and can homogenize materials, reducing its mass and volume. This treatment favours the return of organic matter to the soil and their reintegration into natural cycles.

Figure 139: Composting cycle (Corner Farm Chicago, 2013)

The composting process is based on the activity of microorganisms such as fungi and bacteria. Its duration can vary, depending on various factors (system, technology, space available…), between 10 and 16 weeks (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013).

The process takes place in two stages: decomposition and maturation. In the first phase, the more easily degradable molecules disappear releasing energy (temperature of 60-70% is reached), water, carbon dioxide and ammonia. Biopolymers such as cellulose and lignin are partially altered and become, in the subsequent maturation phase, the basic structures of macromolecules which will include some of the nitrogen content in the starting materials creating organic matter similar to the soil humid substances. This first stage usually lasts between 4 and 6 weeks, but if carried out intensively (indoors and forced aeration) it can be reduced to between 2 and 4 weeks.

The second phase is the maturation in which the residue is stabilized and matured. This requires between 6 and 10 weeks and finally a product, compost, is obtained.

Along the process, it is important to get the sanitization of the resulting material. The temperature rise reached along the composting process joined with the competition and antagonism between groups of microorganisms and the formation of antibiotics in the maturation phase, are elements that minimize the number of animal and plant pathogens in the final product.

If significant amounts of waste are treated and depending on the characteristics of the materials, pre and post treatment stages are needed. The first, to adjust the materials for a biological transformation and the second to adjust the products for their destinations.

The term compost is used when the organic matter collected in a separate way is treated. For organic matter which has not been separated in origin, the term bio stabilisation is used. Nevertheless, the bases of the biological process are the same.

Thermal treatments

Thermal treatments such as incineration, pyrolysis, gasification and plasma arc gasification, are characterized by the conversion of the carbon present in the waste under different conditions of temperature and air mainly.

They are no finalist treatment because they generate residues which must be managed properly depending on their characteristics.

Incineration

In the incineration takes place the combustion, chemical reaction based on a total thermal oxidation with oxygen in excess.

The general characteristics of waste incineration are:

- A temperature between 900º C and 1200º C during the combustion of the waste (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013).
- As it has already been said, oxygen is needed in excess to ensure a complete oxidation.
- As a result of the incineration process, combustion gases and solid waste are obtained.
  The combustion gases are composed mainly of carbon dioxide, water, unreacted oxygen, nitrogen from the air used for combustion and other compounds in smaller proportions coming from different elements present in the waste. The minor components depend on the composition of the treated waste. Therefore, they may contain acid gases derived from reactions of halogens, sulphur, volatile metals or organic compounds (such as dioxins and furans) that have not been oxidized. Finally, combustion gases will also contain particles swept along with the gases.
  The solid waste is mainly composed by inert slag, ash and residues from the system in charge of purify the combustion gases.
- The heat carried by the gases leaving the afterburning chamber can be used to heat up water. This water is used as heating or to generate steam for industrial applications. This steam can also be used to generate electricity through a set of steam turbine and alternator.

Example: Incineration plant in Düsseldorf (Germany)

In Düsseldorf there is one of the most modern incineration plants of Germany. The plant takes care of 450.000 t of residual waste every year and produces around 1.000.000 t of superheated steam out of it. This steam is then used for electricity and long-distance heating in other plants. The plant takes care of the waste from around 2.250.000 people, if you calculate 200 kg of residual waste per person every year (Schreiber, 2010; Stadtwerke Düsseldorf, 2010).

The technique

The incoming residual waste gets conducted over six big rolls while it gets burned by a temperature of 1200°C. It takes the waste around 50 minutes to get transported over all the rolls. The speed of the rolls and the air supply for the fire can be controlled by affiliated computer system. This technique was developed in Düsseldorf and is used today in over 200 plants worldwide.

Furthermore a lot of the toxic substances get destroyed because of the high temperature. But still there are some toxic gases left. These are rising up in a tower in which the substance lime milk gets sprayed in. This chemical substance binds with the gas and they turn into a solid material called lime scale (Schreiber, 2010; Stadtwerke Düsseldorf, 2010).

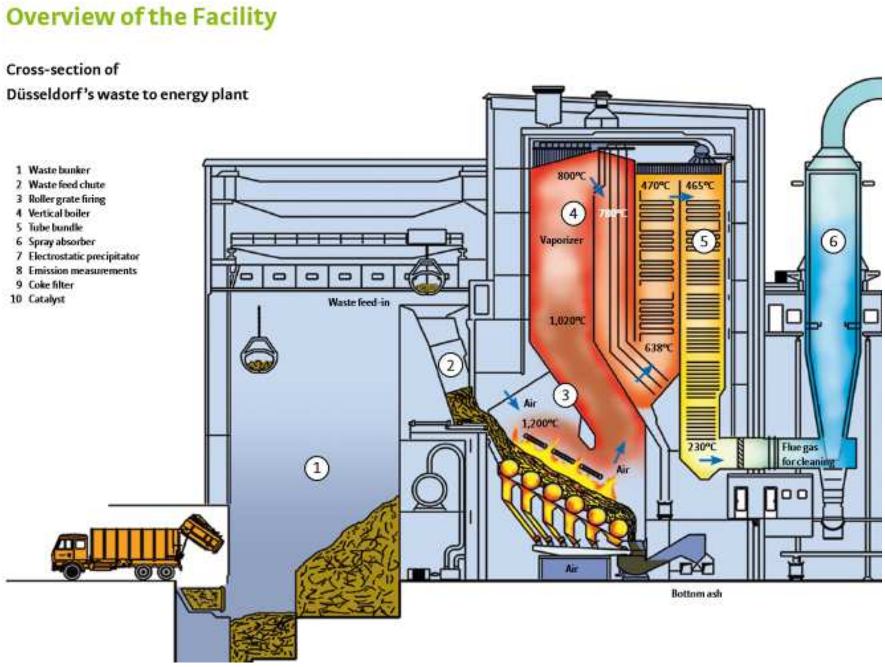


Figure 140: Overview of the facility in Düsseldorf (Stadtwerke Düsseldorf, 2010)

The Out coming Resources

Afterwards there is just ash and metal coming out of the incineration chamber. The metal gets then filtered out with magnets and conductors. In a smelting plant this metal gets recycled into new metal. The remaining ash doesn't include any more useful materials, so it is used for highway construction. The lime scale which is created out of the gases can be used as fillings in mining.

Figure 141: Digital display, viewable for the public outside of the plant (Stadtwerke Düsseldorf, 2010)

In addition to that, the incineration plant has a digital display in front of the building, which monitors the data of the working process every hour. The data includes the mass of incinerated waste, the mass of steam and flue gas that gets set free, as well as other gases like CO_2 (Schreiber, 2010; Stadtwerke Düsseldorf, 2010).

Gasification

Gasification is a partial oxidation process of matter, in the presence of lower amounts of the stoichiometrically required oxygen. In general terms, the features for the gasification process are:

- A process temperature higher than 750º C (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013).
- For providing the oxygen, air, steam or pure oxygen is used. In any case, the amount of present oxygen is inferior to the stoichiometric needed one.
- As products of the gasification:
  Gas, called syngas, composed mainly of carbon monoxide, hydrogen, carbon dioxide, nitrogen (if air is used as oxygen source) and methane in a minor proportion. As secondary products are tar, halogenated compounds and particles.
  Solid residues, composed of non-combustible and inert materials from the feed residue. Generally, they also contain some not gasified carbon. The characteristics of this residue are similar to the slags from incineration plants´ furnaces.
- The gas obtained through the gasification, syngas, can be used for heat production and for generation of mechanical and electrical power. It can also be used as matter to process liquid fuels or chemicals.

Example: Gasification Plant in Nidwalden (Switzerland)

Since 2007 exists the gasification plant from the company Pyroforce in Nidwalden, Switzerland. It is specialised on used wood and fresh wood remains from deforestation. It produces long distance heating for 700 and electricity for 1.000 one-family houses which corresponds to 1,36MW. In 2013 the plant won an award for environmental friendly energy generation. It is a CO_2 neutral energy generation, because the amount of CO_2 that gets set free during the pyrolysis, is the same amount that the tree converted to O_2 (Genossenkooperation Stans, 2013).

The Technique

The wood (fuel) gets conducted into a 2-zone-carburator. In the pyrolysis zone the wood gets heated up until 100-200°C to dry the wood. The second zone is the oxidation zone in which the wood gets burned at 1300°C. In this zone a fumigator gets added, which contains O_2 to speed up the gasification. This part of the process heats up water pipes next to the carburator to receive heat energy. In the end of the carburator no more air gets added to reduce the gas temperature to 160°C. Than the gas gets conducted out to move the ventilator of an engine, that creates electricity through this process (Pyroforce, 2007 & 2008; Genossenkooperation Stans, 2013).

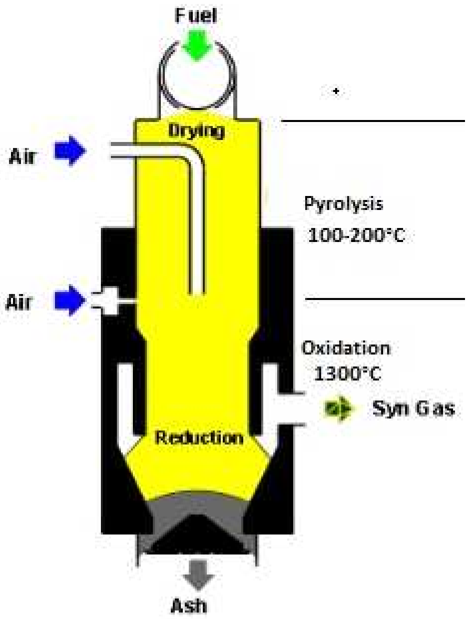


Figure 142: Overview of the process inside the carburetor (Pyroforce, 2007)

Out coming Resources

The carburator produces two energies and one disposal product. The disposal product is the ash, which is not environmental harmful, so it can be used in the soil for different applications. The heat energy that is produced can be used in the company building itself and as long distance heating for swimming pools or heating systems from other buildings. The biggest amount of out coming energy is the electricity which is gained through the gas flow. But the gas needs to be filtered and cleaned with lime in the end, to not pollute the environment, because it still contains ash and grime. In the end it emits the CO_2 that was bound by the living tree before (Pyroforce, 2007 & 2008; Genossenkooperation Stans, 2013).

Pyrolysis

The pyrolysis is a thermal degradation of a substance in the absence of oxygen, so these substances are decomposed by heat, without any combustion reaction. The basis features of this process are:

- Working temperatures lower than in the gasification, ranging between 300º C and 800º C (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013).
- The only present oxygen in the process is the one that is already in the treated waste.
- The process products can be divided into three different groups:
  Gas, composed basically of carbon monoxide, carbon dioxide, hydrogen, methane and volatile compounds, coming from the cracking of organic molecules, together with the already existing in the waste ones. This gas is very similar to the synthesis gas obtained in the gasification, but there is a greater presence of tar and waxes due to the lower working temperature in the pyrolysis.

- Liquid residue, primarily composed of long chain hydrocarbons such as tars, oils, phenols and waxes formed by condensation at room temperature.
- Solid residue, composed of all those non-combustible materials, which have not been transformed or which come from a molecular condensation with a high carbon content, heavy metals and other inert waste components.
- Liquid and gaseous residues can be harnessed by combustion through a steam cycle for electricity production. The solid residue can be used as fuel in industrial facilities, as for example, in cement plants.

Example: Waste Pyrolysis Plant in Burgau (Germany)

The plant in Burgau converts industrial, bulky and residual waste to heat energy and electricity, using pyrolysis. It owns two rotary drums for the pyrolysis and each of them is able to burn 3 tons of waste per hour (Kreisabfallwirtschaftsbetrieb, 2008; locally, 2013).

The Technique

After the waste gets delivered in the plant, a crane grabs it and throws it into a shredder. The crushed waste gets grabbed again by another crane and put into an auger with two hoppers, to conduct the waste in the rotary drum. The drum gets heated up with combustion air from smoldering drums until 500°C and the waste inside gets decomposed without any additional air supply. Afterwards, the pyrolysis gas gets conducted out through a pipe into a burning chamber, burned and then into a turbine. The solid materials semicoke and metal get conducted out and separated from each other (Kreisabfallwirtschaftsbetrieb, 2008; locally, 2013).

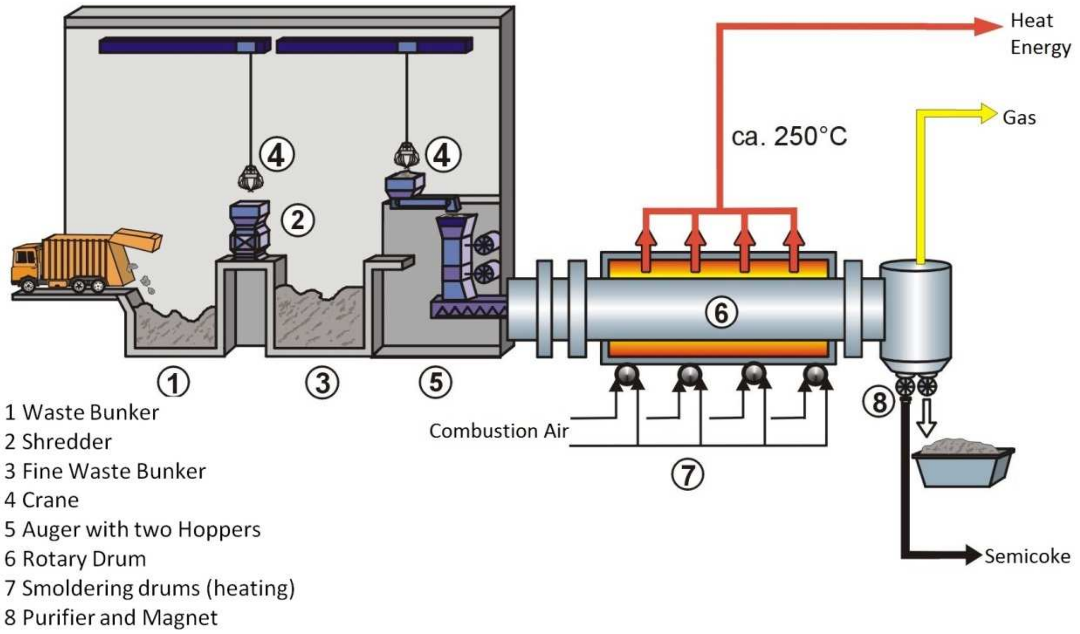


Figure 143: Overview of the pyrolysis plant in Burgau (DGE, unknown)

Out coming Resources

In this process two kinds of energy and two useable materials coming out of the plant. The heat of the burning in the rotary drum heats up water pipes for long distance heating. The pyrolysis gas gets conducted into a burning chamber and burned at a temperature of 1200°C to create more heat energy. The burning gases get than conducted into a turbine to create electricity, but they have to be cleaned to make them environmentally compatible. Semicoke, which is the solid remain from the burned waste, gets conducted over a conveyor belt into containers for disposal. A magnet rotates over the conveyor belt to filter out the left over metal parts which can get melted down again (Kreisabfallwirtschaftsbetrieb, 2008; locally, 2013).

Plasma arc gasification

The plasma is a mixture of electrons, ions and neutral particles. It is obtained by subjecting a gas to high temperatures. The characteristics that define the plasma arc gasification process are:

- The working temperatures vary from 5000º C to 15000º C (Ministerio de Agricultura, Alimentación y Medio Ambiente, 2013).
- The generation of the plasma is performed by flowing an inert gas through an electric field existing between two electrodes.
- The thermal energy content in the plasma, coming from the energy consumed for its generation, is the heat source of the process.
- A final product is obtained, whose basic components are:
  Gas, mainly composed of carbon monoxide and hydrogen.
  Solid residue, consisting in inert slag generally vitrified.

Example: Plasma Gasification Waste Plant in Ottawa (Canada)

The plant was built 2007 by the company Plasco Energy Group Inc. and is one of the first of its kind. It uses high temperatures, generated through electricity, to convert waste in a short time into gas and slag. With this technique, the plant is able to handle around 85 tons of waste per day. Since 2012 a contract is made to expand the plant so it will convert around 405 tons per day, and creating 1, 0 MWh electrical power out of it (Plasco Energy Group 2013; UFH, 2013).

The Technique

Before the waste enters the burning chamber, it gets filtered for recyclable materials. The rest of the waste gets heated up with the plasma arc to a temperature higher than 5000°C. Through this heat a lot of the toxic substances get destroyed and a big amount of the waste gets gasified, leaving only liquids of metal, glass and slag behind. Afterwards the gas gets conducted out of the chamber to generate energy out of it (Plasco Energy Group 2013; UFH, 2013).

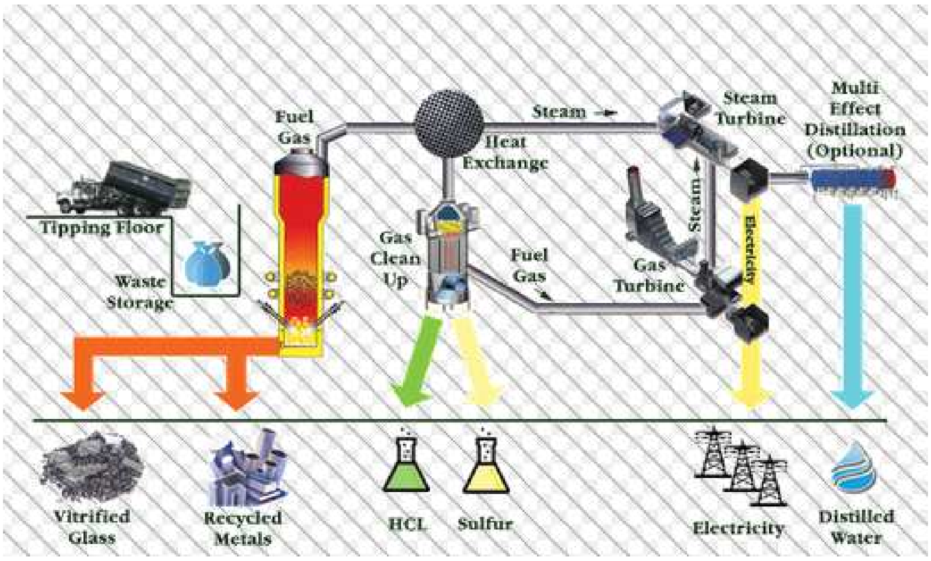


Figure 144: Overview plasma gasification process (Recovered Energy, unknown)

Out coming Resources

After the plasma process metal and glass as liquids get filtered out of the chamber for recycling. The generated gas, which is very hot after the process, gets conducted into a heat exchanger to gain heat energy out of it. Afterwards the gas gets cleaned and conducted into a gas turbine for creating electricity. Parallel to that, the steam from the burning chamber gets from the heat exchanger into a steam turbine to create electricity, too (Plasco Energy Group 2013; UFH, 2013).

LANDFILL

In order to recover as much resources as possible of the waste, the priority is to reuse or recycle. The residual waste is either sent to a biological or thermal treatment plant or, as the last resort, landfilled.

The disposal in landfills is the most traditional method of waste collection and it remains as a common practice in most countries around the world.

A landfill properly designed and well managed can be a hygienic and relatively inexpensive method to get rid of waste materials in a way that minimizes its impact on the local environment.

The main components of a landfill, to can ensure its proper operation, are: a total insulation of the soil where the waste is going to be placed, a system of pipes destined to collect leachates and a technique to gather the gas formed by the decomposition of the waste. With the appropriate operations, this gas can become a reliable energy source.

According to the European Commission (2013), landfills are divided into three classes: landfills for hazardous waste, landfills for non-hazardous waste and landfills for inert waste.

Operations

Landfills are deposits composed of several different layers, each of them with its own composition and function. The overall aim of the disposition is to minimize the impact of the landfill to the environment. Besides a total waterproofing of the soil, there is also a system of pipes collecting leachate and a channelling of the produced biogas inside.

Layers in a landfill

The purpose of a landfill is to provide a place where trash can be buried in such a way that it will be isolated from groundwater, kept dry and not be in contact with air.

In order to ensure a proper operation of the landfill it is composed of several layers. Each level is designed to solve specific problems that are encountered in a landfill.

The layers can be divided into 5 groups, from the top to the bottom:

- Protective cover

When a section of the landfill is completed it is covered permanently, first with the composite cover soil that is going to be explain in the next point and, over this layers, a protective cover is placed. It consists of two layers of soil and vegetation in the top of the landfill. No trees or plants with deep penetrating roots are allowed to ensure the vegetation do not contact with the waste.

- Composite cap system

Beneath the protective cover lays the composite cap system. It is composed of a drainage layer, a geomembrane and a layer of compacted clay. The entire disposition has the aim of preventing excess precipitation from entering the landfill and forming leachate. Also the escape of the landfill gas is prevented.

- Working landfill

In this group are the waste and the daily cover. With the purpose of preventing pests (birds, rats, flies,…) from getting into the trash and maintain the waste away from air contact, each cell in the landfill is covered daily with approximately 15 cm of compacted soil (Environment Agency, 2010). In this way it is possible to reduce smells and keep litter from scattering.

Trying to safe as much space as possible, everyday waste is compacted into areas, called cells. The compression is done by heavy equipment such as tractors or bulldozers going over the waste several times.

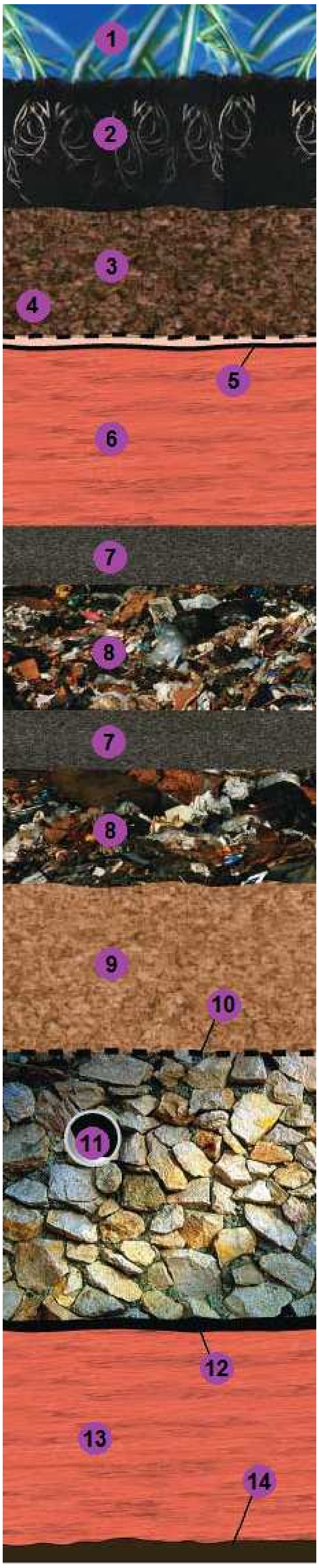
- Leachate collection system

These layers are designed to deal with the leachate problem in landfills. Three layers of sand, gravel and geonet or geotextile fabric facilitate the proper conduction of the leachate toward the collection points in the landfill.

- Composite liner system

The bottom part of the landfill has the important mission to ensure the total insulating of the area in order to avoid serious problems due to leachate leaks or landfill gas escapes. It is composed, from the bottom to the top, of a prepared subgrade to host the landfill, a layer or compacted clay and a geomembrane which must be impermeable and extremely resistant to the attack of the leachate´s compounds.

The next illustration shows a cross section of the standard landfill. It must be clarified that, although most landfills are similar, the exact sequence and type of materials may differ from one to another depending on location, climate, geology and design.



1. Cover vegetation
The vegetation prevents erosion of the underlying layers while it provides a pleasing view of the landfill.

2. Top soil
This soil maintains the growth of vegetation by retaining moisture and providing nutrients.

3. Protective cover soil
Protects the composite cap system and provides additional moisture retention for the cover vegetation.

4. Drainage layer
It consists of a layer of sand or gravel or a thick plastic mesh called geonet. A geotextile fabric may be located on top of the drainage layer to provide separation of solid particles from liquid and to prevent obstructions in the drainage layer.

5.Geomembrane
A thick plastic layer forms a cap that prevents excess precipitation from entering the landfill while hindering the escape of landfill gas.

6. Compacted clay
Is placed over the waste to prevent excess precipitation from entering the landfill and also helps to prevent the escape of landfill gas.

7. Daily Cover
At the end of the day, waste is covered with soil or other suitable material.

8. Waste
Mainly to reduce the volume consumed within the landfill, the waste is compacted in layers within a small area.

9. Leachate Collection Layer
A layer of sand, gravel or a thick plastic mesh (geonet) collects leachate and drives it by gravity to the leachate collection pipe system.

10. Filter Geotextile
In order to prevent clogging of the pipe system, a geotextile fabric may be located on top of the leachate collection pipe system.

11. Leachate Collection Pipe System
Perforated pipes, surrounded by a bed of gravel, carry captured leachate to collecting points.

12. Geomembrane
It is usually made of a special type of plastic called high-density polyethylene.

13. Compacted Clay
Directly below the geomembrane, this clay forms an additional barrier to prevent leachate leaks and landfill gas escapes.

14. Prepared Subgrade
Before beginning the landfill construction, the native soil beneath the location must be prepared.

Figure 145: Anatomy of a closed landfill, not to scale (Waste Management, 2003)

Leachate collection system

Although several steps are taking to avoid water flow in a landfill, there is always some water remaining in the waste or some coming from the rain. This fluid percolates through the cells picking up contaminants and forming the leachate.

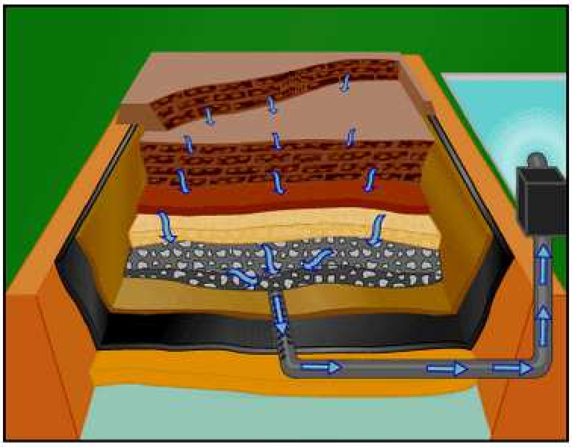


Figure 146: Collection of leachate in a landfill (Global Methane Initiative, 2010)

The leachate is collected thanks to a network of perforated pipes which run throughout the landfill. This way the contaminant liquids are driven out of the trash. By gravity or with a pump system the leachate is finally collected in a pond and has to be treated like any other wastewater.

Gas collection system

The landfill gas is created from the decomposition of organic matter through bacteria by an anaerobic process. This gas contains approximately 50 percent methane, about 50 percent of carbon dioxide and a small amount of different organic compounds such as nitrogen or oxygen (Global Methane Initiative, 2011).

By means of a series of pipes embedded within the landfill, the gas is collected.

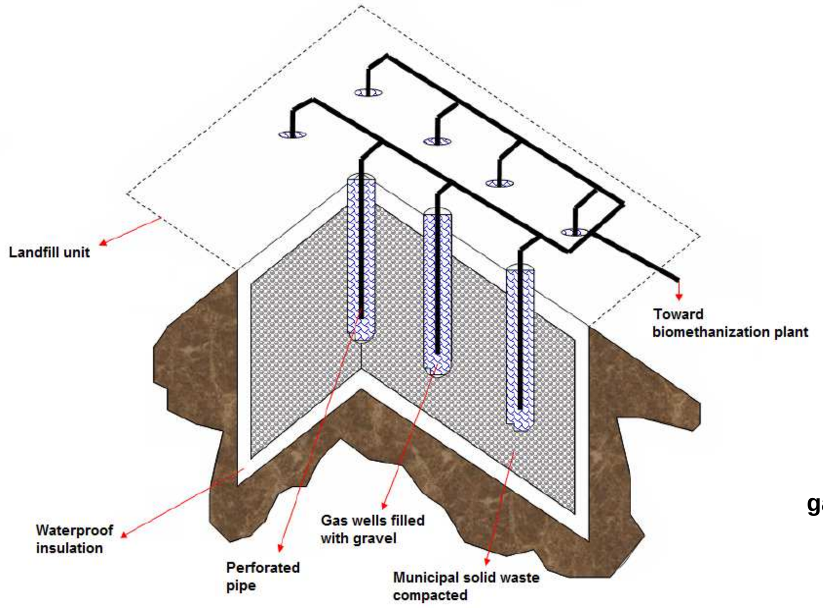


Figure 147: Detail of a draw-well gas (González, B. & Suárez, J.F., 2008).

The landfill gas is a reliable energy source because it is generated 24 hours a day, 7 days a week from waste continuously deposited in the landfill.

The gas can be burned, used to generate electricity, replace fossil fuels in industrial and manufacturing operations, or improved to obtain network gas quality and used directly or processed as an alternative fuel for vehicles (Global Methane Initiative, 2011).

Impacts

Landfill operations may cause many adverse impacts. Repercussions include pollution of the local environment, road damage due to heavy vehicles, visual concerns, nuisance problems such as smell, noise or dust, injury to wildlife, appearance of diseases carriers including rats and flies. Possibly, the most problematic ones are leachate leaks and explosions.

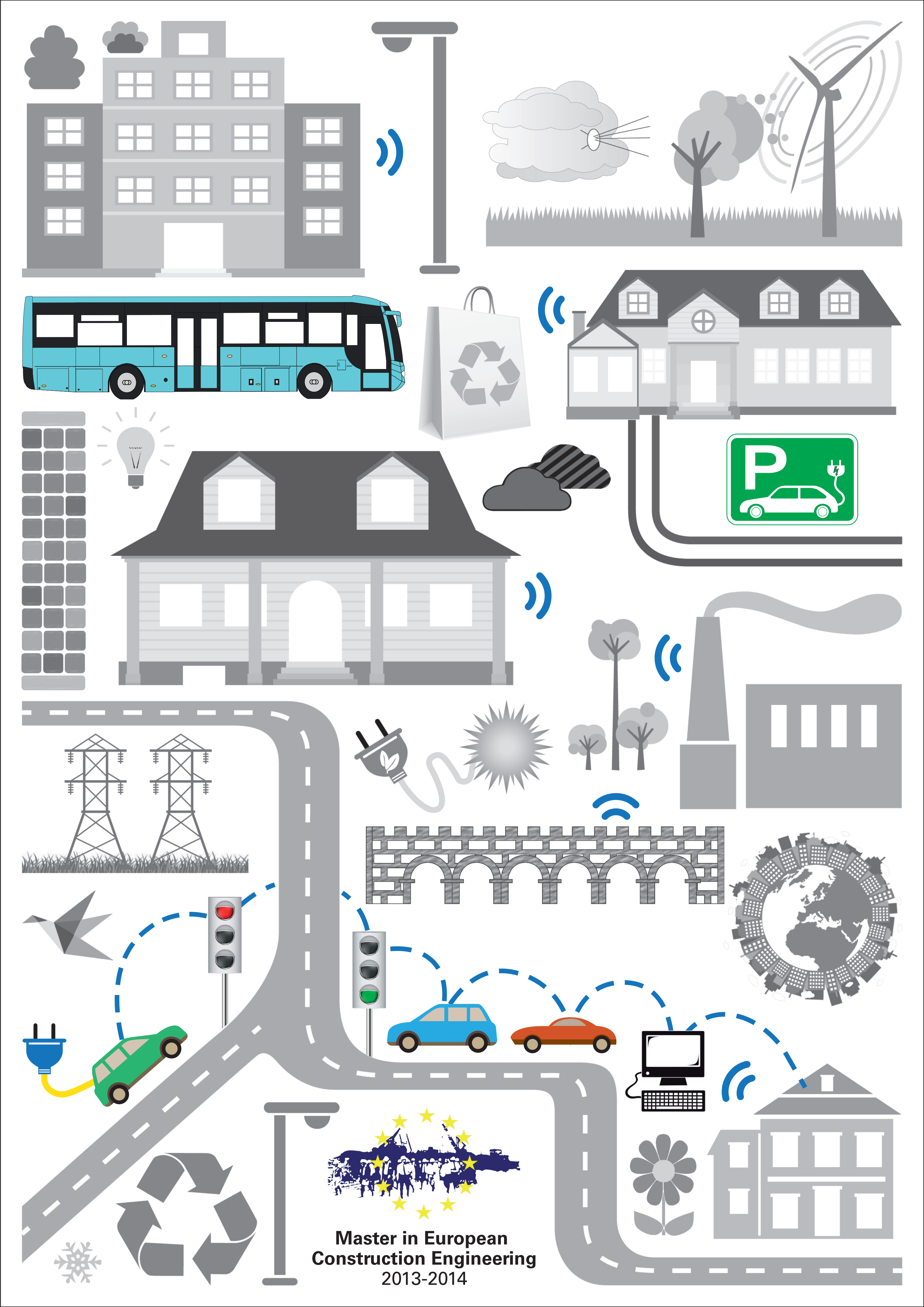
Leachate leaks

The principal problem that appears in landfills are leachate leaks. The bottom liner in a landfill prevents the waste from coming in contact with the outside soil. This insulating bottom layer could be torn or punctured by the nearby rock or gravel layers if it has been placed in an unsuitable disposition.

As a result, leachates percolate into the subsurface and impact groundwater resources by adverse smell, discoloration, increased loading of nitrogen and carbon nutrients, unusual quantity of anion and cation species and the flow of various trace metals or other organic compounds, such as arsenic or benzene, that have a detrimental effect on public and environmental health (Mouser, et al., 2010).

Gas concerns

Methane has a calorific value of 35.9 MJ/m^3. Mixed with air in a ratio of 5 to 15% by volume, methane forms an explosive mixture. Above this upper limit, the methane-air mixture burns and thus poses a risk of fire (Zeng, W.R. & Chow, W.K., 2006). The landfill fires are the result of the explosive nature of the gas, poor waste disposal techniques, and high temperatures in fermentation residues (Mavropoulos & Kaliampakos, 2010).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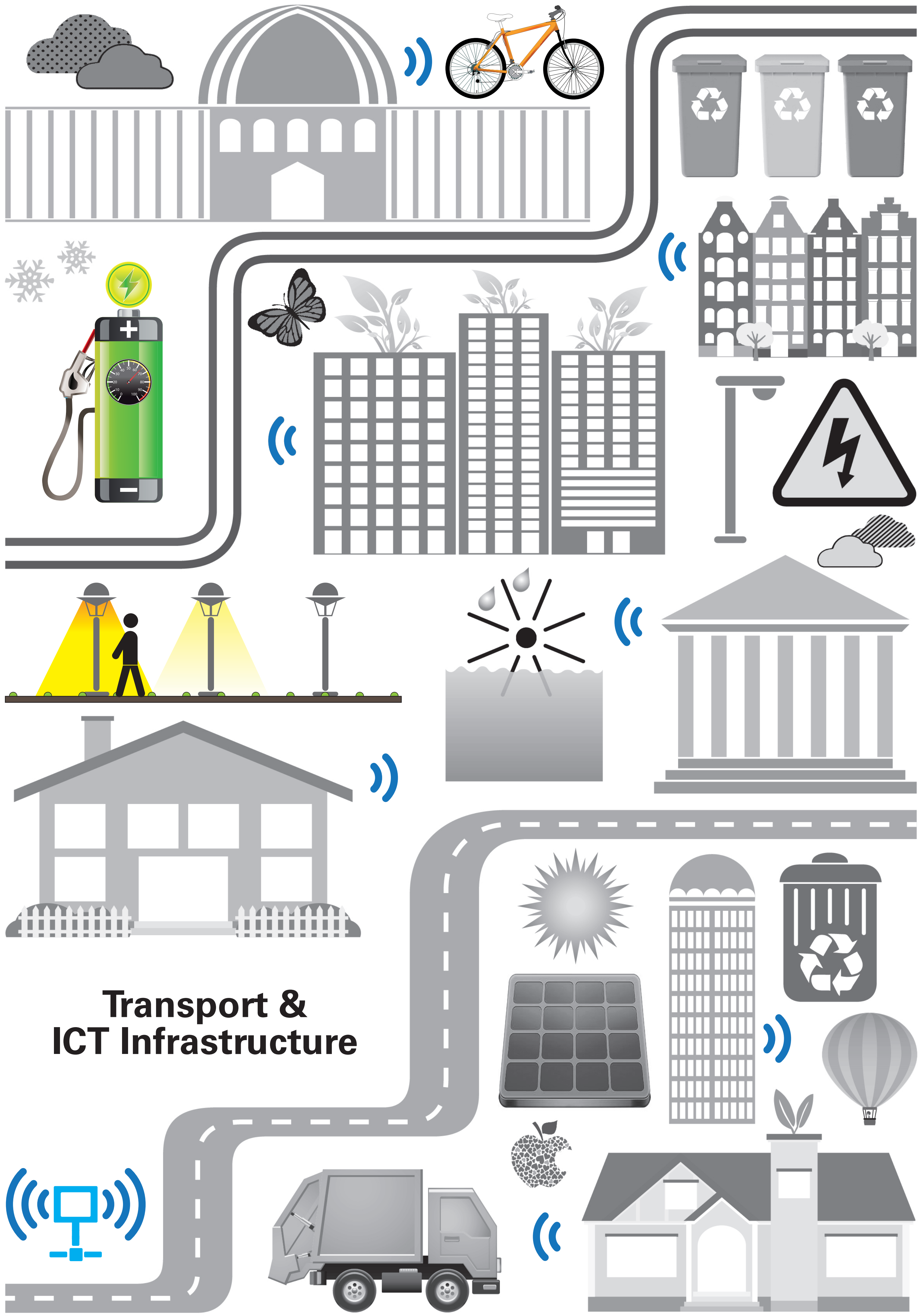
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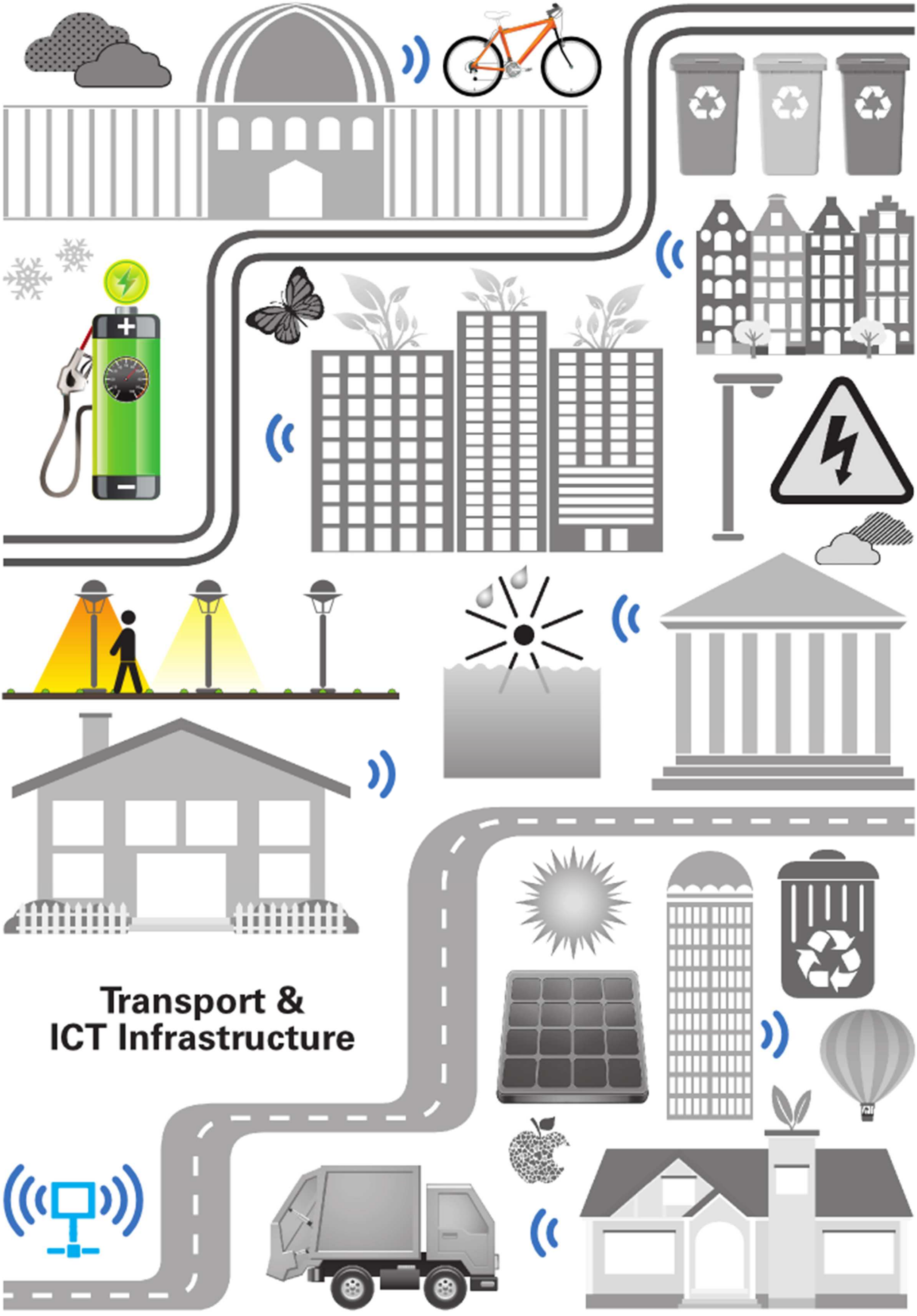
Transport &
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INTELLIGENT TRANSPORTATIONS SYSTEM (ITS)

Traffic problems in the 30 biggest cities of the world cost more than 200,000 million euros per year ("Connected Mobility 2025", 2013).

Populations increase in the principal urban areas of the world and the raise in traffic volumes are resulting in a "paralysis" in these places. Moreover, in these areas, the amount of people migrating to city centres every day is very significant, representing a big challenge for the traffic systems.

Intelligent systems

Intelligent systems can be defined as those which optimize the processes and resources to obtain a desired result. Facilitating permanent information in real time, it allows changes to be made during the management process.

Intelligent system is a telematics system, a combination of informatics and telecommunications. With this, the human capacity is multiply during the operations and failures are avoided in a big term. Because of that the importance of the development and technical innovations in these processes is understood (Frame and IST Information Society Technologies, 2004).

Intelligent transportation systems (ITS)

Intelligent transportation systems are therefore the ones applied to this sector. Because their direct effects on speed, journey time, traffic flows etc. in determined sections with urban congestions for instance, they allow huge benefits to be obtained, as they increase capacities, they decrease or avoid congestions. It can be said that they act as economic growth promoter.

ITS as they are a newfangled system which varies from place to place the technology used, acceptance level and the application are still not defined very clearly all over the world.

Intelligent transportation systems overlay different transport modes such as air transport, railroad, maritime transport and road transport. It is not only the infrastructure that ITS covers, but they also take into account the vehicle and the driver, in order to improve in general the mobility of a place, and more exactly to minimize travel times, carbon emissions, giving more security and efficiency to the driver etc. (Chen, K. and Miles, J.C., 2004, Section 1.1, p.1).

ITS has been shown to be valid and profitable to combine with the exploitation and management of the transport service. Although general benefits are mentioned above, ITS can allow reaching: (Frame and IST Information Society Technologies, 2004)

- Important reductions in traffic accidents

- Rise in the road´s capacity without new constructions
- Savings in travel times (it has been estimated one year per life)
- Significant reduction in vehicle´s pollutants such as CO2.

ITS technology: the way to work

Intelligent transportation systems work in a telematics way. Information and communication are the quality stamps of this system.

The information network works as a chain (Fig.1 ITS information network), which consists of several stages such as the acquisition of the data, prosecution, distribution and utilization. Some external factors as the weather must be taken into account too. (Chen, K. and Miles, J.C., 2004, Section 2.1, p.1).

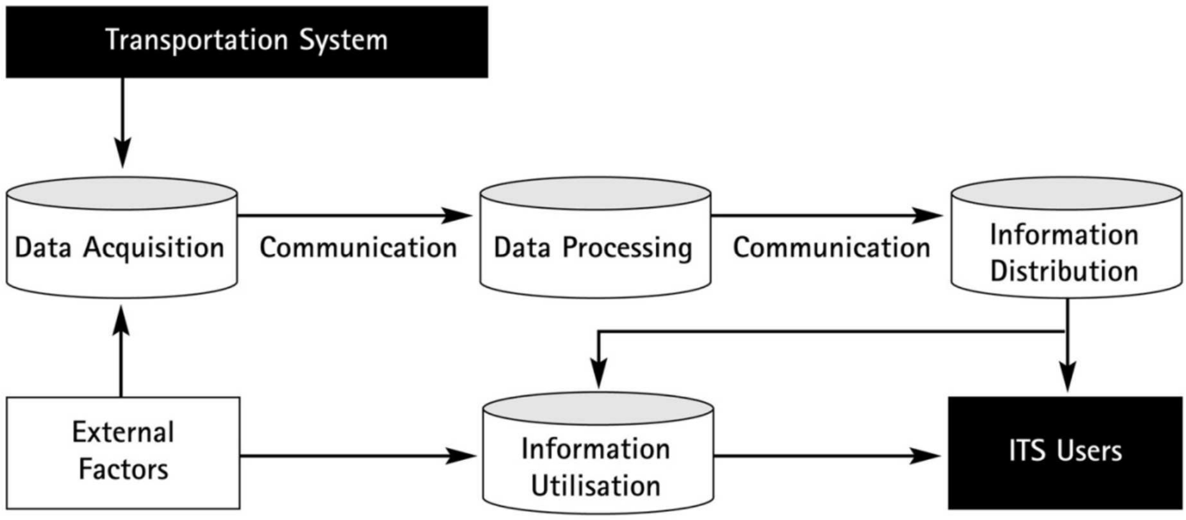


Figure 148: ITS Information network (Chen, K. and Milles, J.C., 2004, Section 2.1, p.1)

The main aspects are:

- Exchange of data and coordination of decision which involves many centres
- Acquisition and integration of data between the vehicle and road
- Exchange data with private companies that distribute the information via mobile phones or internet
- Exchange data with other institutions such as the ones in charge of electronic payments

This system has to work efficiently and for that, it is necessary to have the latest and most modern technologies. It is a requirement to collect data that is reliable and accurate in real time.

The applied technologies can be split up in two main categories, the infrastructure and the vehicle:

ITS TECHNOLOGIES		
Stages in ITS	**Vehicle**	**Infrastructure**
Location	Mobile phone	Digital maps
	GPS	Geographical information system
	Automatic vehicle location	
Acquiring data	Vehicle probes	Traffic detectors (sensor, radar, ultrasonic, infrared, CCTV camera…)
	Automatic vehicle identification	Weather monitoring
		Automatic incident detection
Processing data	On-board computers	Data exchange
	Digital map	Data dictionaries
		Data fusion
Communications	RDS-TMC	Optical fibre networks
	Cell phone receivers	Cell phone networks
Distribution	In-vehicle units	Internet
	Handsets	Dynamic Message Signs
Utilisation	Route guidance	Congestion monitoring
	Assistance systems	Incident detection

Figure 149: ITS technologies (Chen, K. and Miles, J.C., 2004, Section 2.1, p.1)

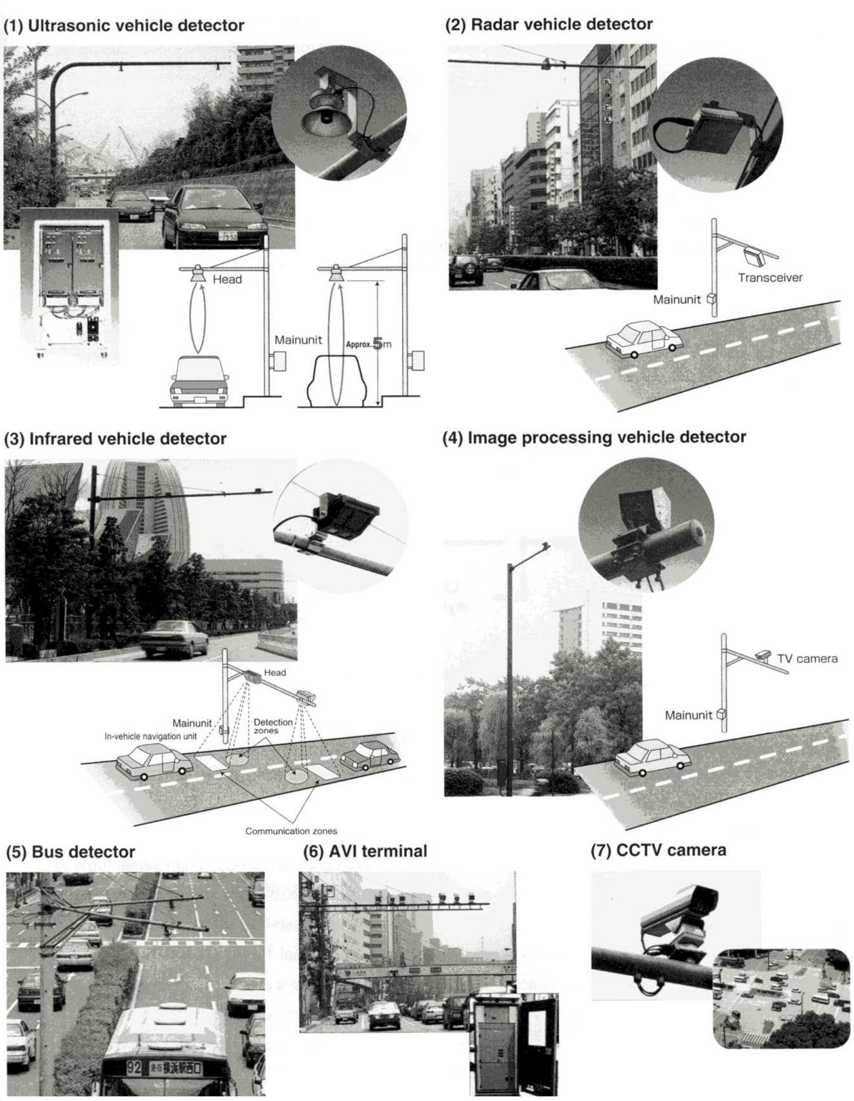


Figure 150: Traffic and vehicle detectors (Chen, K. and Miles, J.C., 2004, Section 2.1, p.1. Source: Japanese National Police Agency)

Wireless Sensor Network

One of the technologies that need a special mention is the Wireless Sensor network (WSN). It consists mainly in sensors that use wireless to communicate. Moreover, external factors such as the weather can be taken into account and monitored with a WSN, which is spatially located.

Architecture and components

The architecture consists of Sensor Nodes (SN) and one Access Point (AP). The first ones extract information, process it and send it to the Access Point. There the information is processed to get an output and send it to some control systems or directly to the users (Cheun, S.Y. and Varaiya, P., 2007)

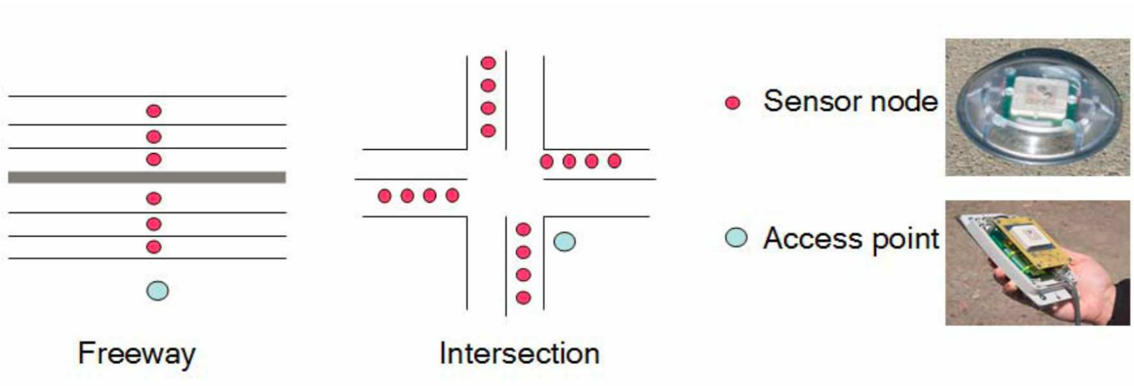


Figure 151: A sample wireless sensor network layout for traffic surveillance (Cheun, S.Y. and Varaiya, P., 2007, p. 27)

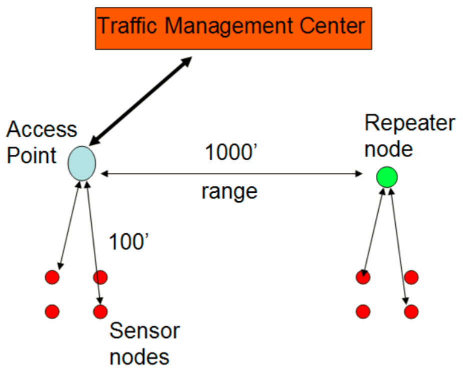


Figure 152: Sensys structure (Cheun, S.Y. and Varaiya, P., 2007, p. 40)

A Sensor Node has several parts:

- Sensors: they take the information which is later transformed into an electric signal.
- Microcontroller or processor: they control different electronic tools with a chip-used computer. Most of them are Digital Signal Processors (DSPs) that convert the signal from the sensor into a digital format.
- Radio: it is a critical part of a WSN, because sensor node´s consumption is mainly based on the radio communication´s energy costs. Also it is important to know the numbers of nodes that are needed.
- Power source: it is essential concerning to the WSN´s lifetime.

Hardware and Software Specifications

In a WSN the Hardware and Software are composed by: magnetic sensor (which detect vehicles by their magnetic disturbances), MICA2DOT (a wireless smart micro sensor mote for smart sensors), battery, Smart Stud container (to deposit the sensor below the pavement), and a network.

In the figures below more details can be shown:

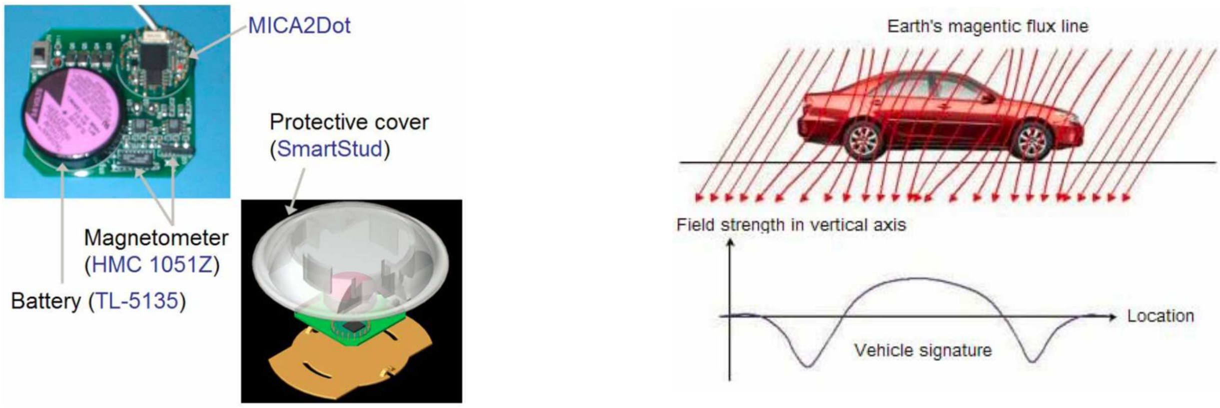


Figure 153: Hardware and Software in WSN and Vehicle´s disturbance (Cheun, S.Y. and Varaiya, P., 2007, p. 30 and 32)

ITS architecture

Intelligent transportation integrated systems need a strategic base framework for designing elections and implementations, such as for the inversions. This is called “System Architecture”.

ITS technologies have to work together as a system to ensure the efficiency. To achieve this aim not only is it necessary a good performance of each part or component, but it is also a requirement that they interface between them. Because of that, there must be an ITS Architecture. It can be said, that it is the system that explains the behaviour of the Intelligent Transportation systems.

ITS Architecture is composed by users, transport agencies and service providers and basically it is a control and a way of providing information between different levels and it defines:

- Functions
- Subsystems and entities for these functions
- Integrate systems where the information flows between these functions and subsystems

It must be clarified that ITS Architecture can be regional, only for a town, national, or for a specific sector, but always it has to ensure some specifications, for instance: (European Intelligent Transport System (ITS) Framework Architecture, n.d.).

- It hast to be easy to manage, extend and maintain
- It has to fulfil the requirements for which it has been designed
- It has to satisfy the users

One of the most principal elements of and ITS Architecture is the “Stakeholder´s aspirations” list. It is focused on the high level objectives and the requirements of everyone involved in the ITS implementation, such as the users, stakeholders etc. that they are known as “interested parts in the ITS”. (Frame and IST Information Society Technologies, 2004).

Furthermore, usually ITS systems include different parts relating to their work´s way:

- General scheme or Conceptual model: high level diagram describing all the system and the way it works

- Logical - Functional Architecture: it is focused on the functionality that the users need.

  The logical architecture represents the processes and data flows that are required in order to perform ITS services. The common area between the user´s necessities and their services is examined, so that the common functions and requirements can be joined up in the same set of processes

- Physical Architecture: it is the way that Applications are provided with the functionality that they need.

  The design is focused on process specifications, functional requirements, interdependencies etc. So the aim and objective of this architecture is to provide physical subsystems with specified processes.

- Communications Architecture: is the way in which the information is delivered and exchange in the Physical Architecture.

Other points of view such as the Organizational view or Information view can be applied. The first one describes business relations between the organizers and the second one provides models for the key data sets.

To show some examples of these different architectures or viewpoints, it is a good idea to focus on the best well known ITS Architecture, which was created in the United States in the 1996. Below, can be seen first the “Logical or Functional Architecture” diagram with all the data flows required for a good performance of the system. Then, the “Physical Architecture”, where the processes defined in the logical one are assigned taking into account the responsibilities of different institutions ” (Frame and IST Information Society Technologies,2004).

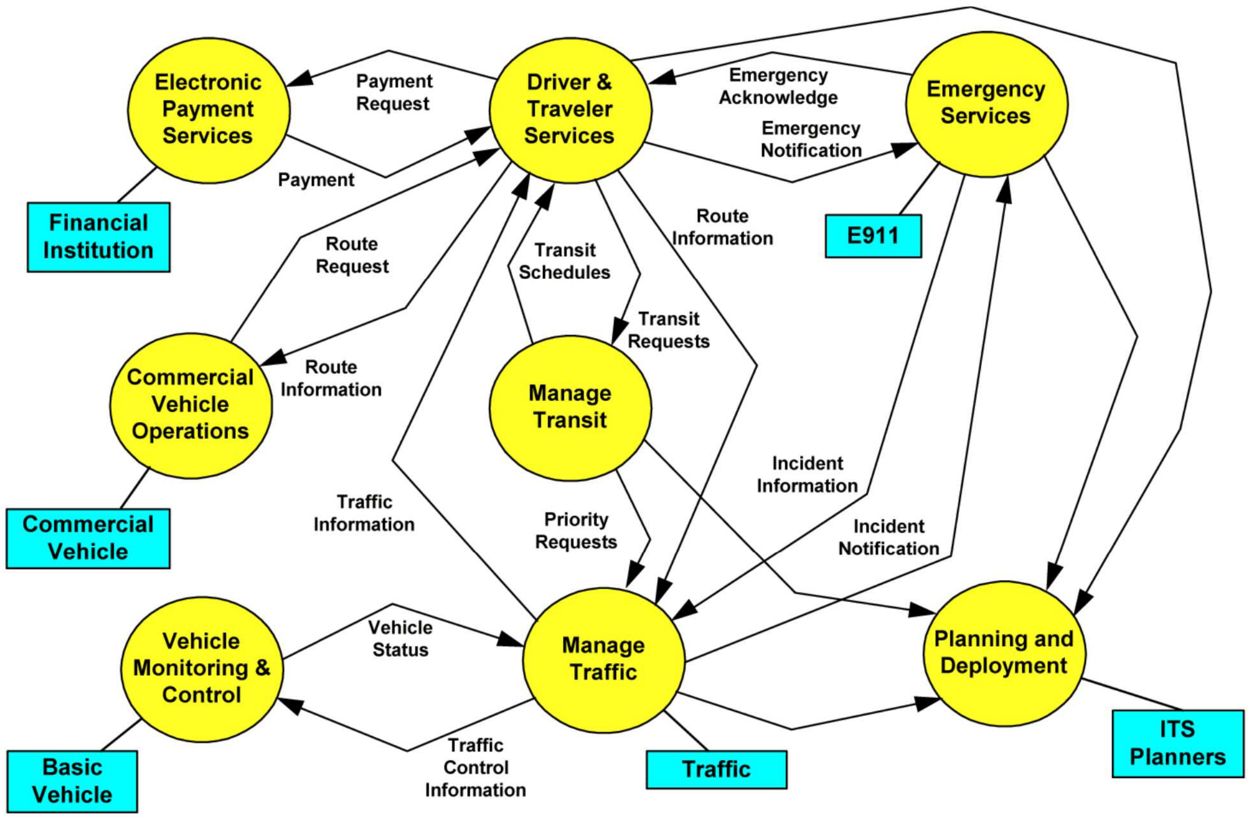


Figure 154: Logical US Architecture (Chen, K. and Miles, J.C., 2004, Section 3.1, p.6)

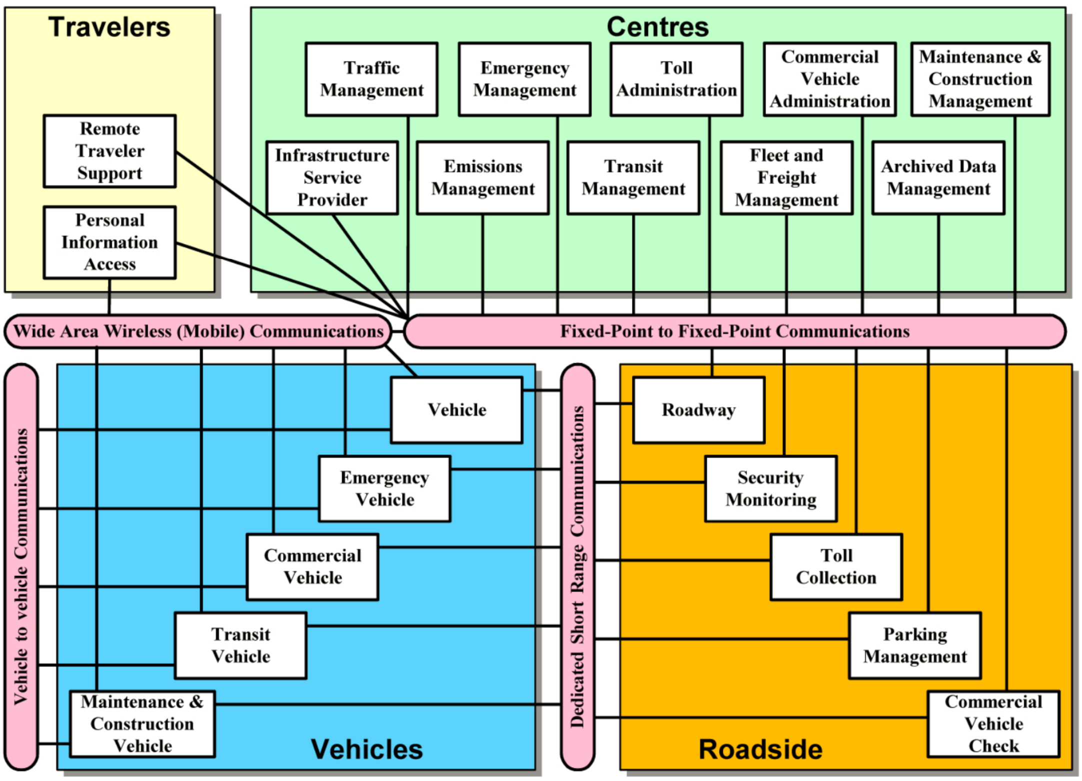


Figure 155: Physical US Architecture (Chen, K. and Miles, J.C., 2004, Section 3.1, p.7)

Finally, the Communication Architecture´s example is given with the European ITS Communication Architecture, which is commonly used nowadays. This is composed by four subsystem components: the vehicle, the roadside, the central and the mobile, which are joined by a network. Communications between all these subsystems are made by different wired or wireless tools.

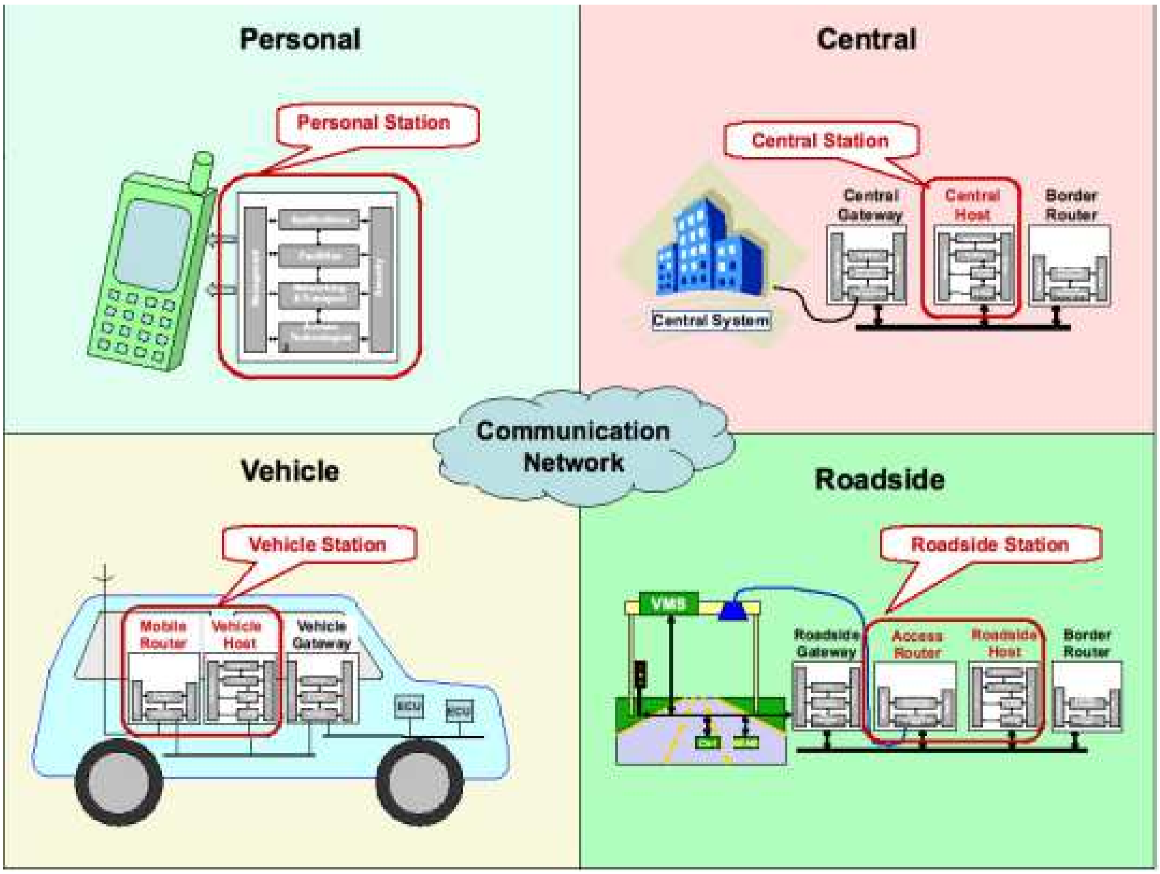


Figure 156: European ITS Communication Architecture (COMeSafety, 2009)

Each of the components mentioned above has its own ITS station and a gateway (node that transfer data in one or two directions) to connect the station to legacy systems.

The communication network enables the communication between all the subsystems, directly from vehicle to vehicle as well as infrastructure-based subsystem or any other combination. It has to be mentioned however, that there are some requirements in each scenario to perform these communications. For example, as it shown in the figure below, in the ad-hoc type of communication, the vehicles need to communicate with the same frequency band using the air.

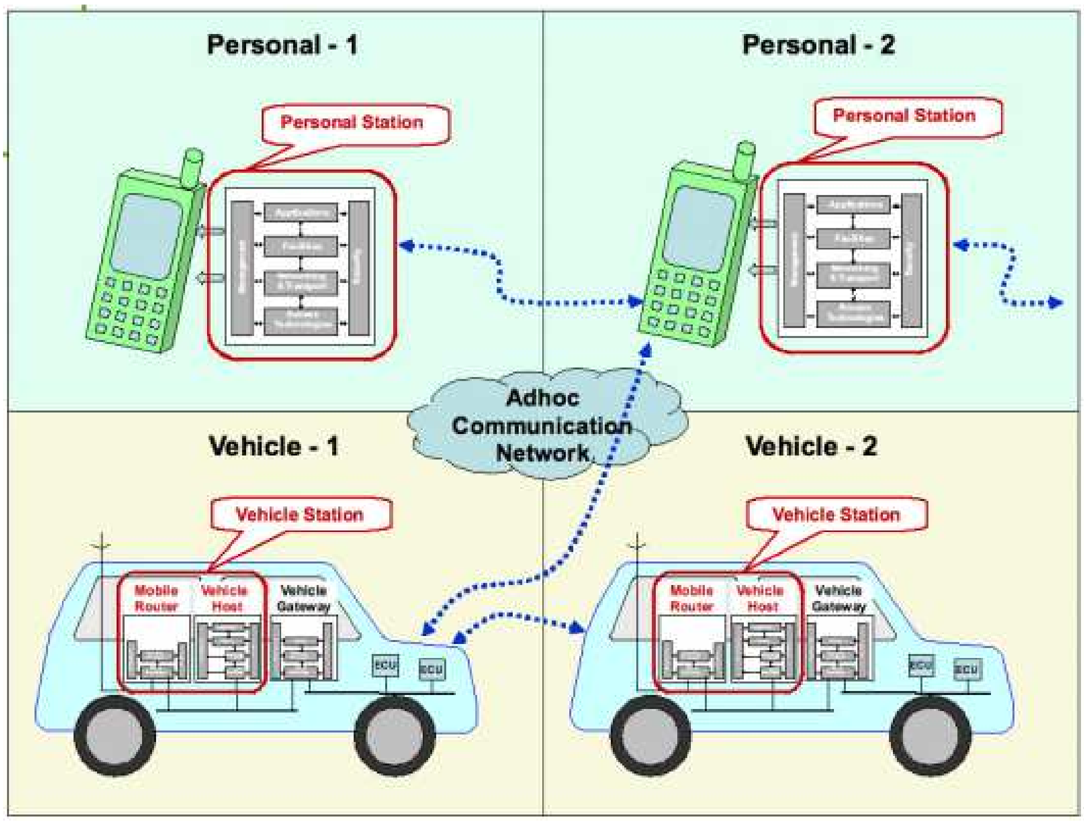


Figure 157: Ad-hoc communication in European ITS Architecture (COMeSafety, 2009)

This communication network that links all the components has to have a protocol, a communication language, to permit the information exchange between them. This protocol has to have a wide spread reach and use, and it has to be adapted to any type of application. In the European ITS Communication Architecture Internet Protocol is used for this purpose. One of its advantages is that it enables the interoperation between the internet legacy and subsystem components.

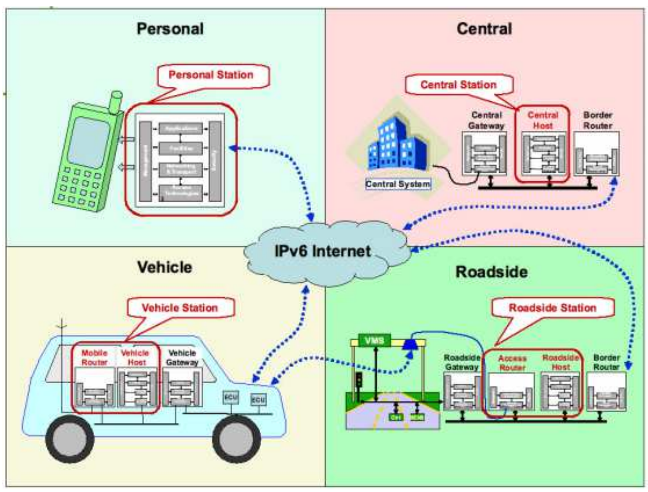


Figure 158 : Internet based communication (COMeSafety, 2009)

European ITS Architecture

Focusing on the situation of Intelligent Transportation in Europe, it has to be mentioned that after a lot of recommendations, European community financed the KAREN´s project, which developed the "European ITS Architectural Framework". Then, this has been amplified and actualized by FRAME´s project, which it has been used in a lot of countries (Jesty, P.H et. al, 2000).

The European ITS Framework Architecture is expressly focused in European ITS users, it provides them with all the requirements that they need, which can be adapted depending on their needs. Because of that, this comprises the user needs and Functional viewpoint, defining the services that are likely to have at a European level.

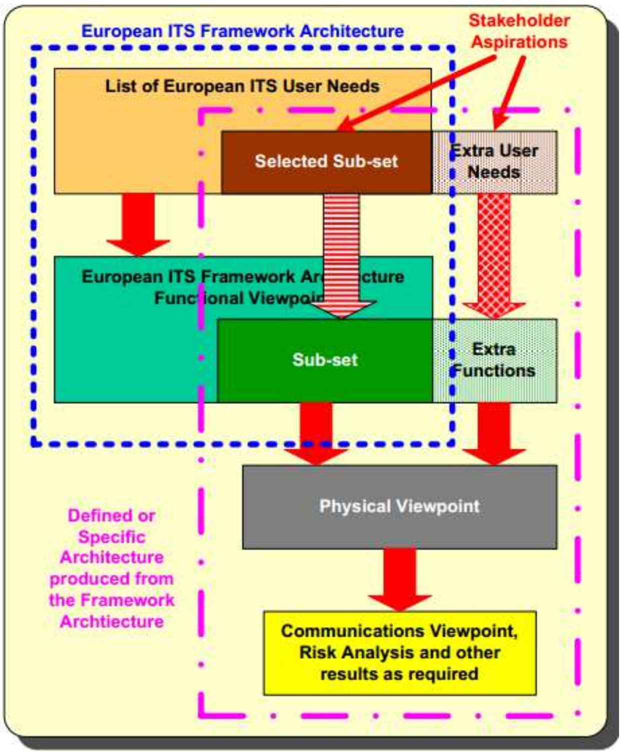


Figure 159: European ITS Architectural Framework (European Intelligent Transport System (ITS) Framework Architecture, n.d.)

Then, each user can form the physical viewpoint starting from the previous functions and finally the communication viewpoint.

How to create an ITS Architecture

The first step to create a ITS Architecture is to identify people and institutions that are going to be involved, the stakeholders. This group has to include: the team responsible for the Architecture creation, review team, and every party interested in the ITS. It is also a good idea to have an expert in the architecture development, an influential person with experience and communicational abilities (Carbonell Romero, A., 2004).

Explaining in a brief way, during the ITS Architecture creation would be necessary (using European ITS Framework Architecture):

- Aspirations of stakeholders that defined the formal user needs.
- Create a Functional Architecture with required processes.
- Create a Physical Architecture locating all the processes

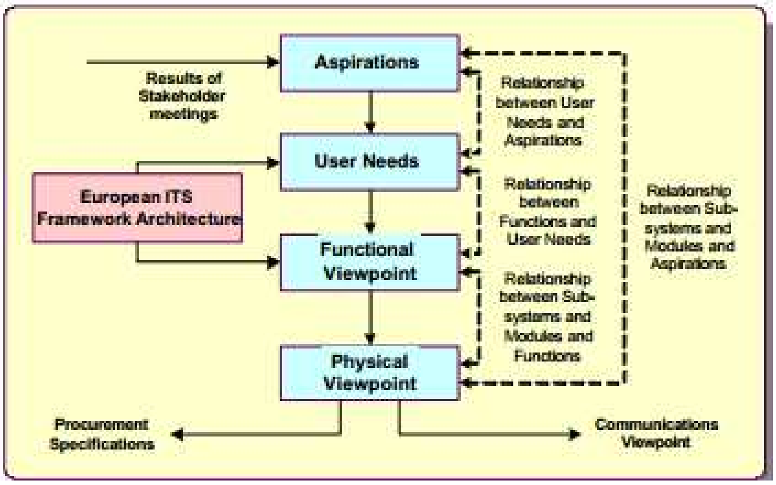


Figure 160: Creating an ITS Architecture (European Intelligent Transport System (ITS) Framework Architecture, n.d.)

- Define Communication Architecture to know how the information flows (required links between locations.

ITS focused in road transport

Nowadays Transport authorities rarely accept that only constructing a new road is the solution to the almost universal problem of congestion. It is fundamental to find ways of managing the traffic efficiently.

The road, because of its high participation in the transport market, it is logically the one that gains more benefits from the telematics applications, is not strange therefore to be the one that utilizes the biggest part of funding destined to R+D in ITS for this sector (Carbonell Romero, A., 2004).

It is obvious that ITS must be applied to the management of the vehicles and pedestrian mobility´s activities, denominated commonly as “traffic” and “transports”.

Intelligent transportation systems or ITS appear constantly as a utility tool in each of the three phases that traffic process could be divided (Rubio Munt, S., 2005):

- Planning: previous studies and pre-projects that establish global solutions to resolve mobility problems. Its fundamental parameter is “function”.

- Ordination and design of the urban grid and its functional schemes, based on the existing infrastructure or the one that can be immediately incorporated. Its final parameter is "space".

- Regulation and monitoring from the subsequent exploitation programs. Apparition or expansion of the control centres for the integrated management of urban mobility. Its operating parameter is "time".

Telematics systems appear in 1960 to optimize urban traffic flows, and during the years there has been a big development in this area, achieving very sophisticated systems (Frame and IST Information Society Technologies, 2004)

At the moment there are several different systems to different uses such as, traveller information, public transport commercial services, freight's support etc. To take advantage as much as possible of these systems, there must be a good coordination through the entire transport network, not only at a national level, but also at European level.

Typical elements for an urban traffic management and control are shown in the diagram below. The existence of an ITS Architecture is the base for further developments and improvements of the system and assure that all the applications have to be interoperable.

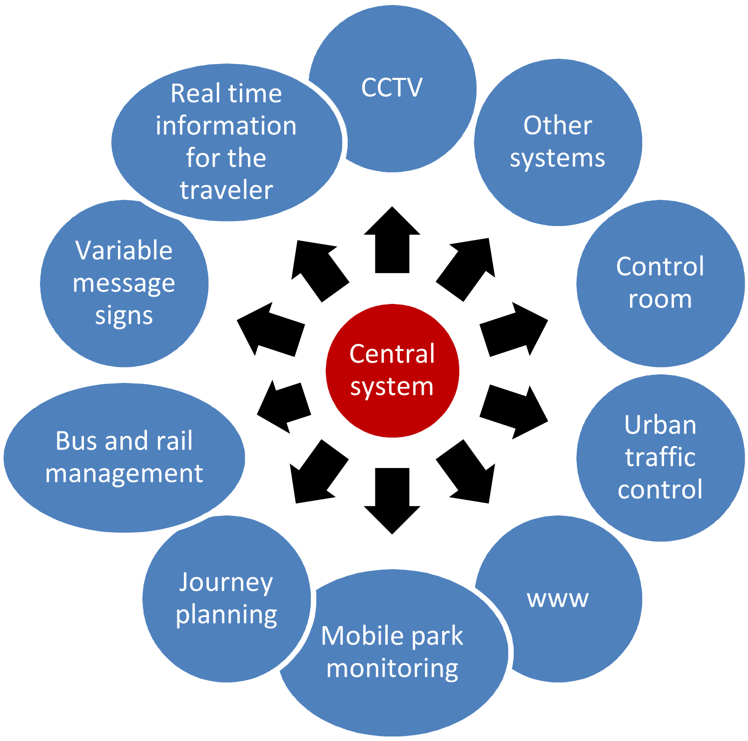


Figure 161: Central system (Frame and IST Information Society Technologies, 2004)

The benefits of applying ITS in a city or town, as has been mentioned before, are many. In order to have as much advantages as possible in different aspects, the ITS is applied in different areas or aspects surrounding mobility, for example:

- Traffic management
    - Urban traffic control (adaptive traffic signal control)
    - Ramp metering
    - Access control
    - Parking Management
    - Incident detection system
    - Public Transport Management system
    - Variable Message Signs
    - Speed adaptation
- Travel and traffic information
    - Traveller Information System / Real time people information

Adaptive traffic control system (ATCS)

Adaptive traffic control systems consist in the use of traffic lights with the ability to response in real-time to the traffic demands, adjusting signal timing (times of the colours of the traffic lights) to vary traffic conditions.

Contrary to common traffic lights performances, these systems are mainly focused on changes of the critical aspects of the signal timing, which are split of the phase, cycle length and offset (Nichols, 2012).

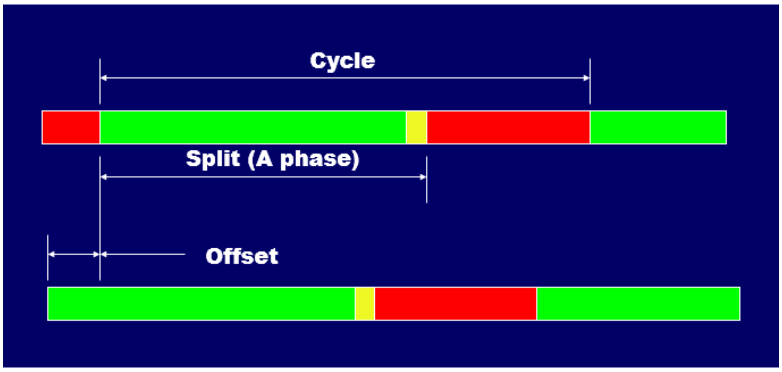


Figure 162: Signal timing concepts (Professional Development and Outreach, 200?)

The cycle length is the time used by the signal to show a complete sequence of colours (green, yellow, red); the split of the phase is the time assigned to each movement of vehicles relative to the cycle length at an intersection; the offset is the time between the beginning of the cycle at an intersection and the beginning of the cycle at another adjacent intersection (Professional Development and Outreach, 200?).

The components which are part of these ATCS are:

- Adaptive traffic signals: signals capable of modifying their signal timings.
- Traffic signal controllers: to manage the signals.
- Specific computer software: to manage the traffic signal controllers
- Vehicle detectors (sensors): placed at each intersection to collect the information required to adapt the signals and improve the traffic flow.

There is a great deal of ATCS. The most famous ones will be described here:

- SCATS (Sydney Coordinated Adaptive Traffic System): this system is used in areas with many intersections. It is a cycle-by-cycle system which evaluates the split, the length and the offset in every cycle, therefore, it does not use signal plans (programmed signal timing schemes). This is achieved by using algorithms to analyse the real-time traffic information from some vehicle detectors. And after each evaluation, it dynamically changes the grouping of signals. Setting the detectors at the intersections, SCATS counts the vehicles at each stop line and measures the space between vehicles when they pass through the detectors. With those data, it calculates the more suitable signal times for the traffic conditions at each intersection and then it synchronizes the traffic signals to improve the traffic flow (Roads and Maritime Services, 201?; Fehon & Peters, 2010).

- SCOOT (Split Cycle Offset Optimization Technique): this system continually calculates the required coordination pattern between the signals and takes actions automatically in areas with many intersections. The times are continuously updated, therefore, there is no need to use signal plans, which are expensive to prepare. SCOOT uses sensors to count the vehicles at each stop line at the intersections like SCATS does. But one of the differences between this two important systems is that SCOOT uses a second set of advance vehicle detectors between 50 and 300 meters before the stop line at each intersection. So, this gives the system more resolution and it is able to count the vehicles in each queue and evaluate the queue lengths. Besides, another difference is that SCOOT provides individual algorithms for the cycle length, the split and the offset and also it automatically recognizes chances for double-cycling minor intersections when there is not much traffic. (Fehon & Peters, 2010).

- Insync: this system is used in arterial roads containing up to 12 intersections; and it does not involve the concepts of cycle length and phase sequence. It consists in the use of the existing traffic control cabinets and controllers and the installation of additional hardware. This additional hardware components are IP video cameras (cameras which send the images directly to Internet) to know the number of vehicles and their waiting time, and a specific processor. In this way, Insync system evaluates the state of the existing signals and say whether these should stay in that state or change to a different one, basing on the demand of traffic at the intersections and the arrivals of traffic from other intersections (Fehon & Peters, 2010).

- ACS Lite (Adaptive Control Software Lite): this system consists in the utilization of a software specifically designed to provide adaptive technologies to arterials. This is a low cost and simple system since it calculates small adjustments to timing to improve the traffic flow. Its algorithm changes a few seconds the splits and offsets of the signal control patterns and plans every 5 to 10 minutes to gradually introduce changes in traffic conditions (Siemens, 2009).

Ramp metering system (RMS)

A ramp meter (or metering light or ramp signal) is a device which can be one simple traffic light or several traffic lights (usually red and green, but in some cases also yellow). It is used in conjunction with a signal controller to regulate the traffic entering a highway or another crowded road according to the traffic conditions of this. This device is implemented at the on-ramps of the highway to reduce the traffic congestion and improve safety.

A first classification of the ramp metering strategies is in fixed time and traffic-responsive (Papamichail, et al., 2010):

- Fixed time strategy: the information about the traffic flow in each moment is collected from historical data because there are not real-time measurements. This is not a very effective strategy (Papamichail, et al., 2010).

- Traffic-responsive strategy: the information about the traffic flow and congestion levels are collected through real-time measurements by sensors or detectors implemented on the road. This is the most common strategy because of its effectiveness (Papamichail, et al., 2010).

Focusing on the traffic-responsive strategy, detectors or sensors (usually induction loops) are implemented on the highway and on the ramp to measure the traffic conditions on the road and the vehicles which enter it. These detectors measure the traffic flow and occupancy of the road. The information is sent to the signal controller, which uses certain algorithms to adapt the cycle timing of the traffic lights (ramp meter) and to change the number of vehicles which leave the ramp. In this way, when the highway is congested, fewer vehicles are allowed to leave the ramp by enlarging the red times of the ramp meter cycle.

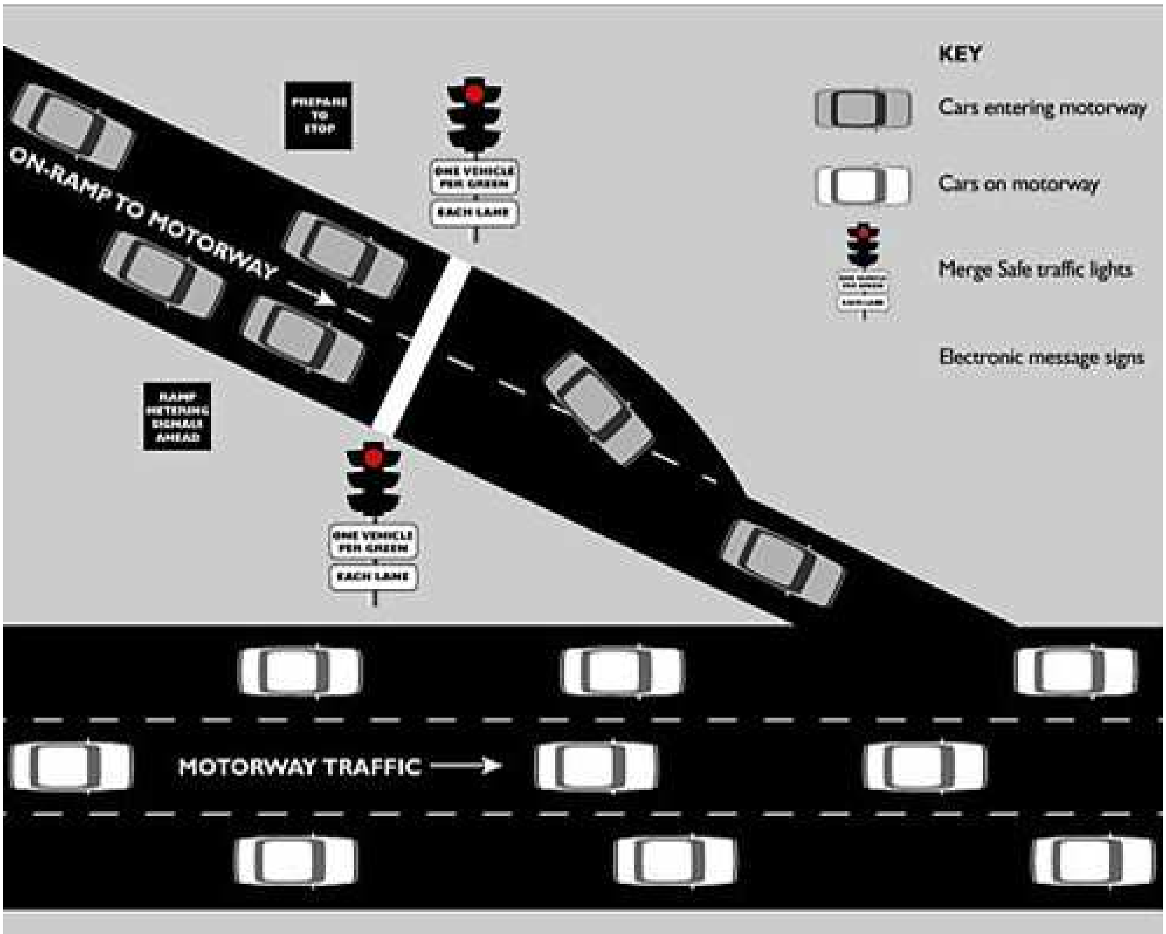


Figure 163: Ramp metering scheme (Aldridge Traffic Controllers, 2008)

There are three ramp metering methods:

- Single lane one car per green: this method allows one vehicle to go into the highway during each signal cycle (with a three-color structure the colours are: green, yellow and red). The time of the red interval have to be enough to ensure that the next vehicle stops. A reasonable cycle time is 4, 5 seconds, having 1 second green, 1 second yellow and 2, 5 seconds red, which would produce 800 vehicles per hour of meter capacity (Chaudhary & Messer, 2000).
- Single lane multiple cars per green (or bulk metering): this method allows two or more vehicles to enter the highway during each signal cycle. This method requires more green and yellow times than the previous one. It is common to find cycle times between 6 and 6, 5 seconds, which would produce a meter capacity of 1100 to 1200 VPH (Chaudhary & Messer, 2000).
- Dual lane metering: this method needs two lanes on the ramp. The signal controller alternates the green-yellow-red cycle for each lane, using either a synchronized cycle or an unsynchronized one. It usually provides metering capacities between 1600 and 1700 VPH (Chaudhary & Messer, 2000).

Smart parking system

In cities, finding free parking lots is one of the biggest problems. Mainly because the citizens waste a large amount of time looking for them and this increases the pollution produced by the vehicles. Besides, the ordinary management of the parking in the cities has an economic repercussion for the governments. People do not park in fee-paying parking lots because they are not able to find them and also it is difficult for the authorities to spot the parking infringers to be fined (Traffic Technology International, 2013).

The smart parking systems solve these problems providing the users of vehicles with information about the availability of parking spots near them and the possibility of making reservations and payments of parking lots, improving the traffic flow and reducing the pollution caused by the vehicles. The information collected by sensors about the availability of parking and other parking data is accessible to everybody. The drivers receive and use it mainly through applications on their smartphones, websites or street panels. Besides, municipalities can use the information to locate the parking infringers or to design other parking spaces after an evaluation of the parking problems.

It is possible to make a division of the architecture of a smart parking system from the point of view of the companies in charge of the implementation in five modules (Giuffrèa, et al., 2012):

- User interface module: it is in charge of dealing with the users (parking information, reservation, cancellation, billing). This refers mainly to applications for smartphones, websites or panels to show the information or guide the driver.

- Communication module: this part consists in the transmission and receiving of the messages (radio waves) with the information between the other modules.
- Function Module: servers and databases in the control Centre to record the information from the sensors or cameras, reservations and transactions.
- Parking Space Controller Module: it is the module in charge of the collecting of data through sensors nodes, routing nodes, repeaters, cameras and other devices.
- Manager interface: in charge of the management of the system.

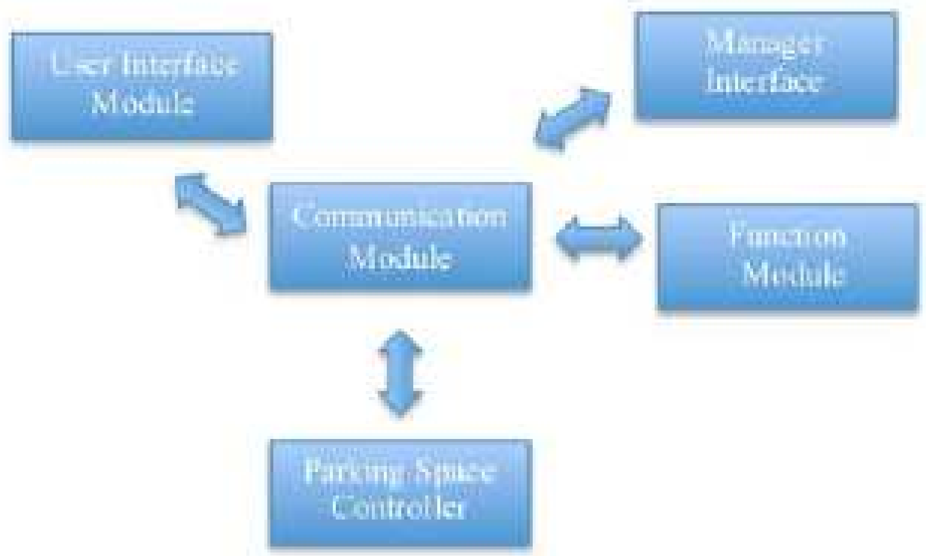


Figure 164: Smart Parking System Architecture (Giuffrèa, et al., 2012)

Smart parking systems can be divided in public and private. Both will be explained below.

Public smart parking systems

Describing the hardware of a general public smart parking system, the devices implemented in the cities forming a mesh network are (World Sensing, 2011):

- Parking sensor nodes: implemented on each parking lot (generally composed of packaging, radio, battery and sensor) (World Sensing, 2011). This nodes send radio waves with a specific frequency containing the information about the availability of the parking lot to the repeaters. With low frequencies, the waves can travel from the sensor to the repeater directly because of their long propagation distance; however, with higher frequencies, it is necessary the implementation of routing nodes, generally in the street lights, to receive the waves from the sensors and help them to reach the gateway (Asín & Gascón, 2011). There is a wide variety of types of sensors to use in the parking spots, each of them detect the presence of vehicles in a different way. Therefore, the smart parking can be applied to every kind of vehicle (cars, motorbikes, lorries…) although it is usually applied to the cars (Idris, et al., 2009).

- Routing nodes: they are usually implemented in the street lights when the signal from the sensor nodes is weak and unable to reach the repeaters because of a too high frequency. They receive the waves and make them arrive at the repeaters (Asín & Gascón, 2011).
- Repeaters or gateways: their mission is to amplify and send the signal from the parking sensor nodes to a control Centre. They must have Internet connectivity via Wi-Fi, cellular or Ethernet (World Sensing, 2011).
- Panels: they indicate the drivers about the location of the parking lots and their availability (World Sensing, 2011).
- Barrier of reservation: although it is not common, it is possible to set a barrier to appear in the parking lots when they are reserved or for spaces authorized only for specific drivers (Giuffrèa, et al., 2012).

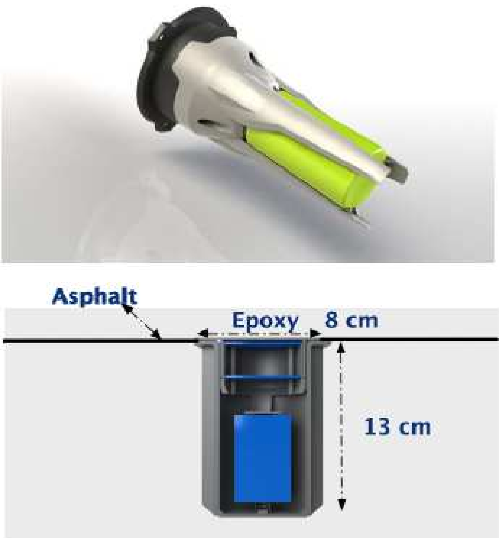


Figure 165: Sensor node (World Sensing, 2011)

Figure 166: Repeater (World Sensing, 2011)

Figure 167: Parking panel (Bielsa, 2013)

Moreover, we have a control Centre which is the space where the data are stored to be used by any person. This control Centre comprises the following software (World Sensing, 2011):

- a data application server where the data and a control platform are hosted.
- a control software platform to analyse, show and manage the information.
- a user account management which let the access through different account levels.

And furthermore there is a great deal of smart parking applications for the smartphones and websites for the communication and interaction with the users.

Figure 168: Smart parking application (World Sensing, 2011)

Private smart parking systems

The methods for private smart car parks are quite similar to the public ones, but mainly there are two different points: the collecting of the data and the way to inform the drivers.

According to the collecting of data, there is a wide variety of options:

- Sensors in each parking spot like in the public parking lots.
- A sensor at the entrance and another in the exit point of the car park to count the number of cars inside the car park and inform about the number of free parking lots (True, 2007).
- A camera which detects vacant parking spaces through the analysis of static images (True, 2007).
- A combination of the previous methods.

Regarding the way to inform the drivers in the private smart car parks, it is usually through panels which show the number of free parking lots, or even guide the drivers to a free parking space. Sometimes lights to indicate the availability of a space are used as well (Charette, 2007).

Figure 169: Baltimore/Washington International Airport (Charette, 2007)

Intelligent speed adaptation (ISA)

This system has different names such as Intelligent Traffic System, Intelligent Speed Authority or Speed Alerting. It consists mainly in monitoring the speed of the vehicles and the application of actions when the vehicles exceed the speed limit.

There are two types of ISA system:

- Passive: they warn the driver of the vehicle when this exceeds the speed limit.
- Active: they intervene and control automatically the vehicle to reduce its speed when this exceeds the speed limit.

The system also uses collected information about the roads of the cities to decide what the correct speed is in every moment and communicate it to the drivers This collected information consists of the location of danger zones, events occurring in the road, the current speed limit and statistics and analysis of the traffic in that zone.

Therefore, apart from warning or intervening when exceeding the speed, ISA systems also alert the driver when is entering a new speed zone (school zones, zones with different speed limit…) and when temporary speed zones are created (zones with lower speed limit because of the weather, traffic jams, accidents…). Besides, many of these systems give information about possible dangers so that drivers reduce the speed (high pedestrian flow areas, railway crossings, radars…).

This system is not mandatory at the moment, but it is likely to be mandatory in the future because of the expected reduction in traffic crashes and fuel consumption (AA, 2012).

Figure 170: ISA device (Stockholms stad, 2011)

Transit management systems

The Transit Management Systems (or Public Transport Management Systems) include every method which uses technologies to improve public transportation (e.g. bus, train or tram).

A common example is the monitoring of the location and the performance of the public transportation vehicles through a technology called Automatic Vehicle Location (AVL) which is implemented in them. The AVL system gives real-time information about the position of the vehicles to inform the users or monitor the schedule fulfilment. This information is sent to dispatchers to manage fleet resources taking actions to improve the schedule adherence (Halkias, et al., 2007).

Although these systems are widely being researched at the moment, they can be categorized in four (Halkias, et al., 2007):

- Fleet Management
- Traveller Information
- Electronic Fare Payment
- Transportation Demand Management

Automatic incident detection (AID)

Traffic accidents, especially on the highways, causes a lot of serious injuries and deaths and sometimes there are secondary accidents with more people involved. Besides that, they provide traffic congestion, delays to the drivers and damages.

The Automatic Incident Detection detects the accidents occurred to take actions as soon as possible, informing a manual operator or implementing pre-programmed responses for the situation. Besides, it reports in real-time the obstacles or other dangers (e.g. stopped vehicles, traffic congestion or pedestrians on the road) to take measures to avoid possible accidents.

These systems are able to shorten the stop time of the vehicles behind a traffic accident and accelerate the rescues in crashes (Civitas, 2013).

The detection of accidents is carried out through AID algorithms used by different data sources which can be (Michek, 2013):

- Loop detectors
- Video detection
- Floating cars (corporate cars with GPS)
- eCall (automatic accident reporting by means of GSM and GPS)
- SOS telephones
- Information from the police or from the drivers

Figure 171: AID information on a highway (Michek, 2013)

Variable message signs (VMS)

They are called Variable-, Changeable-, Electronic- , or Dynamic Message Signs. These consist in electronic traffic signs whose mission is to give information to the drivers about special events such as traffic jams, accidents or road works. But above all, they are used to show any kind of traffic and parking information, thus this panels are the mentioned panels which are part of the systems already explained.

Figure 172: VMS example (Aesys, 2013)

Conclusion

The ITS focused on road transport are solving a lot of the citizens' problems in the cities and collaborating to create smart cities. With the applications explained above and others, people get more safety, comfort and knowledge about the road conditions and parking availability. Now this kind of systems are being researched and implemented in many cities. However, problems like car accidents and discomfort times are not completely avoided, and in the near future we will see new innovative systems in our roads such as cars controlled by themselves with the help of sensors or automatically guided to the parking spaces. But, at any rate, smart cities have gone far with this issue until now.

SMART AND SUSTAINABLE TRANSPORTS IN THE CITY

Nowadays, a huge demographic transformation is taking place, as well as the continuous and unstoppable urbanization process and the controversial climate change, all these issues are generally known and are characteristics of our society. Taking this idea into account, a great deal of challenges comes to our conscience.

It is said that the 90% of the future population will live in cities by 2050. One of the biggest problems related to this kind of overpopulation in cities is the amount of pollution generated by their inhabitants. The majority of these emissions are a consequence of the movement activities so, in the end, they are a direct result of the system of transports that exists in the cities around the world. The mainstream system consists in a huge fleet of private cars and a slight use of public or more sustainable transports. This situation could be changed in the near future by means of a good transport management and new types of transports.

The current situation of the transport in cities is that the streets are congested every day. This brings two main consequences: on the one hand, the traffic is absolutely a chaos and on the other hand, the quantity of CO2 emitted to the atmosphere is getting bigger and bigger while the years pass by.

According to the European Environment Agency, in Europe the most part of emissions that contribute to the greenhouse effect are generated from the transport sector. These emissions reached in 2012 around the 20% of the total. The transports are also a huge source of consumption of energy, around a third of the total energy consumed in the continent.

In relation to these social and environmental problems, the worldwide governments have been aimed to reduce the quantity of vehicles and renew the existing ones by means of different policies. Stimulating the change towards new kind of mobility especially in the cities is the main purpose.

The objective of this part of the report is to give a brief explanation about new kinds of transports that allow the society to save energy as well as reduce the emissions to the environment. These different types of smart and sustainable transports could be adopted in every city so as to bring more profits than what has been never imagined.

Cars

There is no kind of transport nowhere near as famous and used as it is the car. The typical car has been made with an internal combustion engine (ICE) and nowadays it is still the first choice to the majority of those customers who buy a new car. As it has been said before, these kind of traditional transports are the ones responsible of a great amount of emissions, for this reason and in order to take advantage of some benefits, some new kinds of cars have been developed. According to Chan, 2007, there are a lot of different types but the most important and renowned ones are:

Electric car

There are a lot of different considerations and concepts about electric cars. Nonetheless, the pure battery electric vehicles (BEV) are the ones that have no internal combustion at all; as a result, they have to be plug into an electric power grid in order to get their batteries recharged. These batteries are the ones that provide the necessary power to the controller system and then, through the motor, which also recover the energy from the braking, and also through the transmission to the wheels. One simplified scheme of their performance is as follows:

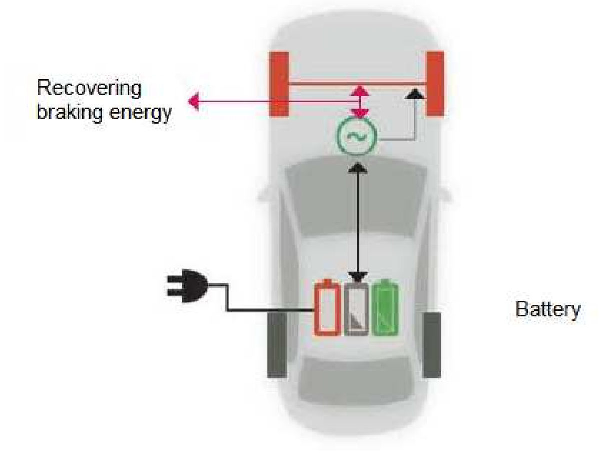


Figure 173: Pure Battery electric vehicle (El observatorio Cetelem Europeo Del Automóvil, 2013)

A common electric car includes: an electric motor, an electronic power converter, a controller and finally, a battery, and one energy management system.

There is also another kind of electric car, which is called Extended-range electric car. This car has a little combustion engine whose only function is to recharge the batteries, it is not possible for this motor to propel the car at all. The performance is exactly the same, with the difference that instead of plugging in the car, the ICE supplies the energy to the batteries.

The charging process related to plug in the car can be done either in the houses or in the recharging points that can be found in the cities.

Hybrid car

A hybrid electric vehicle (HEV) can be propelled by both, an ICE and also an electric motor (EM) or generator which can be located in series or in parallel. The ICE provides to the car the improvement of driving range, whereas the EM achieves the reduction on fuel consumption and, at the same time, the efficiency increases. This is possible due to the fact that there is some energy recovered from the braking and, also, that the excess of energy from the ICE coasting is stored.

The different configurations of the hybrid cars are shown below:

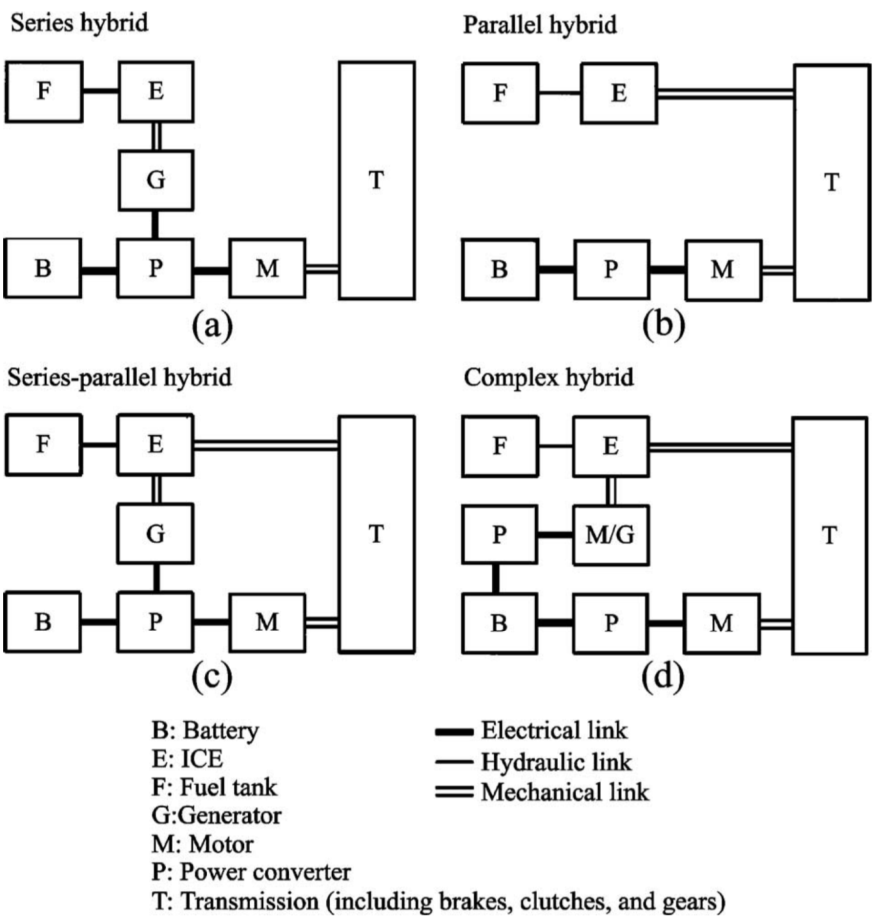


Figure 174: Architectures of HEV (Chan)

These different types of HEVs use the ICE to transfer the energy from the fuel to mechanical energy. This energy is used by the electric motor (EM) in the series HEV, and by the wheels and also by the EM in the parallel or complex ones. In the series HEVs, the mechanical output is converted to electricity by a generator; it can charge the battery or by means of a by-pass propel the wheels with the electric motor, which also can capture the energy from the braking process as it has been said with the BEV. On the other hand, the parallel HEVs have the two motors connected to the final step that is the drive shaft of the wheels.

Hydrogen Fuel-Cell Cars

This type of cars is not commercialized yet, but they can be considered as a hybrid car, more especially a series HEV.

Fuel Cell Vehicles (FCV) use fuel cells that are provided by the hydrogen to generate electricity. This electricity can be used either to propel the car or to be stored in the batteries or ultra-capacitors of the car for future uses. The fuel cells are generated from an isothermal chemical reaction and unlike the combustion engine of diesel or gasoline, it does not produce pollutants due to the fact that their by-product is the water.

Infrastructure

In accordance to what was explained by Tapia, 2010, the infrastructure which is needed to carry out the process of charging in the different types of cars is basically the same.

It is important to highlight that there are different types of charges*. The following table shows the differences:

Type of Charge	Power (KW)	Tension/Amp	Type of Current	Time of Charge
Standard (Slow)	3,7	230 volt, 16 amp, Single-phase	AC	6-8 h
Half-fast	Until 20	400 volt, until 68 amp	AC	2-4 h
Fast	Until 80	400 volt, until 200 amp	CC	15-30 min

Figure 175: Types of Charge (Tapia, 2010)

**The values are from Europe (Spain), in USA the values are different*

Regarding these types of process with their characteristics, the infrastructure varies according to each one of them; the level of communication between the car and the infrastructure is different. To design the architecture of the charging system it is necessary to know the kind of charge and also the characteristics of the electricity supplying system of the area in which the infrastructure is going to be installed.

The charging must be done following the required steps, so as not to cause any damage to the different devices. For this reason it is necessary to have an intelligent management of the process. The main characteristics of an electric vehicle charging infrastructure are:

- Recharging point: It must be capable of ensuring the secure connection between the car and the electric grid and quantify the energy demanded by the car. Sometimes it can also identify which users can recharge in each point.
- Local manager: It is in charge of managing the different flows spread between the different points to recharge.
- Management centre: It manages the relation between all the local managers and is in contact with the energy supplier.

This is the basic structure of the recharging architecture. With the same configuration two different types of points of recharge can be developed:

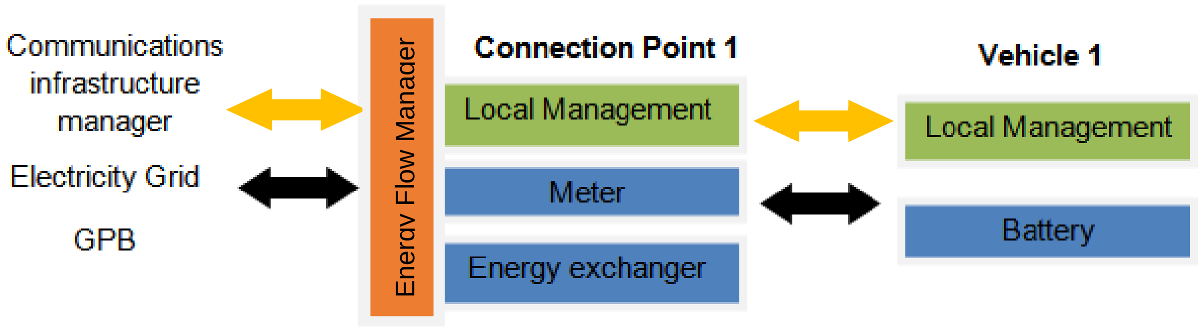


Figure 177: Individual Point (Tapia, 2010)

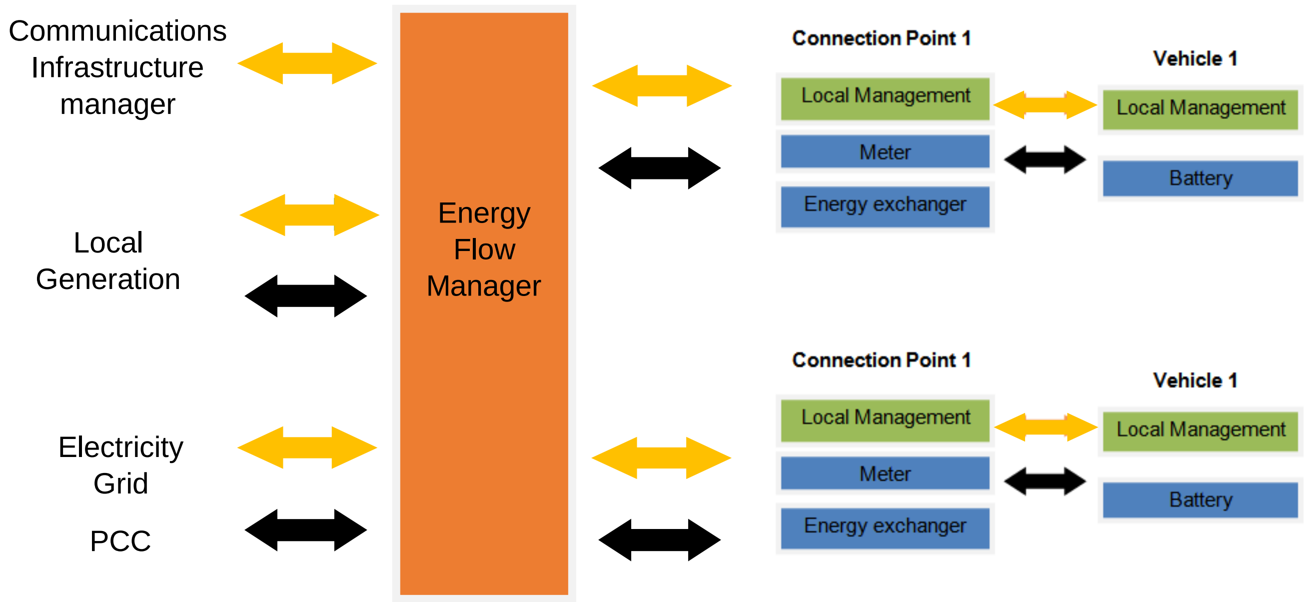


Figure 176: Multiple Point (Tapia, 2010)

Energy GPB: General protection box

Communications PCC: Point of common coupling

These two configurations can be used in different situations such as in the connection in the houses or in a public parking, etc.

Taking into account all the information above, we can conclude in this point that there are a lot of differences between these three kinds of cars. All of them have their advantages and disadvantages, for instance, the BEV do not emit any pollutant, however, its driving range is still smaller than the others, and characteristics like the maximum speed are still waiting to be improved. Regarding the HEV, this car joins the advantages and disadvantages of both the BEV and the ICE car. Finally, the FCV is being improved by means of several researches but it seems to be a great solution as it provides quite good performance and more comfort during it. The only problem related to FCV is related to the hydrogen, its storage, production, transportation, etc. as it is a very dangerous substance. The cost of all of these new technologies in vehicles is a general issue.

Bicycles

It is generally known that, during these recent years, the initiatives to encourage the use of the bicycle have grown (Pucher, et. al., 2010; Vandenbulcke, et. al., 2009). It is considered like a new and more modern alternative to the mainstream transport and also it is more sustainable than other options (Rose 2012; Caville, et. al., 2008). In this part, it is intended to present the most updated information about this so well-known vehicle.

Electric bicycles

One step towards the modern view of the bicycle could be the electric alternative. This type of bicycle has several differences with the traditional ones.

The principal characteristics are (Smart Electric Bike, 2013): They have an electric motor (with around 250 watts) in the rear wheel, this is supplied by a battery (the typical is an Ion-lithium one). The energy is supplied at the same time when the user is cycling like in a hybrid vehicle. There are four different levels of assistance to reduce the physical effort, depending on the level, the autonomy varies from 30 to 100 Km. the electric assistance get disconnected when the speed exceeded 25 Km/h. During the braking process, there is energy recovered to recharge the battery and increase the initial autonomy.

The recharging process is so easy. It is only necessary to plug-in the battery in a conventional plug. Usually, the batteries can be removed from the rest of the bicycle to get more comfort while charging.

This bicycle has both the benefits from the traditional ones and the advantages put in by the electric part. There are a lot of studies about the great deal of environmental, social and economic profits that can be achieved with the use of this vehicle (Chapman, 2007). It is perfectly suitable to reduce the fuel consumption, the noise in the cities and also the pollution and the issues related to the traffic congestion (Martens 2007). The electric bike is a cheap, very comfortable, flexible and quite quick vehicle and, furthermore, its maintenance cost is very low (Castillo-Manzano & Sánchez-Braza, 2013). The only problem with it is its initial inversion, which is still expensive.

Figure 178: Smart bicycle (Smart Electric Bike, 2013)

Parking for bicycles

In order to promote the use of these vehicles either the electric which seems to be more comfortable or the traditional one, the availability of parking is essential. To be useful by the inhabitants, bicycles must be easily accessible and easy and comfortable to park. Taking these premises into account, it is so easy to imagine that the location and the design of bicycles parking are crucial for the following development (Castillo-Manzano & Sánchez-Braza, 2013); they also must be safe and conveniently situated.

Broadly speaking, the most suitable system in the cities is the one related to “Bike Sharing”, during these last years, this kind of programs has increased a lot. They consist in a fleet of public bicycles available to be hired by all the people for a very low price, or even for free. Applying the new technologies and the entire infrastructure that is supposed to be developed in a Smart City which is the objective of this report, it would be easy to use a bike due to the fact that it is only required a card or a mobile phone to do it.

To implement a Smart parking for bicycles in a specific city it is necessary to install a complete system. According to Midgley, 2011, this system consists in:

- Fleet of bicycles: They must be designed to be easily identified so they must be distinctive. All bicycles must be equipped with GPS or RFID systems so as to be located all the time.

- Parking and locking mechanisms: There are two main systems depending on the system to get the bicycle. The common parts are the physical structure to lock them, the smart system to check the vehicles in and out and the power structure to provide energy to the whole system. If the system is based on smart card there is no additional elements, the operation is done in the general station; but if the system consists in “Call-a-bike” by phone, in each vehicle there must be a device to introduce the code that is given to the user.

- Station and user interface: It is necessary a previous registration which is made in this point. The interface must be easy to understand and quick, so as to encourage people to use it.

These systems do not need almost any maintenance, except the one related to the bicycles themselves and also the redistribution of the bicycles using the information provided by the GPS and the RFID tags so as to get the availability in all the stations (Altaplanning+design, 2013).

These systems are commonly used to public bicycles, nonetheless it can be developed a mixed parking in which there could be public and private bicycles. It is also the same situation with the electric bicycles, these vehicles due to their cost are not widely used, but it would be a good combination to introduce them in the public ones.

There is also a great deal of researches about innovative parking for bicycles, these kinds of investigations can be used to save space and get more safety in the systems previously explained. One example:

Figure 179: Bike sharing system (Altaplanning+design, 2013)

Biceberg is only one example between the huge quantity of existing ones, It is a parking patented by a Spanish company which allows to store the vehicles underground and it allows the users to take them in only few seconds with a simple operation. The capacity is variable and is a good method against robbery (Biceberg, 2013).

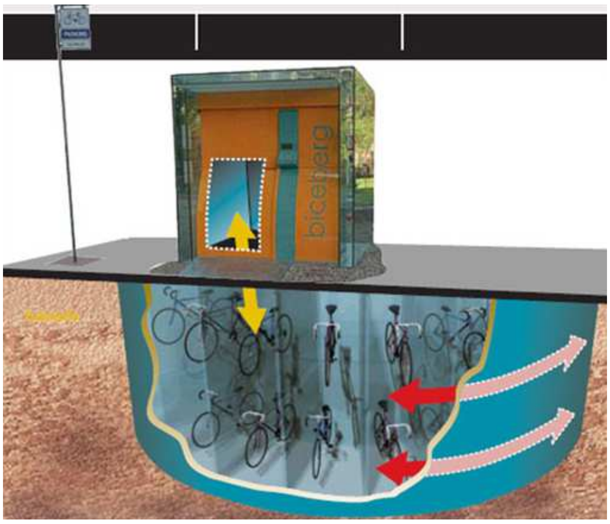



Figure 180: General view of Biceberg (Biceberg, 2013)

Buses

In this point, it is necessary to mention that it is almost the same information that the one explained in the part devoted to the cars, the buses share this basic and essential information. There are also the same categories for the heavy vehicles such as the buses (Chan, 2007). There are also Battery electric buses (BEB), Hybrid electric buses (HEB) and Fuel-cells hybrid buses (FCHB) which have the same principles than the car ones. The main difference is the driving range that can vary, because the power demanded by the buses are much higher than the cars, because of that the batteries have to be bigger too.

Bus Rapid Transit (BRT)

Apart from these innovations related to the type of vehicles, there are other ones which can be achieved with the infrastructure of buses in the city. This is the case of the Bus Rapid Transit (BRT). It is a system which is not so innovative because it has existed for many years but, even though all the advantages that it presents, it has not increased significantly until some years ago. In Europe these systems are not so common yet, but there are implementations all over the world.

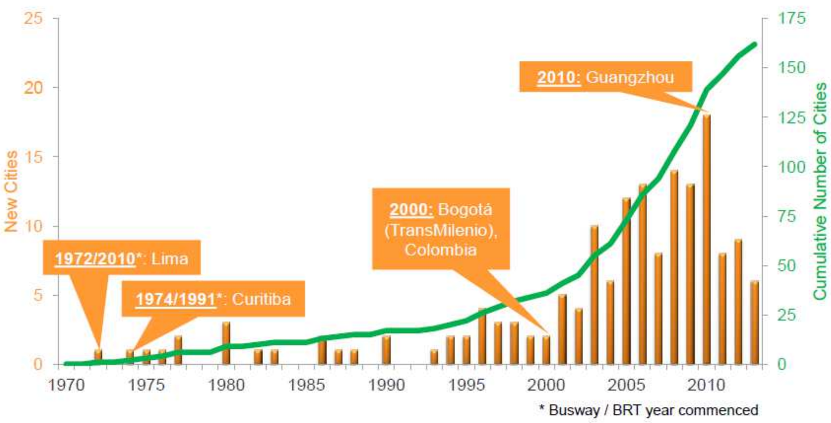


Figure 181: Growth of the BRT around the world (World Resources institute (WRI), 2013)

BRT is a mode of public transport which enables the efficiency of it (Wright & Hook, 2007). This system consists in a combination of buses, stations, services, running ways and also intelligent transportation systems (ITS) like the ones explained in previous states of this report, all of them integrated. It is also a high quality system that allows the users to have more comfortable, faster and lower cost mobility in the city. This is not a uniform system; in each city, it can have different specifications. Nonetheless, in accordance to Hidalgo, et. al., 2010, there are several common characteristics in the general infrastructure:

- *Vehicles:* They should be as sustainable as possible with low emissions. They also must be easily accessible and with multiple doors.
- *Stations:* They must have the platform at the same level of the door of the buses, to make easier the access to the users. The payment is done in advance so as to avoid delays.
- *Ways:* There must be segregation or, at least, priority to the buses, control in the corners and intersections, traffic priority signal and they must fulfil the minimum geometric requirements to the circulation.
- *Intelligent transportation systems (ITS):* Traffic signal priority and real-time control of the buses position. The management of the tickets will be electronic.

Figure 182: BRT "Transmilenio" in Colombia (Wikipedia, 2013)

Figure 183: BRT in China (Bus Rapid Transit (Across Latitudes and cultures), 2013)

All these characteristics of the system permit to reduce the time of the route, the time of the different operations and, also, the waiting time. As well as this, the BRT allows to get better global environmental conditions (PNUMA, 2010). The mobility in the city by means of this system gets improved in general terms and, as a result, the traffic congestions are reduced. The recent interest in BRT could be associated to these improvements and, to the fact that, this high performance is achieved with a low cost and short time to be implemented (Wright & Hook, 2007; Díaz, et. al., 2004).

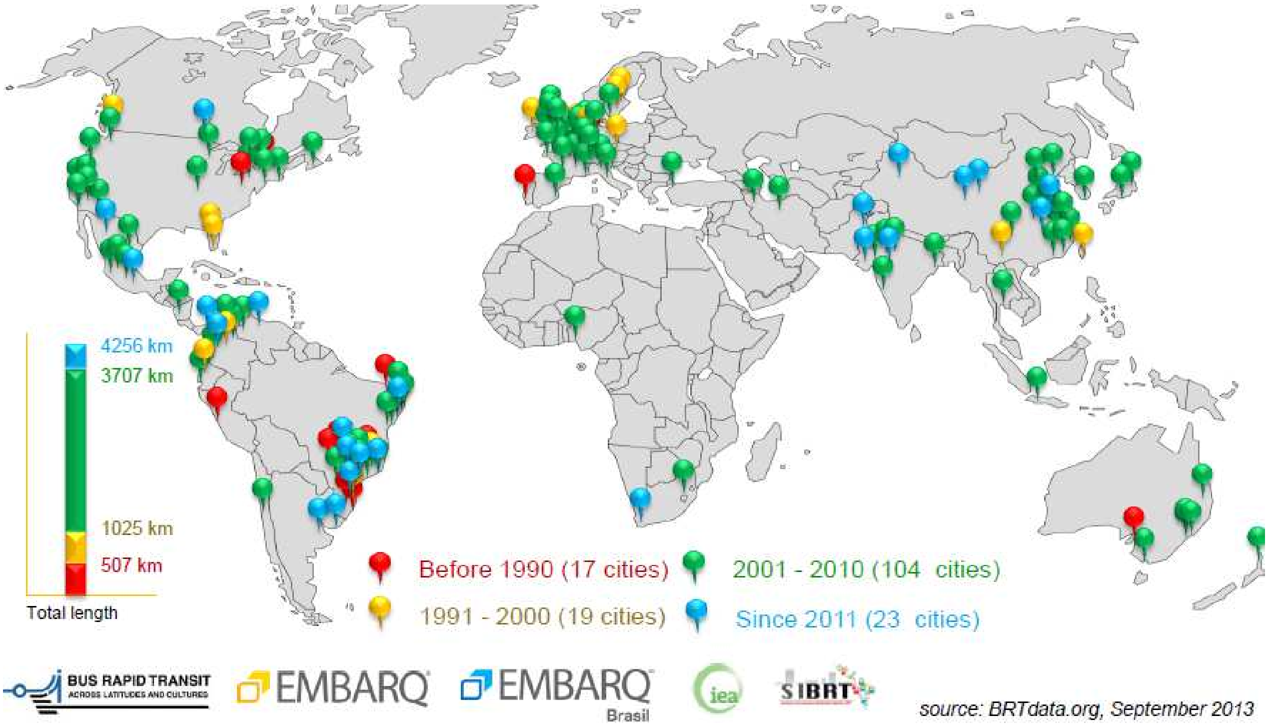


Figure 184: Situation of the BRT (World Resources Institute (WRI), 2013)

The reason for the late implementation or the no use of this system in some cities especially in Europe might be because it is seen like the second best option following the train or the rail transports in general (World Resources Institute (WRI), 2013). The inexistence of a uniform infrastructure is also a problem to be solved.

Group Rapid Transit (GRT)

This kind of transport is a new generation of smart buses that do not need a driver; they are automatic and electric and provide a secondary service to the demand. They connect different important places such as hospital, stations, industrial areas, etc.

The system is quite similar to a lift, the user get inside and pushes a button to select their destination; the bus does the rest, taking people in the bus stops where it is required. In case other users demand get picked up or left in some intermediate point. These vehicles usually follow the same route but, by means of the new technologies such as GPS, GIS, etc. the routes can be calculated in real time depending on the demands of the users.

These are electric vehicles so they provide clean, ecologic and sustainable mobility and with short waiting time. They are controlled by a central system and they have the ability to avoid obstacles; regarding their speed, it is limited, so they can interact with other types of transports (NICHES+, 2007).

There is a good implementation of this system in Netherlands:

Rail Transports


Figure 185: Parkshuttle de Rivium (NL) (Connected Cities, 2013)

This part is devoted to the most recent kind of rail transports and the ones which have more possibilities to be developed in the future. These transports are the kind of intelligent or smart transports that can travel without a driver as the GRT explained above.

Personal Rapid Transit (PRT)

This new transport is quite similar to the previous one explained, but having the difference that this is a rail transport. This consists in several automatic and electric vehicles called "podcars". These vehicles provide a personal service as if they were a taxi, and service the secondary demand.

They also work as a lift, the user pushes one button to ask for a podcar, and when it comes, the user pushes again another button to choose the destination so then, within a short time; the podcar directly follows the route indicated without any stop in the middle.

As it has been said before, the podcars run by separated rails. They do not share the same space with the other transports, so their speed is quite high. They are also a clean, ecologic and sustainable transport, and the service is similar to the private cars (NICHES+, 2007).

There is a successful implementation in the airport of Heathrow:

Figure 186: Heathrow podcars (CNET Australia)

Finally, which is sure is that a better future involves, without any doubt, the transition to the smart and sustainable transports that have been presented here. There are researches that are being carried out so as to avoid the congestion in the roads, and they involve the transport of people in evacuated transit tubes (ETT). They would allow people to travel all around the world in the time of about 6 hours. This seems unimaginable now, but nobody knows in the near future.

To sum up, what can be said in the end of this part of the report is that clearly the future of the transport in cities is directly related to the abandon of the mainstream transports, and especially the ones which use petrol. These transports, which are being used nowadays, are producing the majority of the harmful emissions responsible of the greenhouse effect. A change in the transports is absolutely necessary in order to achieve a more sustainable way of life and a better performance of the traffic in the city, the benefits that could be achieved by modernizing the transports system would improve the wellness greatly.

Water smart irrigation

Irrigation is defined as the application of water to land or crops, mainly to contribute to the growth of vegetation. There is archaeological evidence of primitive irrigation systems in ancient Egypt and Mesopotamia channelling water from the rivers to crops. This technique has evolved during the centuries, joining up improvements and technologies from each era, ending as the irrigation we know nowadays. The environmental impact of the irrigation must be taken into account since water is a limited natural resource. Since 1950 the global water consumption has tripled, reaching 4.300 km^3/year in 2006. Between 1900 and 1995 this consumption rose six times, more than the double of the population growth rate, and since 1960 the water consumption for irrigated lands has raised 75%. Over-irrigation causes three basic problems:

- Pushing water beyond the root zone and waste it.
- Excessive run-off, which contributes to non-point source environmental pollution.
- Degradation of plant health.

The main purpose of the smart irrigation is to save water adapting the irrigation to the needs of the ground. These needs may vary very often, because of the weather conditions that must be controlled by using different sensors. These sensors are mainly focused in the control of the evapotranspiration. According to the California Irrigation Management Information System, *"evapotranspiration (ET) is the loss of water to the atmosphere by the combined processes of evaporation (from soil and plant surfaces) and transpiration (from plant tissues). It is an indicator of how much water your crops, lawn, garden, and trees need for healthy growth and productivity…" (CIMIS, 2008).*

In a basic irrigation system we can distinguish two main elements:

- Channels: such as pipes, valves, emitters or sprinklers that distribute the water.
- Controllers: devices that activate, deactivate and manage the system.

Water smart irrigation technology is focused in these second elements by using smart controllers. The control of the irrigation is a key issue for achieving water savings, but there are other factors that must be taken into account, such as the design, the installation or the maintenance of the irrigation system.

Technology

Smart irrigation is a relatively new technology, only a few studies have been published, so the amount of reliable data regarding test results is not wide. As it has been said before, smart irrigation is an evolution of the modern irrigation systems that use a programming based on a calendar to control the amount of water needed for a specific day or time. This evolution is based on the incorporation of two new elements:

- Sensor: device that collects data from the environment.
- Smart controller: device that operates the irrigation system using the data collected by the sensors.

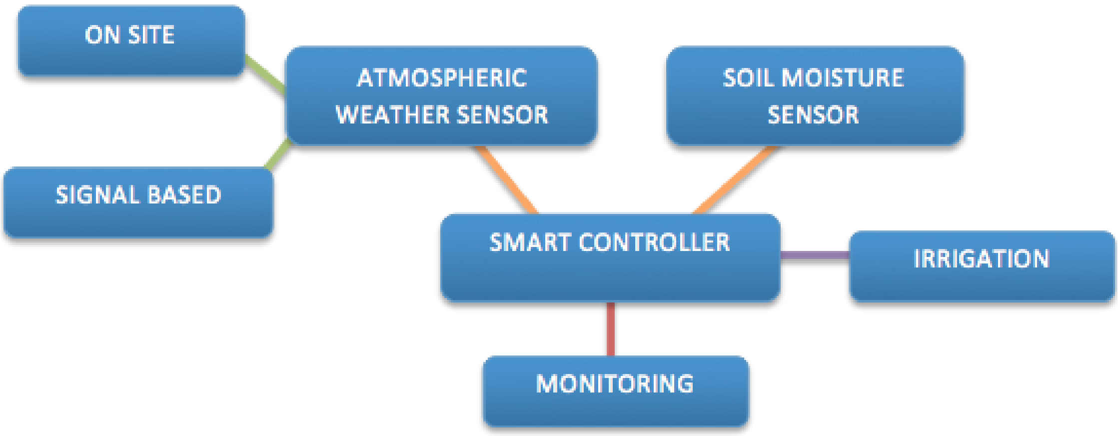


Figure 187: Smart irrigation system scheme

The main principle of this technology is to adapt the amount of irrigated water to the needs of the soil. This can be achieved by using the data collected by sensors, soil moisture levels or weather forecast, in order to know the status of the soil. Smart controllers are able to analyse this information and adapt the irrigation process.

As part of the *Smart City* concept, the monitoring of the irrigation will be a key fact of the system. It will provide real time information about water consumptions and will help to prevent or detect failures.

Sensors

A sensor is defined as *"a device which detects or measures a physical property and records, indicates, or otherwise responds to it" (Oxford Dictionary).* For irrigation different sensors can be utilised to measure evapotranspiration, temperature, rainfall, humidity or solar radiation. We can classify these sensors into:

- Soil moisture sensors: measure the water content in soil. They are placed on site, buried in the ground.
- Atmospheric weather sensors (weather stations): measuring atmospheric pressure, solar radiation, air humidity, temperature, wind speed (anemometer) and rainfall (pluviometer). They are placed in the proximity of the area, using lampposts or any other public item if it is possible.

These sensors can provide two kinds of information to the controllers:

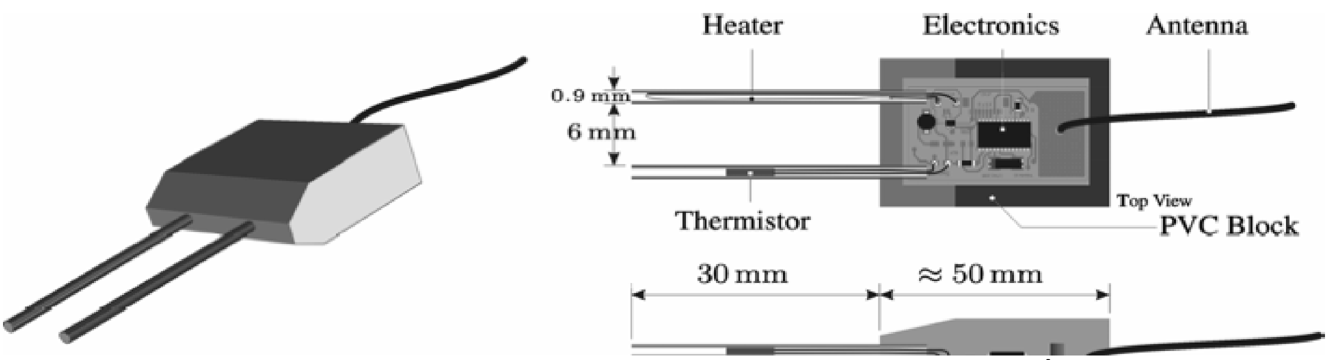


Figure 188: Soil moisture sensor (Raul Morais, A. Valente, C. Serôdio)

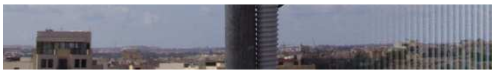
- Real-time measurements: data of the current situation of the soil collected on-site.
- Forecast measurements: upcoming data predictions based on the analysis of the data collected in several weather stations.

Controllers

Once the information of the soil is collected it is transmitted to the controller in charge of the managing of the irrigation. The Irrigation Association, an American organization dedicated to promoting efficient irrigation technologies define these devices as follows: "Smart *controllers estimate or measure depletion of available plant soil moisture in order to operate an irrigation system, replenishing water as needed while minimizing excess water use. A properly programmed smart controller requires initial site specific set-up and will make irrigation schedule adjustments, including run times and required cycles, throughout the irrigation season without human intervention." (Irrigation Association – SWAT).*

According to the sensors described above, the controllers may operate in two ways depending on the data they receive. The Smart Water Application Technologies (SWAT), part of the Irrigation Association, has labelled the controllers as:

Figure 189: Real-time atmospheric monitoring station (University of Malta)



- Onsite Sensor Based Controllers: a sensor-based controller uses real-time measurements of one or more locally measured factors to adjust irrigation timing. The factors typically considered include: temperature, rainfall, humidity, and solar radiation. A sensor-based system often has historic weather information (i.e. an ET curve) for the site location programmed into memory and then uses the sensor information to modify the expected irrigation requirement for the day.
- Signal Based Controllers: a climate signal-based controller receives a regular signal of prevailing weather conditions via radio, telephone, cable, cellular, web, or pager technology. The signal typically comes from a local weather station (or series of weather stations) and usually updates the current evapotranspiration rate to the controller. A climate signal based controller may also have an on-site sensor, such as a rain sensor.

Figure 190: Rainbird ESP-LXD controller (Rainbird)

Design and installation

In order to get the best performance of the smart irrigation system the design phase is crucial. The irrigation area must be divided into zones, each one will have its own sensors to adapt the amount of water to irrigate. These sensors are connected to the controller by wires, one controller will be in charge of several areas. The controller will also have a wireless connection to the weather sensors and the control and monitoring system.

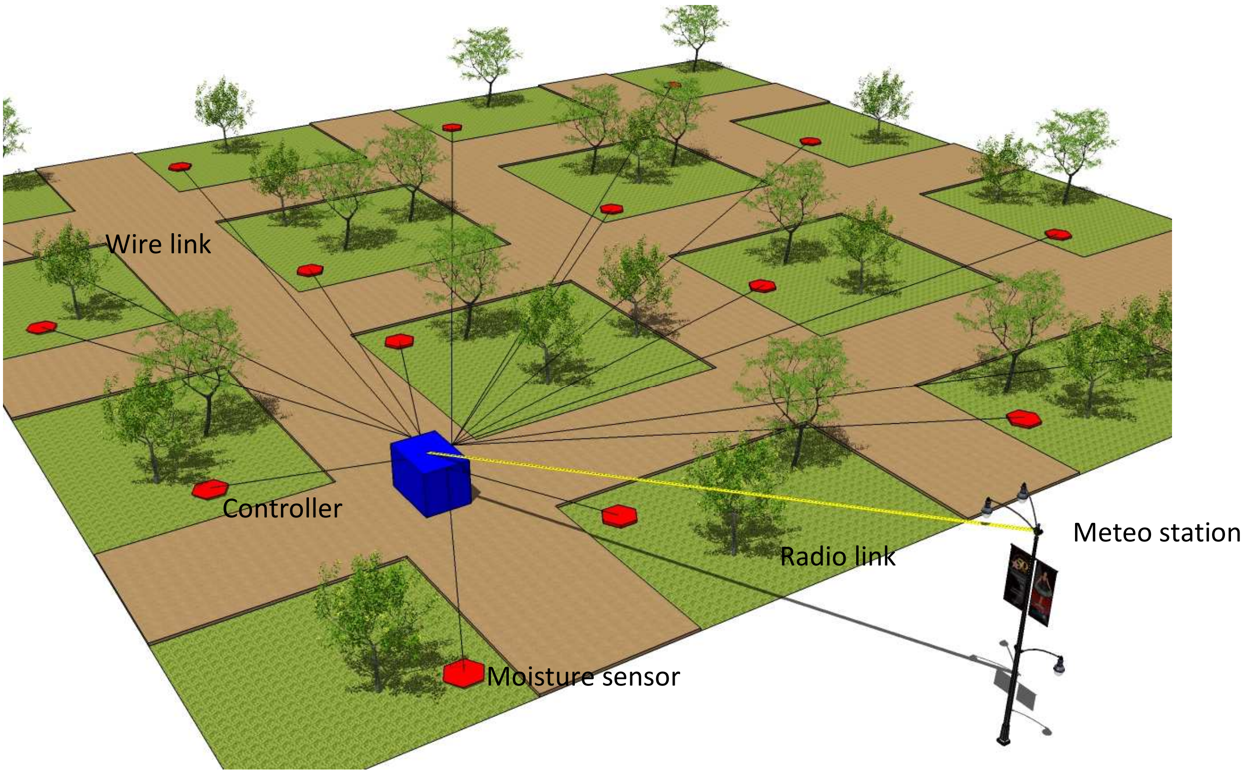


Figure 191: Sensors and controller deployment

Patents

At moment there are a lot of brands commercializing smart irrigation systems, mainly in the United States of America. The technology is quite similar, the difference can be found in the data source (own on-site sensors or weather stations data) and the number of zones they are able to manage.

SMART IRRIGATION PATENTS		
Company name	**Weather data source**	**Station or zone capacity**
Accurate Weather Set	On-site solar and rain sensors	8-48
Aqua Conserve	Historic ET curves with onsite temperature sensor	6-66
Cal sense	On-site ET sensor. Soil moisture sensor	8-48
ET Water Systems	Public and ETWS weather station data managed by centralized computer	1-48
Hunter Industries	On-site weather station with full set of sensors	1-48
Hydro Point	Public and Private Weather stations managed by central computer and wireless delivery	6-48
Irritrol Systems	Public weather stations data managed by ºcentralized computer server	6-24
Rain Master	Automatic, historic or manually entered ET or optional on-site weather station	6-36
Toro Company	Public weather station data managed by central computer server	6-24
Weathermatic	On-site temperature and rain sensors and solar radiation estimated based on location	8 to 48

Figure 192: Patent features of the top 10 smart irrigation companies in the USA (California Urban Water Conservation Council)

Users

This text is focused on water smart irrigation for smart cities but this technology can be used in a wide range of sectors. We can split the possible user in three groups:

- Public: big green areas (parks and gardens) of cities or towns. Several sensors are deployed throughout the zone. Managed by the municipality.
- Private: small scale of the public one. Used by private owners in gardening.

- Agriculture: the first sector in which the smart irrigation was implemented. The cost of the water has a big importance in the profitability of the harvest.

Conclusions

Smart irrigation is a logical improvement of the irrigation systems used nowadays. Saving water is not only a matter of money for the city, but also a matter of sustainability. This technology can be used not only to avoid excessive irrigation, it can avoid under-irrigation and help maintaining the health and appearance of the landscapes. Some studies have been carried out to quantify the improvements of a water irrigation system. The report presented by *The Metropolitan Water District of Southern California and The East Bay Municipal Utility District* in 2009 showed a total reduction of 6% of the amount of water used for irrigation after installing smart irrigation systems. Considering that California (USA) has a warm climate we can guess that that figure will be higher in areas with higher mean annual precipitation.

The use of the *Information and Communication Technologies (ICTs)* is important not only for developing the system, also for monitoring it and carry on a failure control. It is also clear that smart irrigation is just a part of the whole irrigation system. To obtain good results in water savings an optimal performance of the rest of the system is needed, such as good design, correct maintenance or leaks prevention. The best performance will be obtained by combining other water management policies like rainwater tanks to collect the excess of rainfall water and use it afterwards for irrigation.

Smart public lighting

In the previous section we have analysed one of the things in which local governments spend big amounts of money: the water for irrigation. Other resource that must be considered in terms of energy savings is the consumption of electricity for public lighting. The production of electricity requires a use of natural resources, having a negative impact in the environment. Following a sustainable strategy we must be able to reduce the consumption of energy and public lighting is a field where some smart strategies can be developed.

In Spain, for instance, the cost of the public lighting bill has doubled in the last five years. Spanish public entities spent 450 million euros in public lighting in the year 2007, according to the latest estimations they spent 830 million euros in 2012. In this cost rising, the continuous increase of the electricity price has been also a key factor. Even though some policies to reduce this waste of energy have been created, we are quite far from positive results. In 2012 the consumption of public lighting electricity per inhabitant was 113 kWh, while the objective of the strategic plans was 75 kWh.

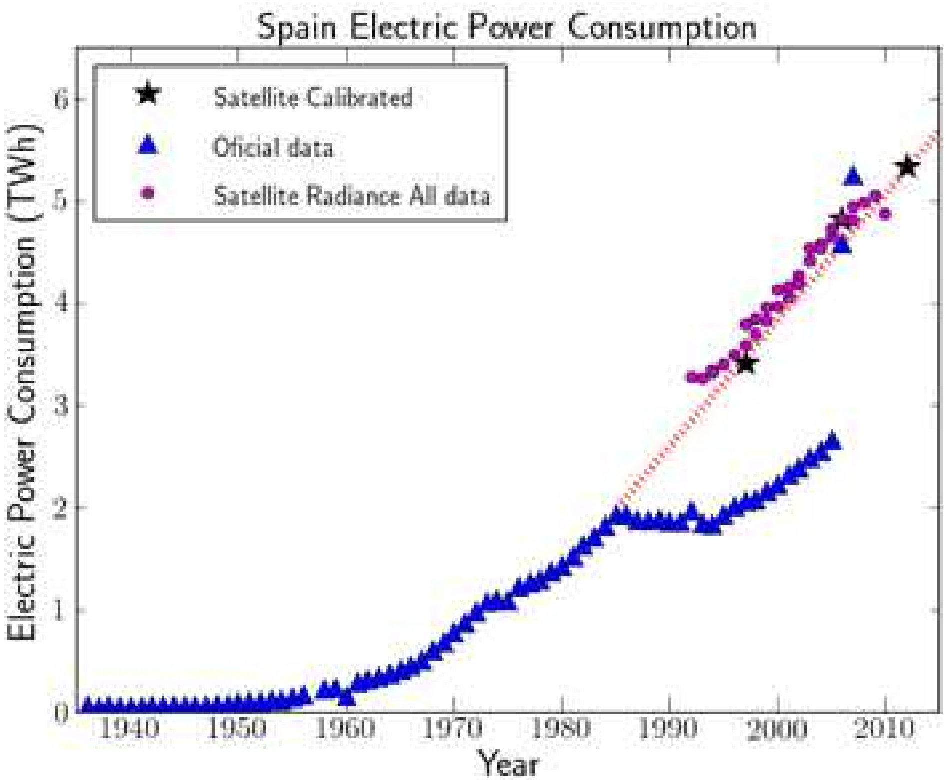


Figure 193: Spain electrical power consumption evolution (Universidad Complutense de Madrid)

The problem is similar in every country, public lighting is essential for the safety of drivers and pedestrians and cannot be reduced. The development of *Light-Emitting Diode*

(LED) technology is a first step to achieve energy savings that can be implemented with the Smart Public Lighting.

Technology

The main objective of the Smart Public Lighting is to adapt the lighting of public areas to the real needs. These needs change during the day and are different in every zone so there is not a strategy to fit all of them.

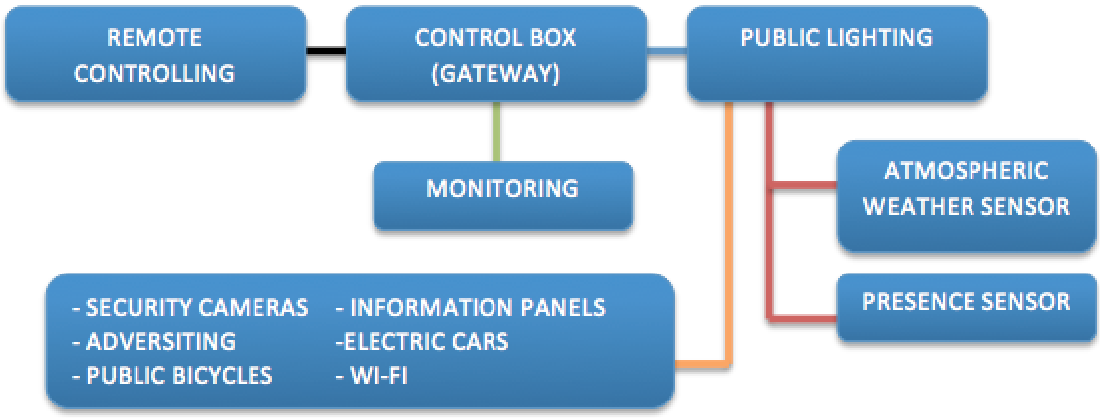


Figure 194: Smart public lighting system scheme

This can be achieved by using sensors to measure physical properties that can affect the needs of lighting and taking advantage of the *Information and Communication Technologies (ICTs)* to have a total control of the system.

Monitoring

The term monitoring can be defined as *"observe and check the progress or quality of (something) over a period of time; keep under systematic review" (Oxford Dictionary),* and that is precisely the purpose of the smart management of the public lighting: keeping updated data of the energy consumptions of every lampposts to prevent or detect failures.

By grouping all lampposts of light emitters in segments a controller can be assigned to everyone, this device can collect the measurements for the data Centre in charge of monitoring.

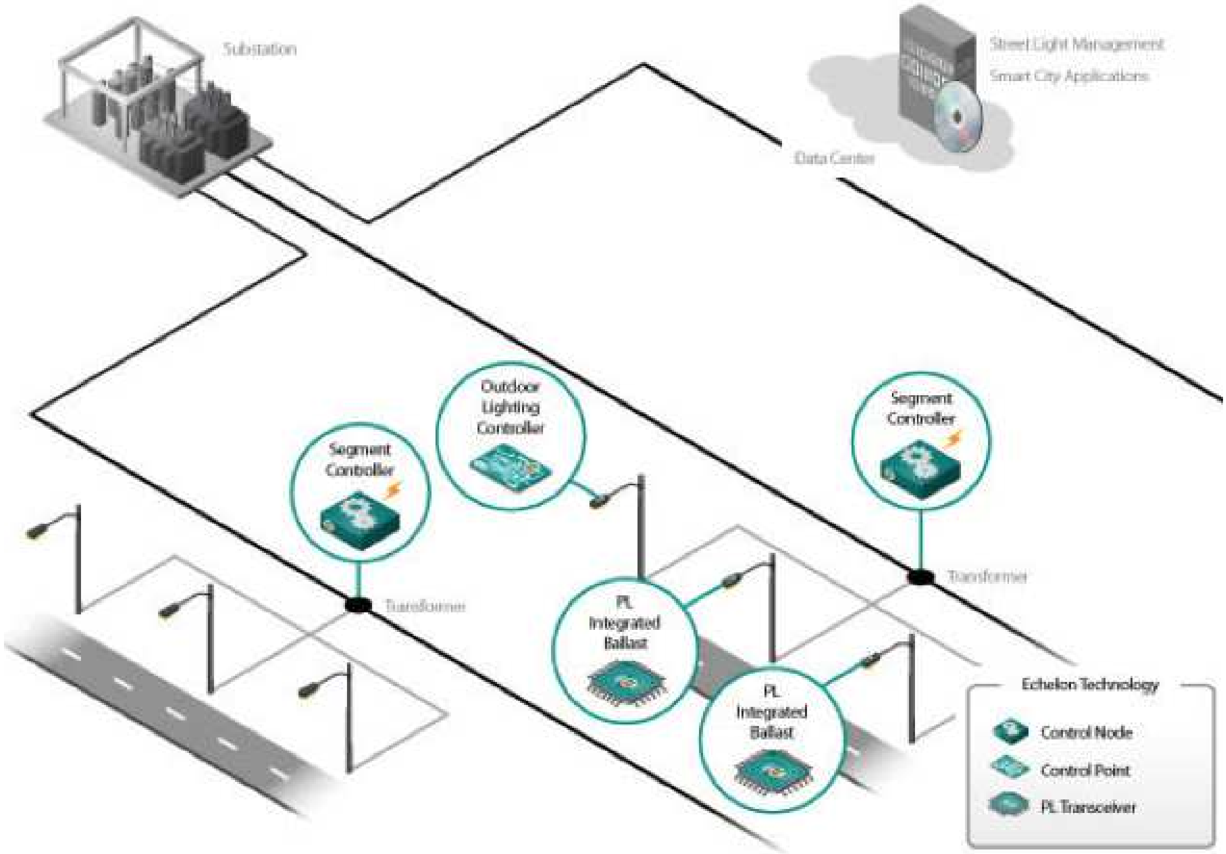


Figure 195: Smart Lighting scheme (Echelon)

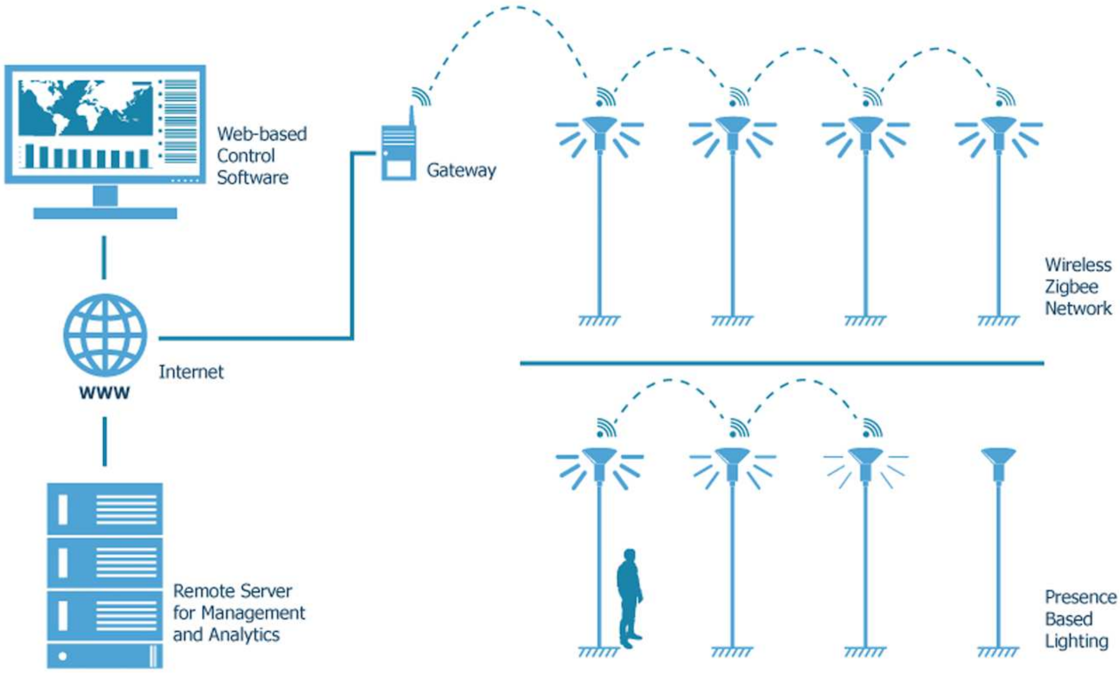


Figure 196: Connection scheme (Zigbee)

Sensors

In addition to the management of the energy, the public lighting can be improved by using sensors. These sensors can quantify different variables that can affect the needs of light in a specific area. Two types can be highlighted:

- Atmospheric weather sensors: weather conditions can affect to the lighting needs. These devices, mainly solar radiation sensors, can detect periods of time when the need is higher.
- Presence sensors: by installing these devices the light emitter can be activated when a person or vehicle is approaching. In this way, when there is no need of light its energy consumption can be lower.

The first ones can detect when a higher rate of lightning is needed, for example in a rainy or foggy day. The second ones can detect periods of time when the standard level of lighting is not needed and can be replaced by a lower one.

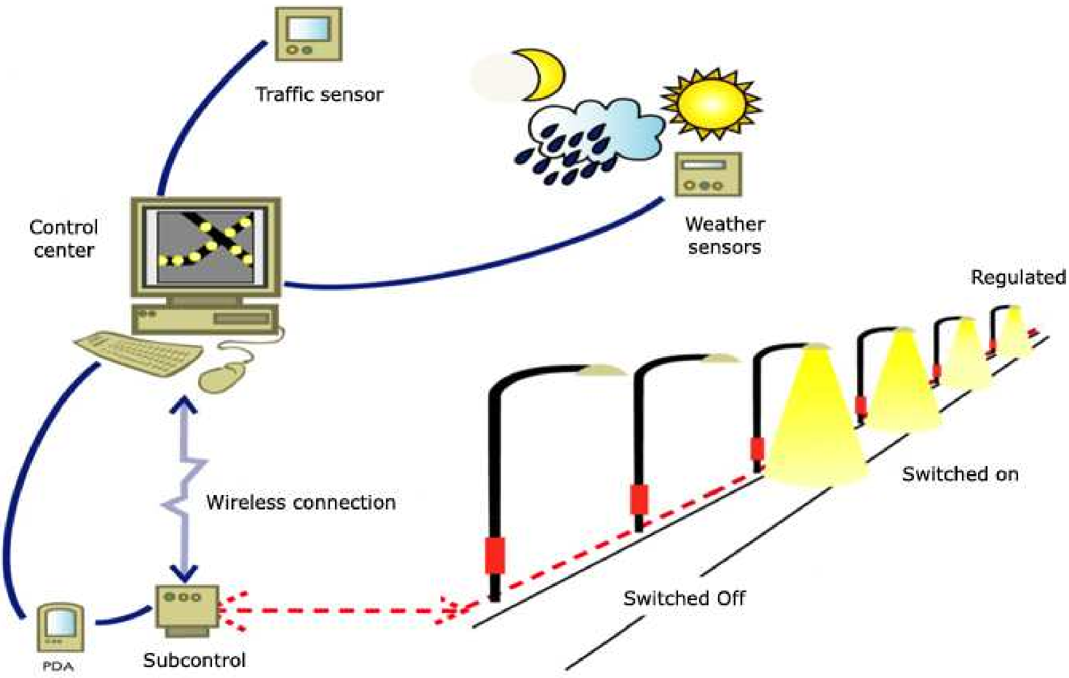


Figure 197: Sensor deployment for a road (Roberto Tovar)

Integration with other public services

Other public services related with the *Smart City* can take advantage of the smart public lighting infrastructure. In order to take up the less public space possible, boxes, post and channels can be used by:

- Security surveillance cameras
- Public information panels
- Advertising panels
- Electric cars charge stations

- Public bicycles stations
- Public Wi-Fi repeaters

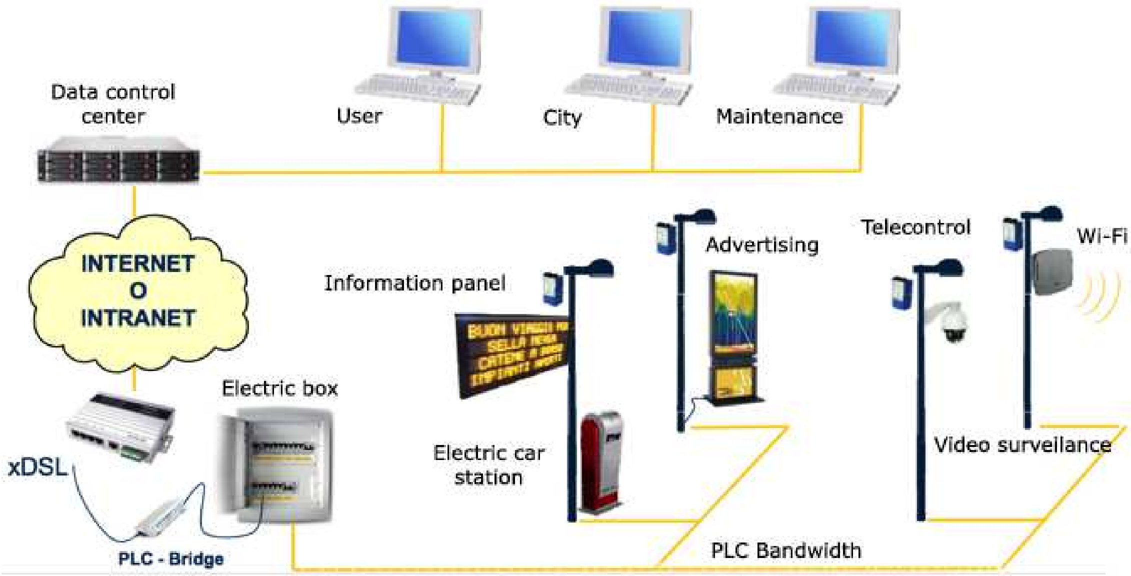


Figure 198: Smart services integration (Minos-System)

Conclusions

Adapting the amount of light provided to the public areas to the lighting needs is the best way to reduce energy consumption. A good design strategy is basic to avoid under or over-lighted areas that can suppose either a danger to the safety of the inhabitants or an energy waste. This must be complemented with sensors, which are able to measure the current necessities. The use of ICTs for remote controlling and monitoring will assure a precise performance of the system.

Replacing old incandescence bulbs by the modern LEDs is the first step to reduce energy consumption. The cost of implementing these services is quite high so it is recommended to take advantage of the installation works for the main technology to install other secondary. In this way the trouble for the inhabitants will also be lower.

SMART GRID SYSTEMS

The main aim of a smart grid, is to use ICT (information and communication technology) in an electric grid in order to collect and provide information useful to obtain higher levels on efficiency, availability, sustainability in the production and distribution system (U.S. Department of Energy, 2012).

In fact nowadays the common energy production is carried on through a limited number of industries concentrating the electricity production in only some big fossil fuel and nuclear power plants. The transmission and the distribution systems are then **unidirectional**: from here the electricity flows in the high voltage dorsal, and then departs in the networks to reach up this infrastructure, among other things complex and costly, provides the users electricity. The final users in this way result to be just **passive** loads for the network. This approach brings to many disadvantages:

- In the long connection lines from the production plants to the users there occur many Joule losses;
- The absence of protocols in the dynamic management of energy flows brings to ineffective management into the system;
- It is difficult to completely take advantage of renewable energy sources;
- In case of wide black-outs it is quite impossible to get a proper response time, with the consequent inability in containing the chain reaction in voltage and consequent interruption and interference in the energy flow.

The problems in the existing power line can be remedied through the application of Smart Grids technologies.

The smart grid is an evolution of existing power distribution networks to answer to the increasing demand for energy and use of renewable energy sources and the information technology development.

The growing demand for energy has brought nowadays raising problem in economic and environmental costs that make it difficult to use the old paradigms for the expansions and upgrades of the power grids.

In addition, the ongoing advances in **ICT** (Information & Communications Technology) have caused scientific and industrial interests in these technologies to implement production, accumulation, transport, distribution, sale and consumption of **energy**. The combination of ICT and energy is commonly known as **Smart Grid**.

Architecture and performance of a smart grids

The principal fundament of smart grid focuses on the integration of Distributed Energy Resources (**DER**), such as cogeneration, solar panels, hydropower plants, wind turbines, vehicles to grid, and so on.., in the existing system: all these applications include generators, energy storage systems, and controllable loads in connection to the power distribution system (fig. 1).

Also, in a smart grid there is the ability to control, through protocols and information flows, active loads and generators, and functions in real-time. Electricity network protocols to manage information allow to virtually eliminate the hierarchical relationship between the nodes, including end-user nodes (industrial, commercial and residential customers): they all have the same importance and exchange information and electricity (fig. 2).

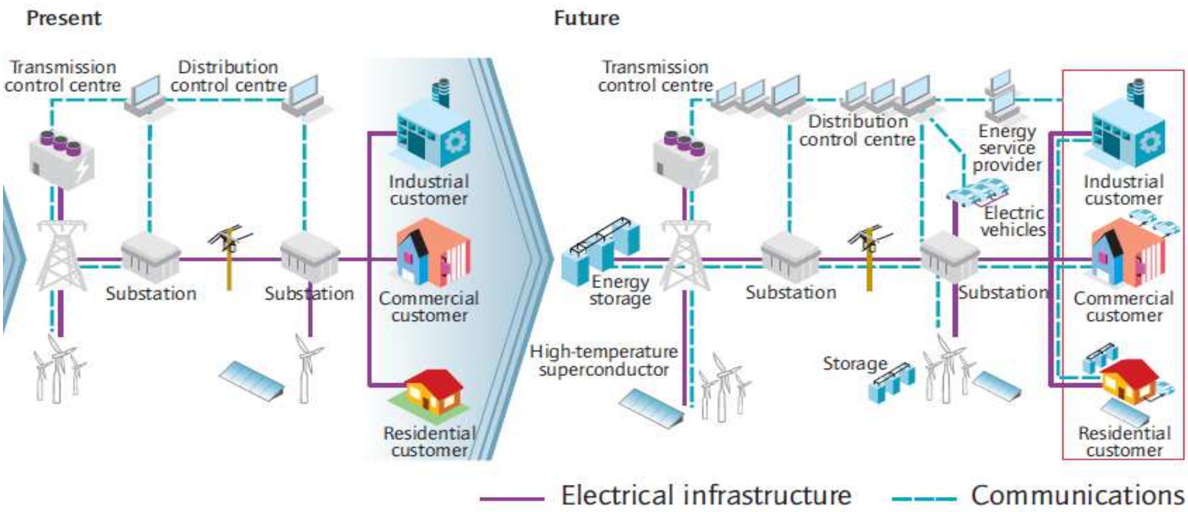


Figure 199: Different schemes between the present power grid and the future smart grids (Source: http://www.energinet.dk/DA/Sider/default.aspx)

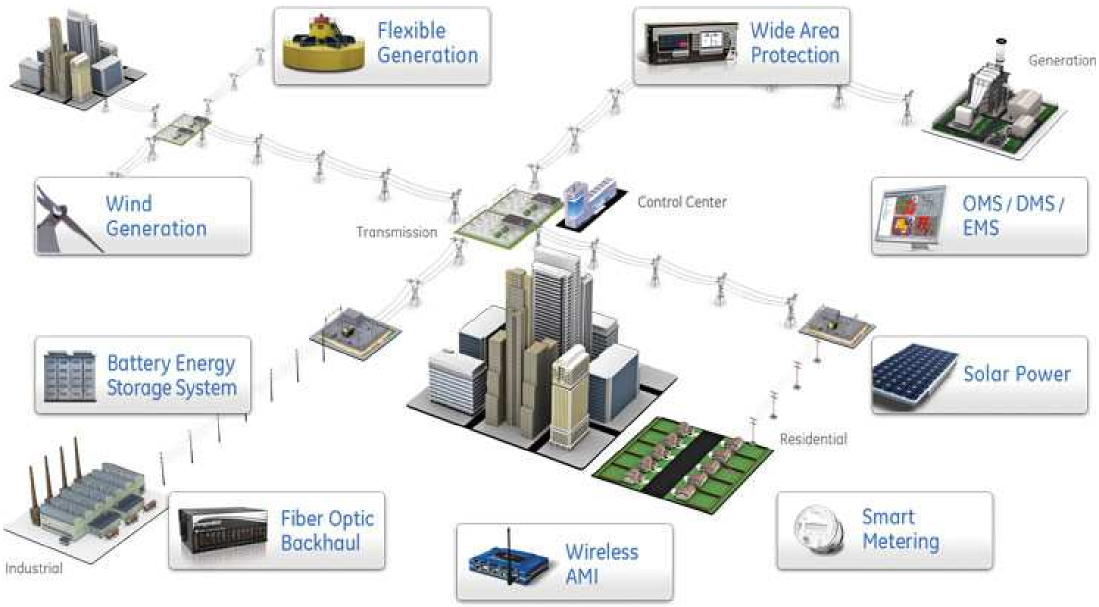


Figure 200: Smart Grid architecture scheme (Source: http://energydeals.wordpress.com/2011/01/14/smart-grid-and-digital-energy-with-smart-metering/)

A smart system of power measurement and communication may include (fig. 3):

- Smart metering and smart meter
- HAN: Home Area Network
- Metering Gateway
- NAN: Neighbourhood Area Network
- Data Concentrator (DC): data concentrator
- WAN: Wide Area Network
- Distribution Controller: Meter Data Management Systems
- Utility

The Smart Metering (or Smart Meter), is the main instrument in a smart grid implementation, because thereby it becomes possible to get a bidirectional communication.

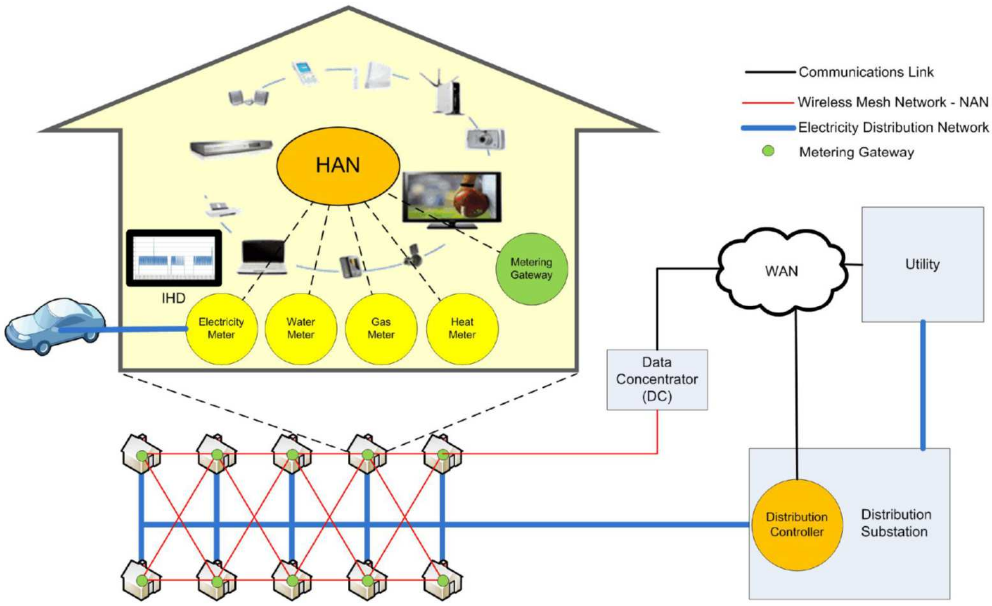


Figure 201: General architecture of a smart grid (http://it.emcelettronica.com/)

They are allocated in houses and buildings to measure many parameters of consumption: electricity, gas, water and heat. All **Smart Metering** within the habitations are connected together in a HAN (**Home Area Network**) and transmit the data they collect to the **Metering Gateway**. The metering gateway receives data packets from the meters and send them on to the NAN (**Neighbourhood Area Network**). All the NANs in the smart grid collect data from multiple HANs and supply them to a **Data Concentrator** (DC). Here the data are organized through specific formatting standards in a data base. Finally in the WAN (**Wide Area Network**) the data bases will be collected and redistributed to the **Meter Data Management Systems** and to the **Utilities**.

Many efforts are made nowadays to define communication standards to ensure compatibility and interoperability between the several system components, independently from the communication technologies (meterings, devices, protocols).

The success of the energy distribution through smart meters and smart grid networks will for sure depend on the availability of open technologies and standards: through them, consumers and suppliers are able to collaborate and interface each other easily and properly.

With the introduction of smart meters in an existing power grid, it occurs the very first transition to a smart grid: from the classical so-called **Automatic Meter Reading** (AMR), which just reads and transfers data from electric meters, the transition is to the so-called **Advanced Metering Infrastructure** (AMI) (fig. 4). The AMI network provides a two-way communication, and as a consequence an efficient interface between suppliers and consumers. In this way many purposes can be achieved sending information to the consumers: time-of-use pricing information, demand-response actions, and remote service control through smart-phones and browsers' applications. Connecting then the AMI system to the business one, it's also possible to operate in demand-response mechanisms.

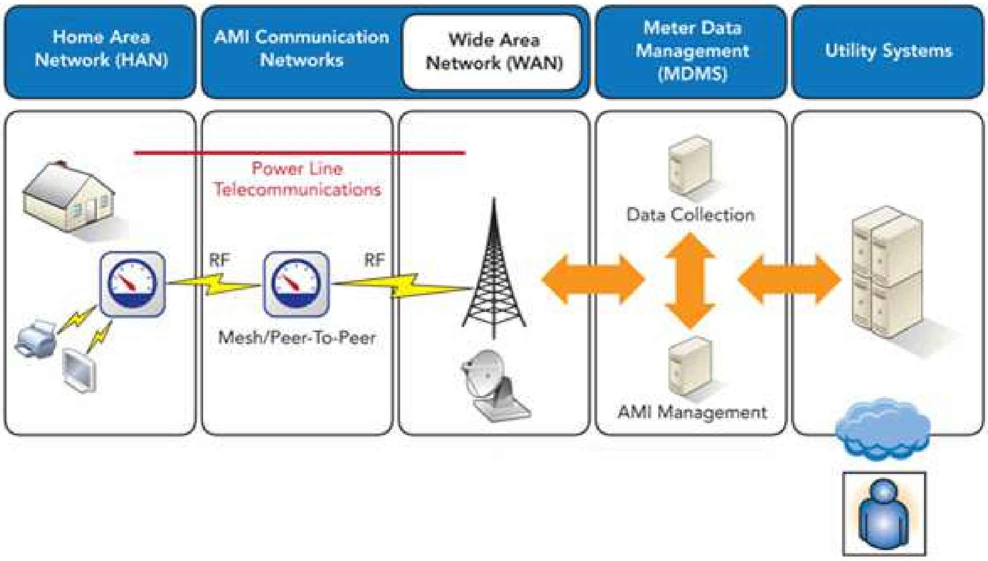


Figure 202: AMI configuration (Source: http://www.electricenergyonline.com/)

Due to the complexity achieved by the network becoming "smart", in which all the nodes have the same importance in sending and receiving information ("mesh network"), the Control Centre becomes an **EMS (Energy Management System)** in which the monitoring and control functions of **SCADA** (**Supervisory Control and Data Acquisition**) are needed.

Scheduling of resources

The flow of information which arise from the smart measurement and communication system, enables to manage in real time the peak loads: as a consequence it is possible to **schedule** operations in order to avoid overloads and save both energy and money.

In fact during peak loads, it is necessary to make extraordinary use of auxiliary power generators (usually in standby) in order to supply energy flows without interruptions. Smart meters and management of loads can avoid these issues, and limit the recourse to such instruments.

In a household intelligent energy management for instance, the appliances can work whenever in the day (starting, suspending, stopping, resuming) without affecting the household dynamics: when the smart metering is in contact with the network under the executive management of the **home power controller** (fig. 5), it's possible, through specific information and control signals, to know when the peak energy time intervals occur. In this way, only in case of the absence of peaks, the smart meter allows the loads. The peak demands are in this way smoothed out. The home power controller coordinates the interactive working between the home appliances and the utilities.

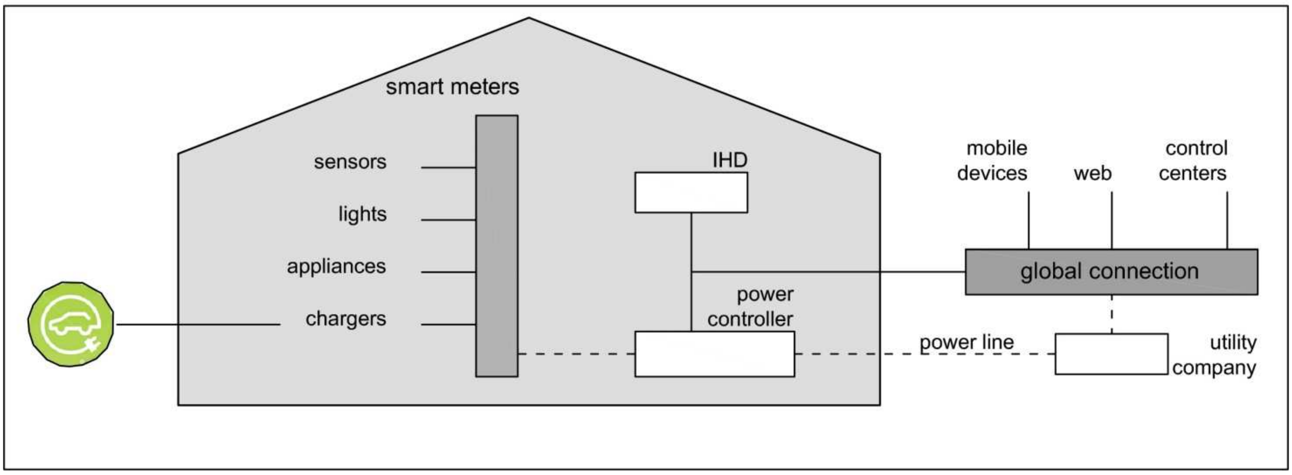


Figure 202: Power schedule system

Organizing the flow of energy during the hours of the day is a strategy connected to the possibility to use also energy storage systems during the load peak intervals. In the same way, electric cars can be charged during the lowest load periods, in order to avoid the overloading of the system in the day time.

Apart from the loads smoothing, other logical benefits are reducing the use of stand-by generators or of new power plants and cost savings for the consumers during peak load time, when the electricity costs more.

The scheduling is also useful to redirect the flow of energy, giving different priorities to specific network clients, such as hospitals and emergency facilities.

The scheduling can be used also in order to share resources, in an automated and dynamic way, between users at HAN level, but also among several NANs. In fact with the wide spreading of distributed energy resources (DERs) sharing exceeding energy can lead to decrease energy waste and costs, with fast transmission of energy.

Communication systems

One major problem lies in the method of connection used to connect household devices and smart meters in every home, and how to send the collected information to the control Centre. The ICT fields in the smart grid instead, are commonly three (fig. 6):

- the SCADA (supervisory control and data acquisition), that is already used in order to monitor and control in a remote way the power distribution on an high level,
- the active distribution grid, that is used to connect the distributed energy sources to the mid-level voltage grid,

- The smart metering field, that is used to collect and recover values on consumption, and nowadays involves also actions such as load outline, monitor the power quality, and remote regulation of the facilities.

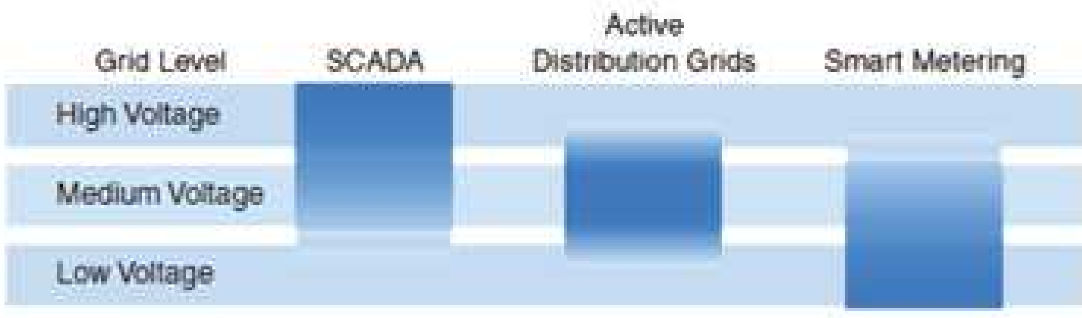


Figure 203: Common ICT applicative areas in correlation with the grid levels (Liserre et al., 2010)

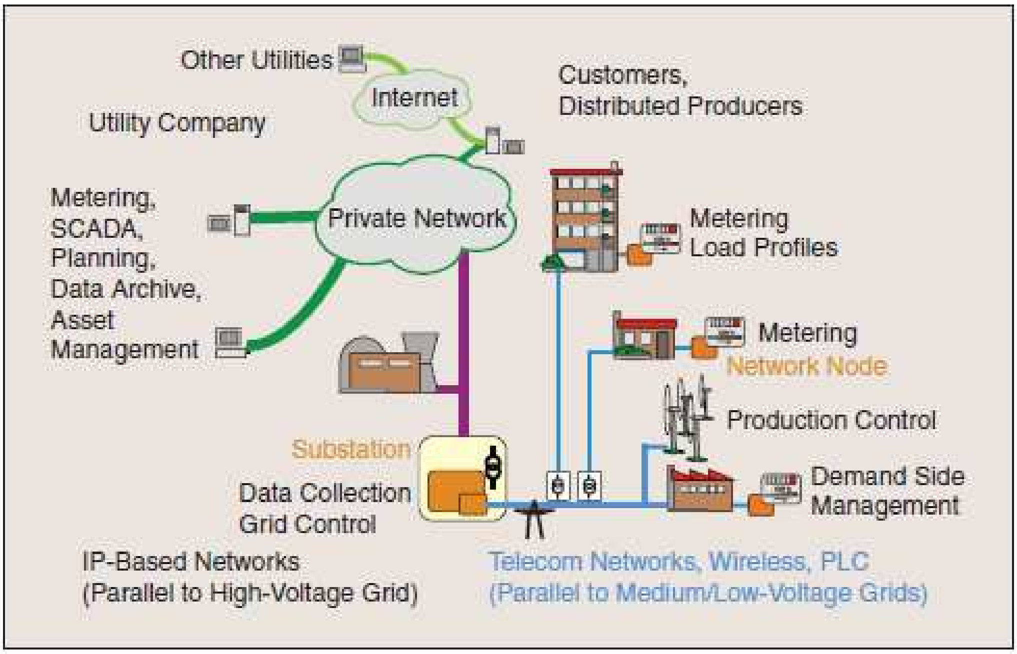


Figure 204: Communication infrastructures in smart grids (Liserre et al., 2010)

In SCADA applications (WAN level) the exchange of information is ensured by existing networks (fibber optic links parallel to the high voltage grid) and allows the connection between primary substations, power plants and control rooms (fig. 7).

In the medium and low voltage levels (HAN and NAN) there are usually not existing communication infrastructures. In this case, these strategies are available (fig. 8):

- public telecommunication networks: systems like GSM, GPRS, UMTS (cheap and wide coverage networks, even though lacks due the increasing number of subscribers and services);
- Wireless networks: these systems are very flexible, even if preferable in small areas, because they are not easy to reach and transmit, especially in urban areas. The transmission in long distances has been recently reached through trunked radio systems in some countries. The most economical, easy and ready to use solutions are the wireless connections such as Wi- Fi (WLAN), Bluetooth (WPAN) or WiMax. Available recently also the ZigBee technology, designed as a communication standard for low cost, low power consumption by the ZigBee Alliance. For networks NAN is also

possible to use the standard cellular data network. For both HAN and NAN a wired network would lead to less interferences in the distance running, but provide higher costs. The cellular networks are existing structures with no additional costs, provide immediate information, but susceptible to congestion and not reliably in emergency situations.

- Power line communication lines: a recent possibility considers that also the existing power grid can be used to transfer information. Although they can overcome the problem of the reachability in wireless connections, they strongly depend on the existing network properties. Challenges are the high costs of devices to connect phases coupled with transformers, but also the regulation of the frequency bands.

Tipe of network	Range	Potential technologies
HAN	tens of meters	ZigBee, Wi - Fi, Ethernet, PLC
NAN	hundreds of meters	ZigBee, Wi - Fi, PLC, cellular
WAN	tens of kilometers	Ethernet, microwave, WiMax, 3G/LTE, fibre optic links

Figure 205: Available communication technologies for different types and extension of power networks

In France it was created the "Linky meter project": this technology connects 35 million of smart meters Linky with traditional meters. The information is then sent to the data concentrators by PLC, and then to the data centres via GPRS (Güngör, 2011).

In Italy, however, Enel uses a hybrid network formed by the PLC technology for the transportation of data from the meters to concentrators (server) of information scattered throughout the territory and GSM technology to send data from the latter to data centres.

Integration of DERs and RES in the smart grid

The distributed generation (DG) is gaining very important nowadays, because of its well-known benefits, such as the decreasing of GHG emissions, sustainable worldwide development, possibility to reduce the current transmission and distribution issues in the power system (voltage support, avoid of overloading, demand-response). One of the immediate transformations brought with the distributed energy resources (DERs) is related to the possibility for the consumers to have more flexible energy uses. Also, the distribution network needs to be transformed into a small integrated system. On the other hand one of the best positive factors in the implementation and development of smart grids technologies lies exactly in the possibility to integrate these kind of energy sources.

The integration of renewable distributed energy sources on a power network, brings the necessity to face with intermittent sources, power outputs not predictable if not with very sophisticated weather forecast technologies. At the same time, it brings the potentials of integrating in the power system two-way energy flows.

This is the reason why many applicative strategies and technologies have been developed in the last years, and are still in charge to improve efficiency in DG smart grid integrations. A list of the principal ones is shown here:

- Demand-response tools in smart grid systems, in order to control and manage dynamically the availability of energy in face to the energy loads, smoothing the peaks;
- Use of hybrid systems, integrating different intermittent renewable sources, in order to avoid leak of energy supply due to the unpredictable weather and wind conditions;
- Energy storage systems, to provide quick and sustainable energy when needed;
- Micro grid systems, to easily integrate DERs systems in circumscribed power networks.

In the next we will concentrate on the energy storage systems, because they are determinant to the integration of DERs in the power grids, and on the micro grids, crucial technology in the future smart energy systems (Tan, et al., 2013).

Energy storage systems

The main benefit in the energy power management thanks to energy storage technologies are:

- The possibility to provide power during the not availability of the non-controlled power output from RES;
- The possibility to improve the reliability and the stability of the power systems (Divya & Østergaard, 2009).

There are various technologies of ESS (Energy Storage Systems) (Koohi-Kamali, et al., 2013):

- Flywheel energy storage system (FESS);
- Electro-chemical energy storage systems (EESS), including Battery energy storage systems (BESSs), applicable also in Electric Vehicles;
- Regenerative fuel cell (RFC);
- Pumped hydro energy storage systems (PHESS);
- Super-capacitor energy storage systems (SESSs);
- Compressed-air energy storage systems (CAESS).

The plug-in electric and hybrid vehicles are becoming more and more popular in the nowadays market, with consequences on the household load requirements in the recharging periods: they are promising technology because useful tools from the environmental point of view. In addition they result to be functional in energy storage.

In the following chapter shows different technologies exploiting the potential of electric and hybrid vehicles.

The potential of PEVs and PHEVs technology systems

The problem concerning the intermittence in the renewable sources' energy supplying brings the necessity to compensate the power loads, which is more difficult in small home systems with not huge RES installed. The electric vehicles can be the solution of the problem in many cases.

The so-called **plug-in electric vehicles** (**PEVs**) and **plug-in hybrid electric vehicles** (**PHEVs**) are very interesting tools in the field of climate change, energy and environmental problems. On the other hand, elevate household loads will be required by electric vehicles in the charging time, with consequent interruption of the power supply and temporary lack of power.

The emerging technology of the smart grids brings the possibility of thinking and taking advantage of EV's further potential inside the SM itself. In fact, firstly, with the demand – side management the EVs can be charged when there are no other household loads; secondly, the so-called **gridable EVs** (**GEVs**), thanks to bidirectional charger devices, not only withdraw energy from the grid, but can also provide energy to the grid.

Recently different technologies exploiting the GEVs have been developed:

- Vehicle to home (V-to-H) systems,
- Vehicle to vehicle (V-to-V) systems,
- Vehicle to grid (V-to-G) systems.

In these different configurations they can be very useful to control loads and DERs too, in an active working (Liu, et al., 2013), with all the benefits brought by distributed energy resources systems.

In V-to-H systems the GEV can, through a control scheme, withdraw or furnish energy to the home grid that is connected to.

In V-to-V systems the GEV, through a controller, distribute energy inside a little grid to be used in the charging of other GEVs. Generally this system works including the V-to-H systems and the GEVs' parking sites inside a local area, taking advance from several GEVs. The electricity exchange occurs between the homes and parking sites in a V-to-V system.

In V-to-G systems the GEV is linked to the power grid. In the same way, a V-to-G system includes many V-to-V systems, and it's possible to engage or not actively V-to-H and V-to-V systems.

Microgrids

A particular electricity system is nowadays represented by the micro-grid, a limited and geographically circumscribed cluster in which distributed energy resources (DERs) and micro generation systems can be easily integrated. Here are the main components of a micro-grid (fig. 9):

- Electricity generation, generally distributed generation technologies (DG);
- Energy storage systems;
- Distribution systems;
- Communication and control systems;
- Local loads, connected to the power generation at low voltage.

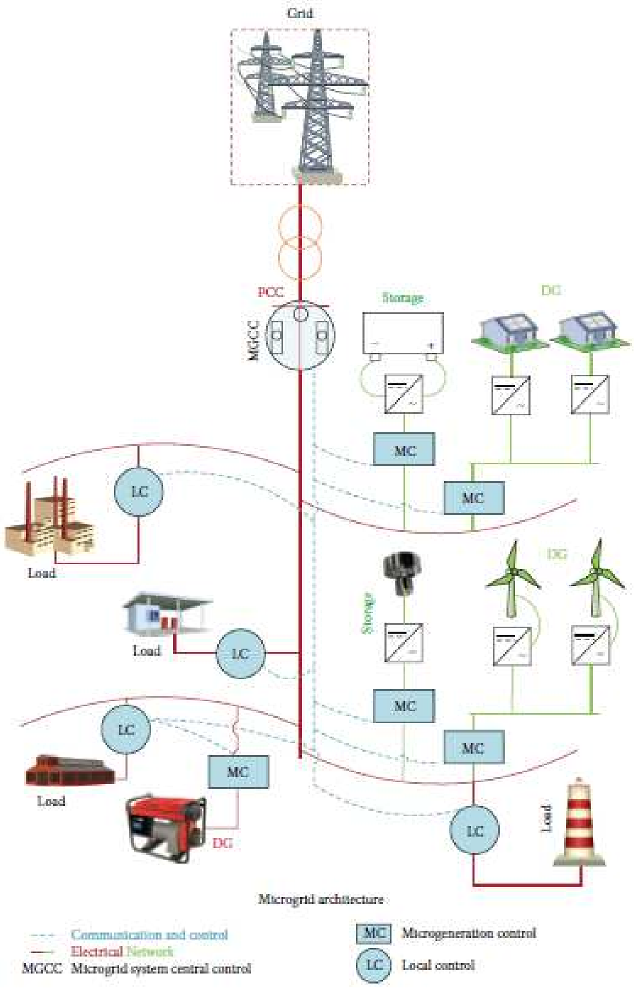


Figure 206: Micro-grid architecture scheme (Mariam, et al., 2013)

One of the main characteristics of the micro-grids is that they normally work connected to a macro-grid, that is to say a centralized grid, throughout power and information lines. The possibility to disconnect this point of communication and power transmission enables the micro-grid to work autonomously. That is the reason we recognize two different configurations in micro-grids:

- Stand-alone configurations,
- Grid-connected configurations.

A grid-connected micro-grid can work with many benefits in a power system: in fact in a wider smart grid many micro-grids can be seen, such as single power generators, providing a single load.

Moreover, other benefits come from the users' point of view:

- supply power locally and without interruptions,
- improve power quality (PQ),
- decrease energy losses due to the distribution system,
- Voltage support.

Architecture of a smart microgrid

- Distributed generation sources: with DG sources we intend both the renewable and non-renewable sources: PV, wind turbines and micro-hydropower generation systems, internal combustion engines, gas turbine, CHP systems (combined heat and power systems) based on micro-turbines, Stirling and IC engines. Power quality issues are largely actual using renewable sources, headed to the local climate conditions, if the proper attention is not paid to the control and storage systems, but less power quality problems occur with micro-hydro generation systems. On the other hand, non-renewable distributed generation systems don't lead these issues, but they are pollutant.
- Storage systems: the RES generation systems are characterized by unpredictable power supply due to the weather conditions, and this brings problematic power fluctuations. In order to avoid issues on voltage and frequency stability, the micro-grids can be provided with special control power equipment, to ensure the power quality. These are commonly known as energy storage systems.

A micro-grid can or cannot take advantage of storage systems. In the Gaidouromandra micro-grid for example (fig. 10), the settlement of 12 houses in the Greek island of Kynthos is electrified with PV panels and a diesel generator. In a building in the middle of the settlement the battery inverter, the battery banks, and the diesel generator are installed (fig. 11).

Figure 207: Gaidouromandra Microgrid in Kythnos Island: general view (http://www.microgrids.eu/)

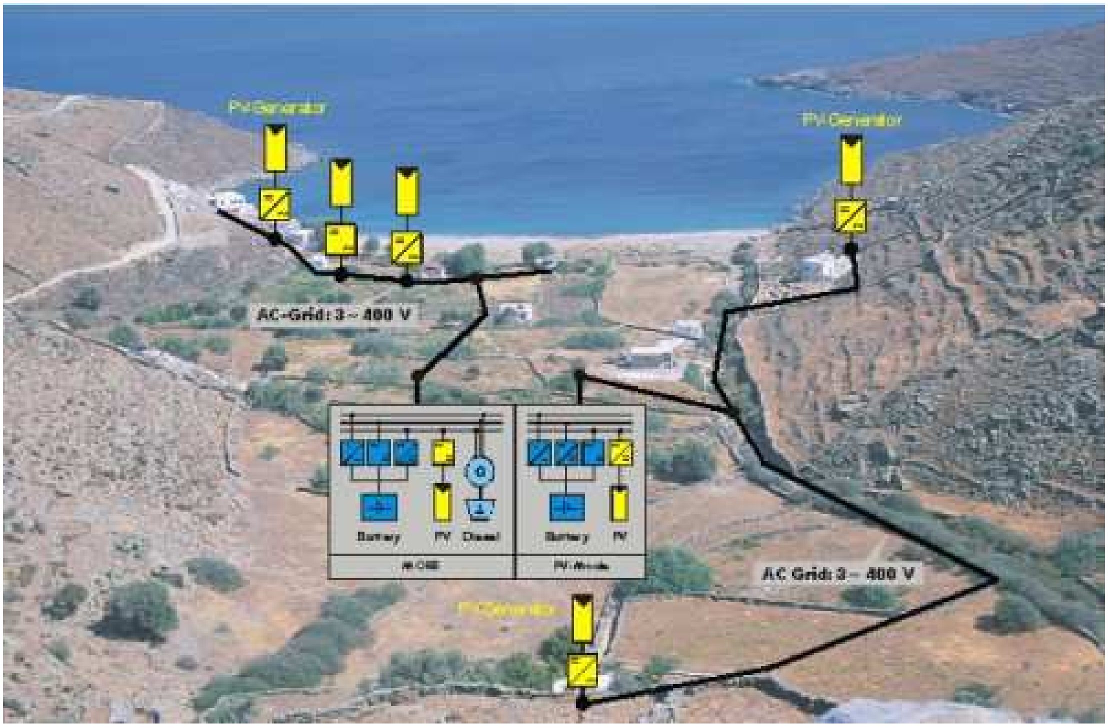


Figure 208: Gaidouromandra Microgrid in Kythnos Island: configuration scheme with storage

On the contrary, the Ramea island micro grid in Canada (fig. 12), applies wind generation system and diesel without any energy storage, providing energy for approximately 600 inhabitants. Here the wind power plant contains a load regulator and a digital control system allows the right integration with the remote grid (fig. 13).

Figure 209: NL Ramea Island wind-diesel hybrid micro-grid (http://news.cision.com)

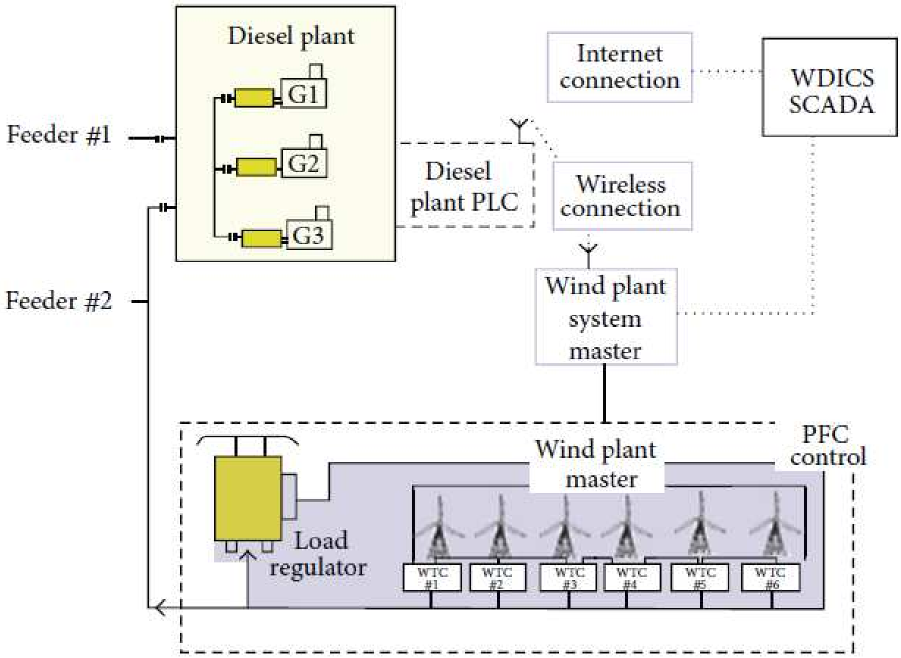


Figure 210: NL Ramea Island Microgrid: configuration scheme without storage (http://news.cision.com)

Generally the energy storage can be provided through:

- Fixed units (flywheel, electro-chemical, pumped hydro, super-capacitor and compressed air energy storage systems) and fuel cells (Mariam, et al., 2012; Tan, et al., 2013; Serban&Marinescu, 2013),
- Electric vehicles (Lopes, et al., 2011).

The main characteristics for suitable fixed storage devices in microgrids are resumed in the following table (fig. 14):

Characteristics	Battery	Flywheel	Supercapacitor
continuous power (W/kg)	50 - 100	200 - 500	500 - 2000
typical backup time	5 - 30 min	10 - 30 sec	10 - 30 sec
losses and standby	very low	variable	high
environmental impact	medium - High	low	low
maintenance	1/year	1/5 years	none
charging efficiency (%)	75 - 95	90	85 - 95
current energy price ($/kWh)	150 - 800	3000 - 4000	4000 - 5000
service life (year)	5	20	> 10

Figure 211: Main characteristics in storage systems in micro-grids (Mariam, et al., 2012)

- <u>Distribution network</u>: there are mainly three types of distribution systems:
- In the Direct Current (DC) distribution system the generating power devices with DC power outputs as well as the DC loads can be directly connected to the Low Voltage DC network. Otherwise they need AC/DC converters. The LVDC network is suitable as the most of the DERs produce DC power and because it is a reliable distribution system. The issue nowadays lies in the fact that many loads work in AC power (fig. 15).

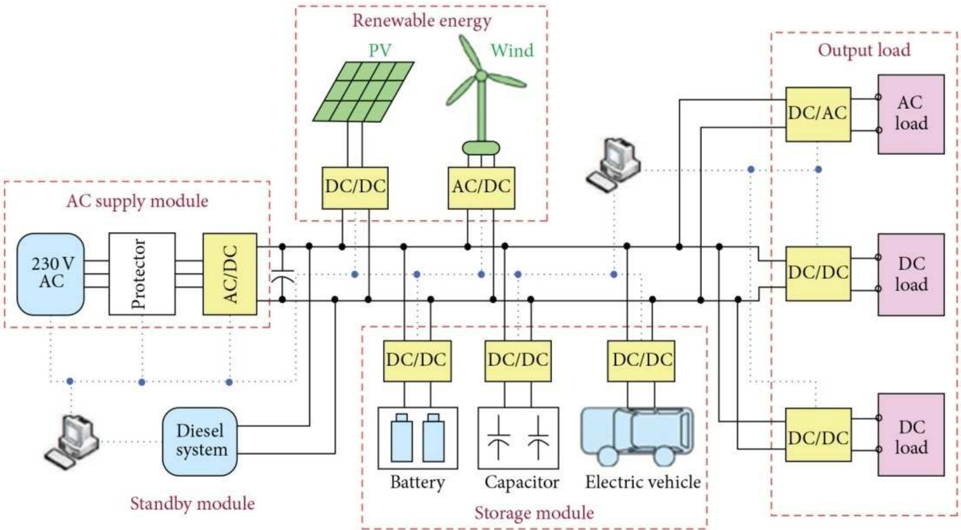


Figure 212: DC micro-grid configuration (Mariam, et al., 2013)

- Alternating Current (AC) distribution system: in this case a bus collects all the DERs and then a DC/AC inverter provides the transformation of the power in 50 Hz AC power. Finally the power is transmitted to the loads level (fig. 16).

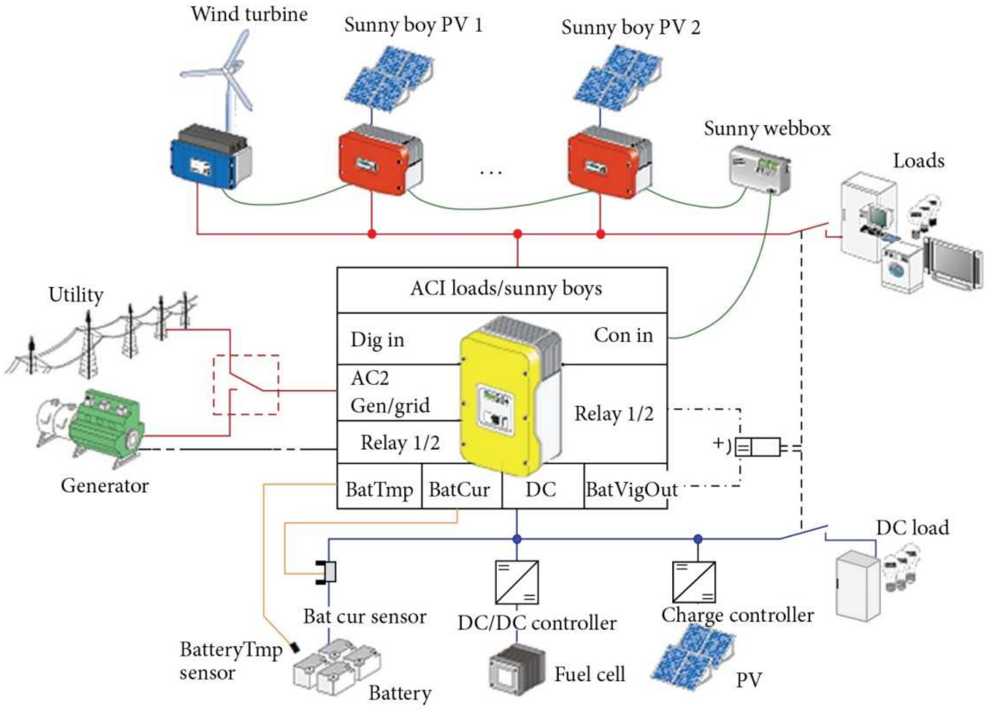


Figure 213: AC micro-grid configuration (Mariam, et al., 2013)

- High Frequency Alternating Current distribution system (HFAC): here instead the transformation to 50 Hz AC power occurs in the load level trough an AC/AC converter, after a previous transformation to 500 Hz AC power. In this way it is possible to ensure a proper connection with the micro-grid (Maria, et al., 2013), even if the risk of power loss may occur (Li, et al., 2011) (fig. 17).

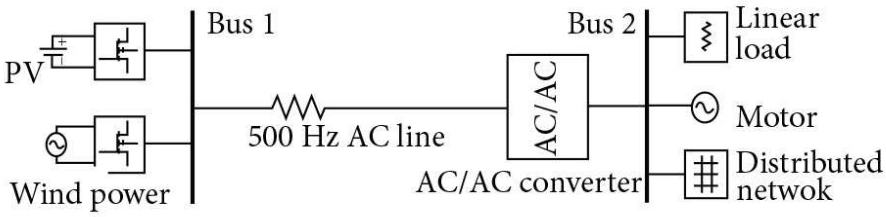


Figure 214: HFAC micro-grid scheme configuration (Mariam, et al., 2013)

- Communication systems: also in micro-grids, the communication systems are necessary for control and protection necessities, at all scales.

European technical standards committees in the EU

The European Community provides five different Technical Standard Committees for the design and implementation of smart grids:

- Smart metering coordination group (SM-CG);
- CENELEC TC 13 (Equipment for electrical energy measurement and load control);
- CEN TC 294 (Communication systems for meters and remote reading of meters);
- CENELEC TC 205 (Home and building electronic systems_HBES)
- ETSI M2M.

CONCLUSION

The aim of this handbook was to bring knowledge about the latest technologies and researches on the development of cities. Four main subjects have been developed. Each of them is focusing on a particular point, but all needed to be developed for their urban area, in an ecological, innovative and economical way.

A Sustainable Energy System is looking for any sources or renewable power, in order to develop a process without impacts on the future generation. Those sources are available and we still don't use them at their real potential level. The sun power seems to be an infinite source, but the construction of panels is not so ecological. Wind turbines can produce energy, have different shapes and productivity level, but also deteriorate the landscape and produce lots of noises. About marine or bio-fuel energy recovery, they are not developed enough to know their real impact on the future and have a limited application due to their constraint of production.

With Green Construction, people want to recreate the nature inside the city, increasing the quality of life and reducing all water issues in the same time. If green roofs and facades can improve the air quality of a city, keep water to avoid floods and can be integrated in any architectural project, they also have a high level of requirements and the upkeep needs to be done regularly. In order to avoid puddle and splash in the streets the use of permeable pavements can be used. But up keeping is a really huge issue and the necessity to switch the pavements make the process more expensive. Finally, sustainable urban drainage systems increase the green area places and avoid floods by taking a large area, which is already expensive and unusual.

Waste Management responds to the needs of the customers and tries to improve the way to do it. Regarding to each level of the Life Cycle Assessment of a material, the end of a products life still requires a lot of energy, which can be used to create new materials and decrease the amount of garbage. Starting with the users to the factory facilities, this report tries to develop all the existing technological breakthroughs, pointing out recycling effects and natural decomposition, but also advanced techniques like pyrolysis. But some waste requires lots of energy to be transformed and created unpleasant odours or lots of harmful gases.

ICT & Transport System looked for optimization of movement in the cities, by focusing on the development of public transports or different kinds of networks. Even if they are renewable and contribute to the diminution of the greenhouses gases, they require lots of facilities inside cities and are really difficult to apply to existent cities or to small cities.

As we have seen in this report, lots of advanced technologies are developed to approach the “Smart City” concept and optimize it, but one of the main point is still unknown: it is the human factor, representing an important part of future developments. No one knows if people are ready and willing to accept these new approaches for a better future world.

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