Outside the Box Portfolio

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The great challenges of the 21^{st} century

Through the portfolio, I will unfold the great challenges of the 21^{st} century, all related to climate change considerations and the modern society. I will develop various related subjects, such as energy and transport.

The importance of energy

There are two types of energy:

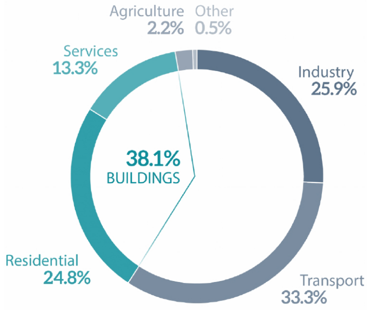
- Primary energy: The energy in its primal form, as is, when extracted from the earth. Oil barrels, uranium, wind, ...
- Final energy: Energy under the form used by a consumer: electricity, gas, diesel, ...

Today, the energy is inseparable from the modern society and lifestyle. It is the easily extractable oil that lead to the economic growth that build the modern living standards. Nowadays, almost everybody has access to powerful appliances that were almost unimaginable a century ago: microwaves, computers, radiators. . . . Power has been made accessible to almost everyone, at every moment.

Current enerrgy expenses

The access to energy has perhaps been too easy during the last century and today humankind is at risk of losing it. One must save energy, consume it wisely.
Buildings currently represent almost 40% of humankind's energy expenses.

Figure 1 – 2014 energy consumption by sector in the EU-28



Data source: Eurostat, 2014.

Energy in buildings

Moreover, most of the energy used in buildings is for space heating, as show the following figure:

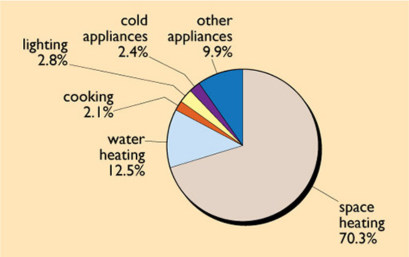


Figure: Energy consumption in the UK for domestic use

Reduce space heating demand

To reduce energy demand, one must first reduce the energy needed for a same result, which means optimising systems: reducing the amount of energy that goes to waste. One must tackle the problem of heat loss regarding buildings, there are three different ways for a building to lose its heat:

- Fabric heat loss: due to heat conduction by the materials that compose a building
- Ventilation loss: due to the air circulation between a building and outside.
- Flue heat loss: due to the heating system inefficiency.

Tackling the fabric heat loss issue

One can assign to every component of a building (say wall, ceiling, floor, windows) a U-value, which is the proportion of heat transmitted by the component regarding a certain temperature between inside and outside.
Which can be summed up by the formulation:

$$\phi = U(T_{\text{int}} - T_{\text{out}})$$

Where ϕ represents the heat power lost every second through the component which has a the U-value of U. The U-value is the inverse of the thermal resistance of the component: the higher the value, the higher the heat loss will be.

Reducing the U-value

There exists a way to reduce the U-value of a building component, which is insulation. There exists three ways for a material to transmit heat:

- Conduction: heat transmitted by contact.
- Convection: heat transmitted by being transported by a fluid (air, water)
- Radiation: heat which is transmitted by light (infrareds in this case)

There exists insulation technologies to hinder those factors. Honeycombed bricks, because air is a great **conduction** insulator, or polystyrene that can be placed between the outside wall and the inside plasterboard for instance.

Tackling ventilation loss

Ventilation is essential regarding the salubrity matter. Indeed, it allows to recycle the air, control its humidity and also reduce the chances of gaseous elements intoxication, for instance: carbon monoxide and dioxide that are produced by heating systems.
But in the case of uncontrolled ventilation, the heat loss can be tremendous as the warm air might be constantly replaced by the cold outside air, therefore making every aforementioned insulation effort useless.
Making buildings more airtight allows to reduce the ventilation heat loss.

Heating systems efficiency

Finally, the heat loss factor that can be tackled is related to heating systems efficiency. For instance, one might want to replace older heating technologies for now ones. For instance, gas boilers can be replaced by condensing gas boilers: water vapour, produced by the combustion reaction is condensed to retrieve the consequent amount of thermal energy that is released during this process, instead of just losing the potential heat by releasing the steam in the outside environment.

One can also use different technologies such as heat pumps, which only use electricity to produce heat in a very efficient way, this is particularly interesting in the case of a low-carbon electricity production.

Electric appliances, lighting

A last place of energy consumption, are the electric appliances and the lighting.
Regarding lighting the old tungsten filament lightbulbs are terribly inefficient as only 5% of the consumed electricity is transformed into light, the rest is pure heat loss. Today there exists compact fluorescent lights and LEDs which are very efficient regarding lighting.
Regarding electric appliances such as fridges, televisions, . . . , one can check before buying the mandatory energy rating of the appliance, to ensure good efficiency and low consumption of electricity.

Nuclear energy, the way to go ?

If, as suggested before, the use of heat pumps increases, power plants are needed to back up this electricity consumption.
From the perspective of reducing carbon emissions to match the objectives of the Paris Agreement, it is unimaginable to produce with carbon-emitting fossil fuel. One of the very efficient ways of producing a low-carbon electricity is the nuclear power plant.

Deep into the fundamentals

To fully understand nuclear power, one must focus on the deep functioning of matter, its description, its structure, its mechanisms. First, there will be a focus on the matter itself, the atoms and radioactivity. Then, we will describe the functioning of a power plant, and more specifically a nuclear power plant, the challenges and the risks they raise.
Finally, a small depiction of the possible future of nuclear energy will be given.

Atoms

Atoms are an elementary brick of the matter that compose the universe. They are the smallest components of matter the unique chemical properties. Those chemical properties are determined by the number of protons (a subatomic positively charged particle) that lays in the nucleus, along with neutrons at the center of the atom. The number of protons is called the atomic number and defines an element, and the number of particles in the nucleus (proton + neutrons) account for the mass number.

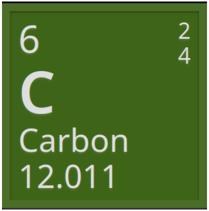


Figure: Carbon's atomic number is 6

Elements

Known elements are all sorted in the periodic table of the elements, introduced by Dmitri Ivanovitch Mendeleïev in 1869.

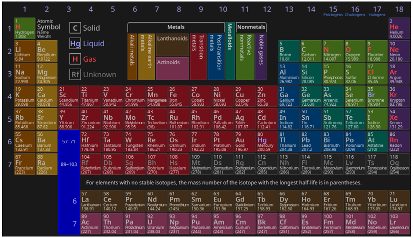


Figure: Current state of the periodic table of the elements.

Isotopes

But there is more, if an element corresponds to one and only one atomic number, it may exists several versions of this element with different mass numbers, with the only difference of the neutron count. They are called isotopes.
Isotopes are everywhere in nature, in different proportions, they are referred as Element-Number of mass. For instance, the most widespread isotope of carbon is called Carbon-12, but another isotope: Carbon-14 is well-known and used in carbon dating.

Radioactivty

Isotopes can be unstable and thus randomly disintegrate into different elements with different mechanisms. That fact is called radioactivity.

Isotopes disintegrate at different rates, a classical metric to designate this disintegration rate is the half-life. It is the time period for an unstable element batch to lose half of its components. For instance, Carbon-14 has an half-life of 5730 years. Which means that a fossil containing 1000 atoms of Carbon-14, will roughly have only 500 atoms of Carbon-14 left by the year 7754.

Nuclear fission

Some of the isotopes of heavy elements (like uranium and plutonium) undergo nuclear fission they are unstable isotopes which split into two smaller atoms when disintegrating. They also emit several neutrons that can be captured by other atoms nearby and then make those unstable which will also undergo nuclear fission and so on, starting a chain reaction.

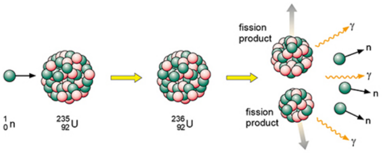


Figure: The example of the fission of Uranium-235

How does a nuclear power-plant work ? I

In the process of fission, an atom loses mass, which is turned into huge amounts of thermal energy, described by the famous Einstein equation:

$$E = mc^2$$

If uncontrolled, the chain reaction basically turns the fissile combustible into a nuclear bomb. In a nuclear reactor, one can control the chain reaction, making it self-sustained but not explosive, to take advantage of the released energy.
A nuclear power plant basically works as any heat powered power plant (like coal or gas-powered). The combustible heats water, which will go through a turbine with high pressure, thus creating rotation: i.e kinetic energy for an alternator producing electric current.

How does a nuclear power-plant work ? II

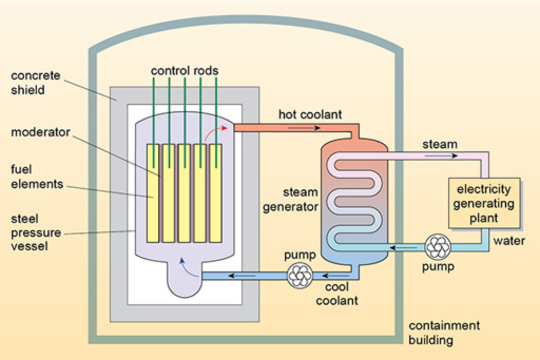


Figure: Simplified diagram of a nuclear power plant.

Famous nuclear acccients

Nuclear plants obviously brings the famous nuclear accidents in mind, which are undoubtedly Chernobyl and Fukushima-Daiichi. There are common misconceptions about those accidents. In the case of Chernobyl, only 30 persons died directly from radiation (mostly the firefighters that fought the open-core fire at the beginning of the catastrophe) and 4000 were exposed to substantial radiation doses. In the case Fukushima, 6 people have been exposed to substantial doses of radiation, and the average dose received by a Fukushima-Daiichi nuclear worker during the accident was equivalent to th dose delivered by an abdominal X-ray scanner. No significant increases in cancer numbers have been observed in 10 years in the surroundings.
As a matter of fact, in Europe, coal-fueled power plants alone are estimated to have caused around 23 000 premature deaths during 2013.

Nuclear energy safety

Chernobyl and Fukushima accidents are considered as the worst nuclear accidents that ever happens and rated level 7 on the INES scale.

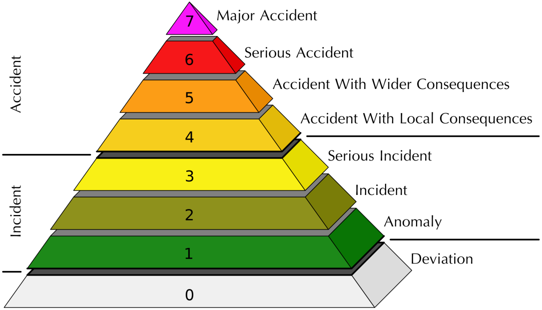


Figure: International Nuclear and Radiological Event Scale (INES)

What about nuclear waste ?

The question of nuclear energy safety undoubtedly raises the question of nuclear waste.
Nuclear fuel, once used, lays behind radioactive components, some of them can be recycled and transmuted into new fuel to use in other types of reactors. Once the nuclear fuel potential of an element has been fully depleted it remains nuclear waste, that stay radioactive for thousands of years and is potentially dangerous for human health if people are exposed. Nowadays, the best solution found is geological storage, which involves vitrification of the high-energy nuclear waste and burying in geologically stable sites.

Is it still relevant ? I

One can ask if nuclear energy, a 70-year old technology is still relevant to take up the climate change and energy transition challenge.

Nuclear energy fits the low-carbon electricity challenge as the only carbon emitted during the life cycle of a nuclear plant is the carbon energy needed to build concrete buildings, which makes nuclear electricity virtually zero-carbon.

Is it still relevant ? II

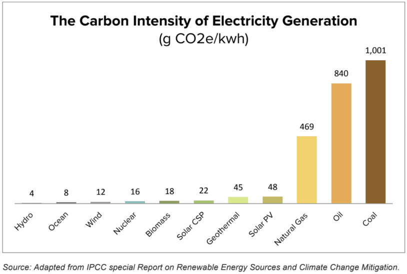


Figure: Carbon equivalent emissions per kWh of electricity for different production means

Nuclear fusion I

Another future perspective for nuclear energy is nuclear fusion. Although it is far from being accomplished yet. The idea is quite the inverse of nuclear fission. In this case, isotopes of light elements, deuterium and tritium (hydrogen isotopes) are fused to make heavier elements, that are lighter than the sum of the masses of fused elements, which means some mass has been converted to energy.

The energy released by fusion of light elements is substantially greater than the energy released by fission which makes nuclear fusion very interesting along with the fact it does not produce long-lived nuclear waste, but mostly helium, an inert gas.

Nuclear fusion II

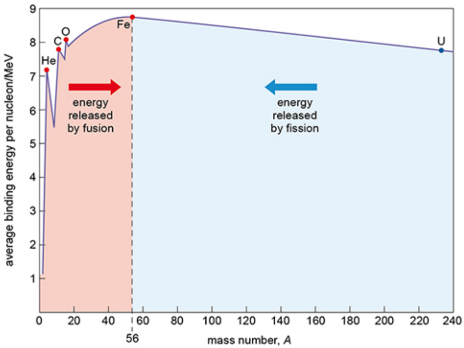


Figure: Energy released by fusion or fission of elements

title

Origins of the passport

Our relationship to passports