Bio-S-TEAM, SAS
87, rue du Président Salvador Allende – 92700 Colombes – Email: *info@bio-s-team.com*
SIRET: 820 809 705 00016 RCS Nanterre

LFree: a project to optimize energy efficiency related to the electricity production from renewable sources and reducing the losses on line

Introduction

A volume of electricity produced cannot be routed to the final consumer without loss. The bulk of these losses is related to the passage of the electric current in the conductive materials which oppose a resistance: This causes a loss of energy which results in a heat release. This phenomenon is called the Joule effect.

With equal delivered power, the higher the voltage and the reduced intensity, the lower the line losses (proportional to the square of the intensity). The current flows over the high and very high voltage power lines on the French power transmission system (63 000 to 400 000 volts). Apart from the large industrial consumers, directly connected to the electrical transmission system, the voltage is reduced on the distribution networks and therefore the losses are more important. On these different networks, the alternating current is used partly for this reason: it allows to raise the tensions, to reduce the intensities thus to limit the losses.

On the electricity transmission system, the French manager (RTE) declares a loss rate between 2% and 2.2% since 2007. On distribution networks, the ERDF Manager (which operates close to 95% of these networks) announces that the total losses amount to almost 6% of the energy transported (20 TWh/yr).

By including the auto consumption of processing stations and the so-called "non-technical" losses (fraud, human error, etc.), losses of electricity in France between the place of production and consumption adjacent 10% on average.

Losses on the power grid

Final energy and primary energy are two concepts not to be confused. The final energy is the amount of energy distributed to the user who is counted to his meter when it comes to electricity or gas and when the latter is connected to a general electricity distribution network.

Primary energy is the amount of energy consumed upstream to provide the final energy. The primary energy corresponds to the real energy consumption of the country, contrary to the final energy. The electrical sector is currently destabilised, because electricity in primary energy ranks very poorly. In fact, it takes 2.58 kwh to provide 1 kwh to the user, due to the low performance of nuclear power plants and significant online losses. Thus, when a final consumption of 100 kwh is translated into primary energy, it remains 100 kwh in the case of gas or oil, but it must be multiplied by 2.58 for electricity.

It is important to note that power plant efficiencies depend on the technology used. Moreover, contrary to an idea received, all fossil fuels do not emit greenhouse gases (GHGs): This is the case with nuclear energy.

1.1 Nuclear power plants

According to Bernard Laponche, a nuclear power plant is "the most dangerous way to boil water". A nuclear power plant heats water under constant pressure to produce steam generating electricity in turn through a turbo alternator. (A nuclear reactor produces steam at high temperatures to operate the steam engine of Denis Papin).

The electrical system measures energy at different levels, in particular:

- The energy billed to the final consumer.
- The energy injected onto the grid by a power plant.
- The raw energy of the power generation plant.

The difference between the energies measured at the input and output quantifies the losses in the system:

- In the control unit to the high voltage transformer.
- In the high voltage transport to the medium voltage transformer.
- In the distribution channels.
- consumer.

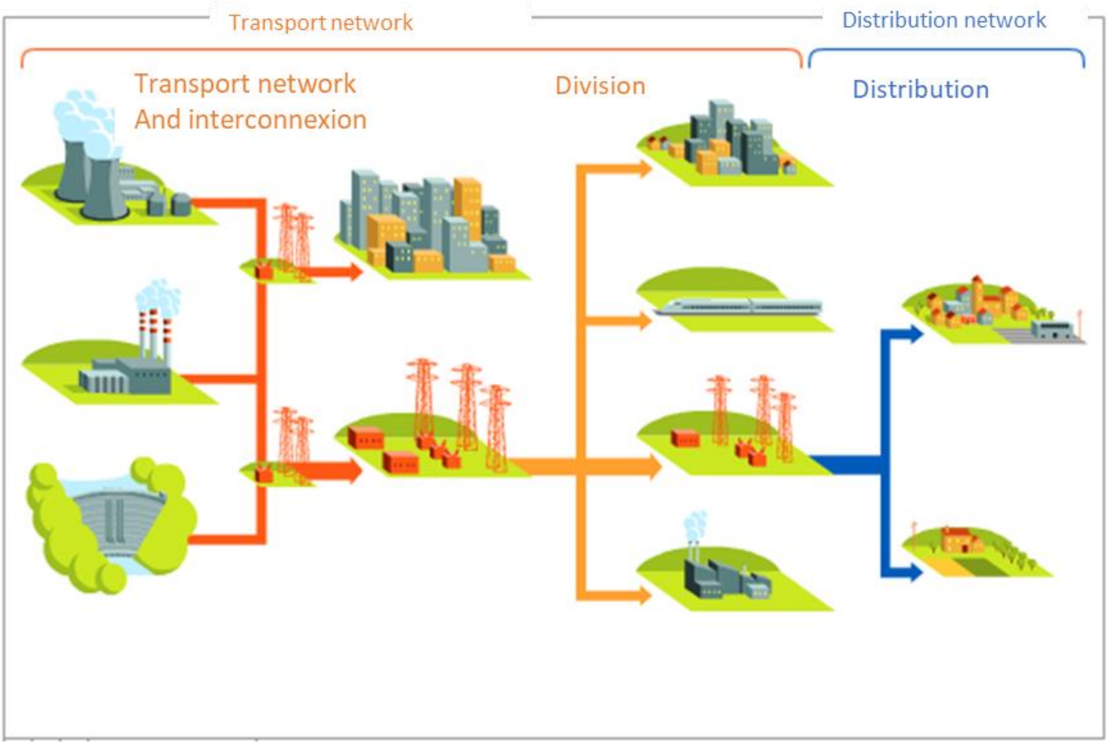


Figure 1: Transmission (high voltage) and distribution (medium voltage) and dispensing (low voltage) network of the power grid.

Network losses — by Joule effect — vary with consumption and distance to be travelled: a very high voltage line (THT) loses 50% of its energy every 1 500 kilometers.

The losses on all networks in France, (32 TWh in 2007), are measured by the difference between the energy injected on the network and the energy delivered to the meter and invoiced. These losses included in official statistics, in the order of 6% in France, do not include electrical loss at the plant level. This discrepancy arises from the discrepancy between the gross production including the operation of the auxiliaries (primary and secondary pumps, transformers, internal uses, etc.), and the net output of the Transformers of the power plants. The latter figure appears in the production statistics (Source: Electrical energy in France, RTE 2007).

Since the Chernobyl and then Fukushima accidents, the generation of electricity by nuclear power plants is perceived as a danger by the populations and the long-term consequences are unmanageable from the environmental point of view.

1.2 Nature of losses on the power grid

it is necessary to distinguish between the peak consumption which is an episodic and strong consumption of electricity and the basic consumption. Peak consumption is opposed to basic consumption which is a constant consumption throughout the year. Local losses may exceed 10%. These uses entail an expenditure equivalent to approximately EUR 600 million per annum which can be considered as financial support for the forms of electric heating.

Network losses may be limited by improving:

• average and low-voltage losses, e.g. in power supply wires or transformers (newer technologies may be useful in limiting these losses). This part of the network's losses is linked to the seasonality of consumption, so when a rural network is demanded in winter by peak consumptions — such as electric heating — that saturate the network and lead to reinforcements paid by the Local taxes and taxation on urban consumers.

• By abandoning or limiting the electric heating, it is possible to limit the winter loss and a share of the network building expenses. The energy gain can then be considered proportional to the decrease of the advanced electric heating.

• All the actions carried out on the use of uses and in particular that of electric heating.

• Injection into the network of alternative sources of energy. These alternative sources of energy whose profits in terms of distribution of the electricity supply are demonstrated without any doubt.

• Adoption of recent optimized technologies (advanced transformers, optimized systems, refurbishing of transformers and equipment). These very high voltage losses remain limited on average to 2% of the total product (2.09% in 2006 RTE source). The amount of electrical loss will tend to decrease if the average transport distances decrease (less centralized system). Gradual replacement of Transformers by thrifty Transformers could improve yields.

Transmission losses account for 55% in power stations. It is also possible to improve energy losses during electricity production by combining several technologies that allow to recycle waste heat and to hybridize several technologies to optimize performance and storage energy. It is the spirit of the LFree project that combines electricity production via local renewable energy, optimization of electricity production through optimized fossil energy conversion and its share through a smart grid) Smart grid).

1.3 The impact of a centralized production system on the environment

A centralized production system has several disadvantages in relation to a local production and distribution. In terms of impact, it is possible to draw up a list of the impact on the environment:

- For the energy cost of building a plant.
- For the maintenance of the plant that produces it.

- Due to the transport and distribution of this energy.
- On health for releases (CO2 and toxic substances).
- For the treatment of the ultimate waste products.

• During the dismantling and recycling of the production plants at the end of their life.

1.4 The future of electricity prices

The medium-term trend is the rise in electricity tariffs. Prices will have to be harmonised to allow competition. With higher costs and increased demand, the price of electricity is expected to continue to rise over the next few years.

Between 2000 and 2006, the price of natural gas was multiplied by 7, such as uranium, and the tonne of coal doubled. The rise in the price of a barrel of oil has a real impact on the tariffs of other energies. When electricity production is provided by nationalized producers, the state prevented prices from rising too quickly by regulating and subsidizing directly the markets.

This position can only be temporary, because a private company cannot produce indefinitely at a loss and a state can no longer finance the electricity Bill of its taxpayers which is heavier from year to year.

1.5 Criticism of the primary energy balance the conversion of electricity in ton of oil equivalent carried out by the Energy Observatory, a French body responsible for drawing up the energy statistics of France, was based on principles Different from the international accounting used by Europe or the IEA. Since 2000, the primary energy balance has given more importance to electricity of nuclear origin, this balance gives excellent results in front of oil and other sources (natural gas, hydraulics...).

The Convention adopted at the international level is currently evaluating the amount of fossil fuels (in toe) that would have been necessary to obtain the same amount of electricity if the fuel had been used, but with the performance of the Sector. It yields artificially high results concerning the share reserved for the sectors with the worst yields in the balance sheets.

The consequences of these changes on the balance sheets are important:

- Total primary energy consumption varies little from one balance sheet to another.
- The final energy consumption is substantially reduced by about 25%.
- The consumption of the Energy producers ' branch is multiplied by 3 or 4.

It is therefore important to warn observers and readers of economic statistics against the dangers of a mixture of the two accounts.

While the palm of yield returns to hydroelectricity that causes significant environmental consequences at the local level, the generation of electricity by converting renewable energies is problematic because highly variable over time or in space while the need remains relatively constant. Optimisation of the use of renewable energy in the energy mix takes 2 complementary dimensions:

1 Optimizing the efficiency of energy production
2 Optimization of energy storage

2. Optimizing the efficiency of energy production

The significant variability of renewable energies and their use in the production of electricity is the main problem to ensure the balance of the distribution network. The LFree project allows local optimization of the means of electricity production to meet the demand of the electrical distribution network at any time. To understand the logic of distribution of electrical energy, just look at his bill. The price of electricity for individuals is made up of production costs, routing costs and taxes.

2.1 The cost of generating electricity

Production costs refer to the costs associated with the production of electricity (in nuclear power plants by other sources). 75% of electricity production in France is of nuclear origin and comes from EDF power plants. Since December 2010, the NOME law has introduced the ARENH device, "regulated access to nuclear electricity", so that alternative suppliers can obtain electricity at a regulated price (42 €/MWh in 2018). It is less and less popular, since the volume of ARENH subscribed for the first half of 2015 was 12.4 TWh (of which 5.3 TWh for losses), compared with 36.8 TWh (of which 5.9 TWh for losses) in the first half of 2015. This is particularly due to the termination of the framework agreement by four suppliers in 2015. At the price of the ARENH are added the costs generated by the production of electricity during peak periods, including the guarantee of capacity.

Suppliers can also buy electricity on the wholesale market (ELIX), the price of MWh is around €42 in 2018. However, unlike the ARENH, the price of electricity in France and Europe can vary greatly from one day to the next, or even from one hour to the next.

2.2 The cost of electricity transmission

The routing costs support the cost of transmission of electricity via the transport networks (high voltage network) and distribution network (medium and Low voltage network). RTE (electricity transmission network) takes care of the long-distance transmission, while ENEDIS (ex ERDF) takes care of the distribution network on 95% of the territory, the remaining 5% being managed by the private distributors (DNN).

The costs are financed by the TURPE, the tariff for the use of public electricity networks, paid by the customer either indirectly via the electricity bill (for small consumers) or directly to the network manager in the case of a Direct contact with the network manager (large consumers in general).

The TURPE for individuals includes:

1. Management component: Covers the management of records, billing. The price of this component is fixed and depends on the connection power. €6.96 for a single contract, €12.96 for the distribution network access contract.
2. Counting component: Maintenance costs, meter reading and rental. The price of this component is fixed and depends on the ownership of the meter: €19.80 for the organizing authorities of the energy distribution (clear majority of cases); and €9.36 if it is owned by users.
3. Filling component: Depends on the subscribed power and the customer's rate option.

2.3 Taxes on the price of electricity

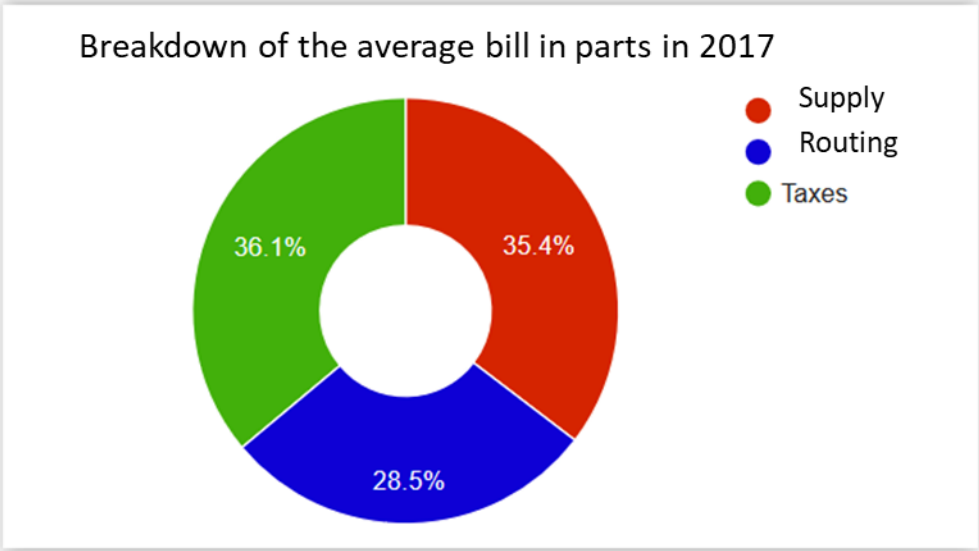
The taxes on the price of electricity for individuals are four:

• CSPE or contribution to the utility of electricity: finances the development of renewable energies, the tariff equalization and the basic necessity tariff. In 2017, its cost is 22.5 €/MWh.

• VAT: 20% on the price of the kWh and 5.5% on the subscription.

• The TCFE or tax on final consumption of electricity is a local tax paid to municipalities and departments. It is capped at 9.6 €/MWh in 2017.

• CTA or Routing rate contribution: 27.04% of the fixed share of the TURPE. It allows the financing of the specific rights relating to the old age insurance of employees of the electric and gas industries.



<u>Figure 2:</u> Composition of the electricity price in France

The increase in demography necessarily implies an increase in demand for electricity and therefore the unprecedented development of the power grid. This stimulates the rural exodus and the LFree project aims to curb this trend by proposing local solutions that provide access to energy and safe drinking water outside a general distribution network.

3. Advantage of LFree Technology

The LFree technology aims to produce electricity locally low voltage for the consumer using a mix energy based on improving the performance of power generation related to the use of renewable energy, the maximization of its storage and optimization of electricity production from fossil energy to ensure a continuous electricity access.

3.1 the continuity of power running electric

The hybridization of the technologies of the past related to the production of steam with innovative technologies to ensure a permanent electricity, without power failure.

The optimization of the production of renewable energy in relation to the improvement of the combustion of fossil energy techniques allows to maximize performance to reduce both the production of greenhouse gases and energy consumption fossil.

The device is used and sized for a home regardless of the weather in the intertropical zone. The inclination of the Sun in temperate zone makes its usage more difficult (Figure 3).

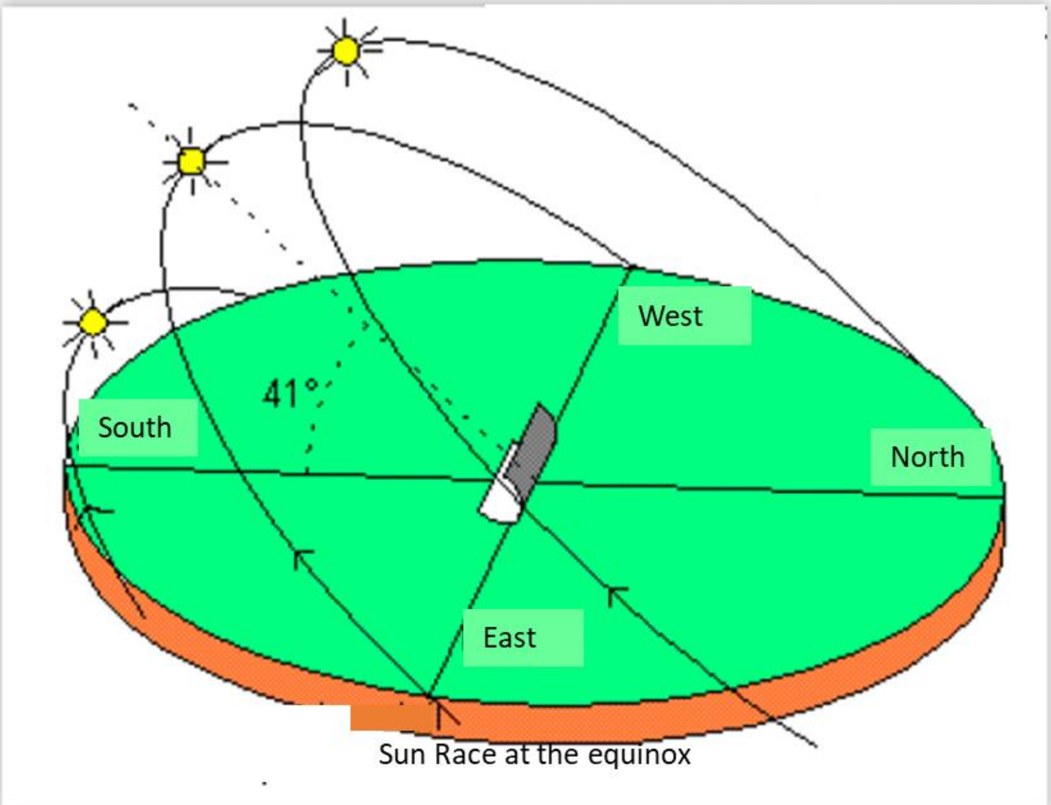


Figure 3: Hybridization of mastered technologies with innovative technologies for the LFree project

3.2 Improved performance related to the use of renewable energy

Improving the performance related to the use of renewable energy through the development of a disruptive technology to the level of the solar concentrator. This development is based on:

(1) perform better surface for the capture of solar energy. The use of the linear Fresnel refraction to reduce the collector area of solar radiation for a better focus of solar energy.
(2) the concentrated solar power optimization can be achieved by reduction of the cosine effect.

When the solar flux gets on a flat surface, that either a mirror or a flat receiver, it extends more or less depending on the angle of incidence, and at the same time it loses its intensity. When the impact is close to normal, the cosine effect is almost negligible, but at low angles of incidence, it becomes insurmountable.

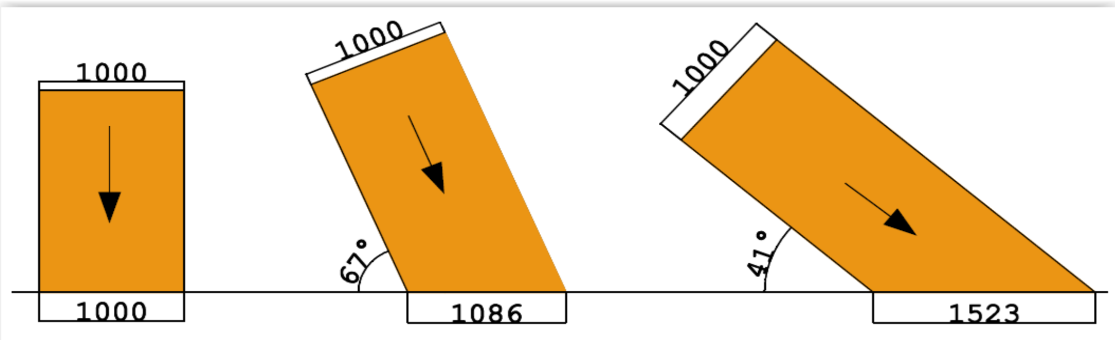


Figure 4: Cosine Effect on a flat receiver

For the convenience of the reasoning, we could distinguish two effects cosine:

-the first is due to the movement of the Sun from East to West during the day;

-the second is due to the change in height of the Sun in the sky during the day and the seasons.

A flat receiver is subject to two effects cosine above, which are combined. During the day, the sun rises in the East and sets in the West. It is therefore a variable cosine of morning (prohibitive to the Sun) noon and effect variable cosine of lunch in the evening (insurmountable late in the day).

A "Fresnel refractor" oriented East-West suffered some effect cosine in addition to the East-West effect, because the mirrors are only very rarely perpendicular to the incident solar rays. "

Perpendicular to mirrors, or their axial plan in the case of mirrors hangers, forms an angle which varies constantly with the incident rays. In the case of a flat linear refractor oriented East-West, as is the case for the Fresnel sensor that interests us here, so we could distinguish the effect of longitudinal cosine parallel to the centreline of the receiver and to the apparent movement of the Sun from the East to West, and the transverse perpendicular to mirrors cosine effect, of a change in height of the Sun in the sky. Both effects are combined, the total cosine effect being the product of the longitudinal cosine multiplied by the cosine transverse effect.

THE REFLECTIVITY OF THE MIRRORS

The reflectivity of the mirrors is never equal to 100%, it varies a lot according to two factors

-the quality of the mirrors; a good mirror polished aluminum has a reflectivity of 90 to 95%

-the angle of incidence under which manages the radiation. Provided by the manufacturers of mirrors reflectivity values are generally valid for angles of incidence near normal; but when the angle of incidence is low, the qualities of reflectivity decreases very quickly, including the specularity of the reflected radiation, which is very unfortunate when the mirror is to focus the radiation it receives. The default of reflectivity of the mirrors just amplify the cosine effect.

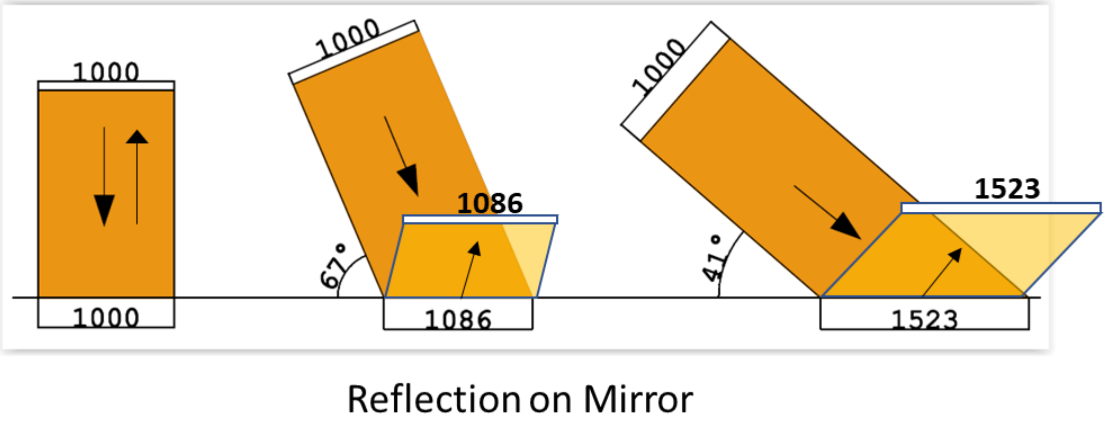
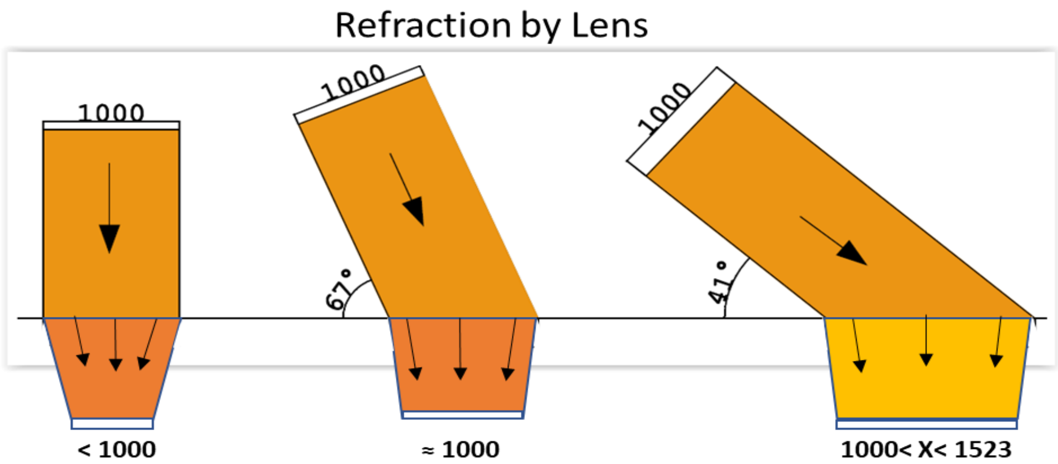


Figure 5: Effect cosine with the reflection of the mirror

Linear Fresnel reflection allows concentration of solar flux that still involves a loss related to the angle of reflection (cosine effect) in the PFD reflected the energy received. This loss can be accentuated by a lower quality of the mirrors (specularity) and cosine effect.

THE REFRACTIVITY OF THE LENSES



<u>Figure 6:</u> Removal or mitigation of the cosine in case of refraction effect

NB: these diagrams show only the general principle. It shows only the concentrative effect of refraction so the direction of the light rays change resulting from the refraction effect. However, the graphic representation is not rigorous, because it considers the exact angle of refraction related to the specific wavelength of every ray of light.

Although the refraction causes a loss of intensity linked to the phenomenon of diffusion and dispersion in the middle of the crossing, the light refraction allows the final for superior refracted light power simply because of the removal of the effect of cosine which applies to the reflection but that is corrected by to refraction. Thus, LFree technology aims to remove the cosine due to the East-West displacement of the Sun and reduce the effect cosine due to the variation of the height of the Sun in the sky during the day to allow an increase in concentrative power while that it reduced the surface of solar collectors to allow individual use of the concentrated solar technology (CSP).

3.3 Optimization of fossil energy production

Electricity production invariably goes through a conversion of energy summed up by the following figure:

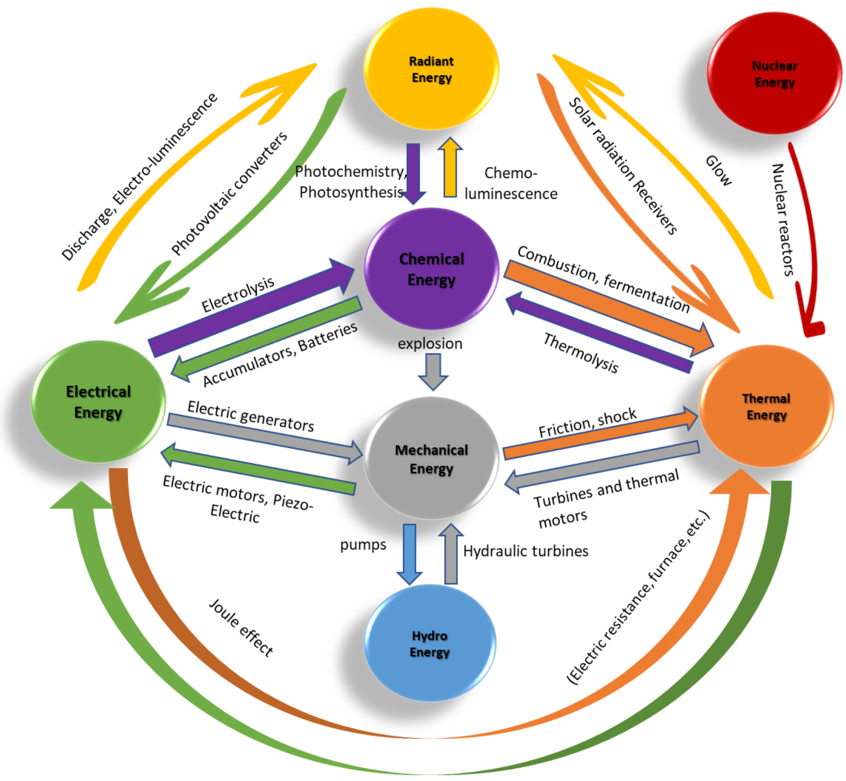


Figure 7: All of the conversions of energy known to date

The renewable energy disadvantage is their high variability in time and space that do not allow to make keystone of electric production for Consumer Staples for a country.

Direct to get electricity energy conversions are from the radiant energy (photovoltaic effect), whose performance (5 to 17%) is very sensitive to room temperature so little adapted to tropical countries, or from energy thermal. The direct conversion into electricity from thermal energy is done by the Seebeck effect. In practice, the Seebeck effect is, at the present time, not interesting from an energy point of view. The tensions involved being very low (on the order of a few µV per ° C of gap), the amount of thermal energy converted into electrical energy is very low. Therefore, it must pass through an intermediate energy (mechanical energy or chemical energy) to efficiently convert thermal energy into electrical energy.

LFree project strategy is to optimize the conversion of intermediate energy (thermal, mechanical and chemical) to increase overall performance. This necessarily requires an improvement in the conversion of chemical energy into mechanical energy and better use of waste heat (thermal energy). Several patent applications are being considered for the LFree project to protect the social and solidarity economy actors.

3.4 the optimization of the conversion of fossil energy into electrical energy efficiency

The major drawback to the use of fossil fuels for electricity production is the production of greenhouse gases greenhouse, responsible for global warming, and fine particles, responsible for air pollution related to the unburned. This production of fine particles is mainly due to the use of fuel oil and diesel.

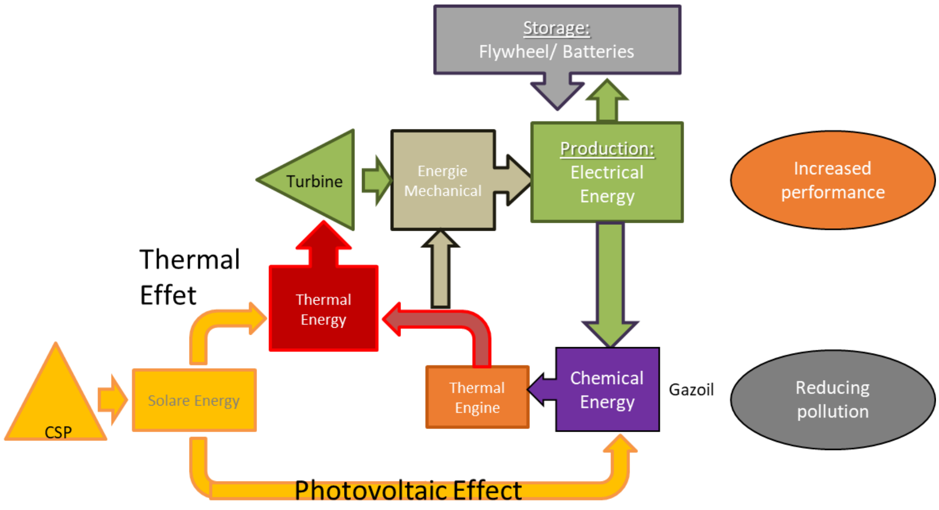


Figure 8: The hybridization of technologies mastered with innovative technologies to increase efficiency of electric production of LFree project.

The solar concentration (CPC) to produce the steam required for the functioning of a micro whose performance of electricity production is higher than that of the photovoltaic panels. Photovoltaic solar energy is the electricity produced by transforming a part of solar radiation by means of a photovoltaic cell. Schematically, a photon of light incident allows under certain circumstances to move an electron, thus producing an electric current.

Photovoltaic cells are manufactured with semiconductor materials mainly produced from Silicon. These materials emit electrons when they are subjected to the action of light. These are ejected material and they circulate in a closed circuit, generating electricity. The influence of light intensity on the efficiency of the photovoltaic panel is low because the intensity of light increases the efficiency of photovoltaic cells. On the other hand, the increase in the temperature of the Panel (consisting mainly of semiconductor) reduced its effectiveness.

Over the past ten years, the average yield of a photovoltaic panel herbal Silicon rose from 12% to 17% and the advent of photovoltaics concentrate allows a maximum theoretical performance of the photon-electron in the order of 85% conversion (the performance of Carnot is 95%). Maximum experimental performance with this technology is for the moment of 44 to 46% according to a recent study (Dimroth, 2014). Is it that the use of photovoltaic panel in the tropics is unsuitable because of the higher ambient temperature.

Conclusions

Beyond the technology that allows a return to acceptable electric production in the face of the increase in the population, there are several strategies to facilitate the development of electric networks in areas of strong rurality. The development of photovoltaic panels (related or not to the electricity distribution network) was big success in recent years but the efficiency of this technology is based on conditions of sunshine and room temperature optimal. Indeed, the efficiency of the photovoltaic effect is reduced when the temperature of the Panel increases, which is the case in the tropics. This technology is so ill-suited to tropical countries for several reasons, among which, a too high ambient temperatures, which reduces its effectiveness and an issue of end of life treatment (related to the cadmium used in the welds tellurium and that is extremely toxic). To optimize energy production and reduce losses, there is now the ability to hybridize several technologies and build smart microgrids of electricity and drinking water. It is the goal of the project LFree: hybridization of technologies well mastered but polluting with technology clean and innovative for greater efficiency.

Fossil fuels	Electric production technology	Yield
	Nuclear Power plant	33 %
	Fossil fuel power plants	40 %
	Co-generation (gaz)	61 %
Renewable energy	Hydroelectricity	70 – 85 %
	Wind turbine	variable
	Solar thermic energy	30 – 40 %
	Photovoltaic pannels	6 – 46 %
Hybridization	LFree	60 – 80 %

Table 1: The different power generation technologies and their performance

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