# A NEW ELECTRICAL REVOLUTION
## FOR DECARBONIZATION

think SMARTGRIDS

FRENCH SOLUTIONS FOR SMARTGRIDS

# EXECUTIVE SUMMARY

While emissions from fossil fuel combustion and industrial processes account for nearly 85% of $CO_2$ emissions worldwide, the electrification of energy uses is one of the main levers for achieving carbon neutrality. Even with the application of strong measures for energy savings and efficiency, electricity production will have to increase significantly, via decarbonized production methods (nuclear and renewable). This observation is unanimously shared by the IPCC, the International Energy Agency (IEA) and the European Union, as well as by RTE and Enedis, which are counting on a growth of at least 30% in French electricity consumption by 2050. The "electrification of uses" will above all concern the three main sectors that emit greenhouse gases, namely transport (around 30% of emissions), buildings (23%) and industry (25%).

But a "new electricity revolution" is absolutely vital and its success depends on a coherent articulation between the deployment of intermittent renewable energies and the growing electrification of uses. To allow the electricity system to integrate massively and at the best cost both these decarbonized renewable productions and the new uses of electricity, the deployment of new energy and digital technologies is crucial. These technologies will allow finer management and optimization of electricity flows, which are needed to guarantee the "flexibility" necessary for the proper functioning of the electricity system. This electrical revolution to decarbonize our energy mix will be associated with multiple positive externalities, such as the improvement of living conditions for Europeans, the creation of jobs in our industries, the reduction of energy expenditure by households and businesses, and finally, France's energy independence.

## KEY RECOMMENDATIONS

For both residential and tertiary **buildings**, the main recommendation is to finance the deployment of heat pumps, which can greatly increase energy efficiency while replacing fossil fuels. Heat pumps and solar thermal energy also offer interesting prospects for decarbonization in the agricultural sector.

For the **transport** sector, while the EU has set the objective of ending the use of thermal vehicles by 2035, the impact on the electricity network must be considered, in particular by developing the smart control of vehicle charging. An ambitious strategy to increase the lifespan of batteries, and to improve battery recycling, must be developed to prevent the risk of unavailability of materials.

For **industry**, the priority is the electrification of thermal and other fossil fuel processes wherever possible. Another important recommendation is to support the development of hydrogen production through water electrolysis and innovation in breakthrough technologies such as waste heat recovery.

With the development of intermittent renewable energies on the one hand, and the electrification of uses on the other, guaranteeing the proper functioning of the electrical system is becoming increasingly complex. It is thus necessary **to widely deploy digital tools** that allow real-time modulation of electricity production and consumption, and provide the flexibility needed to guarantee the stability of the network. Issues of standardization, interoperability of the solutions deployed and support for innovation will have to be considered. Market rules will have to favor the exploitation of flexibility sources.

Renewable energies and electric vehicle charging stations are connected to the grid using **power electronics**. The growing coexistence of this technology with alternative current networks will require major R&D efforts and better coordination of academic and industrial players in the development of new components and dedicated converter manufacturing processes, in order to find large-scale technological solutions to the challenges involved.

**Investing in the research and development of new smart grid solutions and in all the components of the electricity networks** will be essential to guarantee a real time supply-demand balance, network stability, and to preserve the quality of supply. In particular, it will be necessary to rely on innovative digital technologies to enable the flexible management of electricity production and consumption, but also of storage and the electricity networks themselves. This flexibility is a necessary condition for the success of the energy transition.

# INTRODUCTION

Energy is at the heart of our modern societies, essential to our industries, our agriculture, our transport, our communications, our health, and comfort... Nature or geopolitics remind us from time to time how much we depend on it. Choosing the right energy in the right place has always been the challenge, in order to guarantee our supply according to a technical, economic and environmental optimum for the community.

Today, electrical energy represents about a quarter of the final energy consumed in France. At a time when $CO_2$ emissions are a major concern[1], we are increasingly turning to low-carbon electricity for our needs in the building and transport sectors, and in some industrial activities. This is known as the "electrification of uses". Numerous studies around the world agree on this trend and predict a "new electrical revolution", the scale of which may differ from country to country or continent to continent, but for which we must prepare now. Thus, the transformation of the electricity system that began in the early 2000s will be amplified and new "smart grid" solutions must be devised and deployed.

This document is the vision of the Think Smartgrids association, written under the direction of its Scientific Council, chaired by Nouredine Hadjsaid (Grenoble Alpes University).

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1. In France, the National Low-Carbon Strategy sets out the roadmap for achieving carbon neutrality by 2050

# ENERGY CONSUMPTION MUST DECREASE BUT THE PROPORTION OF ELECTRICITY IN THE ENERGY MIX WILL INCREASE

The need to moderate energy demand, which was first highlighted in the 1970s following the various oil crises, has been an essential part of energy policies in France, Europe, and the world for many years. This moderation - whether through energy savings or efficiency - is primarily a response to growing demographic and industrial pressure. Today, it appears to be an essential lever not only in the fight against global warming[1], but also to ensure the security of our energy supply, improve the health of populations and, more broadly, limit the overall environmental impact of human activities, by reducing the pollution linked to energy production methods.

However, even if long-term energy demand must decline to meet decarbonization targets[2], electricity is set to play an increasingly important role in energy policies. Its intrinsic energy performance and its production by decarbonized means make electricity the central pillar of current energy policies. The electrification of energy uses therefore appears to be a necessity and will result in increased electricity production requirements in the years to come, despite an overall decrease in energy demand. The third part of the IPCC's Sixth Assessment Report published in April 2022 strongly emphasizes the role of electrification among the mitigation measures available to stakeholders to combat climate change.

This phenomenon of massive diffusion of electricity use is illustrated at all geographical scales:

- **On a global scale**, the International Energy Agency (IEA) published in 2021 an initial scenario for achieving the objective of carbon neutrality in 2050, a sine qua non condition for limiting global warming to +1.5°C, according to the IPCC experts. This scenario envisages that the share of electricity in the world's final energy consumption will rise from 20% in 2020 to 49% by 2050. In absolute terms, this consumption could increase from approximately 25,000 TWh in 2020 to almost 60,000 TWh by 2050.

- **In Europe**, the implementation of the latest regulatory packages such as "Fit For 55" promotes electrification as one of the main ways to decarbonize the economy.

- **In France**, the reference scenarios concerning the evolution of electricity demand (RTE, ADEME, DGEC) are based on an increase of at least 30% between now and 2050, with some scenarios exceeding a 50% increase.

Electrification will focus on the three main greenhouse gas emitting sectors, namely transport, buildings and industry.

### ELECTRICITY, AN ENERGY CARRIER WITH UNPARALLELED DECARBONIZATION POTENTIAL

**A versatile and flexible energy carrier**

- Produced without $CO_2$ emissions by multiple sources (photovoltaic, wind, hydro, nuclear, electrochemistry, heat...)
- For all types of use (domestic, industrial, transport and mobility, health, digital...)
- Easily converted into another carrier (hydrogen, heat, etc.)

**Exceptional efficiency**

- Distributed and permanently accessible through the power grid
- Very high efficiency in use
- Transportable over long distances, easily and with little loss

1. In 2018, according to the IEA, the production of electrical energy accounted for 41% of global $CO_2$ emissions resulting from the combustion of fossil fuels and industrial processes, i.e., around a third of total $CO_2$ emissions in the world and a quarter of greenhouse gas emissions.

2. The SNBC sets the objective of a 40% reduction in energy consumption by 2050 compared to 2020.

# FOCUS ON DIRECT ELECTRIFICATION IN BUILDINGS, INDUSTRY, MOBILITY AND AGRICULTURE

## BUILDINGS

This sector represents a very large share of the energy consumed in France (43%). Although its share of greenhouse gas emissions is lower (23%, according to ADEME), due to the prevalence of electricity and wood heating in France, the sector is still largely concerned by the objectives of reducing emission levels. **To achieve carbon neutrality by 2050, it will be necessary to act jointly on several levers**: energy savings, energy efficiency, decarbonization of the energy system and electrification to replace fossil fuels with low-carbon electricity[1].

*On average, heat pumps for residential heating produce four times more thermal energy than they consume in electricity. They are a major lever for energy efficiency and for the decarbonization of heating.*

The technical solutions that will make it possible to achieve this last objective are already sufficiently mature and can be widely integrated into new construction and renovation projects. They must now be disseminated much more widely. In the building sector, the main obstacle lies in the time needed to upgrade the existing stock, due to the investment capacity that this requires and the low renewal rate (1%). To accelerate this pace, different approaches will have to be implemented simultaneously. Among these, **the increased use of heat pumps** is one of the most relevant choices, with varied and increasingly competitive solutions, adapted to both individual and collective housing, and immediate gains on the energy bill. The increased use of heat pumps also concerns the tertiary sector, and therefore constitutes an important vector of electrification.

1. The 2020 environmental regulations (RE2020), which will gradually come into force in 2022, aim to reduce primary energy consumption, in line with previous regulations in the building sector, but will also introduce, for the first time, requirements to limit greenhouse gas emissions over the building's life cycle.

## INDUSTRY

The industry sector represents nearly 25% of French emissions and final energy consumption[1]. As the largest energy consumers thermal uses represent the main source of industrial decarbonization. Electrification already provides a certain number of known solutions, the deployment of which must be accelerated, but new disruptive technologies must also be developed. **These solutions include the following levers:**

- Electrification of thermal processes using existing technologies: steam generation by electric boilers, electrification, or hybridization of furnaces (glass, ceramics, etc.), deployment of thermal solutions via resistances, induction, microwaves, mechanical vapor compression, infrared, laser, UV, plasmas, etc.
- The replacement of processes using fossil fuels with processes using electricity.

- The replacement of blast furnaces by electric arc furnaces in steel production is the most prominent example. In the chemical sector, the production of ethylene (currently through hydrocarbon cracking) by co-electrolysis of water and $CO_2$ is currently being developed.

- The development of breakthrough technologies, in particular the recovery of waste heat by high temperature heat pumps: this technology, which has only recently matured, is gradually benefiting from numerous innovations. Another breakthrough innovation is the electrolysis of iron to replace blast furnaces.

In addition to these thermal uses, some processes - notably in the petrochemical industry - are emitting large amounts of $CO_2$. Currently, hydrogen production for industrial applications (petrochemicals and chemicals - ammonia production) is mainly performed by steam reforming of methane, which is a major greenhouse gas (GHG) emitter.

**The production of hydrogen by electrolysis of water therefore represents a solution for decarbonization through indirect electrification**. This will concern the current uses of hydrogen as well as new uses. Hydrogen can, for example, be used in the iron and steel industry during the iron ore reduction phase in blast furnaces, as a replacement for coal, or in the refinery industry to ensure the desulfurization of fuels.

Although electrification represents a major lever for the decarbonization of industry, some processes will be difficult to electrify (chemical processes, very high temperatures...) or will generate process emissions that cannot be avoided by a change of energy (cement, ceramics...). For these particular cases, other decarbonization strategies may exist, including carbon capture and storage (CCS).

*Replacing blast furnaces with electric arc furnaces is a major stake for decarbonizing steel production.*

1. In 2019, industry accounted for 23% of GHG emissions in France (source: UNFCCC) and 25% of energy consumption (source: IEA).

## MOBILITY AND TRANSPORT

The transport sector is responsible for around 30% of emissions, with the main share (75%) coming from land transport, including cars. Initially driven by indicators such as CAFE (Corporate Average Fuel Emission), manufacturers have had to develop increasingly electrified vehicles to avoid penalties. All car manufacturers have defined **an ambitious roadmap** for the deployment of plug-in hybrids (PHEVs), and even more for fully electric vehicles (BEVs).

In recent years, countries have started to announce the end of the sale of combustion engine vehicles in the medium term (2025 for Norway, 2040 for France, 2050 for Germany). But on 8 June 2022, the European Parliament voted to end the sale of new passenger cars and light commercial vehicles with internal combustion engines, including plug-in hybrids, by 2035. This sets a course for 100% battery-electric or hydrogen decarbonized mobility. This decision is part of the "Fit for 55" plan and is consistent with the "Battery" plan (European Battery Alliance) which aims to create a competitive and sustainable European industry. In view of the risks to the availability of materials, **a recycling strategy is being put in place** with progressive targets for recyclability rates.

The decarbonization of mobility also concerns **heavy mobility** (trucks and buses). Whether it is battery or hydrogen powered[1], the electrical system will be impacted. Finally, on **the maritime side**, electrification will also accelerate with the implementation of air pollution emission control areas (ECA) and the European regulation on alternative fuels (AFIR), which will strengthen the obligations concerning shore-side electricity supply[2]. To this end, port smart grid projects are beginning to emerge with the deployment of hydrogen ecosystems.

*With the Fit for 55 plan, the European Union has set ambitious targets for the deployment of charging stations to prepare for the end of combustion engine vehicle sales in 2035. A new European regulation will also strengthen the requirements for battery recycling.*

## AGRICULTURE

In the agricultural sector, energy consumption is responsible for only a small share of GHG emissions[3], with methane from livestock farming and nitrous oxide from soil fertilization being the two main emission sources. The energy performance of agricultural activities is steadily improving. Tractors are becoming more efficient and are gradually turning to renewable gas or electricity where possible.

Heat pumps and solar thermal energy are being developed for various activities. Energy consumption in the agricultural sector is thus gradually decreasing and will be decarbonized through **the electrification of many processes, the use of renewable energies** (including agrivoltaics), **and the arrival of new technologies** such as robots or agricultural drones which will be able to carry out certain tasks currently performed by tractors (with other positive spin-offs such as the reduction of the quantity of pesticides through more targeted actions).

1. The production of green hydrogen is also a source of electrification: the median scenario of the RTE report "Energy Futures 2050" estimates a consumption of 50TWh to produce hydrogen.

2. See article 9 of the draft AFIR (Alternative Fuels Infrastructure Regulation) on shore power supply in seaports: https://eur-lex.europa.eu/legal-content/fr/TXT/?uri=CELEX%3A52021PC0559

3. 12 $MtCO_2eq$ out of 89 $MtCO_2eq$ for 2015, according to the CITEPA SECTEN report.

# IMPACTS ON ELECTRICAL SYSTEMS... AND THE CHALLENGES TO BE MET!

## MAINTAINING THE SAFETY OF AN INCREASINGLY COMPLEX SYSTEM

The historical development of networks and the intensification of their meshing had two objectives: on the one hand, to mutualize production centers for all consumers (which minimizes the overall cost of supply and reinforces the reliability and resilience of the system through the redundancy of the access paths to the resource) and, on the other hand, to make all the individual modes of consumption abound (the aggregation of a large number of erratic behaviors leads to a much more stable and predictable overall smoothing, limiting the need for margins and the costs associated with over-sizing).

The management of such a large and interdependent system on the European plate (now extended to Ukraine) relies on complex tools to ensure real-time **supply-demand balance** (production = consumption), **to preserve the dynamic stability** of the network (i.e., preventing a local incident from rapidly triggering a continental blackout) and **to guarantee a supply voltage** in accordance with the standards.

**The complexity of this control will increase** with the development of variable and intermittent energy production sources (wind and solar) and their progressive connection to the grid via power electronics (see below), and with the rise of demand due to electrification.

**New processes and tools will thus have to be deployed, drawing on all the flexibilities available or to be developed. This principle is at the heart of the Smart Grid.**

## DEVELOPING FLEXIBILITY TO ENSURE THE RESILIENCE OF THE ELECTRICITY SYSTEM

Whatever the energy mix chosen to support the Energy Transition, **the need for flexibility will increase**.

The IEA defines flexibility as "the ability of a power system to manage, reliably and at low cost, the variability and uncertainties of generation and demand, on all time scales". **This includes the levers of action to maintain security of supply on all time scales and to avoid blackouts.** In addition to real-time production/consumption modulation capacities, flexibilities to regulate day/night, infra-weekly, summer/winter (impact of solar) or even year-to-year (wind variability) impacts will be required and need to be planned.

These flexibilities can be of multiple natures:

- **Flexibility of the electricity transmission and distribution networks**

It is the capacity of these physical infrastructures to make the flexibilities of uses and means of production accessible to all, while respecting electrical constraints (stability, voltage, flow). This implies the existence of communication systems to activate flexibilities, or even of physical devices to control electrical flows. The network operators will have to carry out studies on different time scales and send the appropriate signals at the right time to guarantee the electricity supply and associated modulation at any time of the year. In real time, the challenge will be to have an industrial tool (IS environment, Telecom) capable of sending orders to the selected stakeholders in order to activate their flexibility within the required response time.

*The flexibility of the electricity system is essential to secure future electricity supplies, as electricity grids will support the bulk of the energy transition.*

- **Flexibility of means of production**

Whether hydraulic, gas or nuclear, power plants have flexibility capacities already used to compensate for variations in intermittent renewable energy (RE) production. For example, the minimum power threshold of nuclear reactors is currently 20%. Nuclear reactors have the capacity to increase or reduce their power by 80% in less than 30 minutes. Variable RE generation, although less controllable by nature, can also be set to provide flexibility (in active and/or reactive power). Wind power and solar energy, which are not programmable, can be capped (lowered) if production is too high. This is another field of R&D and standardization activities to be pursued in the coming years at a European level.

• **Demand flexibility**

In residential and commercial buildings, communicating objects (IoT) will be the smart medium for new automation systems and the control of flexible uses (heating, water heaters, electric vehicle charging, etc.). However, this will require progress in interoperability (i.e., common protocols and data models to make these objects compatible with each other) and greater reliance on smart meters as an interface with downstream uses. Industrial companies, and especially electro-intensive companies, constitute the largest source of demand flexibility. Their increasing electrification will have to be accompanied by new solutions to take advantage of the flexibility potential of the new uses.

*Smart meters have enabled the emergence of new offers and services for the flexibility and control of energy consumption. The advanced metering infrastructure deployed also contributes to the optimal management of the electricity grid, to the optimization of renewable energy connection solutions and to a reduction of technical and non-technical losses on the network.*

• **Flexibility in mobility and electric transport**

Three lines of research are currently being explored: the management of charging sequences to avoid peaks in electrical demand on the network at a global and/or local level, the correlation between vehicle charging and variable local renewable production, and the provision of storage capacity for the electrical system.

These batteries can be seen as flexible but extremely distributed resources (less than 100 kWh for each battery and powers of a few kW to tens of kW) with uncertainty on availability and energy levels. The flexibility of batteries can also be considered in unidirectional (V1G mode) or bidirectional (V2X mode) mode.

But the V2X mode raises several questions: normative regulations for a terminal that also becomes a source of production (regulations are advancing on this subject under stakeholder pressure), the impact on battery ageing according to the services targeted, and the technology of the bi-directional charger (AC solution embedded in the vehicle or DC in the terminal).

The first V2G network service solutions are coming (RTE has certified a first operator for primary frequency reserve), but there is still some way to go to identify the most technically and economically relevant services.

• **Flexibility of storage** (by battery, or coupled with heat or gas)

This can contribute at three levels: system balancing (power or energy services for short- or long-term horizons), network management (congestion and voltage constraints), and downstream meter optimization (demand smoothing, peak power reduction).

Battery storage is benefiting from the sharp drop in costs driven by the needs of the electric mobility sector. Its modularity makes it possible to envisage applications downstream of the meter or on the grid. In an electrical system with lower inertia, the high reactivity of batteries is an advantage.

However, the main obstacle remains the economic model, which should emerge gradually over the years with the growing share of renewable energy in the mix.

• **Market rules**

They must facilitate the exploitation of these flexibilities, for example through aggregators that offer their producer and consumer specific contracts allowing for the activation of increases or decreases in production and consumption at critical periods. Market rules should also allow the same asset to benefit from several modes of valorization.

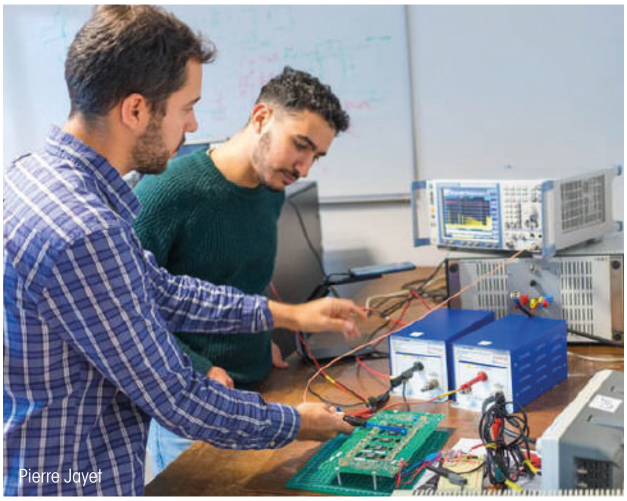
Whatever the type of flexibility, the development and deployment of more intelligence in the networks and information systems will be required to strengthen the capacity to control both production and consumption of electricity, and thus guarantee the future balance of the electricity system.

The integration of this intelligence will be based on digital technologies such as artificial intelligence, which is already used in many cases by network managers, edge computing, which makes it possible to decentralize part of the information systems and to have more efficient and more responsive local automation, and virtualization. Combined with edge computing, the latter will facilitate the deployment of intelligent functions at different locations in the electrical system, by offering standardized processing capacities.

## INTEGRATE THE GROWING ROLE OF POWER ELECTRONICS

While digital technology will indeed support all these developments, there is one technology that is mentioned much less frequently, even though it is becoming increasingly important: power electronics (ELP). The first industrial applications of ELP in networks consisted in High Voltage Direct Current connections (HVDC) or flow control (Flexible Alternating Current Transmission System or FACTS). Today, most RE generation sources are connected to the power system via ELP. This increasingly widespread technology does not offer the same inertia reserve as conventional alternators and their rotating masses, yet sufficient inertia reserve is essential to guarantee the stability of the electricity network and reduce the risk of blackouts. To remedy this, original technological solutions will have to be devised. But beyond these stability issues, the ELP must face major challenges: increasing voltage to allow widespread deployment on high voltage networks, increasing performance and lifetime, reliability, availability, and installation costs. New static converters based on breakthrough technologies will have to address the problems of transient overloads while optimizing their operation in normal conditions, which will require a reconsideration of their architecture and sizing methods.

But the trend is continuing. In low voltage, ELP and DC are already ubiquitous in most grid-connected assets: photovoltaic panels, electric vehicle charging stations, all of our electronic equipment, and batteries. And we are probably only at the beginning, with perhaps in the future DC grids co-existing with the current AC grids.




*Power electronics, which enable the highly efficient conversion and transmission of electrical energy, is at the heart of the energy transition and is the focus of numerous R&D projects in France.*

# ELECTRIFICATION: ANTICIPATING DEVELOPMENTS TO SEIZE OPPORTUNITIES IN TIME

Given that emissions from fossil fuel combustion and industrial processes account for nearly 85% of $CO_2$ emissions worldwide, electrification is the cornerstone of energy policies, enabling the substitution of decarbonized electrical energy for fossil fuels. In fact, **there is now a consensus on a significant increase in electricity demand between now and 2050[1], in spite of the overall decrease in energy consumption, which is necessary to achieve the climate objectives**.

Electrification will focus on the three main greenhouse gas emitting sectors, namely **transport**, **buildings** and **industry**, and will have **a major impact on the electricity system**.

**To succeed in the electrification challenge, it will be necessary to pursue the development of decarbonized production means and to develop all the flexibility solutions (for production, consumption, and electricity networks)** to deal with the variability of renewable sources. It is mandatory to develop all the levers of action needed to maintain the security of supply and stability of power systems, and to avoid blackouts. To achieve this, **it will be necessary to invest in the research and development[2] of new "smart grid" solutions to be deployed in our increasingly intelligent electrical systems**, but also to develop the corresponding industrial sectors.

For example, while power electronics is essential for the development of renewable energies and the electric vehicle, the number of recognized national industrial players in this field is far too low. It therefore seems necessary to ensure strong support for the existing academic and industrial players and to encourage the development of synergies.

**Investments must also be commensurate with ambitions. The European Commission estimates that the electrification of the economy will require massive investment between now and 2050[3]**: for the most ambitious scenarios on the electrification of uses (ALLBNK), the amount of annual investment amounts to 1054.7 billion euros through 2030 rising to 1196 billion euros from 2030 to 2050. For the electricity network alone, this investment averages €60.1 billion per year through 2030 and then €80.3 billion from 2030 to 2050. This is the amount of investment considered necessary by experts to achieve a 55% reduction in greenhouse gas emissions by 2030 and to reach climate neutrality by 2050.

**This electrification also represents an important source of opportunities**. The study by the European Foundation for the Improvement of Living and Working Conditions (Eurofound, an agency of the European Union)[4] assesses the potential impact of a low-carbon transition on employment and the EU economy by 2030. This transition takes place through an increase in the share of renewables in the electricity mix and an electrification of uses (mobility and housing). The results of this study show a positive impact on employment (+0.5% by 2030 for the EU and +0.38 for France), and growth (+1.1 point by 2030 compared to the constant trend for the EU as a whole, 1% gain for France). Similarly, a recent analysis by ADEME[5] shows that for the building and mobility sectors, the benefits of transition strategies involving the electrification of uses are also economic, with the creation of over 500,000 additional jobs by 2030 compared to forecasts, and more than 177,000 by 2050 for the most ambitious scenarios of electrification (territorial cooperation and green technologies).

Finally, in a context where the price of energy is at the heart of concerns, it should be remembered that **electrification is also a powerful lever for reducing energy expenditure** (up to **23 billion euros in savings** could be made by European households)[6] and s**trengthening France's energy independence**.

1. RTE forecasts a rise in electricity consumption from 430 TWh/year today to 645 TWh/year in 2050 in a median scenario called "reference trajectory" (see https://assets.rte-france.com/prod/public/2021 -12/Energy-Futures-2050-main-results.pdf)
2. At a European level, for smart grids: 25% increase in R&I projects and 59% increase in investments over the 2014-2020 period compared to the 2007-2013 period, source: European Commission: Smart Grids and Beyond: An EU research and innovation perspective, 2021, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC125980/jrc125980_jrc125980-sg_eu_outlook_2021_pubsy_new.pdf
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6. Cambridge Econometrics, TOWARDS FOSSIL-FREE ENERGY IN 2050, March 2019, p.6: https://www.cameco

# THINK SMARTGRIDS ASSOCIATION

The Think Smartgrids association federates the French Smart Grids sector, from electricity network managers to major French industrial companies and equipment manufacturers in the energy sector, also including start-ups and SMEs in the digital and electrical engineering sectors as well as the academic and research world.

The association supports the scaling up of solutions that contribute to the decarbonization of the energy mix and to the development of territories, but also to energy savings, security of supply and efficiency of the electricity system, for the benefit of consumers.

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