# Official Energy Statistics

## Past, Present and Future Challenges

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**Historically, energy statistics have been built around annual energy balances, which describe the various stages in the life cycle of energy: from its extraction, through its transformation and transport, to its various uses. This physical accounting is based on numerous conventions, which have a major impact on certain indicators such as the energy independence rate or the share of renewable energy consumption. Monetary accounts have been introduced more recently in France, in particular to shed light on the issues associated with energy in terms of household purchasing power and business competitiveness.**

**Energy statistics are an essential source of greenhouse gas (GHG) emissions accounting and can be used to shed light on trends in GHG emissions by cross-referencing them with statistics from other fields. The energy transition calls for ongoing adaptation of observation systems, to describe new uses (such as electric cars), new forms of energy (such as hydrogen) and also the drivers of this transition, notably building renovation. Increasingly detailed local data is becoming available. Data from smart meters offers interesting possibilities for the evaluation of public policies.**

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Energy policies have multiple objectives that have been expanded over time. Initially, these policies sought to ensure security of supply, energy independence, competitiveness for companies and household purchasing power. With increasing concern over climate change, reducing greenhouse gas emissions from burning fuels for energy has gradually become one of the main objectives of energy policy around the "energy transition" project. National energy statistics have correlated with changing needs to help government decision-making and fuel public debate. They are widely applied in discussions concerning price developments, the origin of France's energy imports or the number of energy-efficiency renovations completed each year.

A defining feature of these statistics is that they concern an asset that can be measured physically. Historically, they have been built around the physical energy balance, with internationally defined conventions. While certain economic indicators such as the weight of energy in the budget have been monitored for a long time, it was not until 2017 that a monetary balance was put in place, expanding and presenting energy price and expenditure statistics within a coherent framework. Public climate and environmental policies and technological developments are leading to regular expansions of the coverage of energy statistics, with figures on associated emissions, renewable energy, energy-efficiency renovations, hydrogen, etc.

> ***Energy statistics were only institutionalised at a late stage, with the creation of the Energy Observatory in 1982.***

In comparison with statistics in other fields, there was a delay in them being institutionalised. The first officially denominated "Official Statistics" service for energy (the *Observatoire de l'énergie* [Energy Observatory]) was created in 1982, following oil price shocks. Many other data producers, some of which were created earlier, still disseminate statistical information (CEREN[1], CPDP[2], network managers[3], ADEME[4], etc.). This results in a continuous re-examination of the scope of what should fall under Official Statistics, in a context of changing and ever-increasing needs. The energy and climate transitions will further increase these needs, creating major challenges for this statistical system. In this respect, the integration of official energy statistics within the statistical office of the ministry responsible for the environmental transition is beneficial, allowing synergies with official statistics on the environment, transport and housing; the last two of which heavily consume energy and emit high levels of greenhouse gases.

After a number of definitions and statistical conventions relating to the concept of physical energy, more recent developments in energy-related economic statistics are presented before addressing the new observation challenges in the context of the energy transition.

1 CEREN: *Centre d'études et de recherches économiques sur l'énergie* (Centre for Economic Studies and Research on Energy).
2 CPDP: *Comité Professionnel Du Pétrole* (Professional Oil Committee).
3 The main network operators are RTE and Enedis for electricity, and GRTgaz and GRDF for gas.
4 ADEME: *Agence de l'environnement et de la maîtrise de l'énergie* (Environment and Energy Management Agency), known as the *Agence de la transition écologique* (Environmental Transition Agency) since June 2020.

## What kind of "Energy" are Official Statisticians Discussing?

> ***Statisticians do not understand energy in the same way as physicists.***

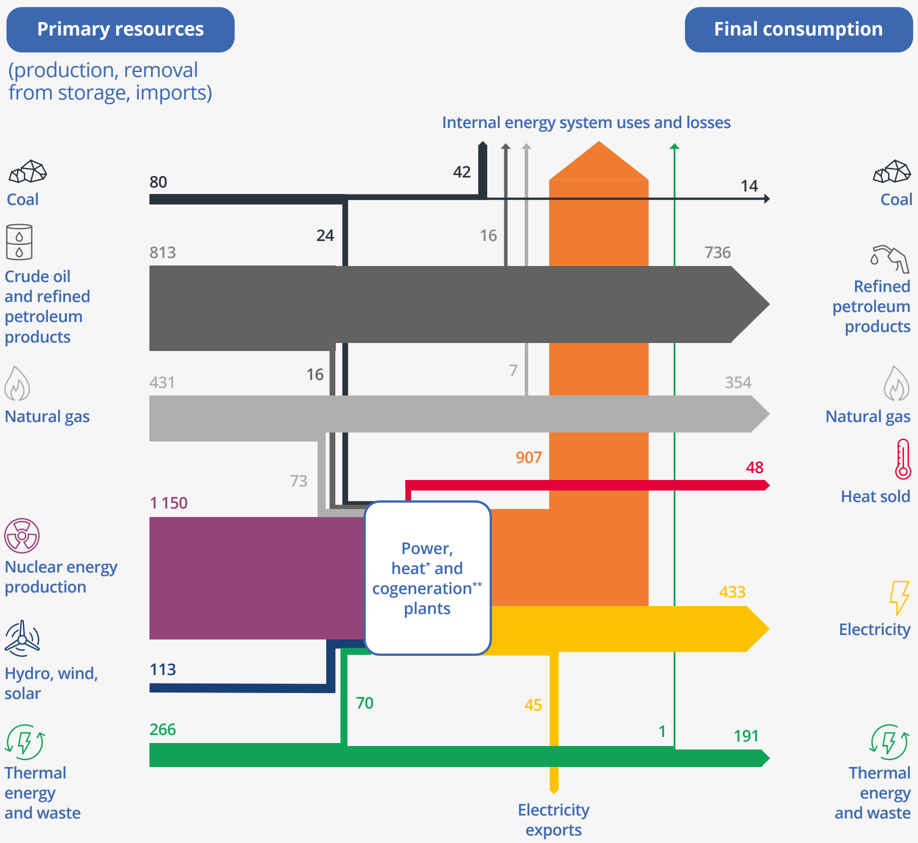
Energy statisticians sometimes borrow the units of measurement used by physicists (joules, watt-hours and their derivatives). However, statisticians do not understand energy in exactly the same way as physicists. As evidence of this claim, the concepts of production and consumption, which are central to energy balances, are alien to thermodynamics[5] or even contradict the first law of thermodynamics, which states that there are only ever transfers of energy. The main reason for this is probably that statisticians adopt an anthropocentric point of view and disregard, in particular, "*[e]nergy existing in nature and not having a direct impact on society*", in accordance with the "*International Recommendations for Energy Statistics*" (UN[6], 2019). However, this definition "by the negative" appears vague and incomplete[7] and people may be surprised that the scope of what is observed is not governed by clearer general principles. For France, as for other EU or IEA Member States[8], this scope actually corresponds to the restrictive list of forms of energy and energy flows contained in the 2005 IEA/Eurostat Energy Statistics Manual[9].

An examination of this list shows that the energy flows taken into consideration are related to a human intervention that is ultimately intended to provide services to consumers, after any transformation process. The purpose of the **energy balance**, the main statistical source on energy, is to describe these flows, setting out resources and jobs, the totals of which should theoretically be balanced for each form of energy[10], thus making it possible to answer the two main questions for a given geographical scope: how is energy supplied? and who consumes what?

Supplies consist of primary production, that is, energy directly extracted from natural resources, imports net of exports and inventory changes (***Figure 1***). A portion of these resources is consumed directly by the end users (for example, natural gas burned directly by boilers in people's homes), while the rest is transformed into secondary energy (for example, into electricity) before its end use. Some of this secondary energy is lost during these transformation processes and during the transport of the energy: the level of final consumption is therefore always lower than that of primary consumption (with the latter corresponding to total supply level with a balance of resources and jobs).

**5** A branch of physics that studies the properties of systems in which the concepts of temperature and heat are at play.
**6** The United Nations coordinates the definition of international recommendations for energy statistics.
**7** In particular, the purpose of energy statistics does not in any way cover the accounting of the total amount of heat absorbed by the Earth and its atmosphere, which nevertheless has a highly significant impact on human societies, as is the case with climate change.
**8** The International Energy Agency (IEA) is an autonomous intergovernmental organisation under the umbrella of the Organisation for Economic Cooperation and Development (OECD). It comprises 30 Member States, mostly oil importers.
**9** Eurostat, the statistical office of the European Union, is responsible for publishing European statistics and indicators, allowing comparisons between countries and regions.
**10** It should be noted that, unlike national accounts for example, the balance of which is based on trade-offs between resource and employment estimates, the energy balance does not seek to reconcile the two quantities, thus revealing a "statistical gap" for each type of energy.

### ▶ Figure 1 - The Sankey Diagram




*Reading note: A Sankey diagram makes it possible to view the energy flows, with the width of the arrows being in proportion with the physical flow represented. Primary resources (imports, national production and inventory changes) are on the left, with final consumption on the right. The transformation into secondary energy and the associated losses (upward flow) are shown in the centre.*

* *Heat plant: a nuclear reactor used as a heat source.*
** *Cogeneration consists of producing fossil-fuel fired thermal energy and mechanical energy at the same time and in the same plant.*

## ▶ The Main Energy Accounting Conventions

Whoever talks about statistics is talking about aggregation, whoever talks about aggregation is talking about equivalence scales, and whoever talks about equivalence scales is talking about convention(s). Thus, while physicists "measure" according to the laws of nature, statisticians "quantify" on the basis of conventions, to use the distinction explained in the sociological study of statistics (Desrosières and Kott, 2005). The conventions adopted in both final energy and primary energy balance sheets should not be overlooked by the user, otherwise there is a risk of potentially significant misinterpretation errors.

As regards final energy, it would ideally be expected that a fixed amount of final energy would provide an equivalent service to consumers regardless of the type of energy. This hypothesis does not always hold true. On the one hand, there are specific uses for certain types of energy, in particular electricity, which cannot be substituted for other types of energy. On the other hand, in practice, the final energy consumption usually corresponds to the quantity purchased by consumers. However, consumers can themselves transform energy before using it (for example, by burning a fuel in a boiler), which generates transformation losses that are not taken into consideration as such in the balance. The result, for example, is that 1 kWh of final energy in the form of fuel oil or wood for heating provides less of a service than 1 kWh of final energy provided by a heating network. To avoid this bias, in its 1983 report on energy statistics, the UN recommended accounting not only for "delivered" energy but also for "useful" energy (UN, 1983, p. 31). This recommendation has not been followed, probably due to the complexity of its implementation.

***Accounting for various forms of energy is the subject of debate.***

As regards primary energy, nuclear accounting has historically been subject to debate. International organisations have adopted the "energy content" method as the official method. This method consists of accounting for the nuclear heat released by the nuclear fission reaction, estimated to be three times the amount of electricity produced. It was preferred over the "partial substitution" method, based on the estimated amount of fossil fuels necessary to produce as much electricity as nuclear power plants. The latter method has the merit of providing a more direct answer to the question of how much fossil fuel energy can be saved by using nuclear power, but has the disadvantage of requiring assumptions about the yields of fossil fuel thermal power plants that do not exist in reality. Making such assumptions goes beyond the usual skills of a statistician, whose job is to observe and not to design an alternative world (or a "counterfactual scenario" as economists say).

The development of solar and wind power has reignited the debate around these accounting conventions. The official convention adopted is to account for primary wind and solar energy using the amount of electricity produced. This is because yields and losses are considered to be barely relevant for these energy types generated from the wind and the sun, with only a very small portion of the energy available naturally being converted into electricity. As a result, the "accounting" contribution of renewable energies to the reduction in fossil fuel consumption and, accordingly, $CO_2$ emissions, is significantly lower than that which would result from the implementation of the partial substitution method, although the latter does not seem to be devoid of shortcomings either (Mesqui and Théron, 2022).

## Territoriality and Energy Independence: Where Does Energy Come From?

The energy balance of a given State is deemed to cover the energy flows taking place within the territory of that State[11]. However, the application of this principle of territoriality relies on the normative choice of what is or is not considered to be a type of energy (*Box 1*). This convention has an impact on the assessment of the energy independence rate, which is defined as the ratio between national primary energy production and primary consumption.

> ***France's energy independence rate would fall if uranium were considered a type of energy.***

The main types of primary energy other than nuclear energy are fossil fuels (oil, gas and coal) and renewable energies. These energies can be used directly or to produce electricity, and fuel used to generate energy is accounted for directly in primary consumption. This is not the case for nuclear electricity, as nuclear fuels (uranium and plutonium) are not considered energy in international conventions. It is the heat generated by the reaction, produced where the reactor is installed, that is considered to be primary energy. This is one of the most disputed energy balance conventions. It has a very significant impact on France's energy independence rate, as the country imports all the uranium it uses. This rate was officially estimated to be 50.6% in 2022, but would fall to 13% if uranium were considered a type of energy (SDES, 2023). Although not explicit in the international methodological documentation[12], the main argument in support of this convention seems to be that uranium is abundant on Earth, particularly in countries that are well-disposed towards the uranium consuming countries. The truly limiting factor in the use of nuclear power is therefore claimed to be access to technology rather than access to fuel[13]. Regardless of opinions in respect of this convention, it emphasises that energy balances cannot be read out of context, especially the geopolitical context.

Constraints in relation to observation also result in certain breaches of the principle of territoriality. Thus, the final consumption of fuels is, in practice, attributed to the country in which they are purchased. This is one difficulty faced when attempting to cross-reference fuel consumption with traffic statistics, especially for heavy goods vehicles, some of which can pass through France without buying any fuel. In addition to the rate of energy independence, there is also the question of the countries of origin of imports. Determining the countries of origin is complex and also follows conventions, with the flow of electrons and natural gas molecules within networks being particularly difficult to track.

11 This is a difference in comparison with the Physical Energy Flow Accounts (PEFAs) component of the environmental accounts; this component, like the national accounts, obeys the principle of residence (that is, it focuses on the energy flows of resident units). In national accounts, a unit is said to be resident when it has a centre of economic interest in the economic territory of the country in question.

12 The 2005 IEA/Eurostat manual mentions the existence of a debate but does not state its terms, while the 2019 UN "International Recommendations for Energy Statistics" completely ignore this. This is all the more striking given that the UN's 1983 report on energy statistics featured a long passage focusing on the uranium cycle and nuclear accounting.

13 Another argument is that uranium is easier to store in large quantities than gas or oil.

### Box 1. The Main Sources of Data

Energy statistics are mainly based on the use of data collected by the SDES*. First, this service conducts statistical surveys, as defined by the Act of 1951** (in particular on electricity generation, heating networks, coal, and gas and electricity prices). Secondly, it collects the data specified by the French Energy Code. The most significant collection operation concerns local energy consumption data. Its results are made available to the public at a highly granular level (down to the building level for residential energy consumption).

These sources specific to the SDES are supplemented by external sources. The main external sources come from Official Statistics, such as INSEE's *enquête annuelle sur la consommation d'énergie dans l'industrie* (Annual Survey on Industrial Energy Consumption, EACEI) or foreign trade statistics from the statistical office of the Customs Authority, for example. The other sources come from organisations such as ADEME, the Commission de régulation de l'énergie (Energy Regulatory Commission) or the Direction générale de l'énergie et du climat (Directorate-General for Energy and Climate), for example.

The annual sources used for the energy balance are described in greater detail in the associated methodological note***.

* *SDES:* Service des données et études statistiques *(Data and Statistical Studies Department). The SDES falls under the umbrella of the* Commissariat général au développement durable *(Office of the Commissioner General for Sustainable Development, CGDD), within the* Ministère de la Transition écologique et de la Cohésion des territoires *(Ministry of Environmental Transition and Territorial Cohesion).*

** *See the legal references.*

*** Sous-direction des statistiques de l'énergie *(Sub-Directorate of Energy Statistics) (2023),* "Méthodologie du bilan énergétique de la France" *(Methodology of France's energy balance), methodological note.*

## Monetary Energy Accounts: a Tool to Supplement the Physical Balance

The establishment of monetary accounts denominated in euro provides another equivalence scale, based on an economic approach using costs, rather than a physical quantity of energy. This monetary tracking is useful for shedding light on two of the objectives pursued by energy policy: supporting the competitiveness of companies and the purchasing power of households. Such monetary accounts make it possible to build indicators, such as the share of energy in the household budget or in company spending. These are more meaningful to the general public than physical statistics using TWh[14]. These accounts also assist with micro- or macro-economic assessment model calibrations.

Interest in monetary energy statistics grows during periods of significant energy price increases and energy crises, such as the recent war in Ukraine. It is therefore logical to see a "satellite account[15]" being proposed for energy starting in the early 1980s, after the two oil price shocks, in the archives of the Energy Observatory. The reverse oil price shock in 1985 and the persistence of low oil prices until the end of the last century probably contributed to the phasing out of this project. The return of energy costs and taxation to the forefront of discussions reinvigorated demand for dedicated statistics and led to the establishment of a "monetary balance" for energy in 2017, which was an international innovation at the time. This monetary balance is similar to a satellite account. However, it is created within a framework that differs slightly from the national accounts framework, with the aim of promoting consistency together with the physical energy balance with which it is disseminated.

**14** TWh: Terawatt-hour symbol, a unit of energy measurement. 1 TWh represents the energy provided in 1 hour by a one trillion watt power source.

**15** Generally speaking, satellite accounts aim to provide more granular information in a particular field than national accounts, as part of a framework that is consistent with the latter. France was a pioneer in drawing up such accounts, with the first sectoral accounts commission, for transport, being established in 1955.

The monetary balance describes the flows, in euros, associated with the energy flows, presented in the physical balance for energy traded on the market (oil, gas, electricity, heat, coal, biofuels, wood, etc.). As with the physical balance, it takes the form of a balance between resources and employment. National energy expenditure is the main aggregate in this case. For each type of energy, this expenditure can be broken down into jobs, by consumer sector, and into resources, in accordance with the various components of prices (imports, domestic production, network management, trade margins, taxes, etc.).

As is usually the case for satellite accounts, the physical and monetary energy balances are presented and discussed in a dedicated body composed of experts and stakeholder representatives. This body, referred to as the "*formation énergie-climat*" (Energy-Climate Unit), was set up within the *Commission de l'économie du développement durable* (Commission on the Economy for Sustainable Development, CEDD), created in 2021, alongside three other units that followed on from the environmental, housing and transport accounts commissions. It is also responsible for assessing work carried out by parties outside the sphere of Official Statistics, for example on energy insecurity (an observatory for which is led by ADEME) or on the evaluation of public energy policies (taxation, energy vouchers, etc.).

## ▶ Observing Energy Prices Has Become More Difficult Due to Market Deregulation

The link between the physical and monetary balances is largely established by measuring energy prices. Observing energy prices generates challenges specific to each type of energy. Gas and electricity form part of network economies, which historically have vertically integrated markets (from energy generation to supply). The liberalisation of these two markets in the late 2000s has made the work of price observation more difficult. There is a dedicated survey on price transparency[16].

> ***Observing energy prices generates challenges.***

Other types of energy each have specific aspects that require various sources. There are two examples that can be mentioned:

- the *enquête annuelle sur les réseaux de chaleur et de froid* (Annual Survey on Heating and Cooling Networks, EARCF) for the price of heating;
- data from the *Centre d'Études de l'Économie du Bois* (Centre for Studies of the Wood Economy, CEEB) for the price of wood (which is nevertheless difficult to measure, with wood being widely traded on the informal market).

Measuring energy expenditure always requires linking the corresponding prices with energy consumption. For electricity and gas, there are several prices linked with the value chain of these markets. Producers, facing competition, can either sell privately[17] or on a wholesale market with the market price as it is defined. In the particular case of nuclear power produced by EDF[18], a specific tariff and sales conditions are established through the ARENH "*Accès*

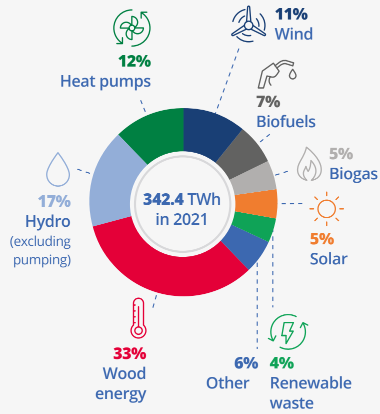
**16** Biannual "*Transparence des prix du gaz et de l'électricité*" (Gas and Electricity Price Transparency) survey.
**17** Direct sale by the producer without using a market.
**18** Électricité de France (EDF), a French public electricity generation and supply company.

## Box 2. Key Energy Figures for 2021

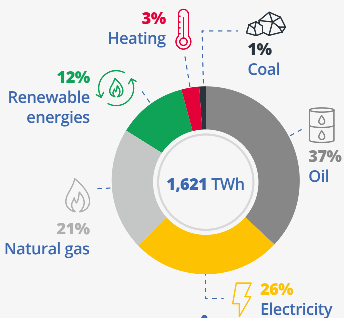
### Energy independence

**55.1%** of the energy consumed was **produced domestically**

### Primary production of renewable energy



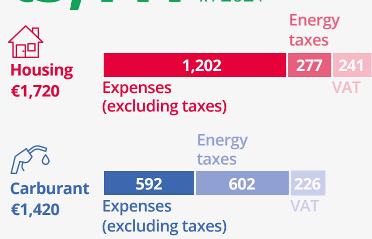

### Final consumption for energy use
by energy type



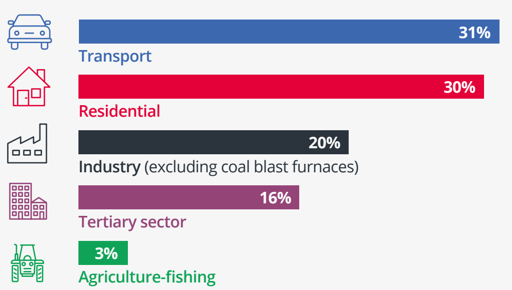

**+9%** in 2021 of **final consumption** for **energy** use

### Household energy bill

**€3,141** in 2021




### Final energy consumption by sector




In 2021, **final energy consumption** for the transportation sector rose by **12.1%**

*Sources: France's energy balance for 2021.* Chiffres Clés de l'Énergie *(Key Energy Figures), 2022 Edition, SDES DataLab.*

*Régulé à l'Électricité Nucléaire Historique*" (Regulated Access to Nuclear Energy Previously Managed by an Incumbent Operator) system of the *Nouvelle Organisation du Marché de l'Électricité* (New Electricity Market Organisation, NOME) Act of 2011. Discussions are under way on the replacement system that will be implemented following the shutdown of ARENH planned for late 2025. Network operators with a natural monopoly are paid a specific fee for network access. Energy suppliers who are subject to competition may offer different contracts to end consumers, including: regulated tariffs (for incumbent electricity suppliers), fixed tariffs over the term of the contract or tariffs indexed to the price of wholesale gas and electricity markets. Public policies can also set a price cap provisionally (as was the case in 2022 with the "tariff shield") or implement redistributive policies for less well-off households (energy voucher). These contracts generally include a subscription, with tariffs being differentiated on the basis of the power subscribed to and peak/off-peak hours (which justifies the economic theory, Percebois, 2001, for a summary).

Prices are not observed directly and price observations remain difficult, regardless of the type of energy. Measuring the consequences of energy crises on stakeholder accounts (company profit margins and household purchasing power and income) more effectively remains a topical issue. Official Statistics offer supplementary products for analysing economic issues: the monetary balance, which has the advantage of being consistent with the physical balance, and surveys such as the EACEI which links company statistics and energy consumption or the *Enquête Logement* (Housing Survey) for households (***Box 2***).

## Energy Statistics at the Heart of the Environmental and Climate Transition

The European Union and France are committed to achieving carbon neutrality by 2050[19]. Energy is responsible for around 70% of greenhouse gas (GHG) emissions in France. This highly ambitious objective therefore requires an energy transition, based on reducing energy consumption and increasing the use of decarbonised energy sources.

> ***The observation systems for the various fields were not initially designed to be interoperable.***

In addition to emission statistics, the description of which is beyond the scope of this article (Carnot et al., 2023), energy statistics are essential data for the proper management of the *Stratégie nationale bas-carbone* (National Low Carbon Strategy, SNBC). Understanding energy-related emission dynamics requires the cross-referencing of these energy statistics with other statistics from the fields of economics, demographics, transport and housing (Mesqui and Theron, 2022). This cross-referencing work is not always easy to perform and can require some re-processing. This is because the observation systems for the various fields were not initially designed to be interoperable. For example, traffic statistics and those on fuel consumption have differences in scope. The System of Economic Environmental Accounting (SEEA) developed by the UN has the advantage of providing

19 By 2050, France's residual greenhouse gas emissions will have to be lower than the absorption capacity of carbon sinks (soils, forests, oceans and technological carbon sinks).

a framework for describing emissions and energy flows that is consistent with the national accounts framework. The Physical Energy Flow Accounts (PEFAs), of which the submission to Eurostat has been mandatory since the 2014 financial year, fit within this framework. They make it possible, in theory, to reconcile the energy consumption of the various economic sectors with the usual scales of the national accounts (production, value added, etc.). However, they still have limited use due to the short span of time covered by the series.

> ***Another challenge is the need among public stakeholders for local statistics in energy.***

Another challenge is the need among public stakeholders for local statistics in these fields, to help them carry out their various planning exercises (local climate plans, for example). Local data on the consumption of electricity, gas, heating and cooling, and fuels are made available on the website of the statistical office of the ministry responsible for the environmental transition, pursuant to Article 179 of the *loi de transition énergétique pour la croissance verte* (Energy Transition Act for Green Growth, TEPCV) of 17 August 2015[20]. For electricity and gas, they include data at the building level (excluding residential buildings with fewer than ten dwellings, to ensure the protection of personal data). The ministerial statistical office is thus placed in the relatively unusual position of performing quality control on the millions of pieces of data provided by others, in this case, network operators. This raises the thorny issue of the scope and nature of this control, which has to be limited.

## New Energy Uses, New Statistical Methods

The energy transition also requires the continuous adaptation of statistical observation, due to the emergence of new uses (such as consumption of self-produced electricity, for example) and new types of energy (***Box 3***). The observation of renewable energies has resulted in a specific publication of key figures. In addition to traditional renewable energy sources such as wood, hydro and waste, this data collection has been expanded over the last twenty years to take into account wind, solar, heat pumps or biofuels. The flows of some of these new types of energy, which are often decentralised, cannot always be observed directly. Statistical and engineering skills may therefore need to be combined in order to estimate these flows. Generally speaking, the methodology is discussed and defined at an international level[21]. A major new challenge is the statistical monitoring of hydrogen. Unlike the types of energy mentioned previously, and like electricity, hydrogen is not a primary energy source. It is an energy vector: it can be produced in various ways and used for various purposes (electricity production, in particular). The first-ever hydrogen balance was published in December 2023 (Andrieux, 2023).

The energy transition also intensifies the need for data to measure its economic effects. The statistical monitoring of investment in energy production, networks and efficiency, in respect of both its physical and monetary aspects (Carnot *et al.*, 2023) must therefore be

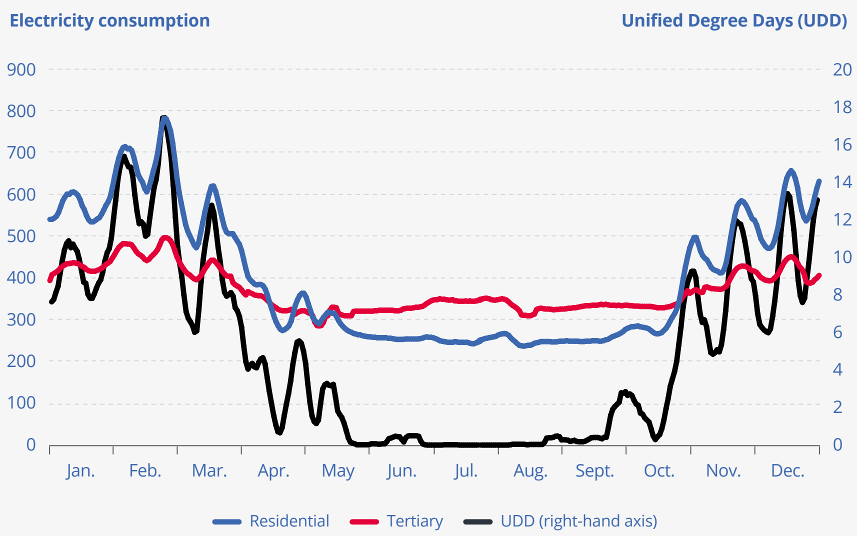
**20** See the legal references.
**21** For example, for heat pumps, heat extracted from the air or the ground is estimated by multiplying their electrical power by the estimated number of operating hours, plus a performance factor.

## ▶ Box 3. What is Adjustment for Climate Variations?

Climate is the main source of changes in energy consumption in the very short term. This is because, the colder it is, the more energy is consumed, and vice versa. Although in the long term, human action has an effect, variations in weather conditions are largely exogenous and public policies have no influence on these short-term variations. In order to identify the role of socio-economic factors in the evolution of consumption and emissions (share of the different types of energy used, energy efficiency, household behaviour and energy sobriety, energy prices, etc.), it is necessary to have energy consumption adjusted for climate variability. Energy consumption is referred to as being thermosensitive. Adjustments are made to energy consumption in the annual energy balance, as well as in the monthly and quarterly sectoral reports (by supplementing these reports with the traditional CJO-CVS* adjustments), based on a climate indicator known as *degrés jours unifiés* (Unified Degree Days, UDDs). Over the heating period, the number of degrees by which the temperature is below 17°C each day is counted. Over the air conditioning period, the number of degrees by which the temperature is above 21°C each day is counted. This indicator was introduced in the 19th century for studies on agricultural yields (Rahman, 2011). The use of DJUs also makes it possible, with the help of appropriate econometric methods, to determine the share of the total energy consumption that is used for heating.

* *CJO-CVS: Adjustment for seasonal variations and working-day effects is a statistical operation performed on the raw series data that aims to eliminate cyclical components (seasonality, number of working days, leap years, etc.) in the data and therefore improve economic analysis (Ladiray and Quartier-La-Tente, 2018).*

### Daily Electricity Consumption and Weather Conditions




*Example for 2018. Seven-day rolling average.*
*Calculation by the authors on the basis of open data from ENEDIS and temperature data from Météo-France.*
*Residential: All dwellings within French territory (continental Europe).*
*Tertiary: The tertiary sector covers a wide range of activities that extend from trade to administration, including transport, financial and real estate activities, services to companies, services to individuals, education, health and social action. The scope of the tertiary sector is defined so as to fit alongside agricultural and industrial activities (the primary and secondary sectors).*

expanded. While some fields, such as renewable energies, are already being monitored in this way, this is not yet the case for nuclear power, for example.

## Measuring the Improvement in the Energy Efficiency of Housing

In the residential sector, one explanation for the fall in consumption and emissions is the improved thermal efficiency of housing (***Figure 2***). Standards for new housing have gradually become stricter (2012 *Réglementation Thermique* (Thermal Regulation), 2020 *Réglementation Environnementale* (Environmental Regulation)[22]). Incentives for the energy-efficiency renovation of the existing housing stock have been increased. For example, the ban on renting out highly energy-intensive housing, introduced in 2023, aims to eliminate the poorly insulated dwellings referred to as "energy sieves". An *Observatoire national de la rénovation énergétique* (National Energy-Efficiency Renovation Observatory, ONRE) was established in 2019 to monitor not only the energy performance of the housing stock, but also energy-efficiency renovation work and the effectiveness of related public policies. The management of this observatory has been entrusted to the statistical office of the ministry responsible for the environmental transition, which has the benefit of having responsibility in the fields of both housing and energy.

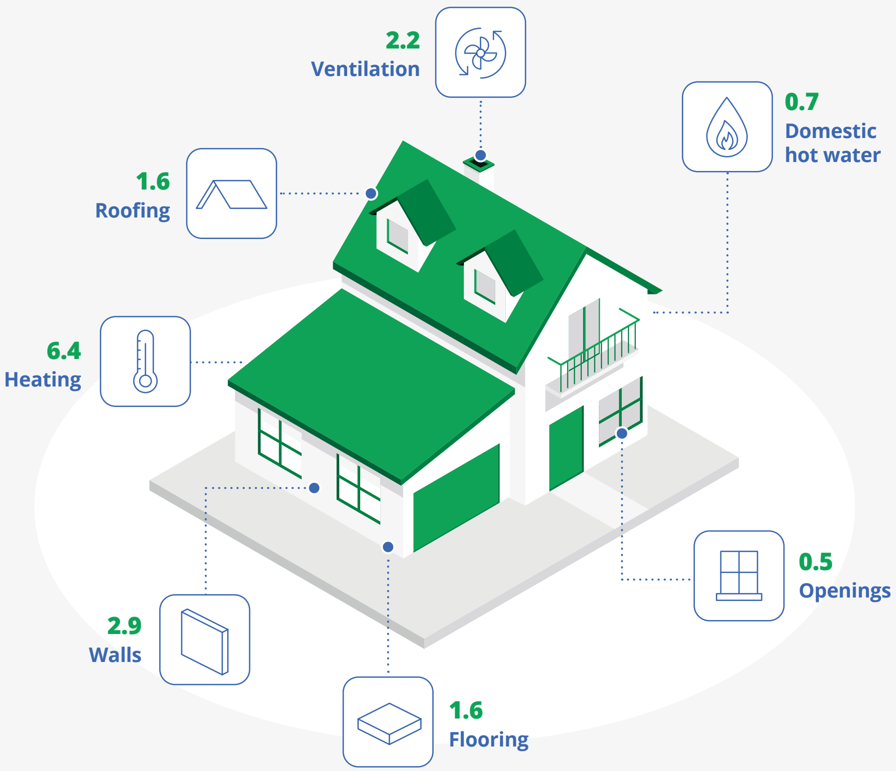
> ***An* Observatoire national de la rénovation énergétique *(National Energy-Efficiency Renovation Observatory, ONRE) was established to monitor not only the energy performance of the housing stock, but also energy-efficiency renovation work and the effectiveness of related public policies.***

There are several data sources available for this monitoring. The energy performance of the housing stock is measured through *diagnostics de performance énergétique* (Energy Performance Diagnostics, DPEs). The performance of a DPE is mandatory when selling or renting out a dwelling. Observations based on the data from the ADEME DPE database, which collects all completed DPEs, are therefore not representative of the housing stock and the data must be adjusted (Le Saout, 2023). In addition, what is measured obviously depends on the DPE definition standard in effect. In particular, the method used to calculate DPEs changed in 2021. The classification from A to G is no longer based on consumption of the dwellings alone, but also on their greenhouse gas emissions.

Energy-efficiency renovation work on housing (Kraszewski and Le Jeannic, 2023) is mainly monitored by taking into account financial support for energy-efficiency renovations, with the main support currently being MaPrimeRenov' and the *Certificats d'économie d'énergie* (Energy Saving Certificates, CEEs). Over time, this financial support changes in terms of the actions covered and the households targeted (less well-off households and affluent households). What is measured is therefore also associated with the administrative arrangements for defining the financial support.

22 See legal references.

**Figure 2 - Average Energy Consumption Gains in MWh/Year from Energy Efficiency Renovations on an Individual Home**




*Coverage: Metropolitan France, households living in individual homes that carried out energy-saving work in 2019.*
*Sources: The 2020 Travaux de rénovation énergétique des maisons individuelles (Energy-Efficiency Renovation Work on Individual Homes, TREMI) survey, used by the SDES.*

Surveys on the energy-efficiency renovation of housing must therefore be carried out regularly in order to allow the measurement of the "hidden" proportion of energy-efficiency renovations, that is, those not receiving energy-efficiency renovation financial support. The 2023 TRELO[23] survey is a very useful source of information in this regard. While previous surveys have until now only covered individual houses (TREMI survey[24]), this survey also includes apartments. However, this extension of the survey poses a methodological challenge (Le Saout and Rathle, 2023), in particular because it involves a new statistical unit for Official Statistics, co-ownership. Within a jointly owned property, renovation work may concern both private and common areas.

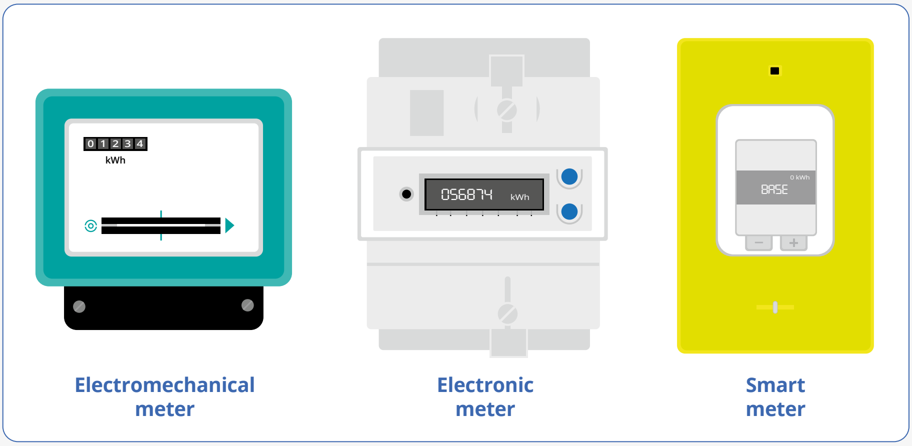
**23** *Travaux de rénovation énergétique dans les logements* (Energy-Efficiency Renovation Work in Dwellings) survey.
**24** *Travaux de rénovation énergétique dans les maisons individuelles* (Energy-Efficiency Renovation Work in Individual Homes) survey.

Statistical observation of energy-efficiency renovations is not limited to the housing stock and the residential sector. Work is ongoing regarding the measurement of energy-efficiency renovations in the tertiary sector, for which energy consumption is high (office buildings and public buildings (schools, shopping centres, etc.)) and is subject to specific reduction targets (*Tertiaire* (Tertiary Sector) Decree of 23 July 2019[25]).

## Smart Meter Data to Evaluate Energy Policies

In the context of the monitoring of the financial support or estimating the energy performance of housing stock, the approach is referred to as "conventional": theoretical consumption (or the theoretical decrease in consumption) is calculated on the basis of the housing's technical characteristics (insulation, hours of sunlight, heating equipment, etc.) and geographical characteristics (climate zone). However, this "conventional" consumption can deviate significantly from actual consumption, due to the behaviour of less well-off households to limit consumption, potential rebound effects (that is, the change in household behaviour in terms of energy consumption once the work has been carried out – Bair *et al.*, 2017) or the unobserved quality of the work, for example if the quality of the thermal insulation used is poorer than claimed (Giraudet *et al.*, 2018). Energy-efficiency renovation policies also have social objectives aimed at reducing energy insecurity. In the event that the use of heating is initially significantly limited due to financial reasons, when the work is undertaken it could potentially result in an increase in comfort rather than a decrease in consumption. Econometric studies (Fowlie *et al.*, 2018; Penasco and Diaz, 2023; Webber *et al.*, 2015) assess these policies in countries other than France and give contrasting results regarding both short- and long-term effects.

**Figure 3 - The Different Generations of Electricity Meters**




25 See legal references.

One of the challenges facing Official Statistics is going beyond this conventional framework to establish a real evaluation of public energy-efficiency renovation policies. To achieve this, monthly data on individual gas and electricity consumption from smart meters (Linky for electricity and Gazpar for gas) will be used (***Figure 3***). This submission of data to the statistical office of the ministry responsible for the environmental transition is authorised (Decree of 10 February 2023[26]), after households have been notified. It concerns a sample of one million households, as well as households responding to Official Statistics surveys. Although the data used do not represent all the individual load curves on an hourly basis (the consumption is monthly), their use already poses a challenge in terms of the volume of data and the statistical methods to be used.

Start-ups (HelloWatt, Homeys, etc.) and the *Institut Français pour la performance du bâtiment* (French Institute for Building Performance, IFPEB) are developing alternative methods based on the predictive modelling of load curves created from data from individual meters with very narrow time incrementations (every 30 minutes) and from questionnaires on energy use. These approaches deliver highly detailed results (at the level of each household), but require the consent of users and therefore have selection biases that are difficult to adjust for in order to obtain aggregated results. In the future, the use of data with finer granularity will be one of the challenges for Official Statistics.

> ***"The creation of a unique identifier for housing and buildings in the future should allow for significant progress in the field of statistical observation."***

Matching local energy data with data from other sources (housing data, tax data, SIRENE company register, etc.) requires the development of ad hoc and innovative record linkage methodologies, given the diversity of address formats. Outside of Official Statistics, the CSTB[27] launched such source matching work through the *Base Nationale des Bâtiments* (National Building Database, which is available in open data format) and the use of machine learning methods[28]; however, the matching quality is difficult to assess. The creation of a unique identifier for housing and buildings in the future should allow for significant progress in the field of statistical observation.

**26** See the legal references.
**27** CSTB: *Centre Scientifique et Technique du Bâtiment* (Scientific and Technical Centre for Building).
**28** Machine learning is a field of study of artificial intelligence that aims to bestow upon machines the ability to "learn" from data, via mathematical models.

## By Way of a Conclusion

At a general meeting of the CNIS[29] in March 2023, a presentation was given on challenges related to the energy crisis confronting the Official Statistics system (Tavernier, 2023). Several topics were identified in order to improve the monitoring of national and European policies (notably the energy sobriety plan and the tariff shield): the origin of supplies, the evolution of consumption and prices, and their impact on the accounts of stakeholders (companies and households). A major challenge for the future is the adaptation of the statistical system to shed light on and evaluate public policies related to the environmental transition, in particular the evolution of the automobile fleet, the disappearance of the poorly insulated "thermal sieve" dwellings, the production and use of hydrogen and electricity storage.

Achieving these ambitious objectives requires work on the provision of new data sources, for the observation of new themes (hydrogen, electric cars, energy-efficiency renovation in the tertiary sector, etc.) but also with a finer level of granularity, in both geographical (local data) and temporal terms. Smart meters make it possible to use highly precise data, albeit limited to gas and electricity; nevertheless, there are specific challenges in terms of legal conditions for access, the volume of data and statistical methods.

**29** CNIS: the *Conseil national de l'information statistique* (National Council for Statistical Information) facilitates interactions between the producers and users of Official Statistics.

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