

The economics of energy renovation

Introduction

Serge Catoire, Engineer General of Mines, General Council of the Economy, **Bertrand Cochi**, President of the Stanford Club of France and Vice-President of Mines ParisTech Alumni, and **Bernard Soulez**, Vice President of the Association of Executives for Social and Economic Progress (ACADI)

The energy renovation of buildings, a market under construction

Philippe Pelletier, Chairman of the Sustainable Building Plan, Chairman of the Executive Board of the Habitat et Humanisme Federation and Chairman of the Development Council of the Greater Paris Region

Beyond the necessary energy renovation of our buildings, isn't there a tremendous opportunity to adapt our real estate industry to today's realities by establishing the act of renovation, in its entirety, as the main vector of real estate development? The article therefore examines the French energy renovation plan for buildings, pointing out its strengths and weaknesses, before outlining the paths of progress that would enable the renovation of buildings to take place on the scale required by changes in usage.

Energy renovation of buildings, a priority public policy in full evolution

Anne-Lise Deloron Rocard and **Florent Martin**, Ministry of Ecological Transition

The energy renovation of buildings is now considered by all – successive governments, elected officials, economic forces and citizens – as an important, even priority policy. This policy, which is the result of years of experience, now benefits from structured management and is based on an approach that is resolutely focused on results and service quality.

Climate change, energy and buildings: a challenge for society

Didier Roux, Academy of Sciences

We present in this article a brief review of the origin of the energies used by man, emphasizing the difference between non-renewable and renewable energies. We will also examine the evolution of consumption and we will draw some lessons from it, such as the characteristic time required to develop an energy production system and the challenges related to energy transitions for a country. In a second part, we will discuss the important role of the construction sector and illustrate, with a few innovations, solutions that will allow it to adapt to these challenges.

An economist's point of view on the energy renovation of housing and its regulation

Matthieu Glachant, Director of i3-CERNA (Center for Industrial Economics) and professor at Mines Paris – PSL

Home energy retrofits has long been considered a low-cost option for reducing carbon emissions. This belief is now being challenged, particularly by new econometric work that identifies much lower than expected energy savings using data on actual work carried out and the actual energy bills of occupants. The main cause of the problem is the lack of skills and information of buyers unfamiliar with the complexities of the subject. This observation calls for public intervention, historically focused on subsidising demand, to be complemented by vigorous regulation of the supply side of the market, aimed at promoting the most efficient renovation companies.

Proposals for an ambitious energy renovation policy

Andreas Rüdinger, Associate researcher at the Institute for Sustainable Development and International Relations (IDDRI) and energy policy consultant

Building retrofits are a priority for the decarbonation of the French economy. In order to reach carbon neutrality by 2050, the building sector has to reduce its emissions by 50% until 2030 and reach, on average, a "low-energy" performance level over the coming 30 years. This is a huge challenge, which requires a realignment of public policies considering two challenges: an unprecedented acceleration of the thermal retrofitting rate; and a massification of deep and performant retrofits, a market which remains currently at an embryonic state.

Building on the work of an expert group coordinated by IDDRI since 2020, this article aims at providing several key orientations for a more ambitious retrofitting policy, based on two key political controversies: the priority granted to decarbonation versus deep thermal retrofits; and the controversy on the benefits and costs energy renovations.

Renovating with (techno-)discernment

Philippe Bihouix, AREP (multidisciplinary architecture agency)

Among the tools for combating climate change, energy sobriety in the building sector, thanks to a "major" renovation program, is a subject of consensus. It is undeniably necessary to improve the insulation of old buildings, starting with the "thermal flaws" in both the residential and tertiary sectors. Decarbonizing heat sources by abandoning oil and gas is also necessary, of course.

However, several weak signals could make us put in doubt the real effectiveness of renovation and our ability to implement a plan of the necessary scope and speed – and compatible with the climate challenges – while the "industrial" ramp-up of the pace of renovations is still too slow. What if we were to broaden our thinking on the uses of heat, on the range of possible interventions, or question our historical approach to "comfort" in order to renovate with (techno-)discernment?

The energy renovation of the buildings of the State real estate: organizational innovations and prospects

Hervé Le Dû and **Nicolas Blondel**, General Directorate of Public Finances/Directorate of State Real Estate (DIE)

With a heritage of nearly 100 million m² whose management is part of an increasingly demanding regulatory context, the State is particularly mobilized on the subjects of improvement of the energy performances of its real estate. After a first successful experiment in 2018 that led to the renovation of several administrative housing estates, the State Real Estate Directorate (DIE), which represents the State as owner, has implemented the call for projects method as a tool for selecting operations to be financed. This led to the launch, at the end of 2019, of the Travaux immobiliers à gains rapides en énergie (TIGRE) program, and then, in 2020, on a larger scale, the renovation program for the State's public buildings as part of the recovery plan. Despite the tight deadlines, a penalizing health situation and a project selection method that was not very common until now, these programs are great successes. Indeed, they are transforming the usual operating methods in terms of managing the renovation of public buildings, in a European context where environmental requirements will lead to an acceleration of renovation projects for the State's building stock.

Industrialization of energy renovation

Sébastien Delpont, Director of EnergieSprong France and Associate Director of GreenFlex

Meeting our climate objectives in the building sector will only be possible through the development of a much more advanced industrialization of high-performance energy renovation. The Dutch EnergieSprong model, which is being successfully deployed in France and around the world, is promising and inspiring from this point of view. It is rethinking the way things are done on both the supply and demand sides, with the implementation of new forms of public policy, new business models and the emergence of new cooperative ventures. Although France will be the second largest market in Europe for heavy industrialized renovations by 2022, the next steps in structuring the sector have yet to be taken. France must dare to make high-performance renovation an industrial priority. It will be a key lever for building new imaginations and better attracting talent to the building industry.

Condominiums, a socio-technical and economic object to be renovated

Raphaël Claustre, Managing Director of Île-de-France Energies

The climate objectives require the renovation of the entire building stock to a low energy level. This market is being driven by public policies, which will certainly encourage the development of new, high-performance housing, but will also respond to changing demand by encouraging the renovation of older buildings. In the condominium sector, it is a non-professional project manager who will have to make complex choices in terms of global or step-by-step renovation programs, and therefore in terms of the performance to be achieved, and, of course, in terms of profitability. It is however appropriate to question this notion of profitability and the way in which the co-owners, these non-professional decision-makers, apprehend it.

Truly efficient renovation: reconciling the end of energy poverty and the fight against climate change

Vincent Legrand, Managing Director of Doremi

Truly efficient renovation, which is currently marginal, is the only way to achieve the performance objectives of the national housing stock and to offer households a "cash-flow balanced" financial package: it transforms the savings made on annual "consumable" expenses (heating) into cash that allows, for an equivalent amount, the repayment of the investment made (the monthly payments of the renovation loans). The household thus benefits from a comfortable, healthy and upgraded home, without losing purchasing power. The massification of this renovation requires an ecosystem based on trusted technical (work operators), financial, and proximity (support) third parties. Redirecting public funds that are currently dispersed in inefficient "gestures" towards efficient renovations will allow, in addition to a strong reduction of our consumption, to create several hundred thousand local jobs and to get out of energy insecurity on a massive scale, while fighting effectively for the climate – it is a win-win industrial project for France.

CUBE, the national competition for energy savings between buildings

Cédric Borel, **Christophe Rodriguez** and **Emmanuelle Bertauière**, French Institute for Building Performance

The principle of the CUBE competitions is very simple: make the maximum energy savings for one year in buildings under occupation, without making large investments only by improving the building's management and mobilizing the occupants. Created in France in 2013, the CUBE is apparently just a simple challenge between buildings. But with accurate performance measurement, it creates a unique collaborative framework that lasts a full year. Through a simple

"hourglass" effect and the mobilization of good will, this challenge breaks down barriers, helps advance the cause, and mobilizes and affects the entire organization to build a new use for buildings. The average savings to date on more than 1600 buildings are 12%, with some candidates reaching more than 40% in one year when their building was poorly adjusted and used.

Example of strategies developed and results obtained by winners of the national CUBE competition

Cédric Borel, Christophe Rodriguez and Emmanuelle Bertaudière, French Institute for Building Performance

Buildings in the tertiary sector represent only a quarter of the existing building stock but are currently responsible for a third of its consumption. Reducing their consumption and emissions is therefore an important issue. High targets for this category of buildings – 40% by 2030, 50% by 2040, and up to 60% by 2050 compared to 2010 consumption levels – have been set in the Elan Law, whose implementing decree, the "tertiary decree", came into force last September. To make progress everywhere and right away, all owners and occupants can implement simple actions that will result in significant savings and a quick return on investment. Through these "low investment" actions, the CUBE competition represents what can be done immediately and in all buildings in order to accelerate or initiate its energy saving approach. In fact, some candidates to the competition achieve savings of more than 40%, i.e. the objective of the "tertiary decree" for 2030 in only one year!

Innovation in building renovation, a key element of the ecological transition

Christian Brodhag, Civil engineer of mines, doctor of science, professor emeritus at the École des mines de Saint-Étienne (member of the Institut Mines Télécom)

The article will consider innovation in the deep renovation of buildings, which alone makes it possible to meet European climate objectives. Innovation concerns economic approaches and the creation of value. Deep renovation requires the implementation of technical systems that simultaneously address the envelope, materials and energy. The necessary resources and skills must also be approached by a system approach. Support for the territorial innovation system will make it possible to lower the overall cost of renovation.

The contribution of technologies in numerical simulation

Bruno Peuportier and Patrick Schallbart, Mines ParisTech and Lab Recherche Environnement VINCI ParisTech

The scale of the environmental impacts, and the associated external costs, make an energy and ecological transition necessary. This context makes it essential to thoroughly renovate the existing building stock. To massify this renovation, it is useful to seek solutions at lower cost, and to reassure investors by guaranteeing

performance. It is also necessary to ensure that energy efficiency does not degrade other environmental criteria, nor the level of thermal comfort, because buildings must be resilient in the face of climate change. To meet these objectives, ecodesign tools based on numerical simulation can be applied to renovation projects.

Eco-Energy Decree for Commercial Buildings: Methodology and issues at the scale of a real estate portfolio

Nathalie Tchang, Director of Tribu Énergie

The Tertiary Eco-Energy Decree, often referred to as the "Tertiary Decree", is a regulatory obligation that commits players in the tertiary sector to greater energy sobriety. It imposes a progressive reduction of energy consumption in tertiary buildings in order to fight against climate change. All these buildings with a surface area of more than 1,000 m² are now subject to a double obligation to reduce their energy consumption and to display the results obtained.

To achieve this, the actions deployed go beyond the energy renovation of buildings. They also concern the quality and operation of equipment, as well as user behavior.

The choice of geothermal energy for the Airbus headquarters

Carole Amoros-Routié, Head of maintenance at Airbus France

AIRBUS wanted to create, for the AIRBUS headquarters in TOULOUSE, an environmental showcase to match its global ambitions. Geothermal energy is part of this project.

It is a thermal production by earth/water exchange, via Vertical Geothermal Probes. 141 probes dive to a depth of 205 m and supply a water loop which produces heat and cold for three office buildings, a restaurant, a concierge and a sports hall, i.e. 50,225 m².

The studies (technical, financial and environmental) and the implementation were carried out on schedule. The results are there. The overall annual yield of 5.4 (heating/air conditioning/DHW) is higher than the objectives.

Energy renovation of the Hôtel de Vendôme, the historic heart of the École des mines de Paris

Catherine Lagneau, Deputy Head of Department of the General Economic Council and Deputy Director of the École des mines de Paris

The flagship site of the École des mines de Paris, located on boulevard Saint-Michel, is also its historic home, which embodies both the history of the mining engineers and the place where they reinvent their contribution to society. A cauldron where they draw their roots and build their wings, this majestic building has always accompanied the school's evolution and must now embody, in its stone flesh, the major challenges for which the school prepares its students: in particular, the energy renovation of its envelope will

make this showcase the sign of its collective's resolute commitment to the ecological transition. The vast renovation program begun in 2021 and supported by the stimulus plan aims to achieve a 36% gain in energy performance. The school's unprecedented collaboration with a start-up from its laboratories will make it possible to actually measure this performance before and after the work is completed and, as always, to compare theory with practice.

Technological developments and market position of air-to-water and geothermal heat pumps

Pierre-Louis François, Atlantic Group

A proven solution that has reached industrial maturity, heat pump technology is now the basis for so-called "decarbonization" policies for heating and hot water in European homes.

Last year, sales exceeded one million units, compared to less than 300,000 in 2015. Over 90% of these are air-to-water heat pumps, also known as "aerothermal" heat pumps. The remaining 10%, geothermal heat pumps, are mainly used in boiler rooms of collective housing or upstream of heating networks.

Reversible air conditioners, or "air-to-air" heat pumps, meet cooling needs and have energy performance levels equivalent to those of air-to-water heat pumps. But they cannot meet domestic hot water needs and do not have the smart-grid options mentioned above. Finally, they cannot replace an existing installation using a fossil fuel, without first modifying the heat distribution system in the house.

The heat pump industry is currently working to improve the energy performance and environmental impact of the refrigerants used. They are also working to reduce the cost of production and installation of heat pumps.

Nordic countries' strategies for home energy renovation

Julien Grosjean, French Embassy in Sweden

The building sector accounts for 44% of the energy consumed in France and a quarter of CO₂ emissions, making it a strategic sector for achieving the national objective of carbon neutrality by 2050 and for reducing our dependence on imported fossil fuels, which are currently the source of heating for more than half of French homes. Feedback from the Nordic countries, which are global pioneers in decarbonizing buildings, provides a valuable context that deserves careful consideration. Several of them (Sweden, Norway and Iceland) have already moved away from the use of fossil fuels to heat their homes. Recent Nordic strategies have focused more on substituting RE (biomass, geothermal) for fossil fuels than on energy efficiency. These strategies allow the Nordic countries to present a record carbon footprint per square meter and to show a low dependence on fossil fuel imports, with a direct consequence: their resilience to current energy shocks is reinforced. Wood construction is also booming in these countries.

The interest of solar thermal energy in renovation

Olivier Godin, President and founder of SolisArt and vice-president of Enerplan

Energy is becoming less and less abundant. Their price and the tensions weighing on their supply are increasing. Air quality is deteriorating and global warming is getting worse every year. Faced with this implacable fact, what solutions are available to us to cover our needs for heat (heating and hot water)? In this respect, solar thermal energy, this inexhaustible and free energy, is profitable, sustainable and recyclable. It allows us to preserve our purchasing power, our energy independence, our air quality and, more generally, our planet. With its many advantages – source of local job creation, improvement of our trade balance, fight against energy insecurity – it keeps on developing year after year. When should it be used? What is its profitability? Is it possible to be autonomous thanks to it, to do without a boiler using fossil fuels?

ISUPFERE: a training program in energy engineering from Mines de Paris directly linked to the challenges of building renovation

Pascal Stabat, Head of the ISUPFERE engineering program

In this article, we show the originality and advantages of engineering training through apprenticeship, using the example of the energy engineering apprenticeship at École des mines de Paris, which is presented here. The alternation between school and company is the best way to reconcile theory and practice. Four testimonies from apprentices show that they are already players in the energy transition, even though they are still in training.

Apprenticeship engineering courses are appreciated by companies and young people. However, after a strong development between 2006 and 2014, with an increase of 135.4%, the number of these apprentices tends to stagnate. Nonetheless, today 14% of engineers trained in France go through the apprenticeship route, which makes it possible to diversify the profiles of engineers. These profiles meet the needs of companies to recruit specialized engineers with good technical skills. Lastly, engineering apprenticeship is a means of social openness by enabling young people to access higher education.

Why does energy renovation need an operational human resources policy?

Dominique Naert, Director of the Executive Real Estate and Sustainable Building Master's degree at École des Ponts ParisTech, and **Marjolaine Meynier-Millefert**, Vice President of the Commission on Sustainable Development and Regional Planning and President of the HQE-GBC Alliance

As the demand for renovation becomes more and more consensual and pressing, the question of the offer of adapted artisan services becomes more crucial. If we want to succeed in the energy renovation of nearly 5 billion m² of buildings in France by 2050, a sine qua

non condition for achieving the set carbon neutrality objectives, it is urgent that the players in the building sector develop a consensual strategy to increase the productivity of craftsmen and building workers, 95% of whom are involved in energy renovation in France... While implementing a campaign to attract operational building trades, a targeted learning pedagogy and a process of increasing the skills of qualified professionals.

Therefore, we must carry out an objective inventory of our production capacities and begin, from there and without delay, the reforms which will have to allow a double revolution: that of a massive growth of the global renovation offers and in parallel that of the profound transformation of habits and uses. Massification is on track. However, at the same time, it comes up against equally radical and rapid regulatory changes, which are shaking up the professions and the organization of the sector which must support this massification. The new DPE, the RE2020, the AGEC law and the implementation of the REP, the fight started against the too rapid artificialization of the soil and the brake given to new construction... provide concrete and necessary answers to the ecological and sustainable but are revolutionizing the habits of the sector and the know-how of professionals.

The majors and ETIs, which are more agile in absorbing these transformations, are starting to organize themselves at their level to face this challenge and are already meeting with notable successes. Nevertheless, the exemplary projects undertaken by the latter do not yet represent most of the construction and even less that of energy renovation. Renovations are carried out by craftsmen and SMEs which do not have the same resources for investment, innovation, R&D, transformation, and adaptation as large companies. However, it is essential that all these companies also succeed in their transformation. All the driving forces in our sector, down to the smallest link, must both considerably change their practices and put themselves in a position to respond to the demand thus massively increased.

Today, it is not necessary to be a great cleric to understand that we are not there, and beyond that, that we are doing too little to remedy it: the current diffuse artisanal offer is not (and will not be) able to undertake this necessary double revolution without solid support and considering the various parameters that we have tried to explain. It is therefore a concrete search for technological and social progress that must be undertaken, a development approach that will therefore be truly sustainable. For the moment, there is nothing to suggest in 2022 that the objectives of carbon neutrality in real estate and construction will be achieved: the account is not there. The equation is not solved... It is not enough to decree more and more ambitious objectives so that, on the ground, masons or carpenters take up the titanic challenge that is thrown at them... these new "cognitive workers" will have to respond to the increasing complexity of the systems which will require hybrid, personalized support, constant development, and training throughout life. But the good news is that the sector is ready to take up this challenge with the

help of the rising generation, provided we have, for and with them, the ambition they deserve.

After all, what is the alternative? Can we be content to deliver our craft businesses to complexity and instability with little or no support? Can we simply declare them obsolete? Can we achieve our climate goals without them? Do we have the necessary time and the means to develop new industrial processes that would put them in the past?

It therefore seems time to decree a major inventory of initial and continuing training, a task force on employment in the construction industry like that which has been set up on financing or third-party financing energy renovation. Observe and identify good practices, like the report "Renovating better: lessons from Europe" presented by the High Council on Climate... And subtly support the transition by allowing the immediate increase in the productivity of craftsmen and workers in the building. Our article already offers some lines of thought that should make it possible to open the debate as quickly as possible.

Massifying the energy renovation of housing with IMOPE, the national building observatory

Jonathan Villot, Henri Fayol Institute, GEO Department, Mines Saint-Étienne

As the main consumer of energy, the building sector must undertake a fundamental transformation of the old building stock. However, energy renovation, as the main source of savings, is far below the stated objectives. Massification is therefore the main action to be implemented. To do so, a detailed knowledge of all buildings in France is necessary. As a first essential step to the chain of grouped actions, it requires however to be able to characterize millions of disparate dwellings. IMOPE, the national building observatory, is responding to this thorny problem. By providing qualified data on the entire French building stock, coupled with an intuitive Web tool, IMOPE gives local stakeholders the tools they need to start implementing optimized and grouped actions for simplified massification.

Distribution of heating costs in collective housing and energy renovation: a beautiful synergy

Éric Vorger, Co-founder of Kocliko

The energy consumption of a building results from the complex interaction between the envelope, the systems and the occupants behavior, so that the three subjects must be treated jointly, to achieve high performance.

The Heat Cost Individualization (HCI) tackles the problem of uses, by encouraging sobriety in buildings with collective heating. Now mandatory, the HCI provides the opportunity to massively deploy measurement equipment on existing buildings that will be renovated in the next years.

Kocliko has developed a new technology for measuring individual heating consumption, using the measurement of ambient temperature and a calculation of heat losses via a digital twin of the building.

The data collected is extremely useful for managing collective heating during the operating phase, but also for carrying out effective renovations: precise knowledge of the state before work, optimization of the renovation scenario, Measurement & Verification of ex-post results, long-term user awareness.

The Energy Efficiency Renovation Pathway (EEPR): political, economic and strategic issues

Florence Presson, Deputy Mayor of Sceaux (92)

When a mayor's political will and commitment are combined to facilitate and accelerate the energy renovation of homeowners, this leads to the development of local construction companies and a decrease in the number of unemployed. When the relationships between industrialists, building professionals and elected officials are transformed, cooperation in the general interest develops and the beginnings of a mobilization and implementation of public and private investments take shape. When all the inhabitants of a community benefit equally from tailor-made support, the right to live in good conditions, under a healthy roof, and a significant improvement in their finances and their standard of living, it is because the energy-efficient renovation program is being deployed and is producing its first effects!

Energy renovation and architectural quality: a major challenge for the common good

Corinne Langlois and **Fabienne Fendrich**, Architecture Department of the Ministry of Culture

France has set itself the goal of dividing its carbon emissions by six by 2050. The targets assigned to the building sector have not been met. Thinking about energy renovation means modifying the building and its environment, but it also means changing the living environment of its occupants, for better or worse: for worse, it means restricting uses by unsuitable technical measures; for better, it means combining energy improvement and new uses. This is why energy renovation must not be dissociated from the architectural project. Architects are responding to this challenge through new forms of intervention, always driven by a search for quality for all, more sustainability and high added value in both new and rehabilitation. The renovation of the existing stock, being an alternative to demolition, makes it possible to be consistent with the objectives to be reached in terms of greenhouse gas emissions and energy balance. The Ministry of Culture, and particularly the architecture department, is committed to supporting all positive and experimental initiatives related to these contemporary issues.

Accelerating renovation in Europe with artificial intelligence

Quentin Panissod and **Pedro Gomes Lopes**, Vinci Group

The RenovAlte project is a French-German initiative aimed at accelerating the renovation of buildings and roads and improving their environmental and economic performance thanks to artificial intelligence. This project is based on a situation that seems paradoxical at first glance, combining, on the one hand, the climate emergency and, on the other hand, the need for massive investment in the development of resource-intensive artificial intelligence technologies. Moreover, these technologies are not among the key needs for accelerating energy renovation. Yet it is a lever that can change the game and has succeeded in bringing together an eclectic consortium around innovation for renovation: the Leonard innovation platform and several other entities of the Vinci group: the Action Logement group, the OFFIS research laboratory, the VIA IMC innovation center and the French sovereign artificial intelligence platform ALEIA. Together, we will commit 8 million euros of research and development work to conquer gains in environmental and economic performance through the renovation of housing and roads.

In this article, we describe the stakes of this approach, the different artificial intelligence applications that exist in the field of renovation and the content of the RenovAlte project, whose initial work began in March 2022 and will continue until March 2025. It is also a call for contributions and a pooling of efforts between all European players in the sector with the aim of sharing our practices and creating a world leader in this field of application.

Building 4.0: a prerequisite for any energy renovation

Emmanuel François, President Smart Buildings Alliance (SBA)

The digital transition characterizes, as much as the energy transition, the evolution of our collective socio-economic organization.

To combine these two transitions, Emmanuel François, chairman of the Smart Buildings Alliance, proposes to deploy a Common Digital Infrastructure for 4.0 buildings as a priority, this infrastructure hosting platforms (digital and interconnected) for services to occupants; among these services (building or urban), electrical mobility and electrical vehicle charging.

*Issue Editors: **Serge Catoire**, **Bertrand Cochi** and **Bernard Soulez***