# Contrat Fléché ED-Erasme

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**Titre du sujet : Energy Renovation Decisions in Confominiums : A Theoretical and Empirical Analysis of Heterogeneous Incentives and Collective Dynamics**

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# Energy Renovation Decisions in Condominiums: A Theoretical and Empirical Analysis of Heterogeneous Incentives and Collective Dynamics

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# 1 Introduction

Residential buildings represent a major share of energy consumption and carbon emissions in France, particularly due to the use of heating systems in collective housing. Current estimates indicate that nearly two-thirds of building emissions originate from residential dwellings (Service de la Donnée et des Études Statistiques (SDES) 2024). Despite strong national ambitions in favour of energy transition, only a limited proportion of condominiums undertake energy renovation works. Recent evaluations suggest that approximately ten percent of condominiums engage in such works, which highlights the gap between policy expectations and actual outcomes (Agence nationale de l'habitat (Anah) 2024).

Energy renovation therefore constitutes two strategic challenges. It plays a central role in diminishing energy poverty, especially for vulnerable households living in poorly insulated buildings. It also represents a necessary condition for reaching the objective of carbon neutrality by 2050. Existing policies that focus mainly on individual houses tend to neglect condominiums, although collective housing is extremely prevalent in urban areas and exhibits substantial renovation potential. The collective nature of decision-making in condominiums creates additional constraints that are absent in the context of individual property ownership. Each renovation decision depends not only on the perceived benefits of a single owner but also on the willingness and capacity of all other owners to approve, finance and coordinate renovation works.

The coexistence of owner-occupiers and landlords, together with heterogeneous levels of income, time horizons and perceived benefits, generates coordination failures and may lead to systematic blocks in energy renovation (Brisepierre 2012). These specific features raise the central research question of this project: *how can public or private actors effectively incentivize condominium stakeholders to engage inenergy renovation works despite heterogeneous preferences, asymmetric information and collective decision-making constraints?* This question motivates the present PhD proposal. The objective of the thesis is to create academic knowledge while producing operational tools for the evaluation and design of renovation incentives adapted to the collective context of condominiums.

# 2 Literature Review

The literature on energy renovation has grown a lot in recent years. A large number of contributions focus on the behaviour of owner-occupiers and analyse the determinants of renovation decisions in terms of costs, perceived benefits, behavioural biases, regulatory constraints and available subsidies. This literature provides valuable insights into individual decision-making processes. However, it remains limited in its ability to explain renovation dynamics in collective housing.

First, landlords have received comparatively little attention although they represent

a large proportion of condominium owners in France. Their incentives differ from those of owner-occupiers because they balance renovation costs against potential increases in rental income or resale value. Second, existing theoretical models of collective decision-making are generally too abstract to capture the institutional specificities of French condominium law, which regulates voting rules, financial arrangements and governance structures. Third, interactions and externalities between dwellings are seldom integrated into economic models even though the energy performance of one dwelling may depend on the renovation decisions of other units within the same building. Finally, data on energy renovation remain really scarce across several sources, including administrative databases, energy performance registries and commercial market data.

These limitations indicate that a comprehensive analysis of condominium renovation requires a new methodological framework combining microeconomic modelling, behavioural economics, collective decision theory and experimental methods. It also requires the construction and integration of novel datasets at both the individual and collective levels.

# 3 Research Objectives

The thesis has three interconnected objectives. The first objective is to develop a theoretical model of the renovation decision made by landlords. The model will incorporate uncertainty regarding rental income, resale value, and future regulatory conditions associated with the energy performance of buildings. The model will use a real option approach to characterise renovation as an irreversible investment made under uncertainty.

The second objective is to integrate the individual model within the collective context of condominium governance. The decision to renovate a building depends on the aggregated choices of all owners and on the coordination mechanisms established by the condominium management structure. The project will therefore mobilise the Mean Field Games (MFG) framework to represent the strategic interdependence of many heterogeneous agents. The MFG approach will be combined with principal-agent theory in order to model incentives designed by public authorities or condominium managers under conditions of asymmetric information.

The third objective is to validate the theoretical model empirically and to use the results to evaluate different public policy instruments. The research will rely on econometric analysis, simulation methods and experimental economics. The goal is to estimate real-world decision thresholds, identify behavioural barriers to cooperation, and compare the effectiveness of alternative policy tools such as direct subsidies, subsidised loans and tax incentives.

# 4 Methodology

The methodology combines theoretical modelling, empirical investigation and experimental analysis. The first step consists in developing a microeconomic model of the landlord's decision under uncertainty. The model will represent rental income and housing values as stochastic processes influenced by market conditions and the current energy class of the property (McDonald and Siegel 1986; Pindyck 1986). A common representation is given by a Geometric Brownian Motion, which defines the evolution of the asset value over time through the equation

$$dV_t = \mu V_t dt + \sigma V_t dW_t.$$

This representation captures the uncertainty faced by landlords and allows the identification of critical thresholds at which renovation becomes financially optimal.

The second step consists in merging the individual model within a Mean Field Game framework. In this approach, each landlord chooses a renovation strategy by anticipating the average behaviour of all other owners. The agent seeks to maximise an expected utility that depends on the trajectory of the energy performance of the dwelling, the cost of renovation and the incentives provided by the principal. The mean field represents the aggregate renovation rate across the whole building and determines externalities and feedback effects (Lasry and Lions 2007; Achdou, Bardi, and Cirant 2020; Elie, Mastrolia, and Possamaï 2020).

The principal, who may be a public authority or the condominium manager, selects an incentive mechanism that maximises social welfare while respecting a budget constraint. The principal-agent interaction reflects information asymmetries concerning renovation costs, energy gains or individual preferences. The analysis aims to characterise the optimal form of incentive mechanisms under realistic constraints.

The third step consists in validating the model through empirical work. The thesis will mobilise several complementary data sources, including ADEME databases, the FIDELI and DV3F datasets, and webscraped data from rental platforms. These sources provide high-resolution information about individual housing units, ownership structures, rental market dynamics and building characteristics.

Finally, a discrete choice experiment will generate original data regarding cooperative behaviour in condominium assemblies. Participants will be confronted with hypothetical renovation scenarios in which collective decisions depend on the interaction between individual preferences and majority voting rules. The experiment will provide insights into cooperation, negotiation and potential deadlocks observed in real-world assemblies (Chaton, Lesgards, and Zitouni 2025; Brandts, Gerhards, and Mechtenberg 2022).

# 5 Expected Results and Contributions

The research is expected to contribute to the literature on energy economics and collective decision-making. It will produce a theoretical model of landlord behaviour under uncertainty that is specifically adapted to the context of condominiums. It should make it possible to identify the conditions under which individual owners decide to renovate and to assess the influence of key parameters such as renovation costs, subsidies and market dynamics.

The integration of the individual model within a Mean Field Game framework will provide a rigorous analysis of the strategic interactions between heterogeneous agents. It should make it possible to characterise collective equilibrium outcomes and to derive optimal incentive schemes for a principal operating under a budget constraint. The empirical and experimental components are expected to deliver unprecedented evidence on cooperative dynamics in condominium assemblies and to identify practical barriers to collective renovation.

Beyond academic contributions, the thesis aims to produce operational recommendations for public authorities. The results will support the design of targeted subsidies, innovative financial instruments and decision-support tools that can be implemented to accelerate the renovation of condominiums. The combination of theoretical rigour and empirical validation should ensure that the proposed tools are both scientifically robust and operationally relevant.

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