The impact of energy efficiency and green performance on the value of corporate real estate portfolio

Abstract. *The aim of this paper is to investigate whether energy efficiency is capitalized in rent and asset value. We apply hedonic methods on a real estate investor's portfolio which is composed of industrial, commercial and office buildings. This approach contributes to the research on "green buildings" by developing a patrimonial approach using hedonic regression modeling on a set of existing buildings in the French corporate real estate context. This model emphasizes two main results: energy efficiency is more capitalized in rent than in asset value and this relationship differs regarding buildings' type. The model suggests that premium for energy efficiency is stronger for commercial and office buildings than for industrial buildings.*

Keywords. *Green Building, Sustainable Real Estate, Energy Efficiency, Hedonic Model.*

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Introduction

This article investigates the impact of energy efficiency on the economic value of existing buildings in a real estate investor's portfolio. Sustainability is becoming a major issue for real estate sector, as building and associate activities are approximately responsible for 30% of greenhouse gas emissions (Royal Institution of Chartered Surveyors, RICS 2005). The improvement of sustainability in real estate is largely supported by a reinforced regulation such as the *"Grenelle de l'Environnement"* in France and the emergence of rating systems which certifies buildings for sustainability such as the Environmental Protection Agency's *Energy-Star* or the label of the U.S. Green Building Council "*LEED*", the *BREEAM* label in the U.K. or the *H.Q.E* and *H.P.E* labels in France. However, the diffusion of sustainable principles also allowed the actors to consider the potential value created by sustainable buildings in a context of *corporate social responsibility* (Waddock and Graves 1997; Pivo and Fisher, 2010). Following this, a body of research studying "green buildings" has emerged.

The potential value of green buildings is generally attributed to attractiveness for occupiers due to energy efficiency, productivity, employees' well-being, potential gains on tax and other incentives, "socially responsible" image (Kats 2003; Robinson 2005; Yudelson 2007; Ellison et al. 2007; Eichholtz et al. 2010a); and decreased risk for investors due to less obsolescence (Sayce et al. 2004; Lorenz and Lützkendorf 2008; McNamara 2008). A growing number of empirical works demonstrate that these advantages can turn into rental premium, higher occupancy rates and thus higher asset values (Miller et al. 2008; Dermisi 2009; Fuerst and McAllister 2009 and 2011; Eichholtz et al. 2010a and b; Wiley et al. 2010). These works concern mainly U.S. buildings from the *CoStar* database which are certified *Energy-Star* or *LEED* and use hedonic regression modelling to estimate the impact of green labels on rent and sales prices.

The aim of this article is to contribute to the growing literature on "green buildings". Most of the contributions in this literature deal with recent buildings that are certified for sustainable performance and concern mainly U.S., U.K. and Australia which represent 75 % of academic publications (Sayce et al. 2010). This highlights the interest to study the potential valuation of sustainable practices for existing buildings. A fundamental contribution of this paper is to develop a patrimonial approach using hedonic methods on a set of existing buildings in the French context where studies on green buildings valuation remain scarce. This approach is supported by a research convention which allows us to have access to a real estate investor portfolio including data on energy efficiency. The data come from the portfolio of *Poste Immo*: the landholding trust which optimises, develops, manages and maintains real estate assets of the French Post Office operator (*La Poste*).We thus investigate the potential valuation of green performance (energy consumption) into rent and asset value on a portfolio of existing buildings using hedonic regression modeling. This approach also allows us to overcome the lack of data available in the French context concerning office buildings certified *H.Q.E* or *H.P.E* for sustainable performance. The results of the model emphasize a positive impact of energy efficiency which is capitalized into rent and asset value. This effect seems stronger for rent than for asset value and differs regarding buildings' type.

The article is structured as follows: first section describes the theoretical and empirical background on green buildings; second section presents the method by describing the dataset and the specification of the hedonic model; the results are discussed in the third section; finally, the fourth section concludes.

Background

Sustainable development and climate change issues have become a major concern for the real estate sector. In the context of corporate real estate, sustainable principles emerged with the reinforcement of regulation constraint such as the *"Grenelle de l'Environnement"* in France.

However, as pointed by Eichholtz, Kok and Quigley (2010b), sustainability concerns methods of production as well as qualities of consumption and attributes of capital investment, it thus "reflects popular concern for environmental preservation, but it may also reflects changes in tastes among consumers and investors". This is particularly true for corporate real estate in a context of *corporate social responsibility* (Waddock and Graves 1997; Pivo and Fisher 2010) as a new business model expressing the companies' willingness to embrace sustainable principles. The diffusion of sustainable development allowed the actors to consider the potential value created by environmental performance of buildings, defined in the literature by the notion of "green value". Sustainable performances of buildings are expected to improve attractiveness and to increase value.

This improvement of actor's interest about green value is largely supported by the development of rating systems which certify buildings for sustainability and environmental performance. In the U.S. buildings are certified "*EnergyStar*" for energy efficiency by a joint program of the Environmental Protection Agency (EPA) and the U.S. Department of Energy. According to Wiley, Benefield and Johnson (2010) 4,100 buildings earned the EPA's *Energy Star* by the end of 2007, including 1,500 office buildings. Buildings are also certified for sustainability by the U.S. Green Building Council (USGBC): Leadership in Energy and Environmental Design, "*LEED*". The *LEED* certification aims at encouraging the adoption of sustainable building practices by promoting a whole-building approach to green design and construction including site planning, energy, water management, indoor environmental quality and material use. In the U.K. the *Breeam* label (BRE Environmental Assessment Method) certifies buildings for sustainability regarding management, health and well-being, energy, transport, water, material and waste, land use and ecology, pollution. These three rating systems have been considerably developed and are now internationally used. In France, buildings are certified for energy efficiency regarding the *H.P.E* label (High Energy Performance) and certified for sustainability regarding the *H.Q.E* label (High Environmental Quality) which relies on fourteen targets concerning the impact of the building on its external environment and its ability to create a qualitative internal environment. These two rating systems are increasingly used for corporate real estate in the French context in order to certify sustainable performance of buildings.

This section emphasizes the main factors of attractiveness for sustainable buildings, and the growing number of empirical researches estimating the impact of green attributes on office buildings valuation.

Environmental performance and attractiveness for office buildings

Several researches argue that sustainability may improve buildings' attractiveness for occupiers and decrease risk for investors. The main advantages for occupiers are well documented in the recent literature on green buildings. They rely on savings on operating expenses due to energy efficiency and other utilities, productivity gains and improvement of employees' well-being, potential gains on tax and other incentives by adapting to a changing regulation, and competitive advantages linked to marketing and "socially responsible" image (Kats 2003; Robinson 2005; Yudelson 2007; Ellison et al. 2007; Eichholtz et al. 2010a). A potential occupier will thus consider these advantages which should lead to higher occupation rate and rental premium for sustainable buildings. The key question consists in evaluating the occupier's "willingness to pay" for these advantages which drive the rental premium (Fuerst and McAllister 2011). A growing number of studies investigate these advantages for users based on concrete examples and surveys conducted across actual green buildings' occupiers (Heerwagen 2000; Edwards 2006; Paul and Taylor 2008; Brown et al. 2010). The surveys conducted across occupiers by Jones Lang LaSalle (2008) and Cushman and Wakefield (2009) in London, or DTZ (2009) in Paris confirm the improvement of sustainability among other strategic factors for buildings' attractiveness and a willingness to pay a premium for green-certified buildings from 1-5 % to 10 %. A recent study based on a survey conducted across a large sample of corporate real estate managers shows that sustainability impacts location choice of users in the French context (Nappi-Choulet and Decamps 2011).

Moreover, the "green value" is also estimated in terms of risk and depreciation for investors by protecting buildings against premature obsolescence (McNamara 2008). The impact of sustainability on risk decrease and growth expectations is underlined by several studies using the Discounted Cash Flow method (Sayce et al. 2004; Lorenz and Lützkendorf 2008; Muldavin 2008). Consequently, improving sustainable performance of buildings should lead to higher values for investors or landlords generally by more than the extra costs to go green (Miller et al. 2010). This hypothesis is also supported by recent studies highlighting the low cost of "going green" (Bubny 2009; Kats 2009). The survey conducted by AtisReal (2008) in U.K. highlights potential lower risks and premium values for investors, whereas Myers, Reed and Robinson (2008) suggest a weaker interest for sustainable properties into investors' portfolios in New Zealand.

Several factors support the idea that sustainable performances should improve buildings' attractiveness for occupiers and lower risk for investors. This should lead to higher occupancy rates, rent premium and higher asset values. A theoretical framework of the price premium of green buildings can be found in Fuerst and McAllister (2011). However, the main research contributions on economic value of green buildings are empirical studies.

Empirical research on green office buildings valuation

In order to demonstrate that advantages of green buildings can be capitalised and turned into higher occupancy rates, rental premium and higher asset values, several empirical studies use hedonic models.

Hedonic regression modeling is the standard methodology for examining price and rent determinants in real estate research. The theoretical framework of hedonic analysis is due to Lancaster (1966) and Rosen (1974) in the context of a competitive market for heterogeneous goods such as buildings. It starts with the assumption that any good or service consists of a variety of utility-bearing characteristics making up the hedonic price function. The hedonic prices derived from the equilibrium framework thus represent *implicit prices* of each characteristic. This "revealed preference" method is often used in the empirical literature of real estate valuation regressing buildings' prices on a set of intrinsic characteristics and location attributes.

However, the application of hedonic models is scarcer for office buildings than for housing. This is primarily explained by the difficulty of collecting the necessary data concerning properties' characteristics, generally less reliable for offices than for housing (Downs, Slade, 1999), especially in the French case (Nappi-Choulet et al. 2007). The largest part of the existing literature on hedonic models applied to office market concerns the determinants of rent: see Clapp (1980) and Sivitanidou (1995) on Los Angeles; Brennan, Cannaday, Colwell (1984) and Mills (1992) on Chicago; Bollinger, Ihlanfeldt and Bowes (1998) in Atlanta; Dunse and Jones (1998) on the market in Glasgow; Nagai, Kondo and Ohta (2000) for the central Tokyo market;

Slade (2000) in Phoenix; or Wheaton and Torto (1994) on a national U.S. sample. The main determinants explaining the formation of rents are well established in this literature and rely on building size, age, number of stories, vacancy level, type of lease and location attributes. Hedonic models have been less applied to office buildings' sales price: see Colwell, Munneke and Trefzger (1998) on Chicago; Downs, Slade (1999) and Munneke, Slade (2001) on the Phoenix market; Tu, Yu and Sun (2004) on Singapour; and Nappi-Choulet, Maury (2009) on the Paris office market. The main determinants of the sales price used in the literature concerns building size, age, number of stories and location attributes.

A growing number of empirical works adapt these hedonic regression methods in order to demonstrate that green buildings allow for rental premium, higher occupancy rates and thus higher asset values (Miller et al. 2008; Dermisi 2009; Fuerst and McAllister 2009 and 2011; Eichholtz et al. 2010a and b; Wiley et al. 2010). These works concern mainly U.S. office buildings and use Energy-Star or LEED certification as proxies for green design. Certified buildings are compared with a set of "regular" office buildings in order to estimate the impact of certification on rent and value using data from the CoStar database and hedonic regressions. They all conclude to a positive impact of sustainable certification. Depending on the studies, the rent premium is estimated between 2 and 9 % for Energy-Star certified buildings and between 4 and 18% for LEED certified buildings. The studies investigating the impact of certification on sales prices estimate a premium between 13 and 26% for Energy Star buildings and between 11 and 25% for LEED buildings. However, all these authors are realistic in pointing out the very preliminary nature of the linkage. This part of the literature is widely developed in U.S, U.K. and Australia which represent 75 % of academic publications (Sayce et al. 2010). This type of studies is difficult in the French case due to a lack of data available, especially for *H.Q.E* or *H.P.E* certified buildings. In this article, we overcome this limitation by accessing to a real estate investor's portfolio including data on energy efficiency (the full dataset is described in the following section).

Moreover, this growing amount of works on green buildings' valuation focuses on new certified buildings regarding comparable ones. This highlights the interest to study the potential conversion to sustainable practices for existing buildings, "since no more than 2 % of the existing stock is built in any one year" (Miller et al. 2010). A fundamental contribution of this paper is to carry a patrimonial approach by applying hedonic methods to the existing portfolio of a real estate investor. We thus investigate the potential valuation of green performance (energy consumption) into rent and asset value on a portfolio of existing buildings (the dataset is described in details in the following section). The aim of this paper is to contribute to the growing literature on green buildings by conducting an analysis on a portfolio of existing buildings in the French context where empirical researches on green buildings remain scarce.

Method

This paper investigates the impact of energy consumption on the economic value of buildings using hedonic regression modeling applied to the existing portfolio of a real estate investor. This section describes the construction of the database coming from the investor's portfolio and the specification of the hedonic model.

Data Source: an investor's portfolio

The data collected for this article come from the portfolio of *Poste Immo*: the landholding trust which optimises, develops, manages and maintains real estate assets of the French Post Office operator (*La Poste*). *Poste Immo* is a major real estate operator in the French context with a portfolio composed by 13,300 buildings, 7 million square metres, 4 million of which are fully owned. This major real estate operator allowed us to have access to a sample of its portfolio for which audits have been conducted to measure energy efficiency and sustainable performance. The buildings of this sample represent the most important ones in the portfolio which are classified by *Poste Immo* as "*Strategic*" or "*Significative*". The accessibility to these data is the results of a research convention which aims at promoting sustainable development in the real estate sector.

The data base of this article represents a sample of 558 buildings characterized by the following variables (2009-2010).

- Asset value and rent.

- A set of buildings' intrinsic characteristics which are usually used in hedonic literature, as mentioned in the previous section: buildings' size (in square metres), age, number of stories, and type of lease which is differentiated if the occupier is *La Poste* or an external company.
- The type of building in our sample of *Poste Immo*'s portfolio, which can be: *Industrial*, *Tertiary* or *Mixed – Post office* (buildings characterized by a post office activity and at least another use).
- The own *Poste Immo*'s classification for buildings, which can be: *Strategic* or *Significative*.
- The location code of the *French National Institute of Statistics and Economic Studies* for each building which allows us to specify two types of local variables: the employment level of each building's location and a set of dummy variable controlling for each local market. These two local variables are coded at two different scales defined by the *French National Institute of Statistics and Economic Studies* to avoid potential colinearity problems: *"Communes"* for employment level and *"Departements"* for dummy variables.
- The energy consumption (in kilo watt per hour per square meter per year) for each building. This variable is the main interest variable of our model as it represents energy efficiency. A classification in 9 items (from A to I) is produced by the French official *Energy Performance Diagnosis* method regarding performance in energy consumption.

The descriptive statistics of this dataset is detailed in Table 3 and 4 (Appendix A). A limitation of this dataset is the relatively low number of buildings in our sample regarding the contributions using the CoStar database. However, this article supported by the accessibility to the portfolio of a real estate operator provides two main contributions. Firstly, it allows us to overcome the lack of data available in the French context to analyze the economic valuation of green buildings (to our knowledge, this is the only hedonic model which tests the impact of sustainable performance on buildings' economic value in the French context). Secondly, it contributes to the academic research on green buildings by investigating the potential value of energy efficiency for existing buildings rather than recent certified buildings.

Specification of a hedonic model

In order to explain rent and asset value of buildings in our sample, we specify the usual log-linear hedonic model which is adapted to test the impact of energy efficiency.

$$\ln P_i = \alpha + \beta_i X_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \qquad (1)$$

In this formulation, $ln\ P_i$ is the natural logarithm of rent or asset value for building i; X_i is a vector of locational and intrinsic characteristics of building i (with every quantitative variables transformed in natural logarithm in order to be interpreted as elasticities); C_i represents the energy consumption of building i (dummy variables for each consumption class in kilowatt per hour per square meter per year); LM_i is a set of dummy variables controlling for each local market (corresponding to the administrative zoning in *"departements"* of the *French National Institute of Statistics and Economic Studies*); and εi a random error term which is assumed to be normally distributed (this property is confirmed by the test of *Jarque-Bera*).

This log-linear formulation of the hedonic model is widely used in the main contributions concerning green buildings (Miller et al. 2008; Dermisi 2009; Fuerst and McAllister 2009 and 2011; Eichholtz et al. 2010a and b; Wiley et al. 2010). However, a Box-Cox transformation (Box and Cox 1964) has been estimated here in order to justify this specification choice. This method allows an endogenous estimation of the functional form of the model by estimating a parameter λ for the explained variable. The Box-Cox transformation is based on the following form:

$$P_i^{(\lambda)} = \begin{cases} \ln(P), & \lambda = 0 \\ \dfrac{P^{\lambda} - 1}{\lambda}, & \lambda \neq 0 \end{cases}$$

The functional form of the model thus depends on the value of the estimated parameter, especially between 0 corresponding to the log-linear specification and 1 corresponding to the standard linear specification. The λ parameter is estimated using the maximization of log-likelihood. The results of this estimation are presented in Table 9 (Appendix C) and systematically confirm the log-linear specification for the model.

Following this, two models are specified: Model 1 explains asset value and Model 2 explains rent.

Model 1

$$ln\, V_i = \alpha + \beta_{1i}T_i + \beta_{2i}S_i + \beta_{3i}lnBS_i + \beta_{4i}NS_i + \beta_{5i}A_i + \beta_{6i}lnE_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \quad (2)$$

In this model, V_i represents the asset value of building i; T_i is buildings' type (dummy variables for each type: *Industry*, *Tertiary* or *Mixed – Post Office*); S_i is a dummy variable which is equal to 1 if the building is a *Strategic* one and 0 if not; BS_i represents the building size (in square meter); NSi is the number of stories (coded in dummy variables); A_i the age of building i (coded in dummy variables); E_i represents the employment level of building i's location and LM_i is the set of dummy variables controlling for each local market. Employment level is measured at a different scale (administrative zoning in *"communes"* of the *French National Institute of Statistics and Economic Studies*) than local market dummies to avoid potential colinearity problems. Finally, C_i represents the energy consumption of building i (in kilowatt per hour, per square meter, per year). The energy consumption is specified in two different ways (Model 1a and 1b). First, we use dummy variables for each class of consumption of the French official *Energy Performance Diagnosis*. However, our sample's buildings are highly concentrated in the central classes D, E and F (see Table 4 in Appendix A). We thus introduce the deciles of energy consumption in order to have a more equitable distribution of buildings in the different classes of consumption. The consumption thresholds corresponding to each decile are given in Table 1 for the different subsamples.

Model 2

$$ln\, R_i = \alpha + \beta_{1i}T_i + \beta_{2i}S_i + \beta_{3i}lnBS_i + \beta_{4i}NS_i + \beta_{5i}A_i + \beta_{6i}lnE_i + \beta_{7i}LT_i + \gamma_i C_i + \delta_i LM_i + \varepsilon_i \quad (3)$$

In this model, R_i represents rent in building i. All the explanatory variables are the same as in Model 1, as well as the two specifications for energy consumption (Model 2a with consumption class and Model 2b with consumption deciles). We add a variable LT_i concerning the type of lease contracts which is differentiated if there is an external occupier in the building.

Equations of Model 1 and Model 2 are both estimated using the standard OLS technique, where the potential heteroskedasticity of residuals has been taken into account with a robust covariance matrix estimated using White's (1980) method. Potential colinearity is tested using *VIF* statistics (*Variation Inflation Factor*). The hedonic weights assigned to each variable are equivalent to the characteristic's overall contribution to the variability of rent or asset value (Rosen 1974).

Table 1: Deciles of energy consumption (kilowatt per hour per square meter per year)

	Overall Sample	Industrial	Tertiary	Mixed – Post Office
D1	172	188	147	172
D2	208	213	173	212
D3	226	231	210	223
D4	253	259	244	245
D5	276	283	261	266
D6	295	299	276	284
D7	327	340	327	312
D8	367	381	368	343
D9	436	460	496	387
D10	>436	>460	>496	>387

Results

The results of the models confirm the capitalization of energy efficiency in asset value and rent. This relationship appears to be more important for rent than for asset value and differs regarding buildings' type. Model 1 and Model 2 are firstly estimated to test the impact of energy consumption on asset value and rent on the overall sample. Then, each model is specified separately on three types of buildings: *Industry*, *Tertiary* and *Mixed – Post Office*.

The impact of energy consumption on asset value and rent.

The results of Model 1 and Model 2 on the overall sample are detailed in Table 5 and 6 (Appendix B) concerning intrinsic characteristics, location attributes and energy consumption. They suggest that energy consumption impacts asset value and rent. However, this result seems stronger for rent than for asset value.

In Model 1 (Table 5), the coefficients of intrinsic characteristics are usually statistically significant and vary with the expected sign. The elasticity between asset value and building size is estimated at a level of 0.77. There is a positive relationship between asset value and number of stories. Age impacts negatively asset value. Concerning buildings' type, *Tertiary* and *Mixed – Post Office* have a positive impact on asset value whereas the coefficient of *Industrial* buildings is not statistically significant. Concerning local variable, as expected, the employment level has a positive and significant impact on asset value, and the control variables representing Paris Metropolitan Area have the strongest positive and significant effect.

Energy efficiency is specified in two ways: Model 1a with dummy variables for each class of *Energy Performance Diagnosis* and Model 1b with dummy variables for each decile. Coefficients are systematically estimated regarding low performance (i.e high energy consumption): dummy variables for class G, H and I or decile 10 are omitted. The impact of energy consumption on asset value is generally non significant. However, a positive and significant impact is associated with decile 8 (regarding decile 10) of energy consumption which concerns buildings consuming less than 367 kilowatt per hour per square meter per year. This effect can be interpreted as a premium estimated at 20% for leaving the less performing group and reaching the central group which concentrates the majority of buildings.

In Model 2 (Table 6), the intrinsic characteristics are still statistically significant with the expected sign, even if the number of stories is less significant than in Model 1. The elasticity between rent and building size is estimated at a level of 0.81 and age impacts negatively rent. The positive impact of lease type is stronger for an external occupier than if the occupier is *La Poste*. Buildings' type has not a significant impact on rent. As in Model 1, local variable have a significant impact on rent with the expected sign: a positive impact of local employment level and a strong impact of Paris Metropolitan Area.

If energy consumption has not a strong significant effect on rent, this effect seems to be more important than in Model 1. A positive and significant impact is estimated at 20% for decile 8 (less than 367 kilowatt per hour per square meter per year) and another estimated at 18% for decile 4 (less than 253 kilowatt per hour per square meter per year). We thus identify two thresholds for which energy efficiency impacts rent. The first one can be interpreted as a premium for leaving the less performing group and reaching the central group which concentrates the majority of buildings, as in Model 1. The second can be interpreted as a premium for reaching the more performing buildings (regarding central group).

Even if the impact of energy consumption on rent and asset value is generally not significant, the results of Model 1 and Model 2 suggest that energy efficiency can be capitalized at different thresholds. However, this relationship seems stronger for rent than for asset value. This analysis has to be sharpened by differentiating between types of buildings in our sample.

The relationship differs regarding buildings' type.

There are three types of buildings in our sample: *Industrial*, *Tertiary* and *Mixed – Post Office*. We estimate Model 1 and 2 to test the impact of energy efficiency on asset value and rent on each of these subsamples (descriptive statistics of each subsample can be found in Table 3 and 4 in Appendix A).

As mentioned earlier, a limitation of our sample is a relatively low number of buildings. This limitation is increased by creating subsamples for each building's type. We thus modify the models in order to decrease the number of variables regarding the size of the subsamples: the set of dummy variables controlling for each local market is replaced by a unique dummy variable $Paris_i$ coded 1 if building i is located in Paris Metropolitan Area (the strongest effect among local market controls) and 0 if not. In addition, the employment level of each building location is differentiated regarding buildings' type: employment level in industrial sector for *Industrial* buildings and employment level in tertiary sector for *Tertiary* and *Mixed – Post Office* buildings.

As indicated by the models estimated on the overall sample, the results suggest that energy efficiency affects more rent than asset value. The impact of energy efficiency on asset value (Model 1) is generally not significant (the results are thus not reported here), except for *Industrial* buildings for which we only observe a negative impact on asset value (and rent) for the less energy performing buildings. However, the impact of energy efficiency on rent (Model 2) seems to be more significant depending on buildings' type. We focus on the results of *Tertiary* and *Mixed – Post Office* buildings for which the results are very significant (we only observe a negative effect of being in the less energy performing group for the *Industrial* buildings).

The results of Model 2 for *Tertiary* and *Mixed – Post Office* buildings are presented in Table 7 and 8 (Appendix B).

Concerning intrinsic characteristics, the elasticity between rent and building size is estimated at a level of 0.96 for *Tertiary* buildings and 0.66 for *Mixed – Post Office* buildings. This gap can be interpreted by the fact that *Mixed – Post Office* buildings are usually characterized by high building size. The variations of building size thus impact less rent variations than for *Tertiary* buildings. The number of stories has a positive impact on rent for *Tertiary* buildings whereas only a low number of stories has a positive impact on rent for *Mixed – Post Office* buildings. Age has not a significant impact on rent for both subsamples. Finally, lease type has a positive impact on rent only if the occupier is *La Poste* for both subsamples. Concerning local variables, employment level has a positive and significant effect on rent for both subsamples and the *Paris* variable has a positive and significant impact on rent for *Mixed – Post Office* buildings but surprisingly not for *Tertiary* buildings.

Energy consumption has a strong significant impact on rent for these two buildings' types. For *Mixed – Post Office* buildings the coefficients associated with consumption classes of *Energy Performance Diagnosis* emphasize a positive impact of classes F and E (less than 450 and 330 kilowatt per hour per square meter per year) which can be interpreted as a premium for leaving the less performing group which strongly increase for reaching the best performance in energy consumption (class B: less than 90 kilowatt per hour per square meter per year). This result is even stronger for *Tertiary* buildings with a premium increasing all along classes and deciles measuring energy efficiency, from the effect of leaving the less performing group (decile 8 or class E) to the best performing buildings (decile 1 or class B). Even if the value of the coefficient must be interpreted with caution due to the size of the subsamples, this result strongly indicates a positive relationship between energy efficiency and rent.

The hedonic model of this article indicates a positive effect of energy efficiency on economic value of existing buildings in an investor's portfolio and emphasizes two main results. Firstly, this relationship seems to be more important for rent than for asset value. This result can be interpreted by considering that asset value is determined by a market expertise whereas rent involves directly the occupier. It suggests that potential gains linked to energy efficiency are attractive for users. Secondly, the effect of energy efficiency differs regarding buildings' type: if the impact is relatively low for industrial buildings, it seems to play an important role on the determination of rent for *Tertiary* and *Mixed – Post Office* buildings.

The impact of energy efficiency on economic value estimated by the different specifications of the model on the different subsamples is summarized in Table 2.

Table 2: Impact of energy efficiency on economic value

	Asset Value	**Rent**
Overall Sample	Premium for leaving the less performing group.	Premium for leaving the less performing group and reaching the more performing buildings.
Industrial	Negative impact of less performing buildings only.	Negative impact of less performing buildings only.
Mixed – Post Office	Not significant.	Premium for leaving the less performing group and reaching the more performing buildings.
Tertiary	Not significant.	Positive relationship between energy efficiency and rent all along energy consumption thresholds.

Conclusion

The aim of this article is to contribute to the growing literature on green buildings by providing an approach which tests the impact of energy efficiency on the economic value of a set of existing buildings in the French context. This approach uses hedonic regression modeling to demonstrate that energy efficiency has a positive impact on asset value and rent. The model is supported by a dataset coming from a real estate portfolio for which audits have been conducted on sustainable performance of buildings.

The hedonic model estimates the contribution of energy consumption (kilowatt per hour per square meter per year) on rent and asset value regarding the contribution of a set of buildings' intrinsic characteristics and location attributes. The model is specified on the overall sample and then for each building's type in our sample: Industrial, Tertiary and Mixed – Post Office. Two main results are emphasized by the model. First, energy efficiency is more capitalized in rent than in asset value. This result can be interpreted by considering that asset value is determined by a market expertise whereas rent involves directly the occupier. This finding confirm that energy efficiency is attractive for buildings' users and contribute to the body of works showing that sustainable performances are valued by users (see Nappi-Choulet and Decamps 2011 in the French context). The second main result of this article is that premium linked to energy efficiency differs regarding buildings' type. In our sample, the effect of energy efficiency on rent is relatively low for industrial buildings, whereas it is much stronger for commercial and office buildings.

The research perspectives of this article are conditioned to the access of a larger database in order to increase the number of buildings in our sample and to test the relationship between energy efficiency, asset value and rent on other types of buildings. This article is supported by a database concerning one real estate investor. It allowed us to overcome the lack of data on the French context, but a limitation of the model is a relatively small sample. A larger sample with an access to data from several investors' portfolio might overcome this limitation and improve our findings.

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Appendix A

Table 3: Descriptive statistics on quantitative variables

Quantitative Variables	Mean	Median	Std. Dev.
Overall Sample			
Building Size	3,441.48	1,889.13	4,685.82
Age	35.04	29.00	31.17
Number of Stories	2.47	2.00	1.39
Lease Type			
External	0.14	0.00	0.45
La Poste	2.53	2.00	3.59
Employment level	136,344.55	17,669.40	405,388.49
Energy Consumption	295.89	276.50	130.69
Industrial			
Building Size	3,613.60	1,774.97	4,877.34
Age	16.98	6.00	24.85
Number of Stories	1.92	2.00	0.87
Lease Type			
External	0.02	0.00	0.13
La Poste	1.46	1.00	1.11
Employment level	4,909.57	1,202.13	14,363.30
Energy Consumption	306.37	283.00	127.89
Mixed – Post Office			
Building Size	2,035.37	1,616.92	1,383.07
Age	46.71	38.00	26.11
Number of Stories	2.43	2.00	1.05
Lease Type			
External	0.13	0.00	0.33
La Poste	2.56	2.00	1.40
Employment level	51,299.97	8,225.35	191,423.66
Energy Consumption	275.34	266.00	101.00
Tertiary			
Building Size	6,986.14	4,673.85	7,144.98
Age	53.44	50.00	29.12
Number of Stories	4.38	4.00	1.76
Lease Type			
External	0.55	0.00	0.89
La Poste	5.96	4.00	7.81
Employment level	103,998.54	30,347.88	274,487.52
Energy Consumption	296.94	261.50	181.10

Table 4: Descriptive statistics on quantitative variables

Qualitatives Variables	**Observation**	**% of the Sample**
Industrial	247	44.27%
Mixed – Post Office	190	34.05%
Tertiary	86	15.41%
Strategic	74	13.26%
Paris	112	20%
Energy Consumption		
Class_A	1	0.18%
Class_B	11	1.97%
Class_C	24	4.30%
Class_D	143	25.63%
Class_E	217	38.89%
Class_F	113	20.25%
Class_G	29	5.20%
Class_H	14	2.51%
Class_I	6	1.08%
Total	558	100%

Appendix B

Table 5: Results of Model 1 on the overall sample

Asset Value	**Model 1a**		**Model 1b**	
	Coefficient	P-value	Coefficient	P-value
Building Type (T_i)				
Industrial	0.039	0.678	0.035	0.714
Tertiary	**0.295***	**0.006**	**0.285***	**0.008**
Mixed – Post Office	**0.354*****	**0.000**	**0.357*****	**0.0001**
Strategic (S_i)	0.017	0.783	0.026	0.681
Ln Building Size (BS_i)	**0.765*****	**<.0001**	**0.766*****	**<.0001**
Ln Employment (E_i)	**0.067*****	**0.000**	**0.064*****	**0.000**
Number of Stories (NS_i)				
NbStories_1	-0.124	0.151	-0.117	0.177
NbStories_2	**-0.220****	**0.003**	**-0.219****	**0.004**
NbStories_3	**-0.353*****	**<.0001**	**-0.355*****	**<.0001**
Age (A_i)				
AGE_D1	**0.296****	**0.004**	**0.292****	**0.004**
AGE_D2	**0.318*****	**0.000**	**0.316*****	**0.000**
AGE_D3	0.110	0.198	0.109	0.203
AGE_D4	**-0.213****	**0.009**	**-0.218***	**0.008**
AGE_D5	**-0.144***	**0.077**	**-0.140***	**0.087**
AGE_D6	**-0.145***	**0.089**	**-0.146***	**0.089**
AGE_D7	-0.106	0.223	-0.115	0.187
AGE_D8	**-0.158***	**0.061**	**-0.157***	**0.062**
AGE_D9	-0.069	0.414	-0.066	0.438
Energy Consumption (C_i)				
D1 (172)	-0.094	0.303		
D2 (208)	-0.083	0.328		
D3 (226)	-0.015	0.857		
D4 (253)	0.040	0.636		
D5 (276)	-0.078	0.354		
D6 (295)	0.037	0.656		
D7 (327)	-0.006	0.944		
D8 (367)	**0.197****	**0.015**		
D9 (436)	0.048	0.560		
classB (90)			-0.114	0.508
classC (150)			-0.126	0.281
classD (230)			-0.057	0.451
classE (330)			-0.004	0.951
classF (450)			0.107	0.150
Local Control Variables (LM_i)	Included		Included	
Adjusted R^2	0.77		0.77	
Observations	559		559	

Note: $***$ indicates significance at the 1% level; $**$ indicates significance at the 5% level; $*$ indicates significance at the 10% level.

Table 6: Results of Model 2 on the overall sample

Rent	**Model 2a**		**Model 2b**	
	Coefficient	P-value	Coefficient	P-value
Building Type (*T_i*)				
Industrial	-0.075	0.458	-0.071	0.482
Tertiary	0.145	0.213	0.148	0.203
Mixed – Post Office	0.049	0.607	0.063	0.515
Strategic (*S_i*)	-0.022	0.745	-0.014	0.837
Ln Building Size (*BS_i*)	**0.812*****	**<.0001**	**0.815*****	**<.0001**
Ln Employment (*E_i*)	**0.060****	**0.002**	**0.059****	**0.002**
Lease Type (*LT_i*)				
External	**0.126****	**0.017**	**0.117****	**0.027**
La Poste	**0.011***	**0.078**	**0.010***	**0.095**
Number of Stories (*NS_i*)				
NbStories_1	0.100	0.277	0.104	0.263
NbStories_2	-0.075	0.346	-0.075	0.348
NbStories_3	**-0.205****	**0.010**	**-0.215***	**0.007**
Age (*A_i*)				
AGE_D1	**0.336****	**0.002**	**0.323****	**0.003**
AGE_D2	**0.327*****	**0.000**	**0.323*****	**0.000**
AGE_D3	0.064	0.480	0.065	0.471
AGE_D4	**-0.175****	**0.044**	**-0.189****	**0.030**
AGE_D5	-0.022	0.802	-0.023	0.791
AGE_D6	**-0.160***	**0.079**	**-0.160***	**0.081**
AGE_D7	-0.010	0.918	-0.025	0.790
AGE_D8	-0.110	0.223	-0.115	0.201
AGE_D9	-0.062	0.499	-0.060	0.512
Energy Consumption (*C_i*)				
D1 (172)	-0.039	0.693		
D2 (208)	0.045	0.620		
D3 (226)	0.115	0.208		
D4 (253)	**0.182****	**0.047**		
D5 (276)	0.095	0.287		
D6 (295)	0.089	0.320		
D7 (327)	0.113	0.197		
D8 (367)	**0.206****	**0.018**		
D9 (436)	0.044	0.623		
classB (90)			0.018	0.923
classC (150)			-0.078	0.528
classD (230)			0.064	0.436
classE (330)			0.110	0.149
classF (450)			0.112	0.166
Local Control Variables (*LM_i*)	Included		Included	
Adjusted R^2	0.77		0.77	
Observations	550		550	

Note: $***$ indicates significance at the 1% level; $**$ indicates significance at the 5% level; $*$ indicates significance at the 10% level.

Table 7: Results of Model 2 for *Mixed – Post Office* buildings.

Rent	Model 2a		Model 2b	
	Coefficient	P-value	Coefficient	P-value
Paris$_i$	**0,474*** **	**<,0001**	**0,489*** **	**<,0001**
Strategic (S_i)	-0,128	0,190	-0,133	0,172
Ln Building Size (BS_i)	**0,654*** **	**<,0001**	**0,658*** **	**<,0001**
Ln Employment (E_i)	**0,137*** **	**<,0001**	**0,138*** **	**<,0001**
Lease Type (LT_i)				
External	-0,003	0,973	0,025	0,752
La Poste	**0,079*** **	**0,001**	**0,067** **	**0,006**
Number of Stories (NS_i)				
NbStories_1	**0,346*** **	**0,000**	**0,299*** **	**0,001**
NbStories_2	0,032	0,609	0,043	0,483
Age (A_i)				
AGE_D1	0,184	0,121	**0,191***	**0,092**
AGE_D2	-0,047	0,683	-0,060	0,596
AGE_D3	-0,039	0,732	0,039	0,723
AGE_D4	-0,075	0,558	-0,030	0,809
AGE_D5	0,141	0,200	**0,181***	**0,096**
AGE_D6	0,003	0,981	0,074	0,504
AGE_D7	-0,040	0,725	0,025	0,823
AGE_D8	0,009	0,935	0,029	0,791
AGE_D9	-0,053	0,644	0,023	0,841
Energy Consumption (C_i)				
D1 (172)	0,060	0,632		
D2 (212)	-0,002	0,986		
D3 (223)	-0,016	0,901		
D4 (245)	0,150	0,225		
D5 (266)	-0,038	0,752		
D6 (284)	-0,078	0,526		
D7 (312)	0,110	0,336		
D8 (343)	-0,045	0,698		
D9 (387)	0,182	0,119		
classB (90)			**0,606***	**0,006**
classC (150)			0,065	0,700
classD (230)			0,217	0,109
classE (330)			**0,217***	**0,085**
classF (450)			**0,291** **	**0,023**
Adjusted R²	0,72		0,72	
Observations	221		221	

Note: $***$ indicates significance at the 1% level; $**$ indicates significance at the 5% level; $*$ indicates significance at the 10% level.

Table 8: Results of Model 2 for *Tertiary* buildings.

Rent	**Model 2a**		**Model 2b**	
	Coefficient	P-value	Coefficient	P-value
Paris$_i$	0.231	0.174	0.198	0.258
Strategic (*S_i*)	-0.167	0.221	-0.198	0.170
Ln Building Size (*BS_i*)	**0.946*** **	**<.0001**	**0.976*** **	**<.0001**
Ln Employment (*E_i*)	**0.216*** **	**<.0001**	**0.206*** **	**<.0001**
Lease Type (*LT_i*)				
External	-0.110	0.164	-0.123	0.113
La Poste	**0.010***	**0.099**	0.008	0.212
Number of Stories (*NS_i*)				
NbStories_1	**-0.322***	**0.061**	**-0.332** **	**0.049**
NbStories_2	**-0.344** **	**0.032**	**-0.368** **	**0.021**
NbStories _3	-0.042	0.806	-0.017	0.920
Age (*A_i*)				
AGE_D1	0.013	0.952	-0.027	0.900
AGE_D2	0.121	0.550	0.037	0.861
AGE_D3	0.080	0.678	0.043	0.828
AGE_D4	-0.051	0.795	-0.037	0.857
AGE_D5	0.052	0.814	-0.046	0.845
AGE_D6	0.045	0.821	0.055	0.795
AGE_D7	0.262	0.253	0.277	0.262
AGE_D8	0.089	0.679	0.045	0.838
AGE_D9	-0.010	0.964	-0.135	0.547
Energy Consumption (*C_i*)				
D1_conso (147)	**0.770*** **	**0.001**		
D2_conso (173)	0.173	0.487		
D3_conso (210)	**0.552** **	**0.027**		
D4_conso (244)	**0.583** **	**0.017**		
D5_conso (261)	**0.535** **	**0.024**		
D6_conso (276)	**0.670** **	**0.006**		
D7_conso (327)	**0.445***	**0.097**		
D8_conso (368)	**0.475***	**0.055**		
D9_conso (496)	0.335	0.153		
classB (90)			**0.568***	**0.064**
classC (150)			**0.492** **	**0.047**
classD (230)			0.331	0.125
classE (330)			**0.462** **	**0.029**
classF (450)			0.278	0.195
Adjusted R^2	0.89		0.88	
Observations	83		83	

Note: $***$ indicates significance at the 1% level; $**$ indicates significance at the 5% level; $*$ indicates significance at the 10% level.

Appendix C

Table 9: Box Cox Transformation

	Model 1a		Model 1b		Model 2a		Model 2b	
	R^2	Log Likelihood	R^2	Log Likelihood	R^2	Log Likelihood	R^2	Log Likelihood
Overall Sample								
$\lambda = 0$	0.81	-7,580.0	0.81	-7,582.1	0.81	-6,223.2	0.81	-6,224.0
$\lambda = 1$	0.47	-8,683.0	0.46	-8,682.8	0.58	-7,111.0	0.58	-7,111.1
Mixed - Post Office								
$\lambda = 0$					0.75	-2,400.21	0.75	-2,397.44
$\lambda = 1$					0.64	-2,581.94	0.64	-2,580.44
Tertiary								
$\lambda = 0$					0.93	-990.13	0.91	-996.60
$\lambda = 1$					0.75	-1,115.59	0.73	-1,115.55